CRYSTAL

Building Construction with 14 Modules

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TGA Arusha / Tanzania
June 1983

Deutsche Gesellschaft für
Technische Zusammenarbeit (GTZ) GmbH

ARCHITECTURAL DRAWING I

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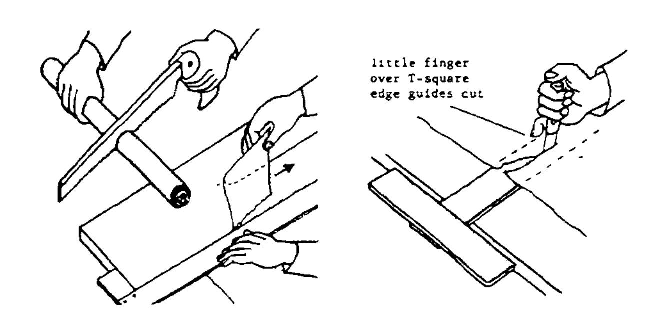

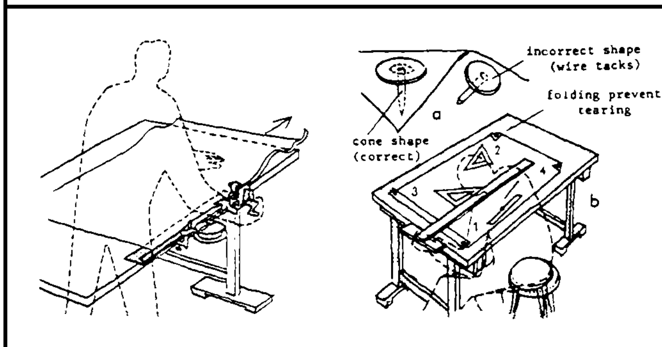

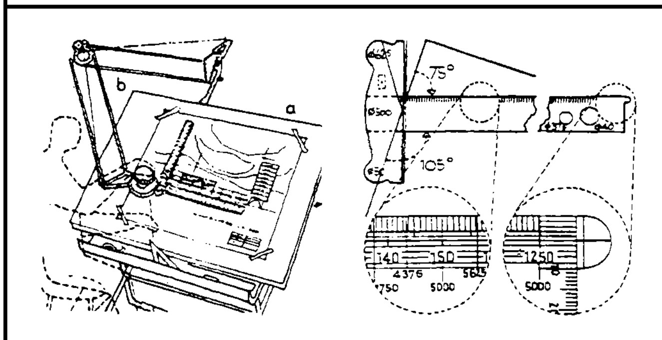

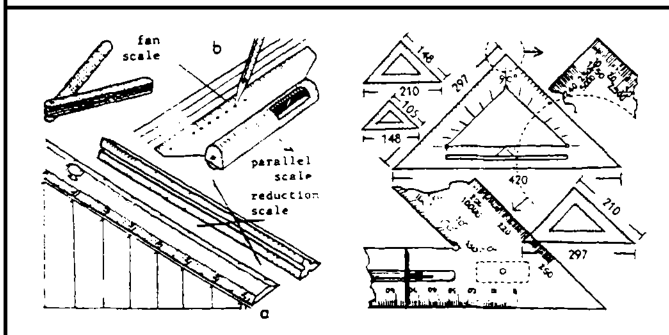

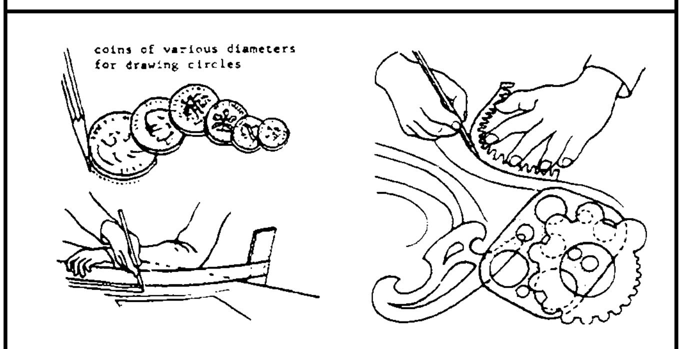

AD I
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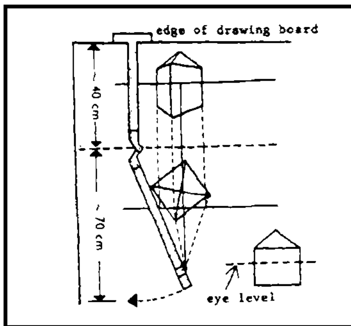
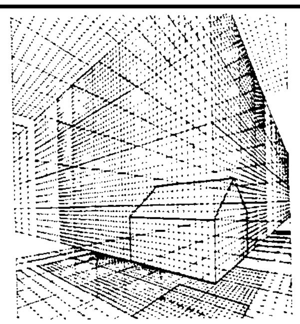
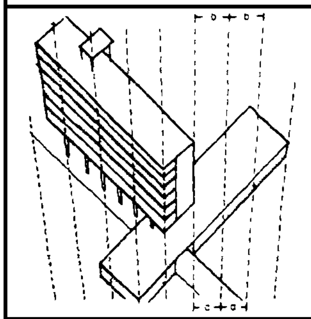
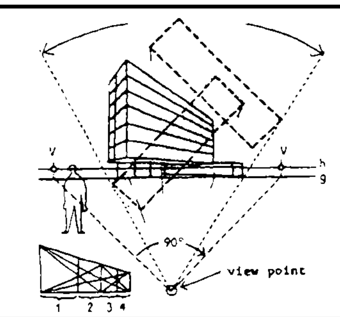
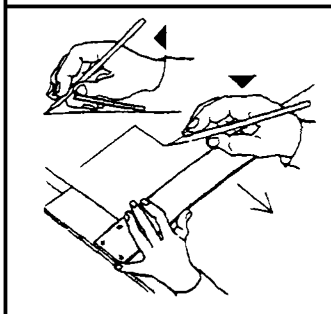
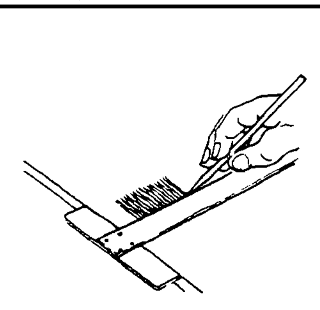
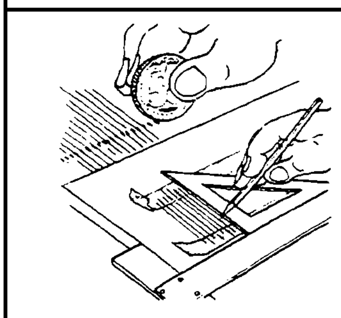
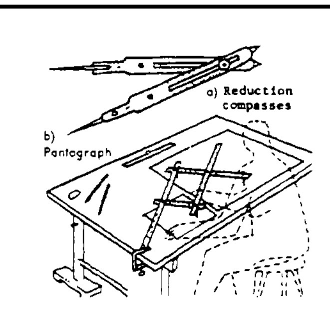
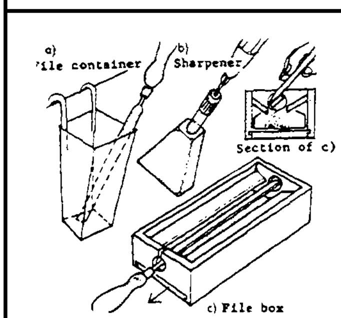
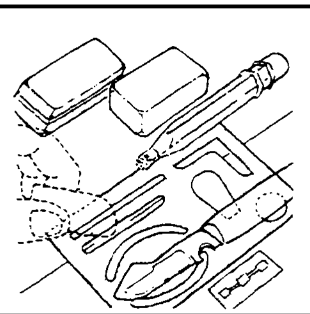
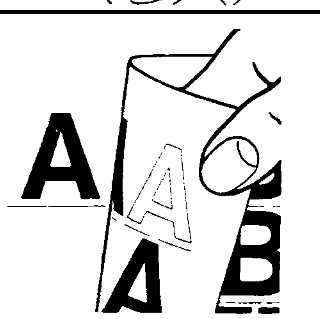








6. GEOMETRICAL CONSTRUCTIONS

6.1 Lines and Angles

6.1.1 To bisect a straight line AB

6.1.2 To divide a straight line into a given number of equal parts

6.1.3 To divide a straight line AB into any ratio

6.1.4 To construct an angle of 90^0

6.1.5 To construct an angle of 45^0

6.1.6 To construct an angle of 60^0

6.1.7 To construct an angle of 30^0

6.1.8 To bisect any given angle

6.1.9 To construct an angle similar to a given angle

6.1.10To draw a line PARALLEL to a given line

6.2 Triangles

6.2.1 To construct an EQUILATERAL triangle

6.2.2 To construct a triangle with given BASE ANGLES and ALTITUDE

6.2.3 To inscribe a circle in a given triangle ABC

6.2.4 To circumscribe a circle around a triangle ABC

6.3 Circles

6.3.1 Basic CIRCLE-constructions

6.3.2 To draw a tangent to a point A on the circumference of a circle

6.3.3 To draw an internal tangent to two circles of equal diameter

6.3.4 To find the centre of a given circle arc

6.3.5 To join two straight lines at RIGHT ANGLES to each other by an ABC of given radius

6.3.6 To draw a curve of a given radius joining two circles

6.3.7 To join two straight lines by two arcs of equal radius

6.4 Basic ARCH-Contructions

REFERENCES:

1. "Draughtsmanship"

2. E. Neufert
"Architect's Data"

3. Dahmlos/Witte
"Bauzeichnen"

4. Landscheidt/ Schlüter
"Bauzeichnungen"

5. E. Neizel
"Fachzeichnen für das Baugewerbe 1"
- Grundzeichnen -

1. AIMS AND PURPOSE OF ARCHITECTURAL DRAWINGS

Architectural drawings are made as a MEANS of COMMUNICATION between
- the client
- the architect
- the engineer
- the building authority and
- the people, who are executing the construction work.

One can define architectural drawings as a LANGUAGE. Therefore the drawings should be:
- easily understandable
- clearly arranged
- unequivocal
- correct
- standardized and
- clean

in order to avoid mistakes and misunderstandings, which may become very expensive.

1.1 Contents of architectural drawings

Architectural drawings should show

I. the ideas and immaginations of the designer (architect)

II. the type of the building or structure, which has to be in accordance with
   - the rules of building construction
   - the availibility of building materials
   - the financial possibilities of the client
   - the regulations, bylaws and building rules of the local authority

1.2 Types of Architectural Drawings

Each type drawing has its special contents and has to save its own purpose.
There are different types of architectural drawings:

1. Sketch Drawings: show the solution of the job with the approximate measurements of the rooms and construction members as well as the arrangement of the buildings on the site.
   common scales 1:500, 1:200.

2. Design Drawings: Show the agreed solution of the job with the exact measurements of the rooms and construction members. For submission to obtain a Building Permit they have to be in accordance with the regulations of the LOcal Authority.
   common scales: 1:100 (1:200)

3. Working Drawings: Have to content all necessary specifications and measurements of the rooms and construction members in order to carry out the job properly.
   They also have to specify the used building materials and structures.
   common scale : 1 : 50

4. Detail Drawings: complete the Working Drawings for specific parts of the buildings in a bigger scale.
   common scales 1:20, 1:10, 1:5, 1:1

5. Special Drawings: give particulars about special constructions such as:
   Reinforced concrete work, steel - and timber work, sanitary or electrical systems etc. For such drawings, other construction members are only shownas far as necessary to understand the drawing correctly.
   Scales as necessary.

6. Accounting Drawings: give all necessary informations for the accounting.
   Scales as necessary.

7. Stock-Taking Drawings: indicate all - for a certain purpose - necessary particulars and informations about an existing building
   Scales as necessary.

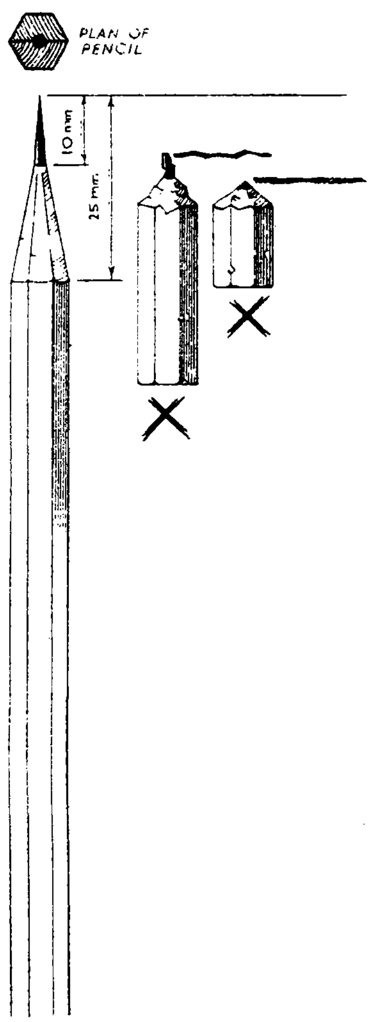
TYPE OF DRAWING	SCALE
1. Sketch Drawings	1:500,1:200
2. Design Drawings	1:100,(1:200)
3. Working Drawings	1: 50
4. Detail Drawings	1: 20,1:10, 1:5, 1:1
5. Special Drawings	as necessary
6. Accounting Drawings	as necessary
7. Stock-Taking Drawings	as necessary

2. DRAWING EQUIPMENT

2. DRAWING EQUIPMENT

In the following, only the principle items of drawing equipment required by the draughtsman are mentioned.
The draughtsman, especially the beginner, is advised to purchase the best available instruments he can effort and he should handle and maintain them carefully.
Well kept drawing equipment is the prior condition for making good drawings.

PENCILS



PENCIL

2.1 PENCILS
Ordinary drawing pencils are made of cedarwood with leads of compressed clay and graphite and are about 175mm long. There are round and hexagonal types available. The hexagonal type is more easily held in the fingers and the pencil does not roll off the board or table. Always try to by the best pencils you can obtain because the leads of which are gritty or crumbly make good draughtsmanship impossible.

When a pencil has been reduced to about half its length by sharpening, the 'balance' tends to be destroyed and it becomes difficult to control. The short length should be put in a holder. In case you cannot find any holder, a stripe of paper can be rolled around the end an gummed, to increase the length and make the pencil more manageable.

Pencil points should be long, round and evenly tapering the exposed lead should be about 10 mm long, and the wood cut back a further 10-15 mm.
The point must be round, and then, if the pencil is slowly revolved as lines are drawn,it will wear away evenly and remain sharp for some time.

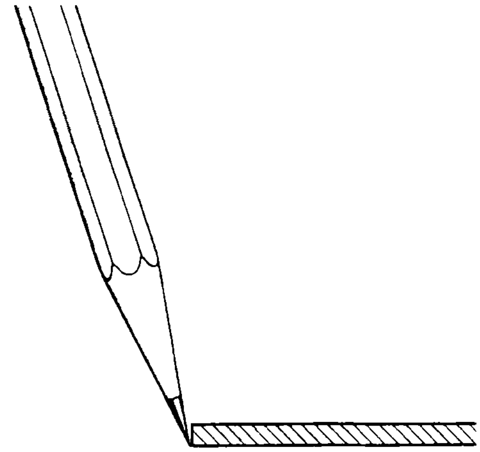
Clutch pencils are a popular alternative to the ordinary pencil of similar shape and size, consisting of a metal lead holder into which leads of varying degrees or various colours can be inserted. A push bottom operates the clutch and enables the lead to be withdrawn or fully protected as required. The main advantage of the clutch pencil is that balance is always constant, but it is heavier than the wooden pencil.

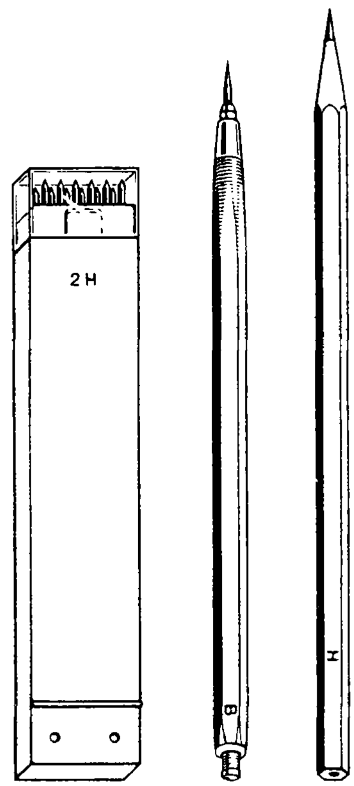
There is a special type of clutch pencil for thinner leads (between 0.3 - 0.9 mm) which makes sharpening unnessesary.

Leads are made in varying degrees of hardness and softness, ranging from 9 H, the hardest, to 6 B, the softest. The extreme grades are very little used. Most drawings can be carried out by using

2 H
H (-hard)
F (-firm)
HB
B (-back)
2 B

Setting out lines and fine work may be done in H, rogh sketching in B. Beginners should not use pencils harder than H on cortridge and similar drawing papers. It is a common error to resort a hard pencil because the point lasts longer and the line is less likely to smudge, properly used HB pencil will keep its point just as long and will give a much better line whilst pomitting greater freedom of wrist action. Hard pencils bite into the paper and make harsh wiry lines. Smudging is due to carelessness and the student should learn to avoid rubbing the lines of his drawing.





Sharpening: The best way of sharpening an ordinary pencil is by means of a penknife. The pencil is held in the left hand, below table-level and pointing downwards so that chips and lead dust cannot fall on the drawing paper. And with the penknife in the right hand inclined cuts are made firmily and regularly to remove the wood ground the point. The final sharpening is done with the penknife blade held more or less at right - angles to the lead - this reduces the risk of a sudden cut going right through the point.

PENKNIFE

Pencils should not be sharpened with the lead held against a thumb - a sure way to make hands and clothes dirty - nor should safety - razor blades be used - they are much too sharp and difficult to control.

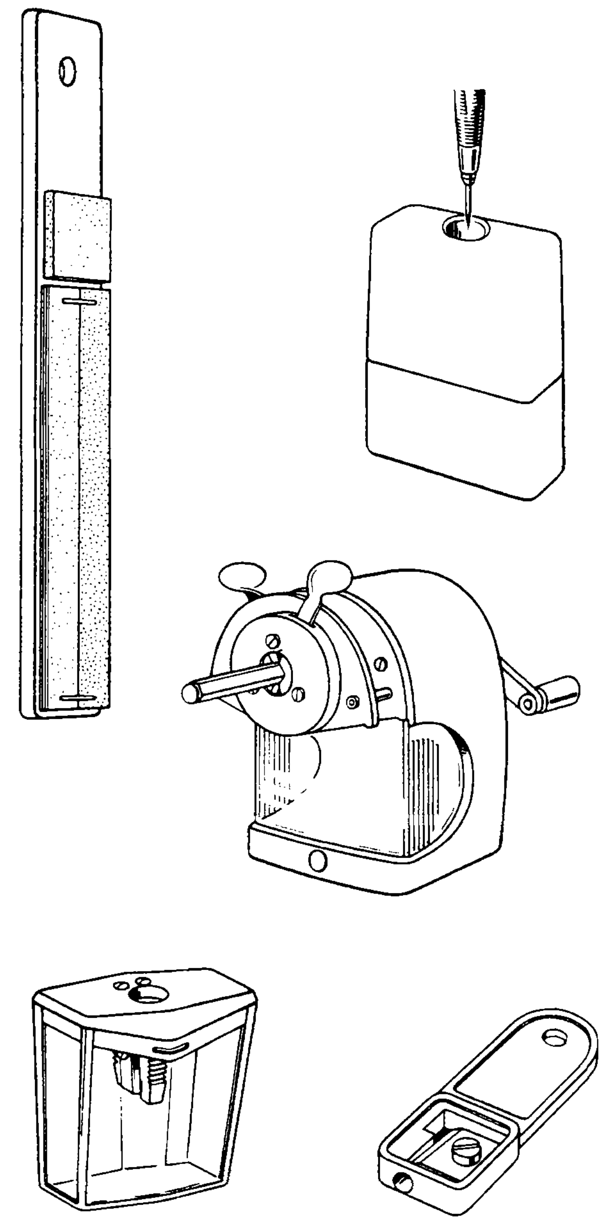
Sand paper pads: should never be used They are not only too coarse to produce anythin like a good point, but they make an intolerable amount of dust which is rapidly transferred to fingers, clothes, and drawing papers.

Mechanical pencil sharpeners which can be screwed either to the table or wall ar generally efficient and save a certain amount of labour, although the points usually need a final touch of the penknife.

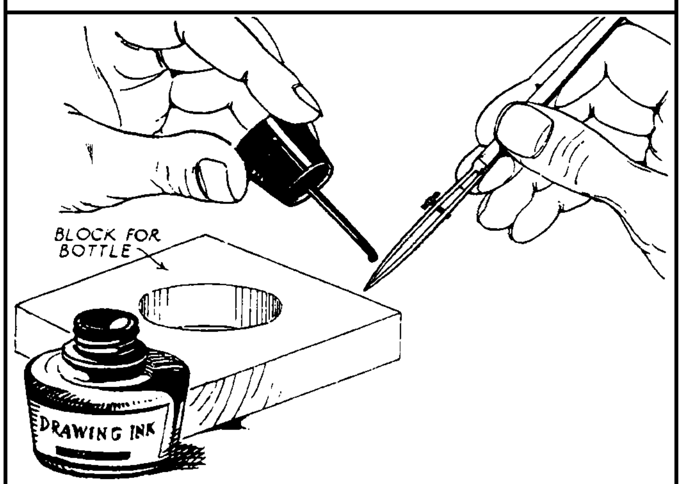
The small sharpeners that can be held in the fingers are quite useful, although care must be taken that lead dust and shavings fall into the waste basket or otherwise safely disposed of.

It must be realised that pencils require frequent sharpening when in continous use, and the beginner should start with a good stock and not be surprised if they wear out quickly.

Sharpening a clutch pencil, small lead pointers are often used, although its use is a potential source of black dust on fingers and paper; it is better to use a special pointing machine.



DRAWING PENS



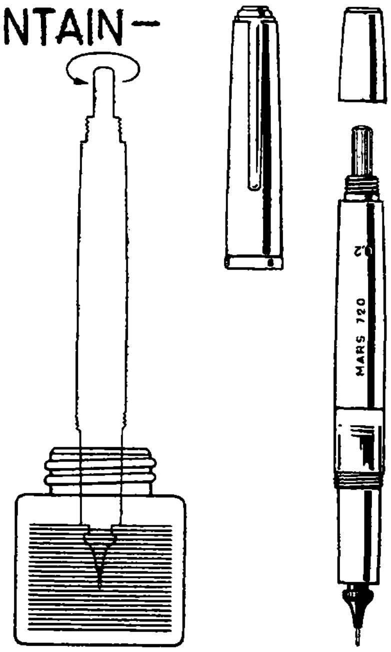
DRAWING INK

2.2 DRAWING PENS:Straight lines in ink are ruled in conjuction with the T-square and set-square (with the drawing board equipment or with a drafting machine) by means of special drawing pens. There are three types of drawing pens
- Ruling pens
- Graphos
- Rapidographs

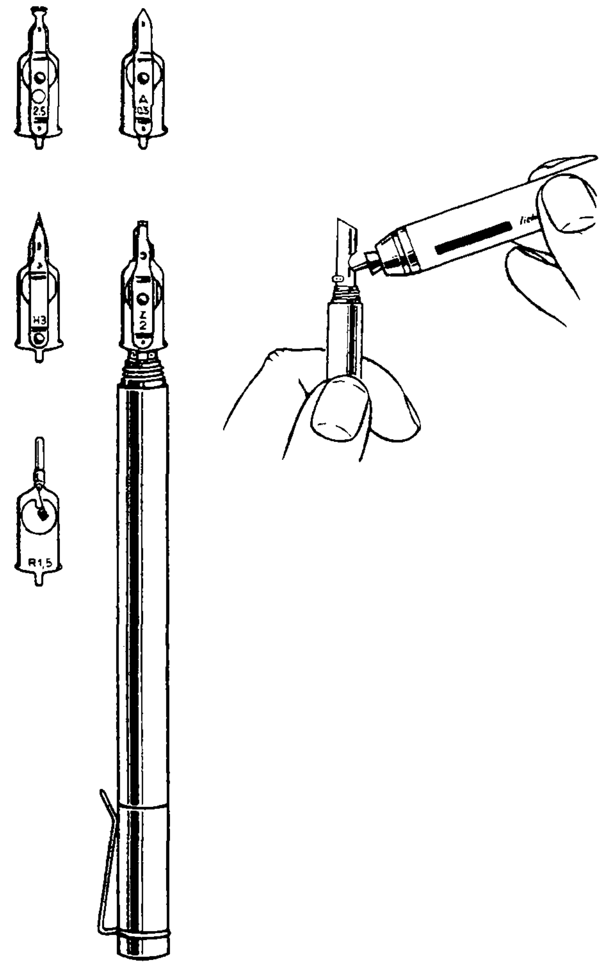
The old type of Ruling pen has frequently to be filled either by means of the dropper from the ink bottle, or dipping an ordinary freehand pen into the bottle and transferring the ink to the blades. It is better not to put much ink between the blades. Practice will indicate how much is satisfactory. The thickness of the line required is obtained by means of the adjustment screw and by testing at the side of the drawing paper or on scrape of similar paper.

DRAWING PENS

FOUNTAIN-PEN

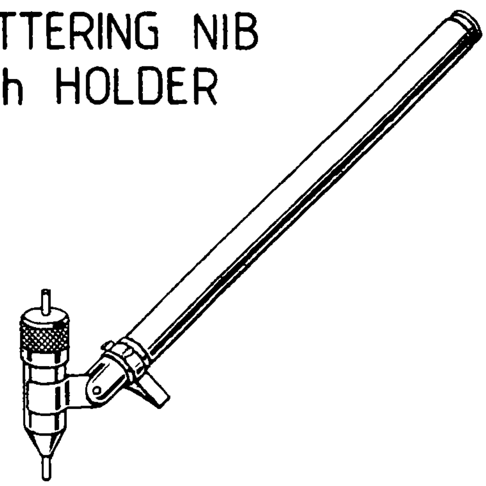


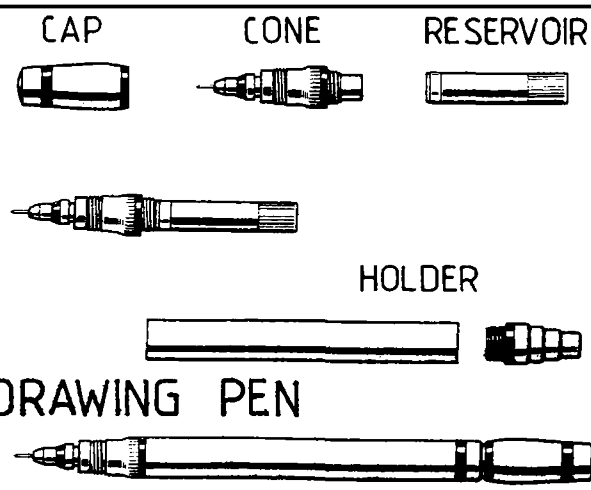
GRAPHOS



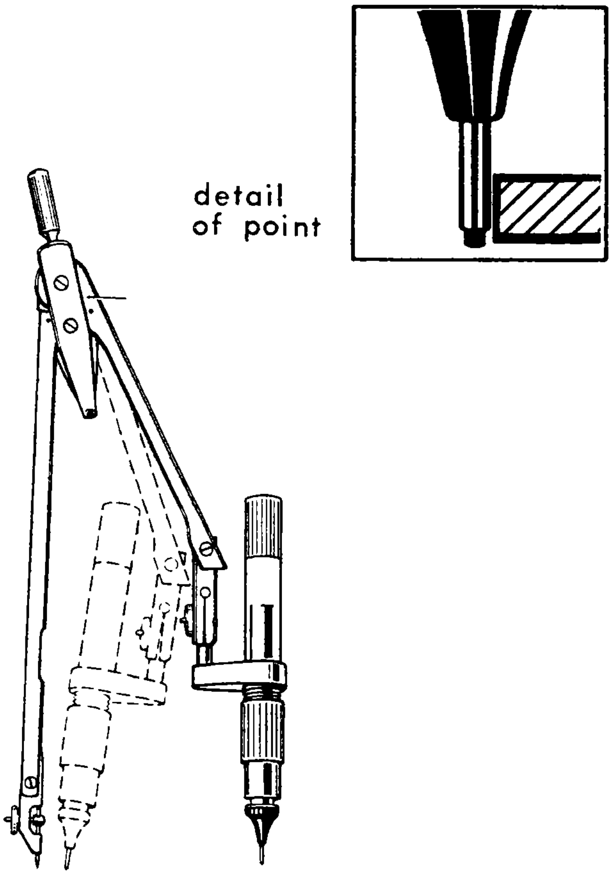
Graphos and Rapodographs are based on the fountain-pen principle, with ink reservoirs, so that they can be used for long periods without refilling. Interchangeable nips or drawing elements are used for different thick - nesses of lines. The most common set consists of 0,18, 0,25, 0,35, 0,7, 0,5 1,0, 1,4, (2,0) mm. The pens are also be used for free-hand drawing of lines and for freehand and stencil lettering. The graphos pen has special nibs for freehand lettering.

LETTERING NIB with HOLDER





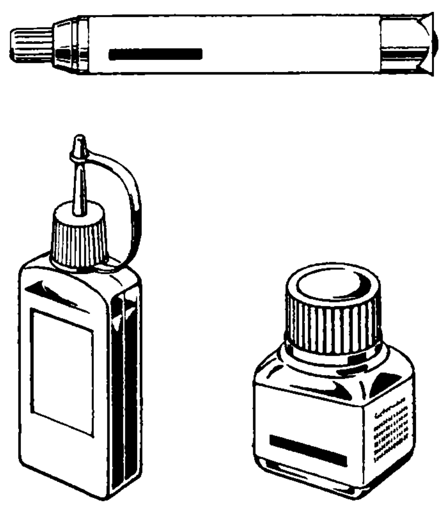
DRAWING PENS

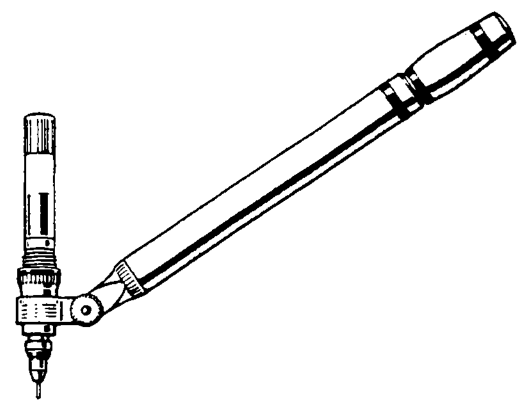


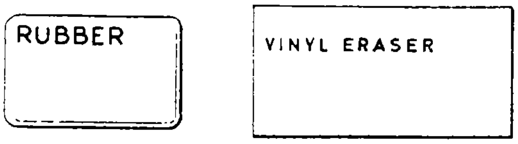
Drawing ink: Water proof black ink is used for line drawing. It can be taken from small glass bottles with dropper or pipette for filling ruling pens and other instruments, from plastic bottles for Rapidographs and similar pens, or from special cartridges for graphos pens etc.
Not all inks are suitable for the drawing pens described earlier or for the use on all kinds of film and the maker's recommendations should be followed.
Containers should always kept closed (exept when pens or instruments are being filled) to keep out dust and to lessen the risk of accidental spills.

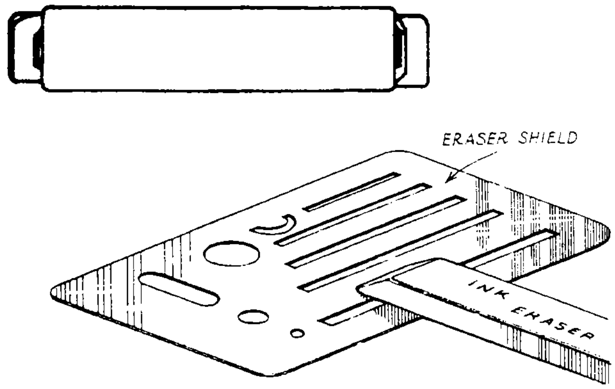
In warm weather it may be found that the ink will run more freely if it is slightly diluted with clean, preferably distilled water. Bottles should not be shaken once they are in use. Inks should never be mixed and dirty pens must not be used: Chemical action may be set up and the ink becomes lumpy.
Drawing inks are obtainable in different colours.

Instruction for use and care come with the pens and it is very important to follow these instructions, especially in regard to cleaning.Keep the pens always clean and do not allow them to become clogged or encrusted with ink, so that undue time has to be wasted in making them work.
All kinds of Drawing Pens should be held perfectly upright against the edge of T - square or set - square, and should be drawn smoothly with even pressure from left to right or in upwards direction.





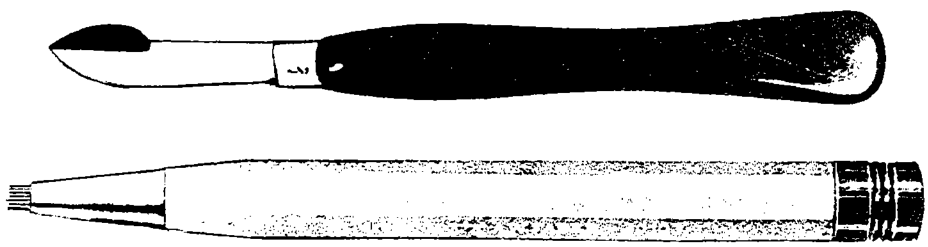




Erasers: Alterations, corrections, and the removal of unwanted lines are best made by rubbing with a soft rubber or vinyl eraser. Erasers should be large enough to be easily gripped, but very large rubbers last too long and, as the outside surface becomes hard and useless in time, it is probably better to keep to small sizes. When the surface of the eraser is affected, it can be cut away or, if not too bad, rubbed clean on an old scrap of paper.

For a large area of paper the so called gum eraser is probably quicker and more gentle to the surface. For removing soft pencil shading, which are smeared by on ordinary eraser, a special putty rubber must be used.

So called 'glass erasers' are generally efficient. They consist of a holder (metal or plastic) into which bristles of glass are inserted. A screw bottom operates a mechanism which enables the glass bristles to be withdrawn or fully protected as required. The main advantage of the glass eraser is that glass bristles are gentle to the surface of tracing paper, but they have to be handled carefully to avoid small particles sticking in your hand, which is quite painful.



Ink lines on drawing paper are removed by hard erasers. As usually only a small portion of an ink drawing has to be removed and the surrounding lives disturbed as little as possible, the rubbing can be don through a thin metal or celluloid rubbing shield, which has openings to suit areas to be erased. Lines on tracing paper are best removed by scraping gently backwards and forwards with a safety razor blade held vertically between finger and thumb.

Electrically operated erasers are sometimes installed in large drawing offices. The machine is suspended over the drawing table and is drawn down to the surface of the paper and a small motor rotates rapidly a piece of pencil rubber or ink eraser.

The small particles of rubber which result from rubbing out should be carefully removed from the surface of the paper by blowing or by lightly flicking with a clean, smooth DUSTER.

COMPASSES

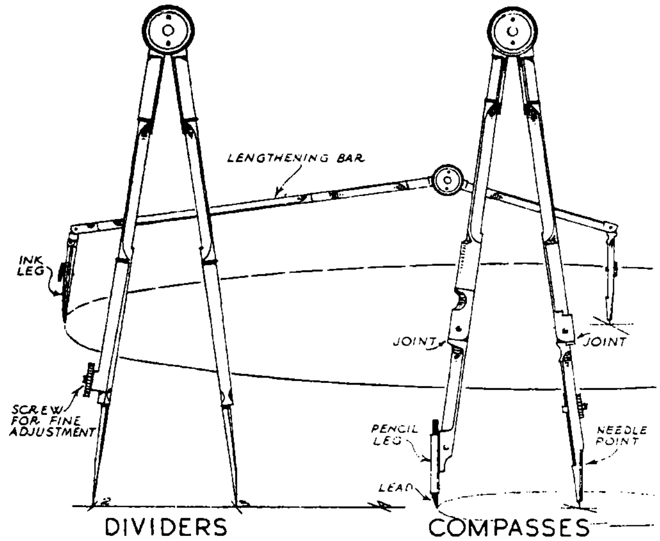
2.3 COMPASSES

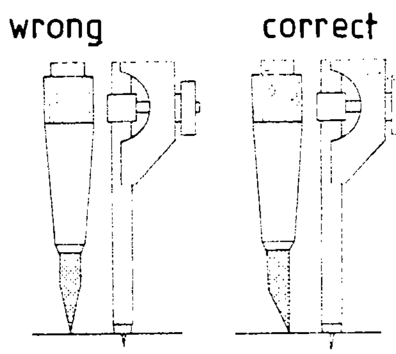
The fig. shows a common pattern of compasses, which are used for drawing circles and arcs. One leg terminates in a needle point and the other leg can be fitted with pencil or pen. An additional needle pointed leg can also be obtained for converting this instrument into a pair of dividers. For large circles and arcs a lengthening bar is valuable. Both legs of the compasses are jointed so that they can be bent to keep the point more or less perpendicular to the paper.

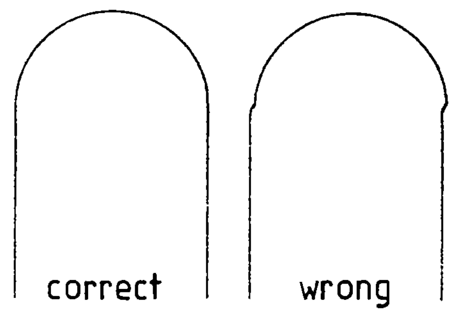
Needle points are removable and are usually shouldered at one end - this end is best for use in drawing circles, as the point does not penetrate the paper too far. The instrument should be held at the top and pressure must be only sufficient to keep the centre from slipping and to maintain a smooth, even line for the curve. The two points of the compasses must be carefully adjusted. The pencil lead should be the same grade as the ordinary pencil being used on the same drawing. A 12 mm length can be out from the bottom of the pencil for the purpose.

It should be sharpened to a fine chisel point and arranged tangential to the circumference, although for small circles a round point is probably better.

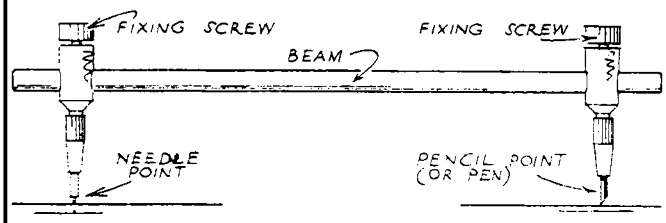
Pens are capable of ajustment in the manner of ruling pens. The thickness of.the ink line should be tested at the side of the paper before the required curve is drawn.
Special compass/pen attachments are available for use with the Rapidographs and with small pump compasses for drawing small circles.







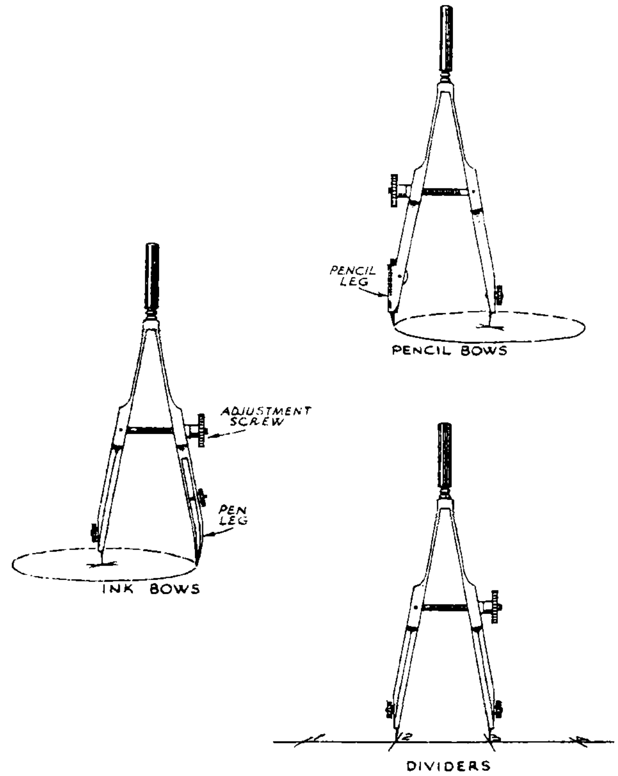
Beam compasses
For drawing larger circles than are possible with ordinary compasses and the lengthening bar, beam compasses can be used. They consist of a centre point and a fitting, with interchangeable pencil and pen legs, which are screwed to a bar to give the radius required.



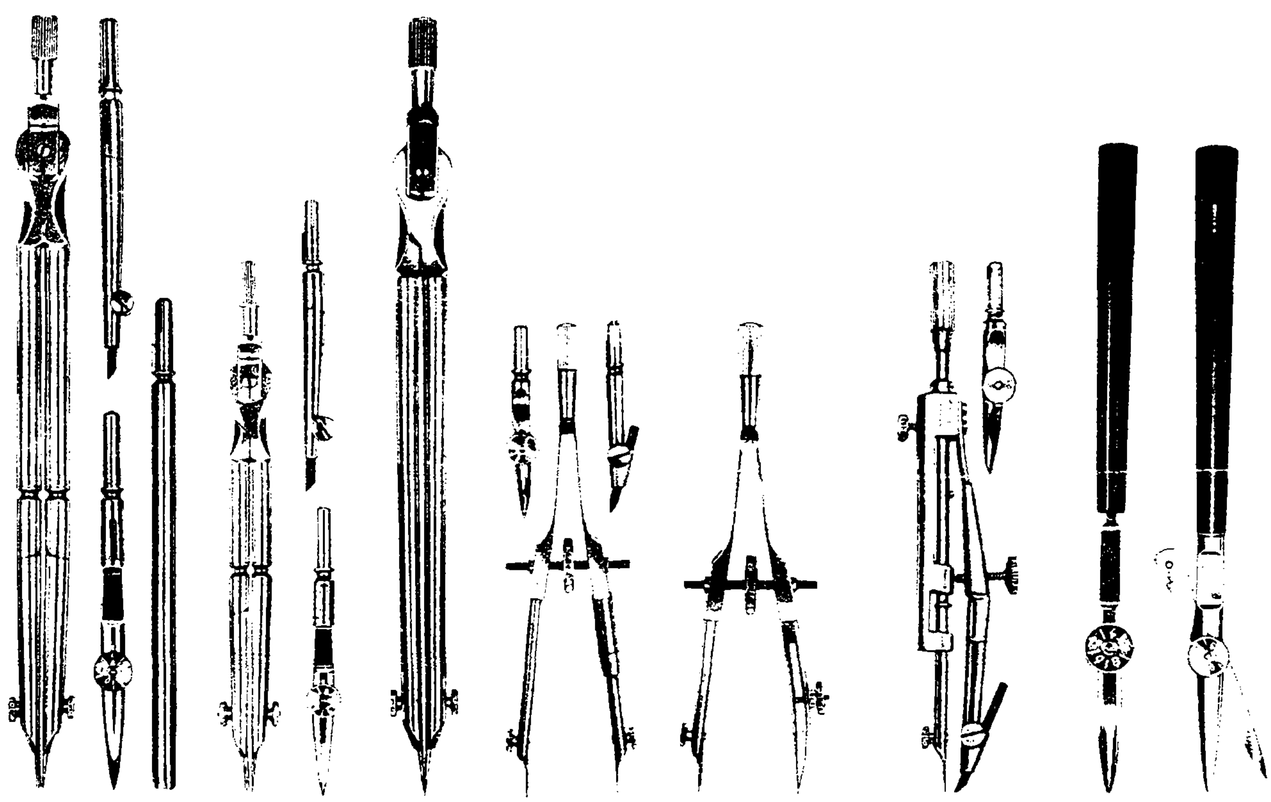
BEAM COMPASSES

Dividers
The fig. illustrates a pair of dividers used for dividing lines into equal units by trial and error and for multiplying or transferring distances. A convenient size is about 140 mm long. A spring screw attachment to one leg for fine adjustment is an advantage. This hinge should move easily but should not be loose.

Spring bows and pump compasses.
Small dividers and pencil and pen compasses for accurate and fine work are called spring bows. Adjustment is made by means of a screw either at the side, or in the middle at the instrument. There are a number of variations of theses instruments including precision - made pump compasses and rapid adjustment compasses. It should be mentiones, however, that for general work small circles and arcs are drawn through templates.



SPRING BOWS



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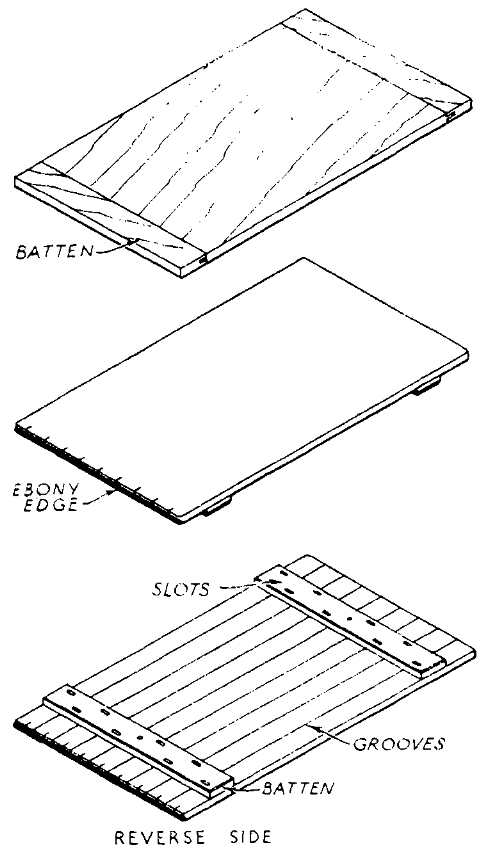
2.4 DRAWING BOARDS:

Drawing boards are made in sizes to correspond with standard sizes of drawing sheets. The most suitable for general use are:

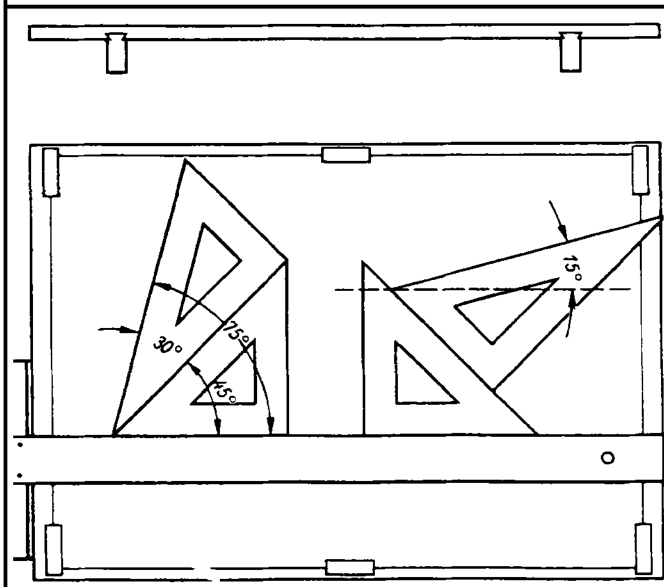
A 1 : 920 x 650 mm
A 0 :1270 x 920 mm

The fig. illustrates three types of drawing boards. Types A and B, not bigger than size A 1, are suitable for the student as they are light for carrying about and are relatively inexpensive. Such boards can be obtained with metal edges. Type C, which is best for office use, is usually made from spruce and has beech battens secured by screws in elongated washers to allow for expansion and contraetion. The back of the board is grooved to resist warping.
Small drawing boards accapting paper up to A 3 size are now becoming generally available. They are precision made with smooth plastic surface, are light and easily transportable and are often supplied with a carrying case. They are provided with positive sliding drawing heads or rules operating rather linke T-squares for drawing horizontal lines and with matching set squares multipurpose design. Alternatively, they can be fitted with miniature drafting machines. They usually have devices for holding drawing paper in position as pins or staples cannot be used and adhesive tapes tend to spoil the board.

DRAWING BOARDS



DRAWING BOARDS



It is important with all types of drawing boards that the faces are perfectly flat and smooth and that they will not twist or buckle with normal use. Edges should be at right-angles to one another. Wooden boards should have a firm even grain, free from knots and should be soft enough to take drawing pins or staples easily and allow the removal without diffeculty. Boards with compostion surfaces can have paper attached by means of spring clip or strips of drafting tabe.

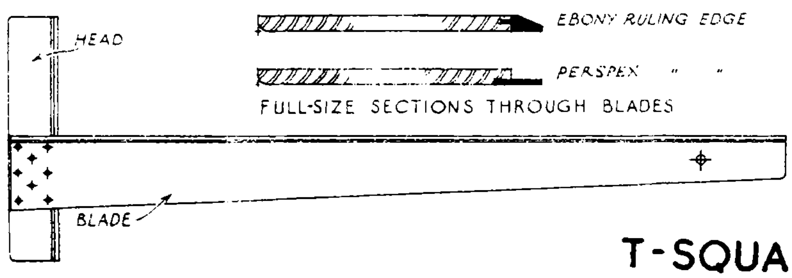
T-SQUARES

2.5 T-SQUARERS

Are used in conjuction with the board for drawing horizontal lines. The head of the T-square being held against the left hand side of the board by the right handed person (reverse T-squares are made for the left handed draughtsmen). Sizes correspond to the lengths of the drawing boards:

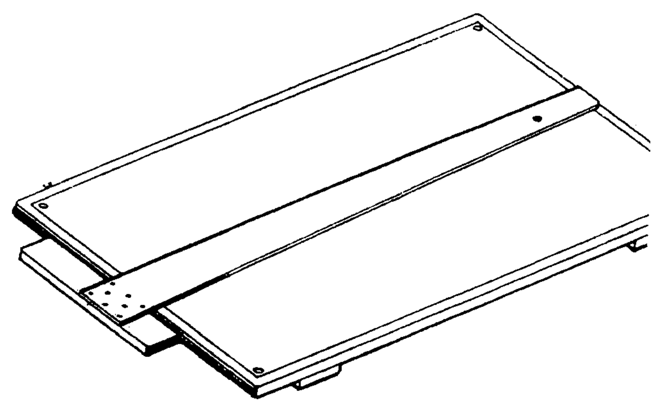
A 1 920 mm blade
A 0 1270 mm blade

T-squares are best when made of mahogony with ebony or clear plastic ruling edges or of clear or coloured plastics. For lightness blades have to be made of thin strips of wood (plastics), but this renders them liable to fracture. Therefore: Dont leave them lying about in bridge positions or leaning against walls.
They should either be left flat or hang on pegs.



T-SQUARE

- Dont use a T-square as a hammer to knock in drawing pins, a loosing of the fixing between head and blade will be the result.
- Dont use the blade as a straight edge in cutting paper in order to avoid indentations along the ruling edge.
- It is important to keep the underside of the blade smooth and clean, and this is best achieved by wiping it periodically with a soft cloth with a few drops of petrol or similar spirit. Water can be used, but is less effective and may cause warping.



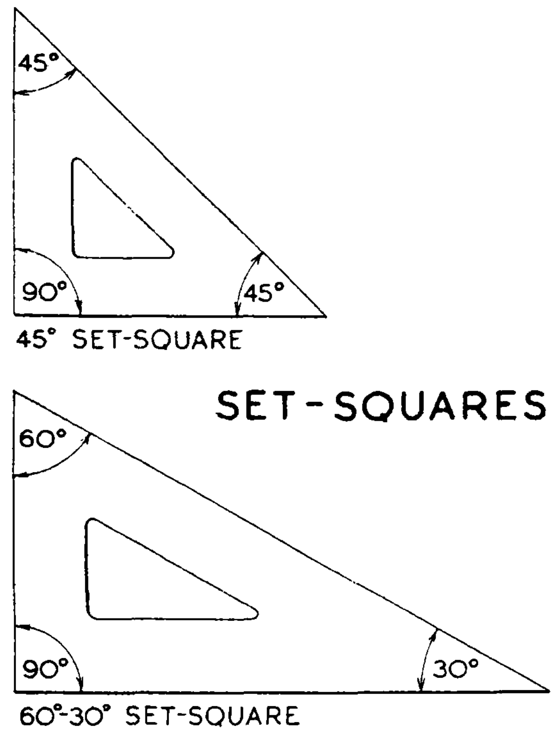
2.6 SET SQUARES

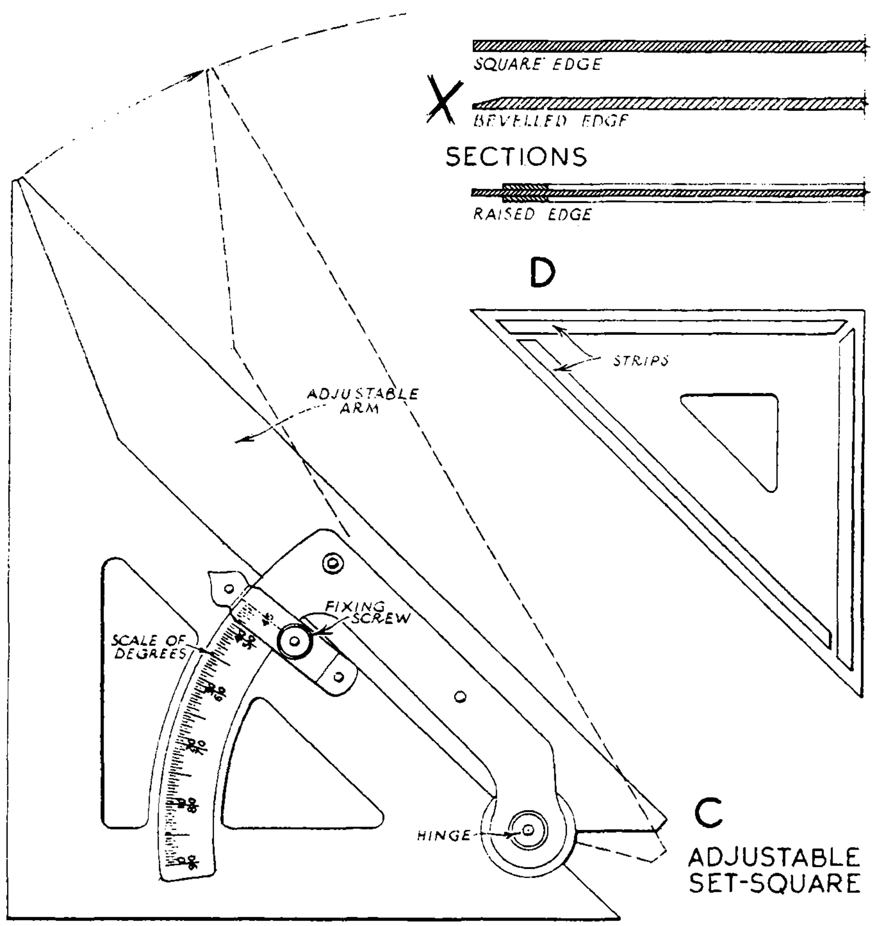
Set-squares are used for drawing vertical and inclined lines. They are triangles of clear plastic about, 2mm thick, and there are three basic kinds as illustrated:

A - 45 degrees
B - 60 - 30 degree
C - adjustable

For general use the length of the longest side should be about 250-300 mm and the edges should be square.

Set squares to be protected from damage. Dents are caused by hard knocks and cutting with a razor blade, etc, along the edge can easily ruin them. They should be kept clean, because dirty set squares quickly transfer the dirt to the drawing.



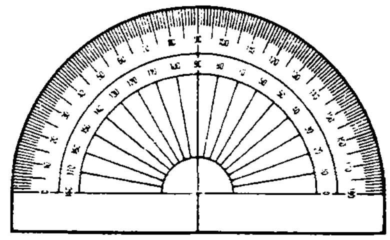


2.7 PROTRACTORS

A protractor is used for measuring or for setting out angles. It is a semicircular (or circular) piece of metal or clear plastic with the arc divided into degrees, reading both to left and right, and with the centre and diameter indicated. The protractor is placed so, that the centre coincides with the apex of the angle and the diameter lies along one line the position of the other line on the scale giving the reading.

The most convenient sizes have diameters from 100 mm to 150 mm. The transparent protractor is to be preferred.

PROTRACTORS



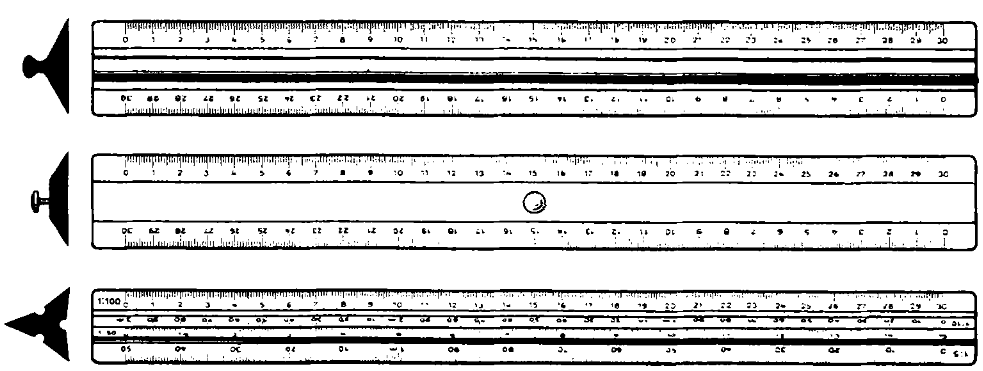
2.8 SCALES

Scales are thin narrow strips of plastic or boxwood with divisions along each edge. These divisions are in various recognized proportions to actual destances and dimensions, and can be used for making new drawings 'to scale' of for measuring, by 'scaling' existing drawings. There are scales available for metric drawings as well as for drawings in which drawings are related to feet and inches.

Now commonly used by architects and draughtsmen are three edge scales with divisions along each edge in the proportion of 1:1 or 1:10/1:100, 1: 200, 1:5/ 1:50, 1:250/1:2500 and others.

Scales are usually 300 mm long. They never should be used for ruling lines or for any other purpose for which they are not intended, the edges are soon chipped and broken.

SCALES

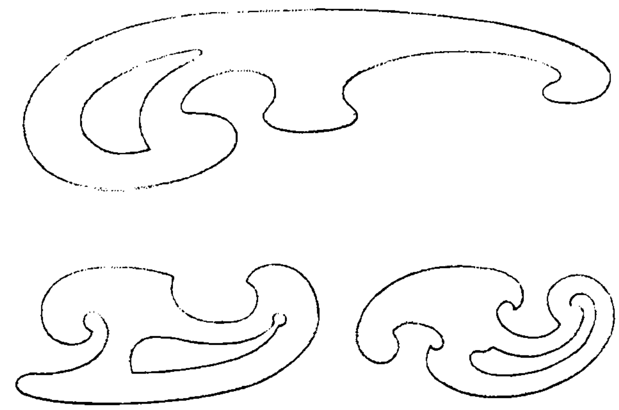


2.9 FRENCH CURVES

French curves are made of clear (or coloured) plastic like set-squares. They can be used for drawing irregular or complex curved lines which cannot be conveniently made up of arcs of circles. Many shapes are available, but one is usually sufficient for architectural drawing. They are not essential, and with practice curved lines can be drawn freehand more rapidly and often with better effected. Long slow curves can be drawn by a series of blended straight lines with acceptable accuracy.

Another device is the flexible ruler consisting of a length of pliable plastic which can be bent to any required curve. Patience is needed to get the correct curvature, but once set the ruler is particularly useful for repetition work.

FRENCH CURVES



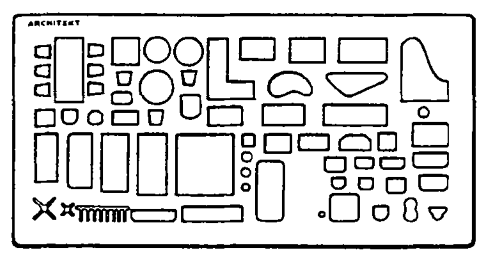
2.10 TEMPLATES

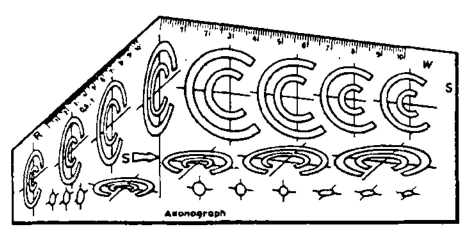
Small circles and ellipses, or parts there of, can often be more easily drawn with the help of plastic templates, which are available for figures of various metric and imperial sizes. There are also special templates available such as Symbol templates for:
- Electrical installation
- Plumbing work
- Furnitures in different scales (1:200, 1:100, 1:50) etc.

The main advantage of these templates is saving time.

Lettering guides, stencil-lettering, transfer-lettering. These are described later under LETTERING.

TEMPLATES





FIXINGS

2.11 DRAWING PINS AND OTHER FIXINGS

Small, flat - headed pins are best for fixing the paper to the board in most cases. They should be well made of brass with sharp round points. The type with the point stamped out of the head is of little use.

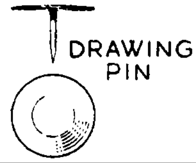
As the heads should hold the paper, the pins must be pressed well into the board. Four pins, one at each corner, should be sufficient if put in about 10 mm from the edge of the sheet. Whenever a drawing is repinned the previous pin-holes, unless enlarged or torn, should be used again. Pins can usually be taken out easily by finger and thumb-nail but the blade of an old penknife can be inserted under the head to rise it up in the case of a stubborn one.

Other means of holding the paper to the board are spring steel clips, staples, and drafting tape. Clips are not always secure and sometimes get in the way of border lines, etc. Staples (the smalles tsize is best) are quick and convenient for fastening the paper and do not interfere the running of T - square and set square, but are a nuisance to get out. Drafting tape tends to be an intidy and rather messy fixing method except for short term use. For holding one piece of tracing paper over another, especially where the piece is relatively small and pins cannot be used because they would damage the sheet below as well as get in the way of T-square and set-square, transparent self adhesive tape, such as sellotape, is most suitable as it can be placed away on completion without effecting the paper.

MINOR ITEMS

2.12 MINOR ITEMS OF EQUIPMENT

In addition to the essential equipment already described the following should be readily available for use as the need arises:



- A good pair of scissors. Cutting knives for thick card and a lighter knife, of which there are many kinds, for thin cardboards and paper. In this connection, a metal ruler or straight-edge is useful.

- A piece of cotton-cloth often washed or soft toilet paper for cleaning drawing pens etc.

- A handy scratch pad for notes, memos, rough calculations, testing pens, etc.

- Provisions for the safe-keeping or transporting of drawings.

- Soap, towels and a hand wash basin with water.

PRINTING PAPERS

2.13 PRINTING PAPERS

Printing papers are used for making copies of drawings by photocopying processes. Copies are usually referred to as 'Prints'.
There are different types of photocopying processes (semi-dry dyeline or dry developed by ammonia gas). They all require a transparent or translucent negative e.g. a drawing or tracing media. This is passed in contact with diazo paper sensitive to ultraviolet light, through a machine in which it moves around a special tubular lamp emitting such light.

Where no machine is available the so called 'sun-print' method can be used. A timber or metal frame in accordance with the size of the drawing, covered with glass, the negative, printing paper, and sun: thats all you need for that method. For developing the same method is used as with a printing machine depending on the type of printing paper.

Dyeline prints can be made on different type of papers e.g. on airmail paper, which is very flimsy and difficult to

TRACING PAPERS

2.14 TRACING PAPER, CLOTH AND FILM

These materials are specially treated paper and linen, and polyester film of transparent or semi-transparent nature; when placed over an original drawing they allow the lines underneath to be clearly seen and so copied or traced. The tracings thus made can then be used as negatives for the making of any number of further copies by the photo-printing processes. Drawings can of course be made directly on the materials in question. Almost all production drawings are negatives of one kind or another.

Tracing paper is most economical if purchased in rolls, but for final drawings it is increasingly the practice in offices and in schools of architecture to use pre-cut sheets in the A-sizes, often with printed border lines, title blocks, and sometimes modular or other grids, etc. Tracing paper can be roughly classified into three categories. thin, medium and stout, and two surfaces: smooth and rough. Different makes vary, however, so that it is difficult to particularise as to the most suitable; personal preference plays some part in selection. Thin papers are usually good enough for preliminary sketches but are too flimsy for final negatives.

Smooth surfaces are best for pencil drawings, as the rough kinds wear down the leads and tend to smudge and smear. For roughing out design and many other uses rolls in short widths are handy.
Tracing cloth is nearly always supplied in rolls, although short lengts can be purchased. The material is usually tinted blue, but white is also available. It is much more expensive than tracing paper, and is used mainly for master negatives in ink, but to a lesser extent than formerly as it is being superseded by film. Film is also expensive but has superior transparency and is stated to be stretch-proof and waterproof. It should be used in accordance with the manufacturers recommendations, for example in regard to type of backing sheets, prepartion before inking, and use of erasers.

BACKING SHEETS

2.15 BACKING SHEETS

Drawing boards should be covered with backing sheets, over which the actual drawing paper or tracing media is placed to provide a firm, even working surfaces. This is particularly important if boards have become pitted, scored, damaged or worn.
Thick white cartridge paper is a satisfactory material, cheap enough to be discarded as it becomes soiled drawing pins can be used. Other and harder materials for backing sheets of a semi-permanent nature are thick, flexible plastic sheets usually with a green surface and cellulose-acetate sheets, which can be printed to standard lay-outs and grids.
In connection with backing sheets, a useful device to minimise the marking of drawings by rubbing of the T-square is the fixing of a strip of folded drawing or tracing paper - three or four thicknesses are sufficient - about 20 mm wide along the left-hand edge of the board. Fixing by drawing pins or staples at the ends only is best.

Drawing boards with an integral plastic surface do not normally require backing sheets, but for working on tracing paper a white under sheet is an advantage.

DRAWING PAPERS

2.16 DRAWING PAPERS

There are two main classifications of drawing papers: 1) machine-made papers, such as cartridge, which are used for exercises and line drawings, and 2) handmade or mouldmade papers used for rendered drawings. Mention is made of other types of paper, where necessary, in later chapters.

CARTRIDGE

2.17 CARTRIDGE

This is sold in rolls and A-size sheets, including pads of 30 sheets up to A2 size, as well as in the old standard sizes of antiquarian, double elephant, and imperial.
The paper is made in three thicknesses: 'thin', 'medium', and 'stout'. The thin is usually too flimsy to be of much value, it is also obtainable in rolls either unmounted or mounted on cotton or holland. The rolls can be conveniently cut into the various standard sheets or used for extra large drawings, and are probably more economical for the busy office.

Unmounted cartridge paper has right and wrong sides which can be distinguished by examination - the wrong side has a slightly but regularly pitted surface, and the cut edge of the sheet is usually turned down towards the wrong side.

The surface is fairly satisfactory for pencil drawing and the 'stout' quality will take ink moderately well, but it is not really suitable for colour washes except those of a most limited nature. White cartridge paper, which is usually of better quality, is to be preferred to that which is cream in colour.

HANDMADE PAPERS

2.18 HANDMADE AND MOULDMADE PAPERS

These are obtainable in sheets of standard sizes, and usually in three surfaces: HP (hot pressed) - smooth; NOT - medium; R - rough. The firstnamed is the kind most used for pencil and ink drawings and various types of renderings, particularly work in wash. All the papers can be 'stretched' and some can be obtained already mounted on stiff card or board. Water colour paper is also sold in pads.

PLASTIC-COATED CARD

2.19 PLASTIC-COATED CARD

For particularly fine pencil line and pen and ink drawings some draughtsmen prefer an extremely smooth plastic-coated card, such as CS 10. Great care is needed, however, in working with thi medium as ink lines are easily smudged. Any removal of lines must be made by gently rubbing with a soft eraser.

handle, on medium paper, which is normal and suitable for general use on stout paper which is the best for mounting, colouring and presentation and cotton-backed paper.

Master copies or new negatives, from which further copies can be made, can also be produced on tracing paper, tracing cloth and polyester-based materials. Such copies are used for the adding of specialist information, as a basic for the preparation of working drawings and for supplying remote sites with means of obtaining local reproductions. All dyeline prints tend to fade on long exposure to daylight.

Mention may be made here of other methods such as: -

- true - to - scale (TTS)
- photostats
- microfiling of drawings
- various kinds of ordinary office coppies: thermographic, electrographic and diffusion transfer. Although these types of copies are developed for the copying of typed or printed documents they are excellent for the rapid copying of small drawings - or large drawings in parts which can be subsequently joined. For paper sizes (up to A 1) the dyeline process should be used.

3. LETTERING

3. LETTERING

Little progress can be made in draughtsmanship without attention being paid to lettering. Almost every drawing has to be titled and many of them, particularly working or production drawings, require descriptive words and notes in order that they can be clearly understood.
Therefore, it is important for the draughtsman, to aquire as quickly as possible the habit of using good lettering on all his work.
And as the study of lettering also affords excellent practice in drawing, it is particularly suitable that it should be dealt with at an earlystage in the training.

PRINCIPLE of LETTERING

3.1 Principle of lettering:

1. Legibility
   depends on
   a shape or form of each individual letter
   b spacing of letters and arrangement of words
   c the size and positions of the lettering according to relative importance.

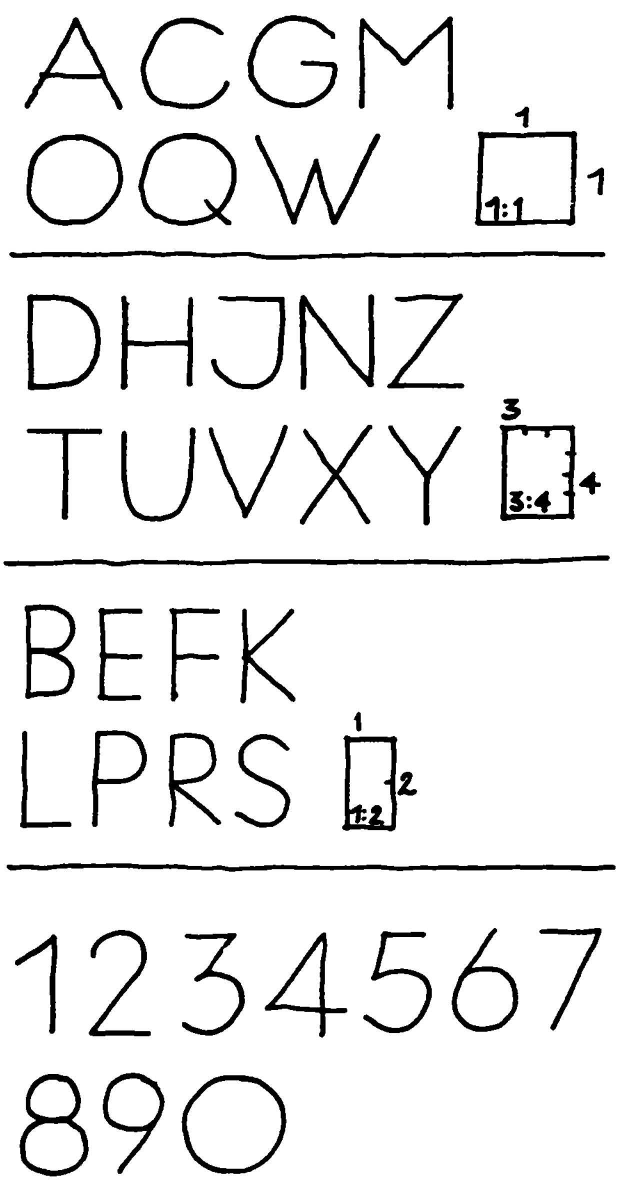
2. Suitability
   of shape to materials and method of execution, thus, lettering drawn in pencil on paper will differ in form to some extent from lettering incised in stone.

3. The Character
   must be appropriate to its purpose. The type of letters and general composition of the wording should be expressive of the quality or use of the drawing, e.g. decorative lettering is completely out of place on a working drawing, just as crude stencil lettering would be on a highly finished perspective drawing.

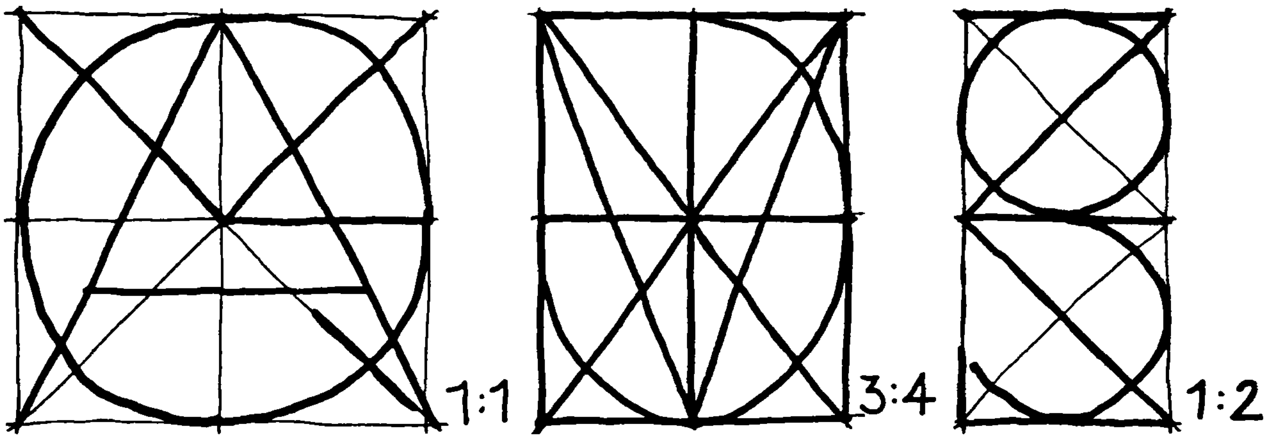
FREEHAND LETTERING

3.2 FREEHAND LETTERING

Absolutely sufficient for Architectural Drawings are 'block letters' with simple, vertical letters, represented with straight lines, circles or parts of circles. Important are the proportions of the letters which are described in the following scheme.



In the following please find som explations how to draw or to write capital block letters:



A take the area of a square. The horizontal stroke should be in the lower third. Other forms look too wide or too thin.

B Should be inwritten into two squares, which are on top of each other. The roundings are parts of a circle.

C consists of a three quater (3/4) part of a circle

D has to be drawn in a full semi-circle

E again should be in written into two squares, which are on top of each other.

F is equal to E, without the horizontal bottom stroke. Both remains horizontal stroke should have the same length.

G has almost the shape of a circle. The horizontal stroke has to be drawn from the centre of the circle to the external line on the right hand side.

H is in-written in a rectangle with the proportions of 3:4. The horizontal line should be drawn right in the centre.

I is only a vertical line without any additions.

J is again in-written in a rectangle with the proportions of 3:4. The lower rounding consists almost of a semicircle.

K fits in an area of 2 squares, one on top of each other. The inclined strokes are drawn from the centre to the top and the bottom under 45^0.

L this horizontal stroke is half as long as the vertical line

M takes again the area of a square. It has to be taken care, that the lines at the left and the right are exactly vertical.

N is to be in-written in a rectangle with proportion of 3:4 three to four.

O has to be drawn as a full circle not oval or in the form of an ellipse.

P has a proportion of two to one, the upper part is drawn as a semi-circle with horizontal parts at the top and the centre of the vertical line.

Q is written like an O the inclined stroke has to be added under 45^0 in the right hand bottom corner.

R is similar to P from the centre of the letter an inclined stroke under 45^0 has to be added.

S is a difficult letter. It may help you to draw it, if you imagine that S is constructed out of two circles, one on top of each other, and which lines are not completely closed.

T fits in a rectangle with the proportion three to four.

U consists of a semi-circle at the bottom, the two ends extend in vertical lines.

V again fits in a rectangle with proportions three to four.

W draw V twice next to each other, fitting in a square.

X
Y all have to be drawn in a rectangle with proportions of three to four.
Z

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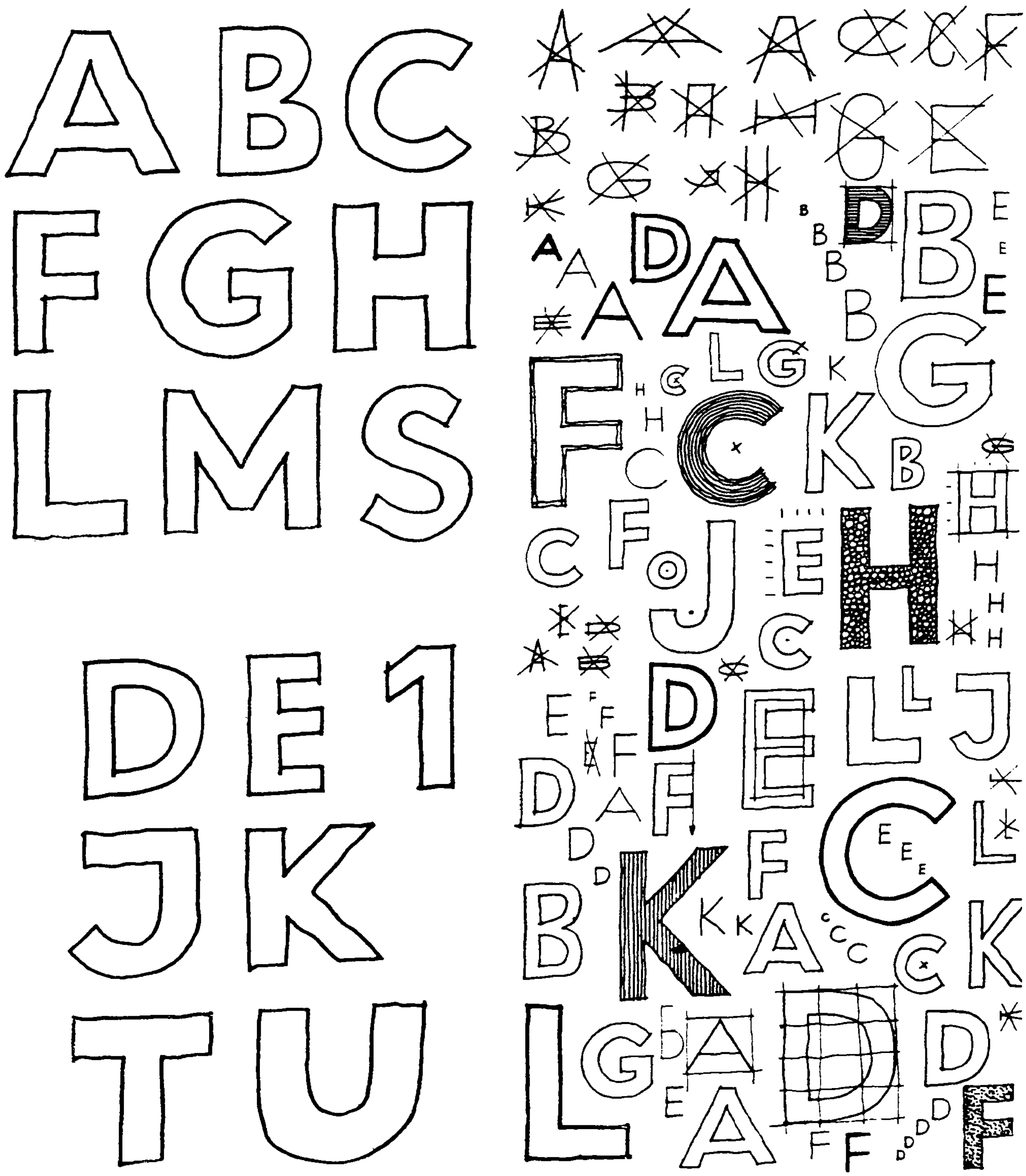
JUNE '83		CET 1o43/13.2 19

FREEHAND



LETTERING

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Writing numerals we have to follow the same rules, their elements are straight lines, circles and parts of circles.

1 The small inclined stroke should never be horizontal, otherwise it could be mixed up with 7.

2 Is in the upper part a semi-circle which continues as a inclined line under 45° downwards.

3 Is only in the lower part a semicircle the upper parts consists of an inclined stroke under 45° with a horizontal stroke on top.

4 ends at the top as a triangle

5 the upper stroke on the left hand side has to be drawn exactly vertical, other wise it might be mixed up with 3

6 + 9 should be drawn as full circles with an tangential inclined stroke under 45° up or downwards.

7 it is advisable to draw a short horizontal stroke crossing the inclined line at the centre, in order to avoid a confusion with 3.

8 consists of 2 full circles, one on top of each other

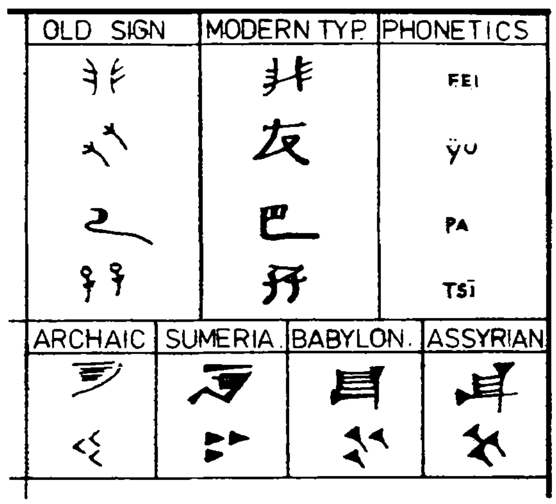
ROMAN

Practicing capital block lettering, always try avoid inclined letters or unnecessary decorations. The same passes for the numerals.

TYPES OF LETTERS

3.3 TYPES OF LETTERS

Writing is a sort of 'language of sings' and it serves the purpose of fixing informations. About 5000 years ago people in China, Mesopotania and Egypt have started to write down their informations. As letters, they used signs and symbols. Later on these sings and symbols have been changed to letters and numerals of different types and even the types of letters and numerals have been modified up to the present day.

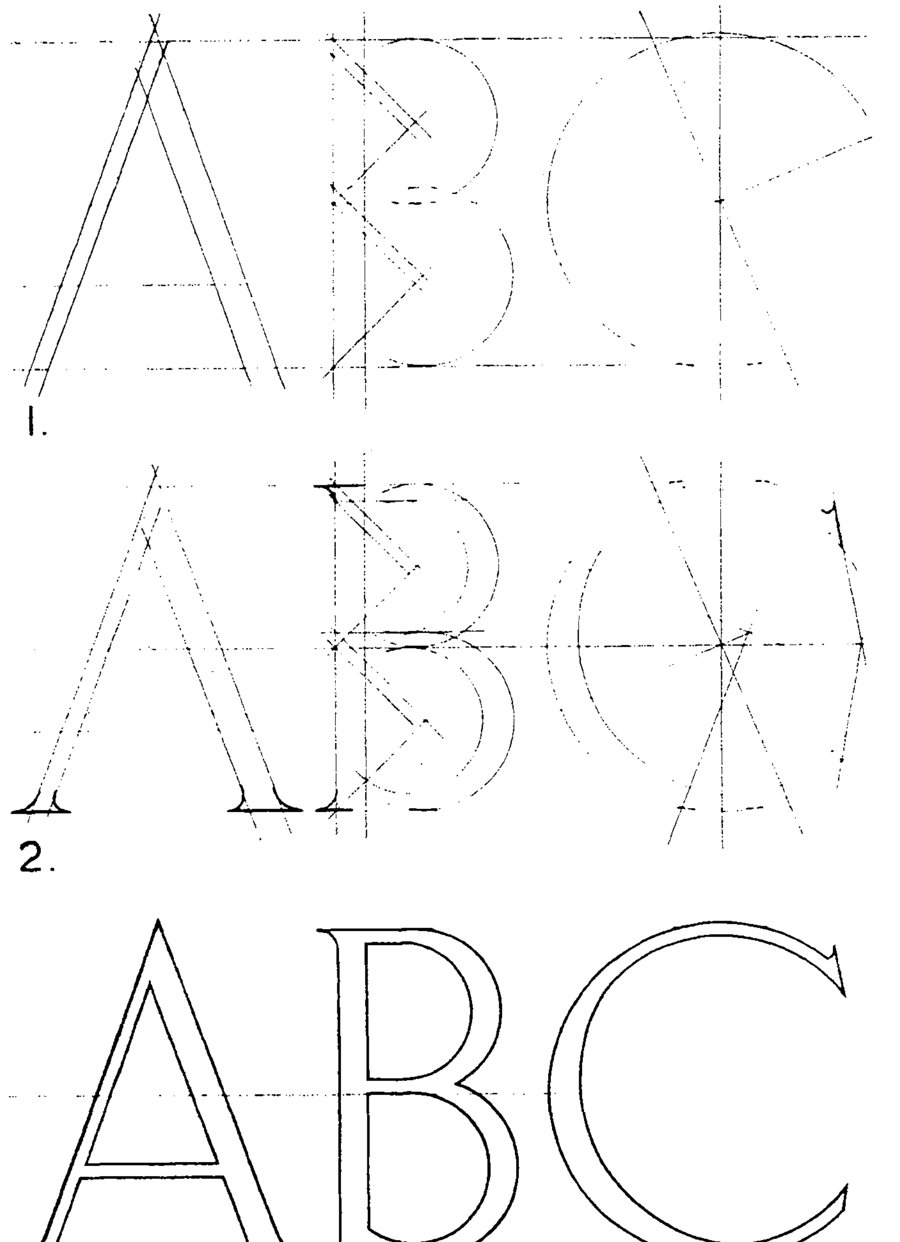


3.3.1 THE ROMAN ALPHABET

In architectural drawings the historical types of letters should not be used except for special purposes, e.g. as decorative lettering in perspective drawings or for titeling in stock-taking drawings of historical buildings. However, there is one alphabet in the history which should be studied carefully. Our modern lettering is derived from that of the ROMANS, and the generally accept as standard is the lettering which was carved on Trajan's Column, Rome, in the second century. A.D. The forms of these letters have now become familar in printing types and flat letters, and the Roman alphabet will always be the basis of good lettering.

The construction of each letter is shown and should be understood:

STAGES IN SETTING UP



ROMAN LETTERS

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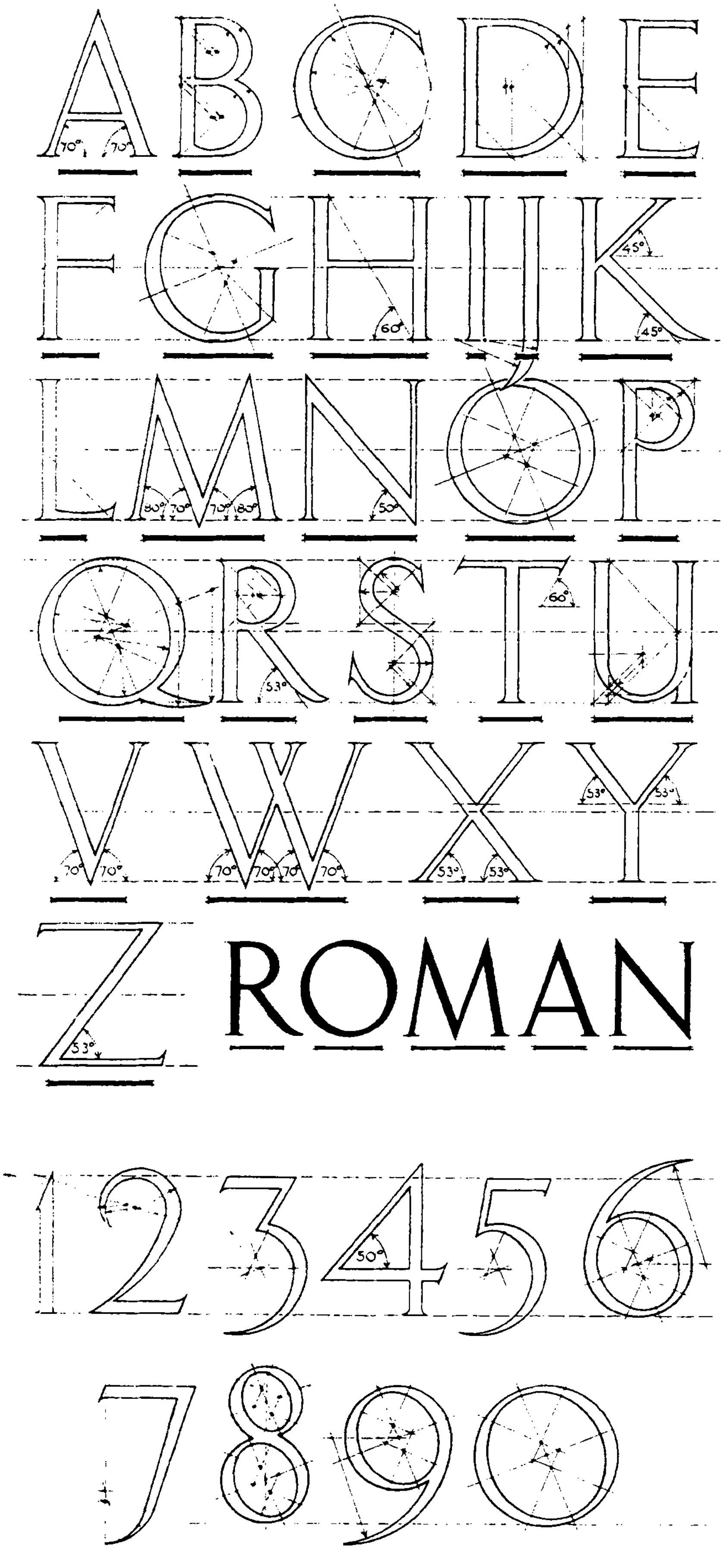

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3.3.2 SANS SERIF LETTERS

In more recent times, letters without serifs, known as 'sans serif alphabets' have been designed and are much used because of their simplicity, clarity and ease of execution. The fig. shows the setting-out of such an alphabet, suitable for the titling of drawings, etc.

3.3.3 INCLINED LETTERING

Sometimes it is necessary to distinguish between two types of lettering, e.g. names of rooms on plan and notes regarding construction. While this might be effected by variations in size, it may be more convenient to use upright lettering for the one and inclined lettering for the other.

The fig. shows inclined lettering sloping uniformly at an angle of about 75 degrees. The slope should not be exaggerated.

3.3.4 SCRIPT LETTERING

The figure shows individually formed capitals, numerals and lower case letters which can be written in pencil or pen. If well executed it is an attractive way of labelling certain types of project presentation drawings.

3.3.5 STENCIL LETTERING

Stencil letters can be used for titling drawings and are a means of achieving uniformity at negligible cost when a number of drawings are similarly titled. The fig. shows an example and how a stencil is used. Special stencil ink can be used or indian ink or opaque colour, etc. The brush must be almost dry, and the plate must be held down perfectly flat and firmly for good results. The description 'stencil lettering' is also commonly applied to guided pen lettering.

3.3.6 GUIDED PEN LETTERING

The figure shows examples of the leters produced by means of special pens and guides. Such lettering is used extenslively for drawings of all kinds, particularly working drawings and details. Its popularity is due to its legibility, speed of execution, and the uniformity which it gives, especially when different draughtsmen are working on the same set of drawings.

Both upright and sloping guides are obtainable for capital, lower-case letters, and numerals in a variety of sizes with corresponding pens. Also drawing pens like 'graphos' or 'rapidographs' can be used.

Used carelessly, this lettering is as bad as the worst freehand and a certain amount of practice is necessary to obtain lettering which is pleasing in appearance as well as very legible.

A few hints are
1) only a small quantity of ink should be put in the pen,
2) keep the pen perfectly upright in use,
3) wash the pen out immediately after use and see that the wire is pushed well home
4) keep the guides clean, do not let the ink clog the letters. A special cleaning liquid can be obtained for pens and guides.

Always rule faint guide-lines for letters and consider the spacing before starting. Sometimes it may be advisable to make a trial setting-out.

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ABCDEFGHIJKLMNOPQ
RSTUVWXYZ 1234567890

INCLINED LETTERING

ABCDEFGHIJKLMNOPQ
RSTUVWXYZ 1234567890
abcdefghijklmnopqrstuvwxyz

ABCDEFGHIJKLMNOPQ
RSTUVWXYZ 1234567890
abcdefghijklmnopqrstuvwxyz

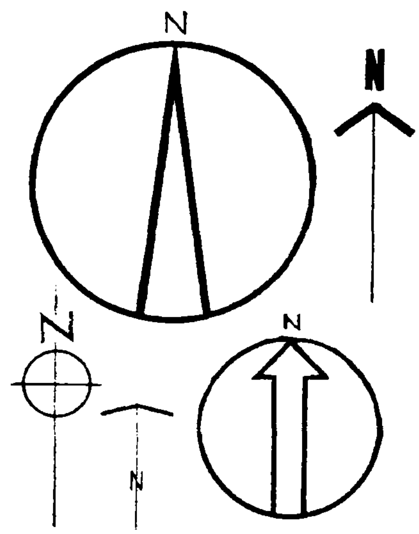
SCRIPT LETTERING

NOTES

GENERAL NOTES SHOULD NOT BE SCATTERED OVER THE DRAWING BUT SHOULD BE NEATLY ARRANGED IN PANELS OF REGULAR SHAPE

THEY SHOULD BE BROKEN INTO PARAGRAPHS FOR EASE IN READING

THE LETTERS AND WORDS SHOULD NOT BE CRAMPED NOR S O W I D E L Y SPACED AS TO BECOME ILLEGIBLE



TYPICAL NORTH POINTS

AD I	LETTERING	ARCH. DRWNG.
compiled : D.VOLKE		LECTURE
JUNE '83		CET 1o43/13.326

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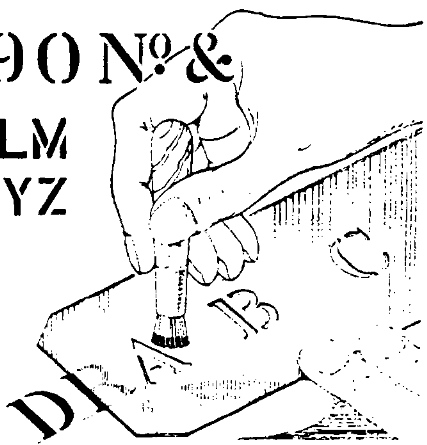
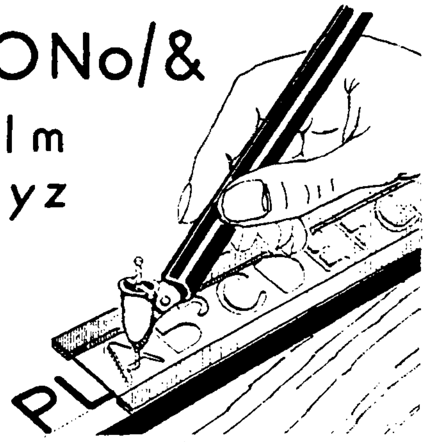
ABCDEFGHIJKLM
NOPQRSTUVWXYZ
1234567890 №&

ABCDEFGHIJKLM
NOPQRSTUVWXYZ
1234567890 №&



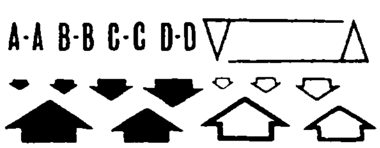
STENCIL LETTERING

ABCDEFGHIJKLMN
OPQRSTUVWXYZ
1234567890No/&
a b c d e f g h i j k l m
n o p q r s t u v w x y z
1234567890No



GUIDED PEN LETTERING

A A A B C D D E E E E E
1 1 1 2 2 3 3 4 4 5 5 6 6 7
ELEVATION SECTION BASEMENT
A-A B-B C-C D-D



******

guide line

AAAABBCCDDDE
AAAABBCCDDDE
AAAABBCCDDDE
AAAABBCCDDDE
IIIIJKLLLM

PRESSURE TRANSFER LETT.

AD I	LETTERING	ARCH. DRWNG.
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JUNE '83		CET 1o43/13.327

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3.3.7 PRESSURE-TRANSFER LETTERING

This kind of lettering, also known as pressure sensitive, is extensively used on all kinds of architectural and planning drawings, particularly for titling and labelling. It is reasonably quick and most effective. It's only serious disadvantage is that it is rather expensive, especially as many letters of each sheet are never used.

The letters are printed on thin plastic sheets, usually 254 mm x 381 mm, although smaller sheets are available, in a variety of types of alphabets, numerals, punctuations, etc. and are protected by silicon-treated backing sheets. A typical example is illustrated. The characters can be applied to any smooth dry surface in any desired arrangement. Having decided on the type and size of letters to be used and estimated the placing on the drawing - this requires some experience - the technique of application is to remove the backing sheet and to position the first letter, on a previously ruled guide line if there are to be a series of letters, and then to shade across the letter from top to bottom using a ball-point pen with moderate pressure. This action is continued until the letter appears lighter, which shows that it has been transferred to the surface of the paper. The lettering film is carefully peeled back until the letter is exposed, it is then moved to position the next letter and the transfer procedure is repeated. On completion of a word, or every few letters, even after each letter of the larger sizes, the backing sheet should be laid over and additional firm pressure applied by the finger or the edge of a scale in order to obtain maximum adhesion. When application is made to tracing paper or film from which dyeline prints are to be obtained it may be necessary to spray the letters with a matt fixative or they will be damaged in the printing process. As the spray will also 'fix' any parts of the drawing on which it may fall, it is advisable to vonfine the area by masking.

Points continually to be kept in mind are: avoid accidentally pressing any other letter when making a transfer; keep sheets flat and unfolded and uncreased in a box, wallet or stout envelope away from excessive heat or humidity when not in use. However, the accidental transfer of a letter to drawing or tracing materials is not usually a serious matter as it can be removed by scraping gently with a razor blade. Incomplete letters can be patched by applying part of another letter or can be made good in indian ink.

Complete words such as PLAN, ELEVATION, EAST, WEST etc. at a size suitable for the majority of production drawings, are available, as are N points, direction arrows, section lines, electrical symbols and other useful architectural characters.

4.LINEWORK and DIMENSIONING

4. LINEWORK AND DIMENSIONING

4.1 Types of Lines
In architectural drawings five different types of lines are broadly used:
1. continuous lines
2. broken lines
3. broken and dotted lines
4. dotted lines and
5. freehand lines

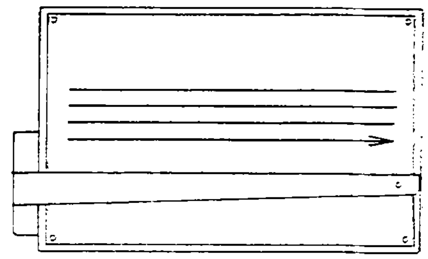
The thickness of these lines is due to their functions in the drawing as well as to their scale and their is classified into
- thick lines
- medium lines and
- thin lines

The following schedule shows type and thickness of lines as well as their use in architectural drawings.
PROPORTION of thickness:

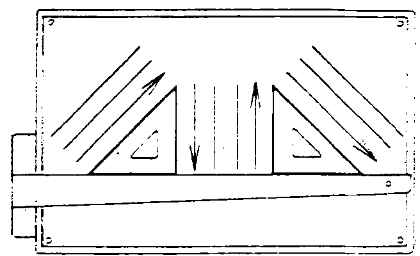
thick	medium	thin
2	1	0,7

Practice the exercises shown in the following as PENCIL drawings with a thickness of lines from 0,18 mm to 1,4 mm for CONTINUOUS lines as well as for BROKEN and DOTTED lines.
Also, the correct and neat drawing of lines meeting or crossing under right or inclined angles should be practiced.

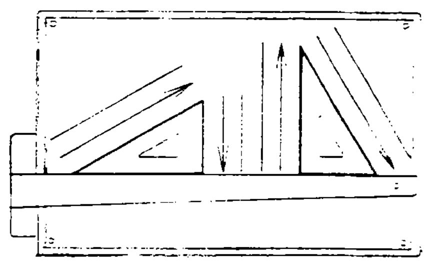
4.2 Pencil drawing
- Use pencils of 2 H to 4 H
- For thicknesses from 0.18 to 0.5mm ONE line is sufficient
  For thicknesses from 0.7 to 1.4 mm (or thicker) a DOUBLE line with the required distance has to be drawn, which has to be filled in afterwards.
- All corners and crossings of lines have to be drawn very exactly.
- It is important to take care that the thickness of the line is INCLUDED with the area of the drawn figure, so that the drawn EXTERNAL dimension is equal to the REQUIRED measurement.
- Draw with the pencil as close as possible along the T- or set-square under an inclination of about 60°



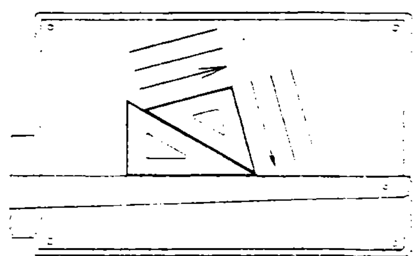
1. HORIZONTAL



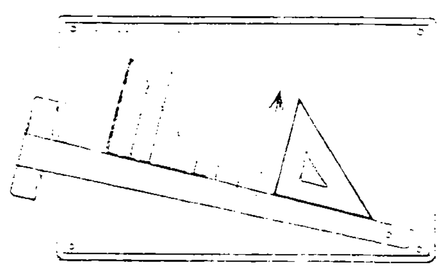
2. VERTICAL AND 45°



3. VERTICAL, 30° AND 60°

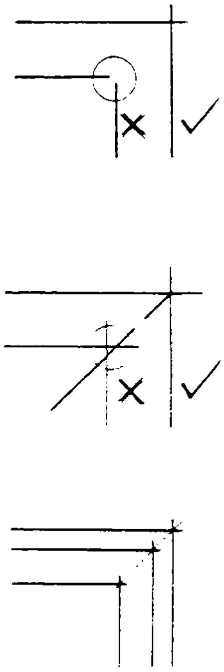


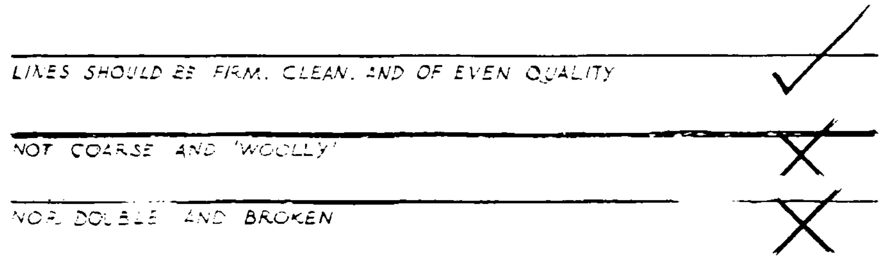
4. 15° AND 75°



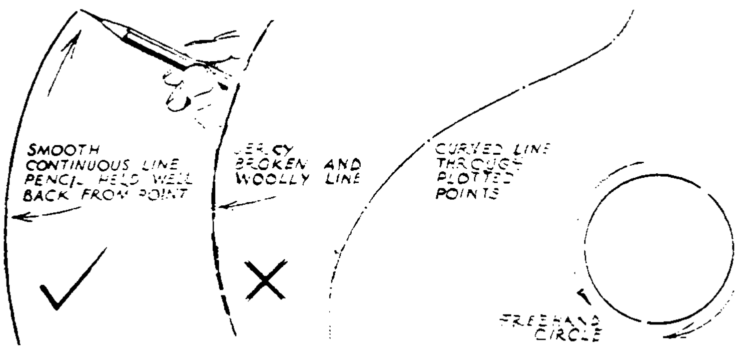
5. PARALLEL TO ANY GIVEN LINE

	TYPE OF LINES			USE
A	CONTINUOUS THICK		1.0 mm 0.7 mm	VISIBLE LINES DETERMINATION OF CUT BUILD. MEMBERS,WALLS≥ 15 cm, CONCRETE, etc.
B	CONTINUOUS MEDIUM		0.5 mm 0.35 mm	VISIBLE LINES DETERMINATION OF ELE– VATIONS OF WALLS AND OTHER BUILD MEMBERS
C	CONTINUOUS THIN		0.25 mm 0.18 mm	DIMENSION AND HATCHING LINES
D	BROKEN and DOTTED THICK		1.0 mm 0.7 mm	SECTION PLANES
E	BROKEN and DOTTED MEDIUM		0.5 mm 0.35 mm	CENTRE LINES, AXES, etc. (big scale)
F	BROKEN and DOTTED THIN		0.25 mm 0.18 mm	CENTRE LINES AXES, etc. (small scale)
G	BROKEN MEDIUM		0.5 mm 0.35mm	HIDDEN OR OVERHEAD ELEVATION LINES, PROPOSED ADDITIONS AND ALTERATIONS
H	BROKEN THIN		0.25mm 0.18 mm	SCREEN OR RASTER LINES
I	DOTTED		0.35mm 0.25mm	PARTS TO BE DEMOLISHED, MINOR BUILD MEMBERS
J			0.35mm 0.25mm	ROLLED STEEL JOISTS PIPELINES etc.
K			0.35mm	BREAKLINE





STRAIGHT LINES

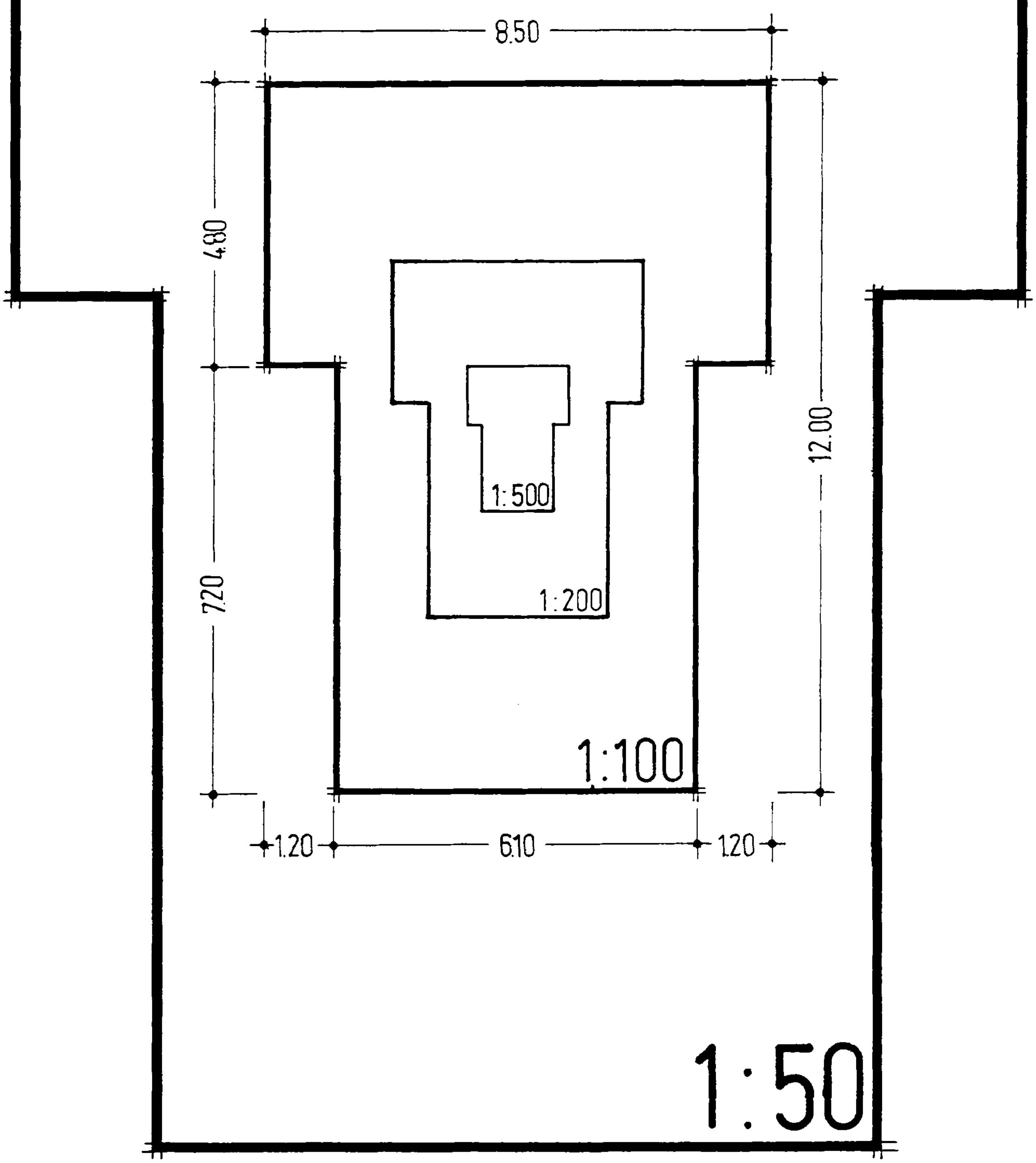


FREEHAND CURVES

- In order to keep the drawing CLEAN:
. Use clean equipment and good pencils
. keep hands clean and touch the paper with your fingers as little as possible
. avoid unnecessary rubbing
. sharpen pencils away from the drawing board or table
. make any erasures carefully and remove all rubber crumbs
. if much drawing is to be done on several small areas of the sheet, cover the whole of it with tracing paper in which suitable'flap windows' through which to work can be cut

4.3. Inking - In
Follow a certain sequency in the procedure of INKING-IN of a drawing. Ink-in:
1. All centre lines
2. All circles and arcs
3. All horizontal lines
4. All vertical and inclined lines
5. Hatchings and black-in sectional parts
6. All dimension lines, freehand lines, arrows and arrowheads
7. Lettering, dimension figures, notes
8. Titles etc.

PLAN OF A BUILDING



AD I compiled : D.VOLKE JUNE '83	EXERCISE	ARCH. DRWNG. LECTURE CET 1o43/14.332
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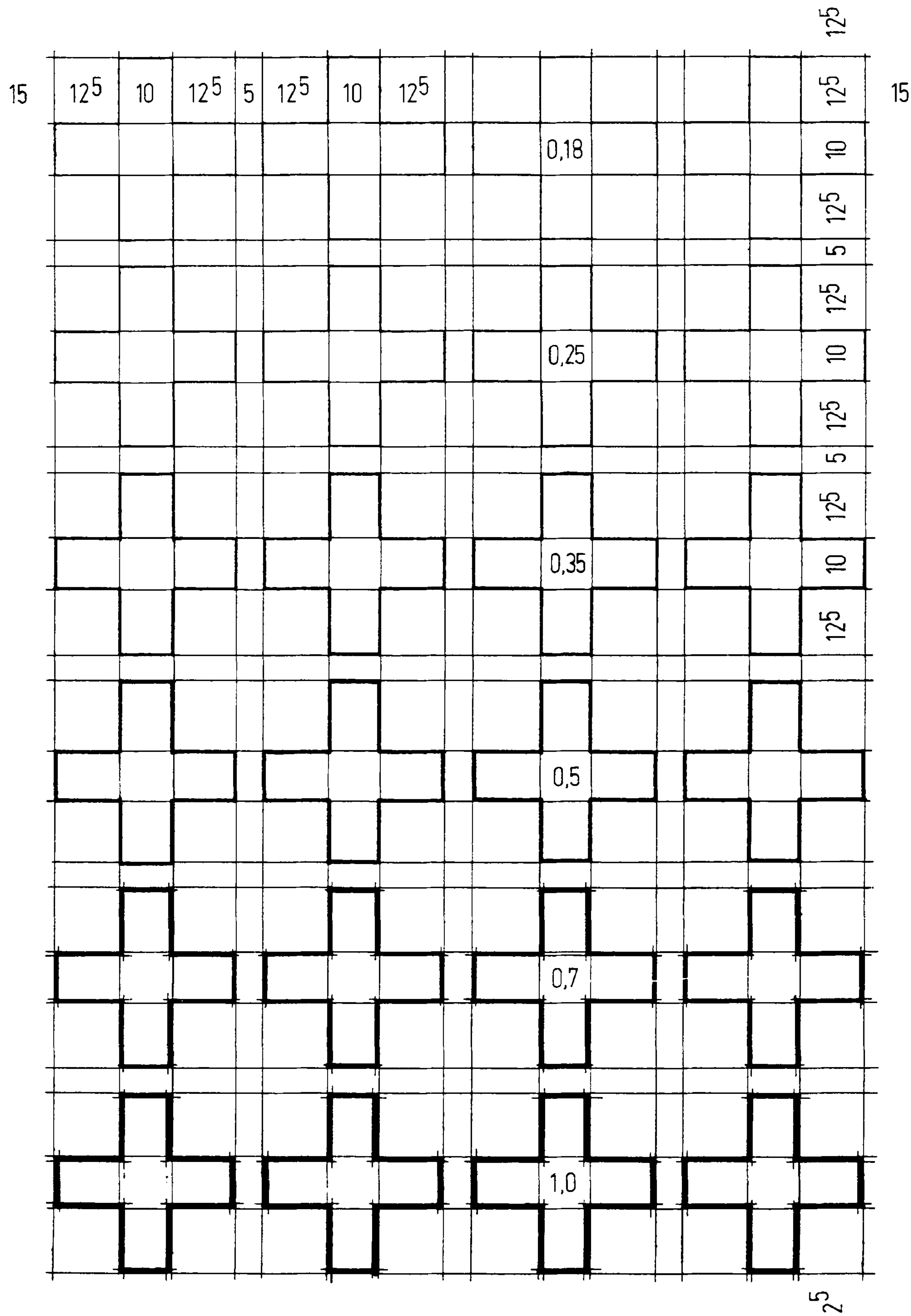

AD I
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EXERCISE

ARCH. DRWNG.
LECTURE
CET 1o43/14.333

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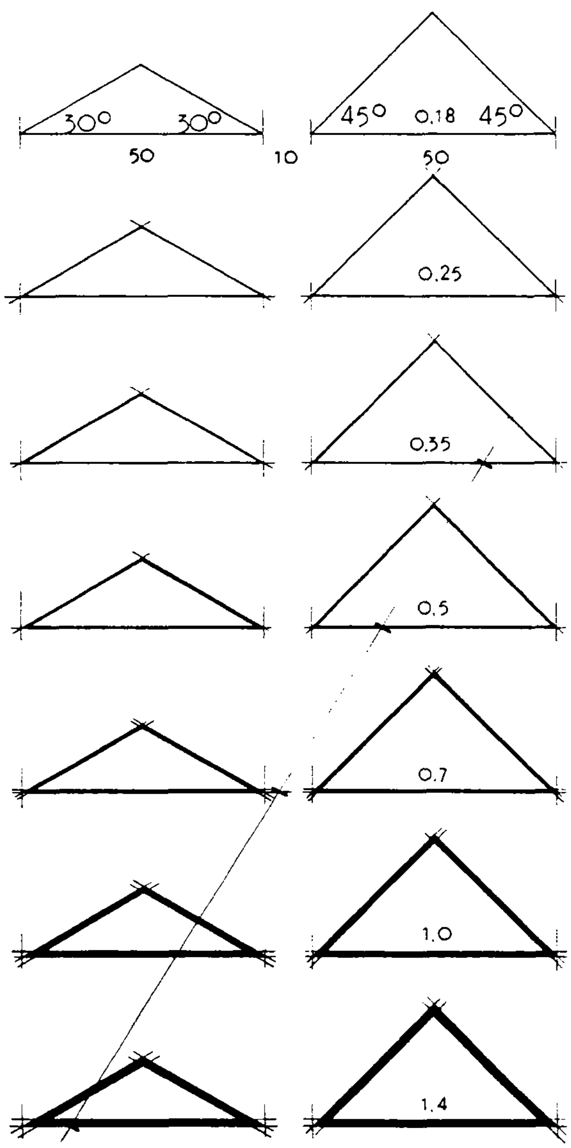
EXERCISE



4.4 Basic Rules of Dimensioning

- The METHOD of dimensioning is due to the type of the drawing (Sketch-, design-, working-, detail drawing etc)
- All for clarification of that particular drawing required measurements have to be indicated
- In FLOOR PLANS there are three main types of dimensionings:
  1. Dimensioning of openings, columns and piers,
  2. Dimensioning of axes of openings
  3. Dimensioning with coardinates
- Different alternative DETERMINATIONS of dimension lines are indicated in the figure

4.4.1 Types of Dimensions

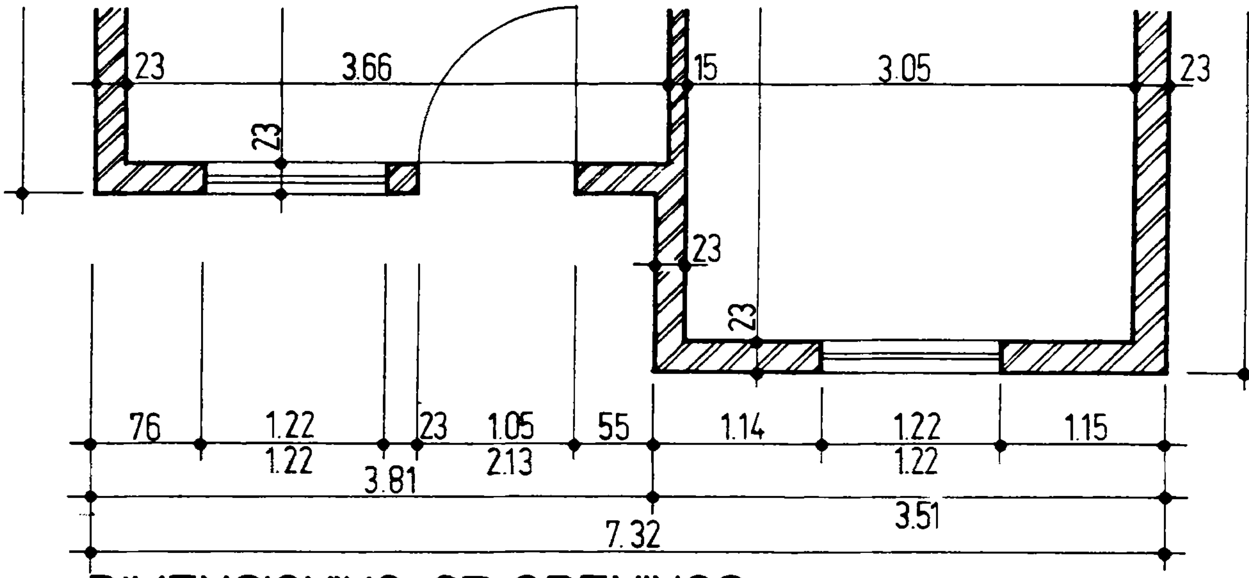
- OVERALL DIMENSIONS indicate the overall LENGTH, WIDTH and HEIGHT. Each object has three overall dimensions.
- DETAIL DIMENSIONS indicate the size of each part or detail of the object

  NOTE: dimension lines and extension lines (they indicate the limits of a dimension and extend this dimension to a convenient place on the drawing) should never cross!

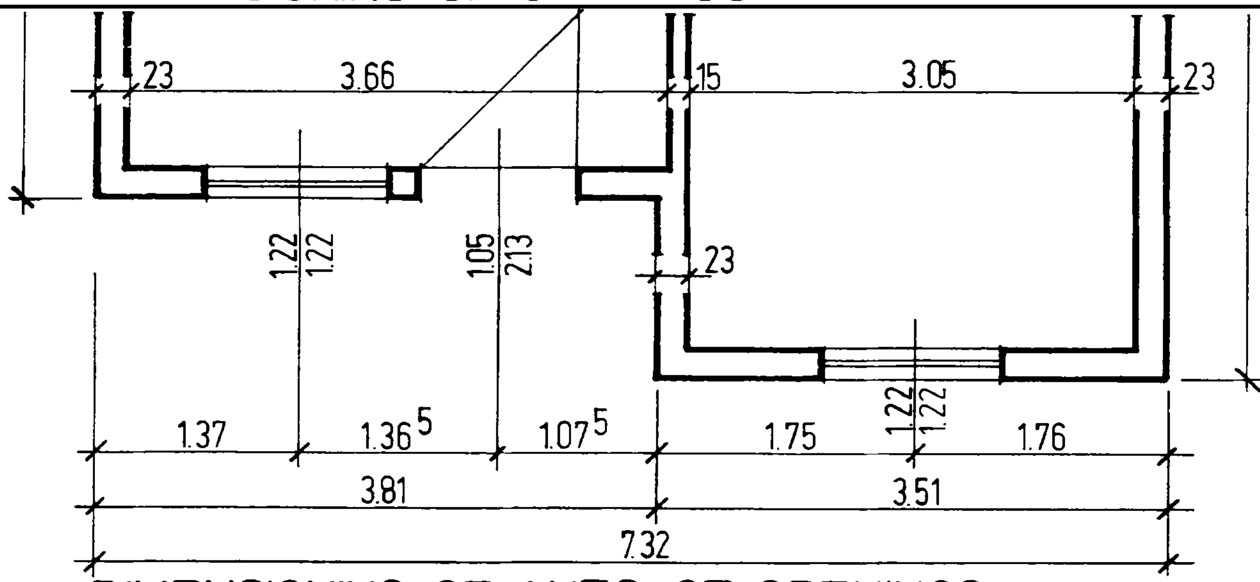
  Therefore the smallest dimension lines are placed nearest to the view.
  Overall dimensions are drawn outside the detail dimensions.

4.4.2 Placement of Dimensions

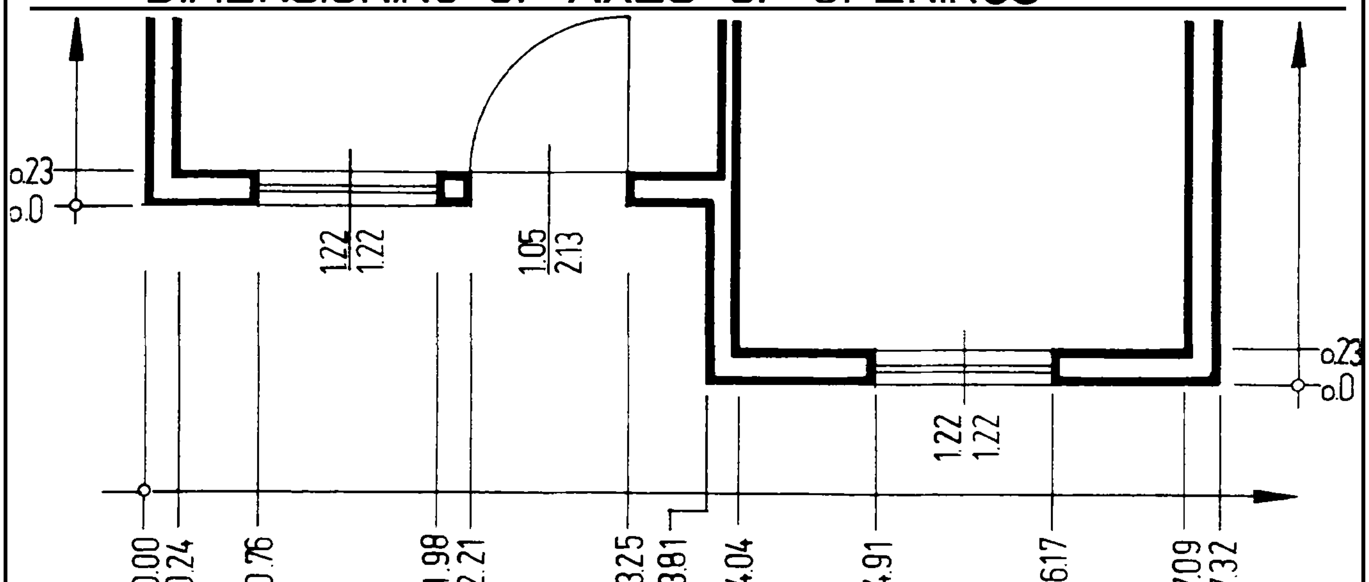
- There are plenty of rules concerning the dimensioning of crawings, and some of them are contradictory. In case two rules conflict, choose the most logical and practical solution.
- Dimensions should be placed so that they can be read from the bottom-side or from the righthand-side of the drawing.
- Normally dimensions should be placed OUTSIDE the outer lines of the views, close to the contour. The should be placed INSIDE, if this could avoid long extension lines.
- Place dimensions in the way they are likely to be measured during the construction work.
- Place dimension lines in line
- For dimensioning CIRCLES or PARTS of CIRCLES refer to the figure.



DIMENSIONING OF OPENINGS



DIMENSIONING OF AXES OF OPENINGS



DIMENSIONING WITH COORDINATES

AD I
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JUNE '83

LINEWORK

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LECTURE
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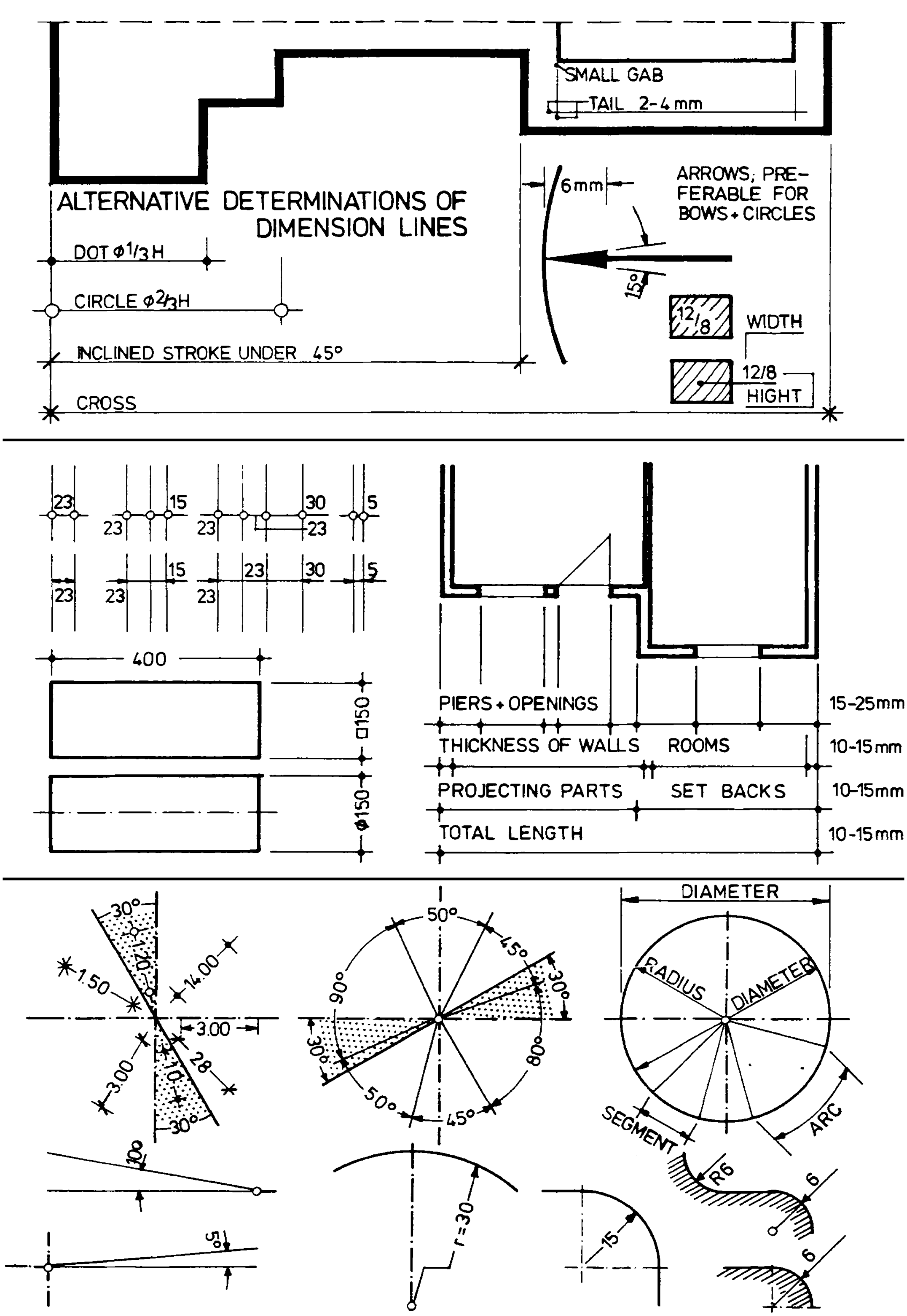

AD I compiled : D.VOLKE JUNE '83	LINEWORK	ARCH. DRWNG. LECTURE CET 1o43/14.436

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5.ENLARGEMENT&.REDUCTION

5. ENLARGEMENT AND REDUCTION OF LINE DRAWINGS

There are various methods of enlarging or reducing a line drawing. Some of the most useful are:
The drawing in the figure consists of irregular or complex lines, draw over it a square grid of light lines (or, if the drawing is to be protected, draw the grid on a piece of tracing paper and place over the original), and then for the new drawing make a similar grid but proportionately larger or smaller as required.With this grid as a guide it is comparatively easy to make the copy to the size wanted.

If a line and its divisions, e.g. a scale, is to be enlarged or reduced in other than a simple mathematical proportion this is a useful method to employ. Line AB with points C and D along it is to be reduced; with centres A and B and radius equal to AB two arcs are drawn to intersect at O, and lines are drawn from O to A,B,C and D. The new length of the line is now measured along OA from O, and a line A'B' is drawn parallel to AB to which it corresponds. Where this line cuts CO and DO points C' and D' corresponding to C and D on the original are found.

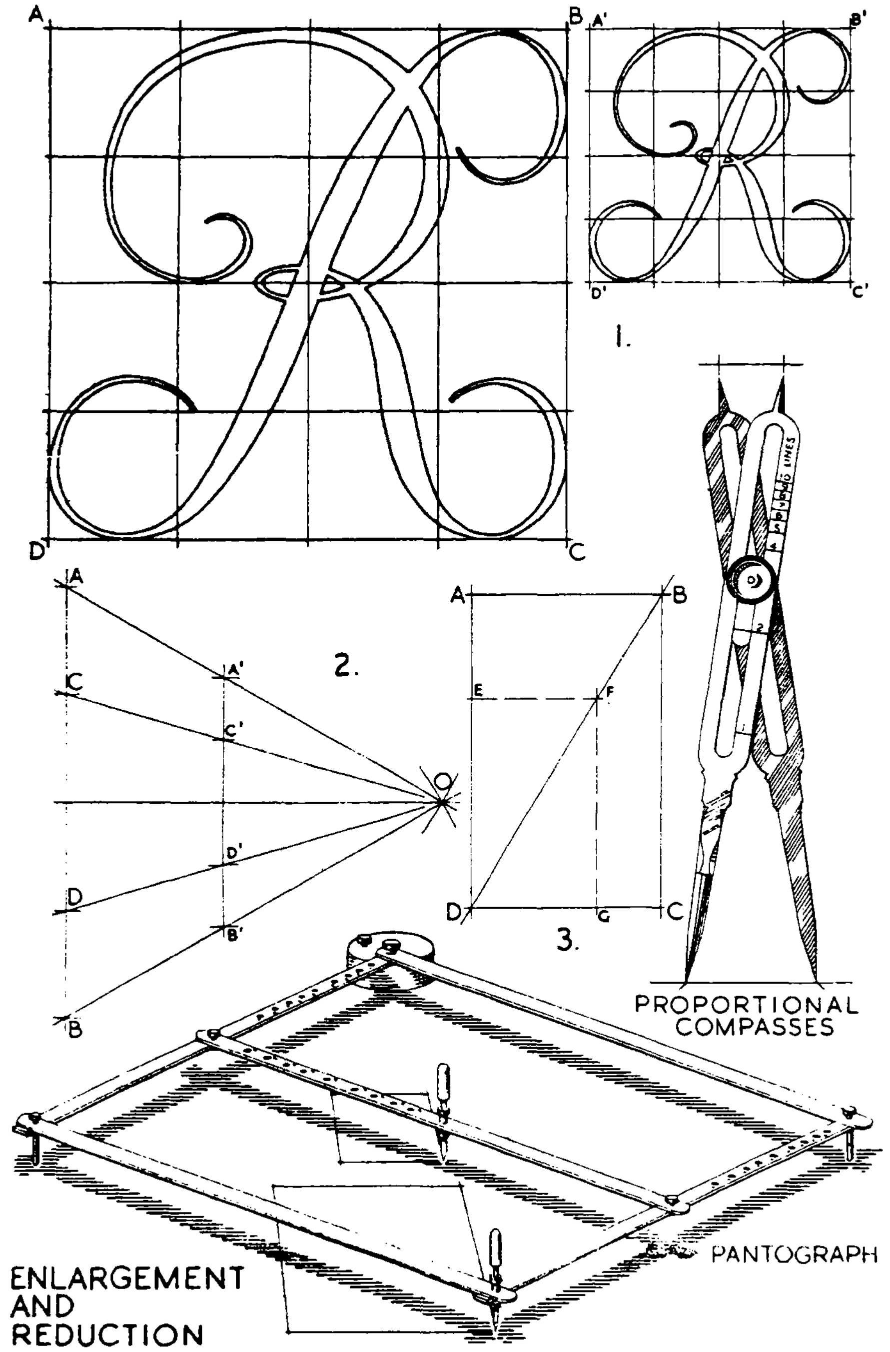
The proportinal enlargement or reduction of rectangles is made by drawing a diagonal so that the alteration of the length of one side automatically gives the required length of the adjacent one. Example: ABCD is the rectangle, BD is a diagonal EFGD is a proportionately reduced rectangle.

Proportional Compasses. These instruments consist of two slotted pieces of metal with points at each end joined by a centre screw, which can be so set that the distance between the long points is equal to that between the short points or is two, three, four or more times that distance up to ten.
They can therefore be used for enlarging or reducing simple drawings in such ratios, although they seem to find little favour with present-day draughtsmen.

Pantograph: an instrument for enlarging or reducing drawings in various ratios. By following the lines of the original with one marker, the other traces them to a larger or smaller scale, as the case may be, and in the proportionate ratio to which the instrument has been set. The illustration shows a simple type. The Eidograph is a somewhat similar instrument, but having only one point of support, is steadier in action. The cost of these instruments is only justified if dealing with a large number of town plans and surveys.

Two other methods are commonly used and they are known as
- OFFSET METHOD and
- RADIAL PROJECTION

For their construction method refer to the drawing.



AD I	ENLARGEMENT	ARCH. DRWNG.
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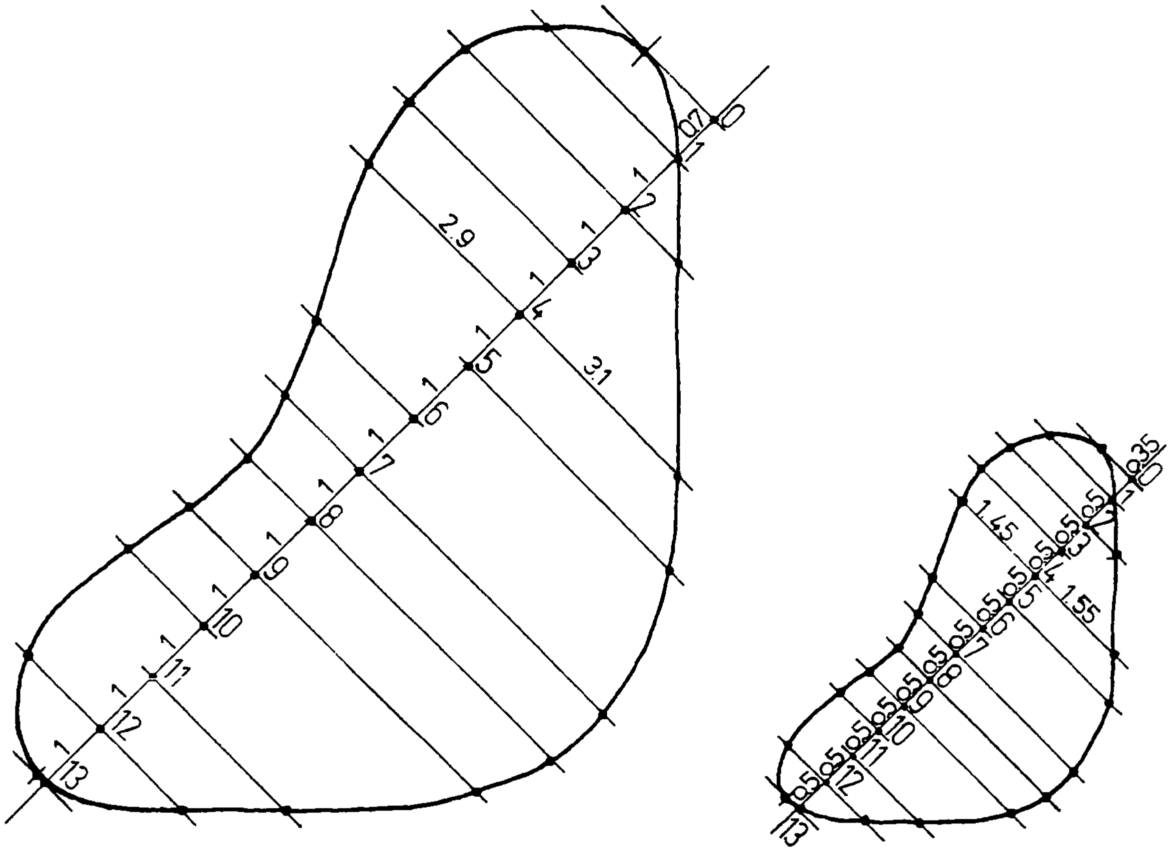
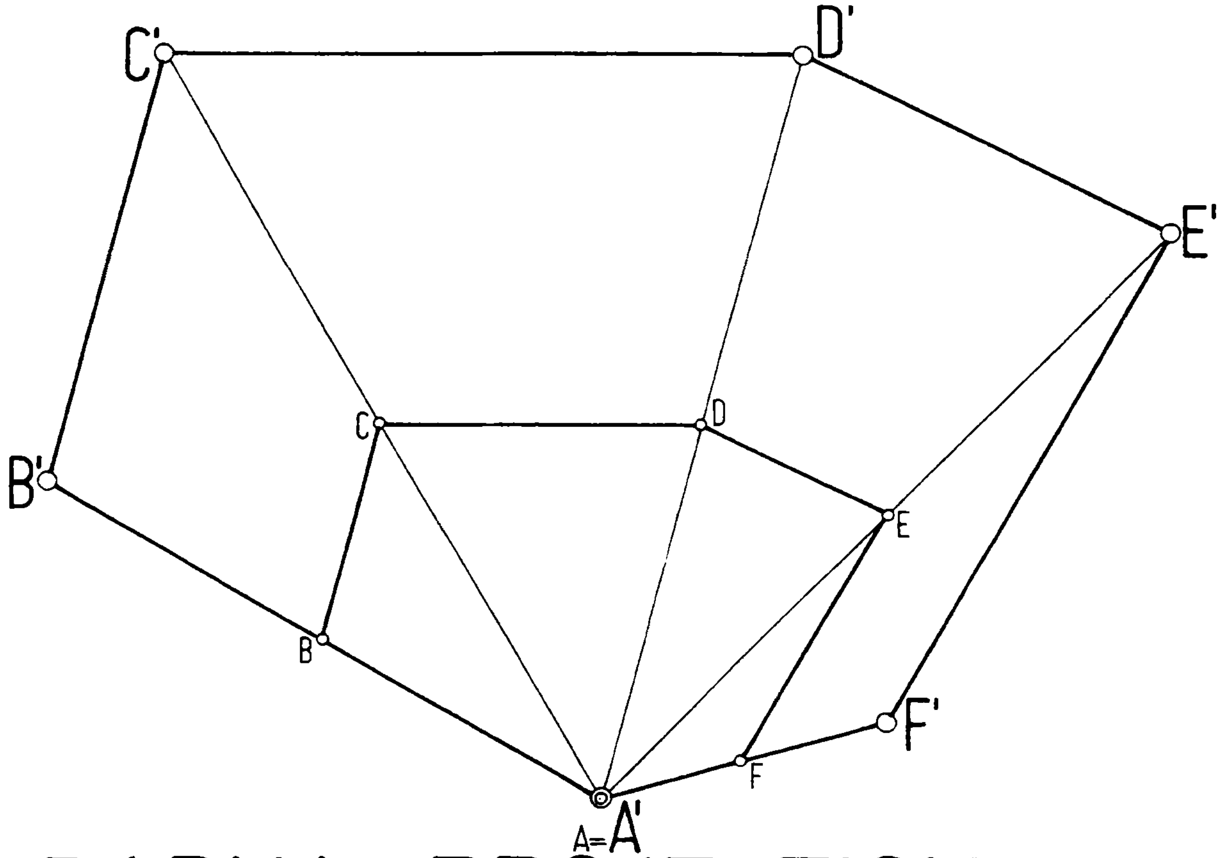


OFFSET-METHODS



RADIAL PROJECTION

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6.GEOMETRICAL CONSTRUCTION

LINES AND ANGLES

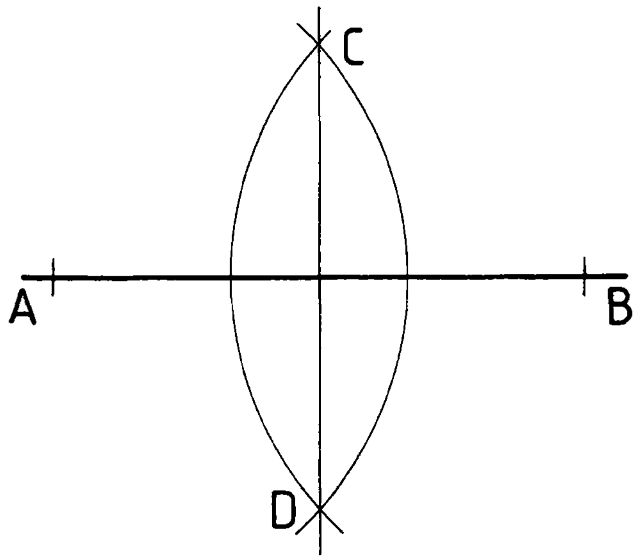
6. GEOMETRICAL CONSTRUCTIONS
In Architectural Drawing a good knowledge about GEOMETRICAL CONSTRUCTIONS is of high importance. In the following constructions are shown with the aim

1. To demonstrate the principles of BASIC geometrical constructions
2. To practice the use of drawing equipment

6.1 Lines and Angles

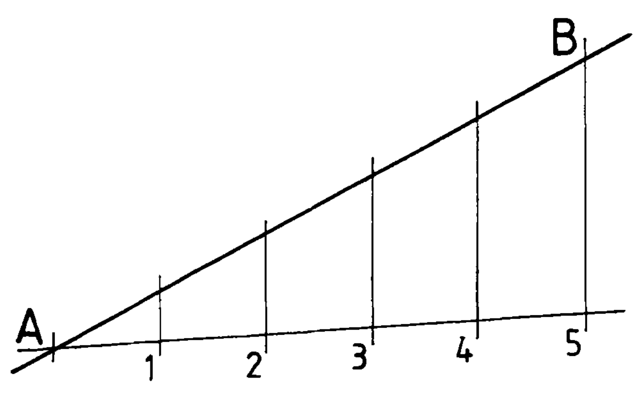
6.1.1 To bisect a straight line AB

- Draw AB
- With centre A and any suitable radius draw an arc
- With centre B and the same radius as before draw an arc to cut the arc with centre A in C and D
- Join CD. CD is the required bisecting line.



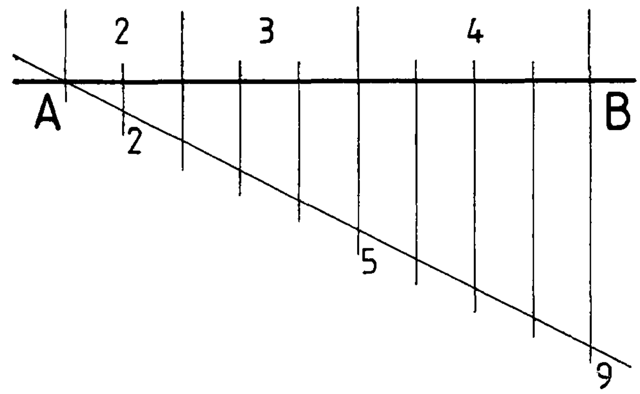
6.1.2 To divide a straight line AB into a given number of equal parts

- Draw AB
- At any suitable angle to AB draw a straight line
- Step off along this line the required number of divisions of equal length (here 5 divisions are shown)
- Number the divisions from A along the line as shown
- Join the last number (5) to point B
- Draw parallel lines to 5 B from the other numbers as shown. AB is now divided into the required equal parts.



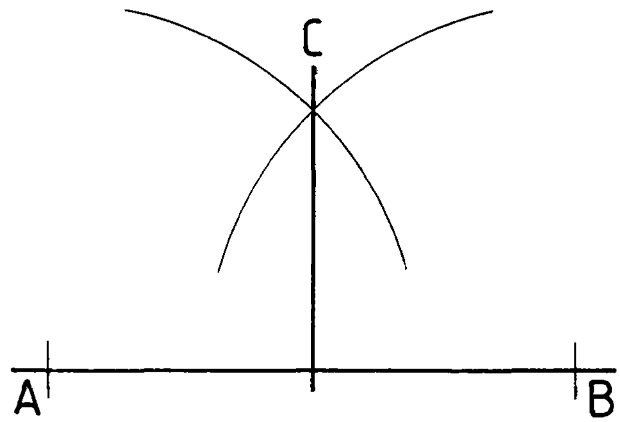
6.1.3. To divide a straight line AB into any ratio

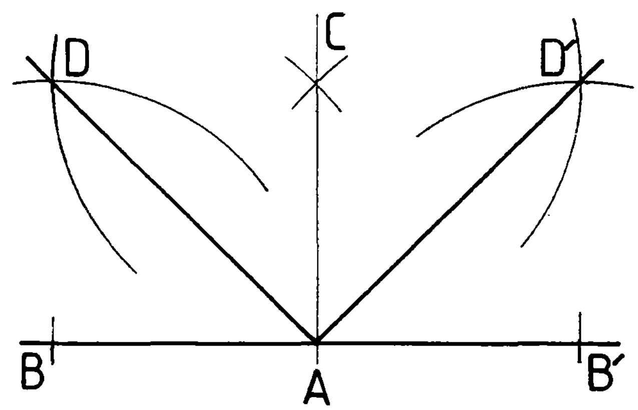
- Let the ratio be 2:3:4
- Draw AB
- Draw a straight line at any angle to AB
- Sum up the ratio (i.e. 2+3+4=9) to geht the number of eaqual divisions required
- Step off, along the straight line the number of divisions of equal lengths required (i.e. 9 divisions).
- Join the last division (9) to B and draw parallel lines to 9B through 5 and 2
- Now AB is divided into the ratio 2:3:4.



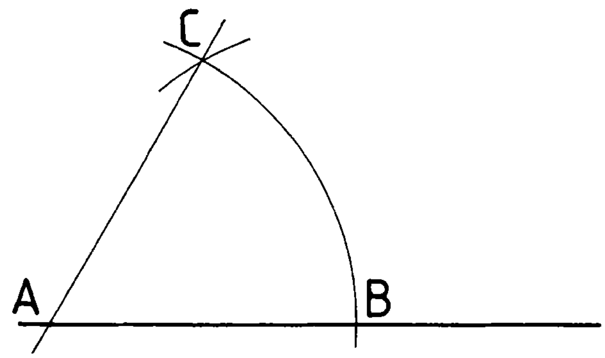
6.1.4 To construct an angle of 90°

- Draw a straight line
- With centre A on that line and any suitable radius draw a semicircle to cut the line in B and C
- With centres B and C draw arcs of any the same radius to intersect each other at D
- Join AD. The Aangles ABD and ACD are the required angles of 45°.

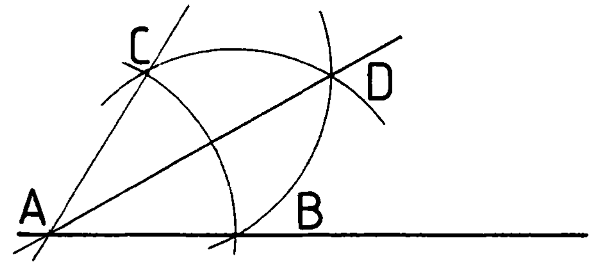




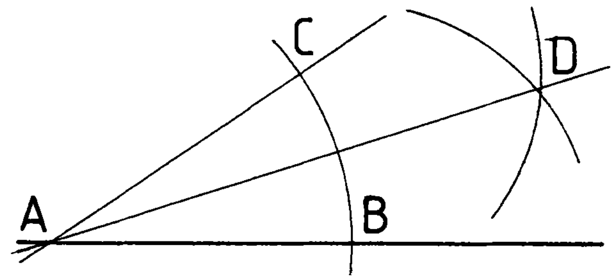
6.1.6 To construct an angle of 60^0.
- Draw a straight line
- With centre A on that line and any suitable radius draw an arc to cut the line at B
- With centre B and the SAME radius draw an arc to cut the former arc at C.
- Join AC. The angle ABC the required angle of 60^0.



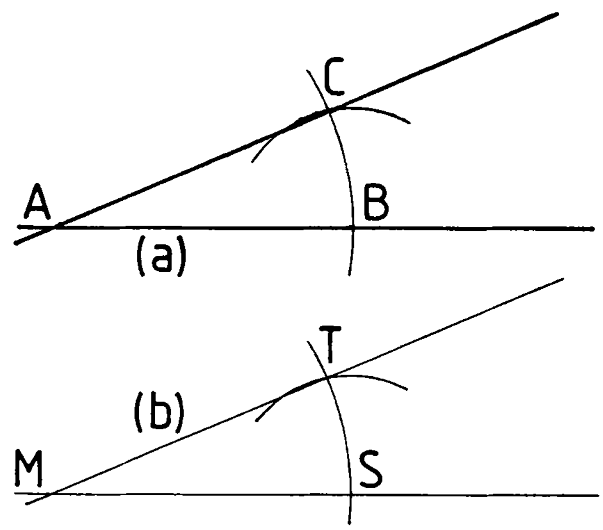
6.1.7 To construct an angle of 30^0
- This can be reached by bisecting an angle of 60^0 as described under 6.1.5.



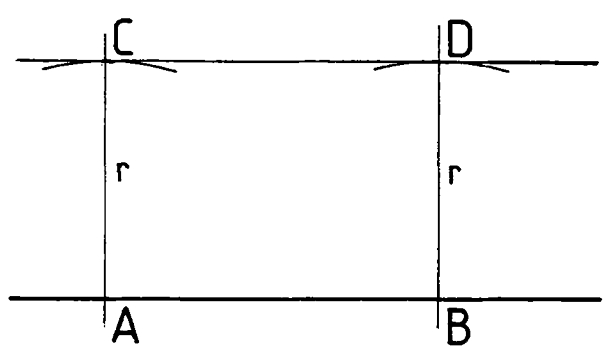
6.1.8 To bisect any given angle
- The same method as in 6.1.5 should be employed here.



6.1.9 To construct an angle SIMILAR to a given angle
- Let the angle shown in (a) be the giver angle.
- Draw a straight line through M as shown in (b)
- With centre A and any suitable radius draw an arc to cut the legs of the given angle in B and C
- With centre M draw the same arc to cut the line through M at S (AB = MS)
- From (a) with centre B take radius BC.
- With centre S and radius BC cut former arc at T
- Join MT and extend the line. The angle MST is similar to ABC.



6.1.10 To draw a line PARALLEL to a given line
- Draw the given line
- Using any 2 centres at suitable intervals along the given line and a radius, equal to the required distance between the 2 lines, draw the arcs C and D.
- Draw a straight line tangential to the arc C and D. This is the required line which is parallel to the given line at the distance of the radius.



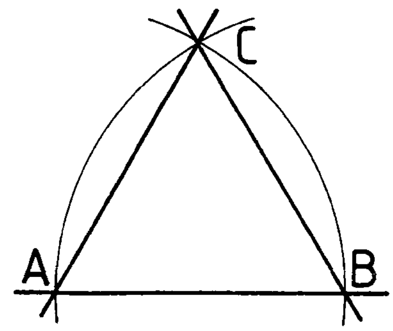
TRIANGLES

6.2 Triangles
Definition: A TRIANGLE is a PLAIN, bounded by three straight lines.

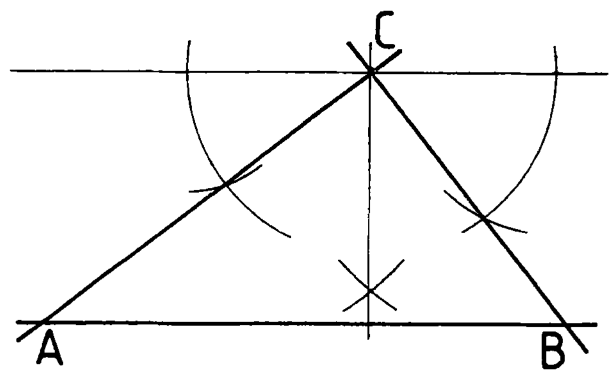
There are 4 types of triangles:

1. scale triangle: all angles and sides are UNEQUAL
2. Isosceles triangle: two sides and angles are EQUAL
3. Equilateral triangle: all angles and sides are EQUAL
4. Right-angled triangle: contains one right angle.

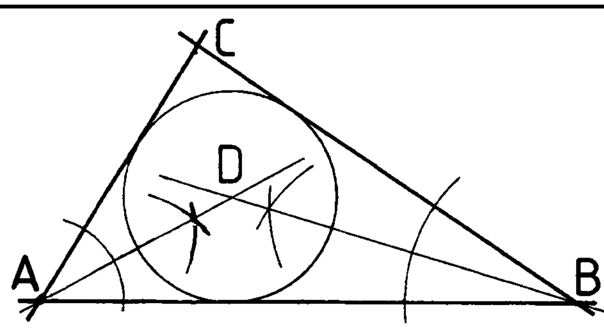
6.2.1 To construct an EQUILATERAL triangle. Given is one of the sides AB
Draw AB
With centres A and B and the radius AB draw arcs to intersect at C
Join AC and BC, the triangle ABC is equilateral.



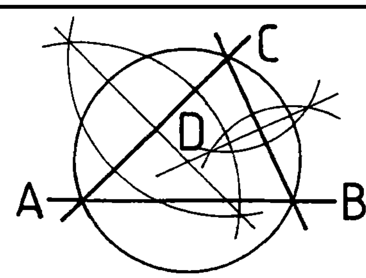
6.2.2 To construct a triangle with given BASE ANGLES and ALTITUDE.
- Draw a straight line
- Construct a straight line PARALLEL to the drawn line so that the distance between the two lines is equal to the altitude (ref.to 6.1.10)
- From any point C on the parallel line draw the given angles as shown so that they cut the straight line in A and B
- Join AC and BC. The triangle ABC is the reuqired triangle.



6.2.3 To inscribe a circle in a given triangle ABC
- Bisect any two of the angles, as shown, so that the bisectors intersect at D
- The centre of the inscribing circle is point D.



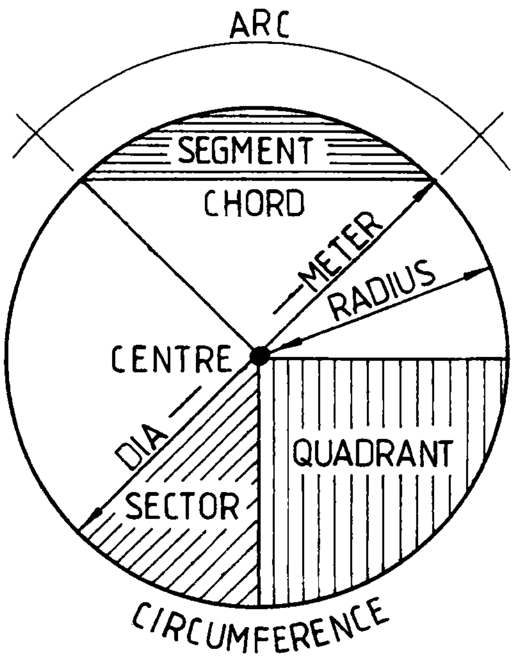
6.2.4 To circiumscribe a triangle ABC
- Bisect any two of the sides of the triangle, as shown, so that the bisectors intersect at D.
- The centre of the circumscribing circle is point D.



CIRCLES

6.3 Circles

A circle is a plane figure hounded by a curved line called the CIRCUMFERENCE; which is always at equal distance from a fixed point called the CENTRE of the circle. This distance from the centre O to the circumference is known as the RADIUS. Other terms are: -



DIAMETER: A straight line passing through the centre and bounded by the circumference

ARC: Is a name given to a part of a circumference

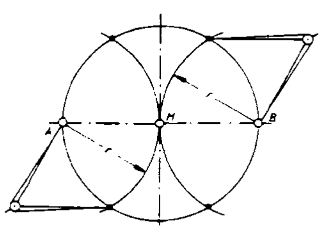
CHORD: A straight line joining two points on the circumference

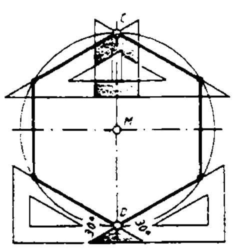
SEGMENT: An area bounded by a chord and the arc it cuts

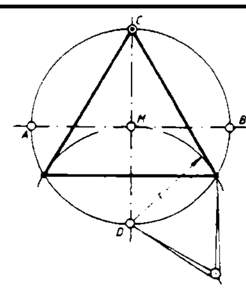
SECTOR: An area bounded by two radii and the arc between them

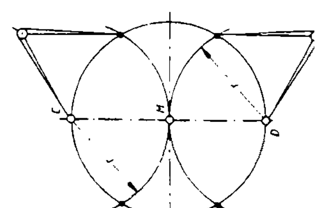
QUADRANT: An area bounded by two radii at right angles and the arc between them. It is a quarter of a circle.

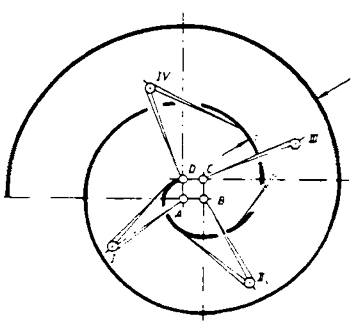
6.3.1 Basic CIRCLE-Constructions

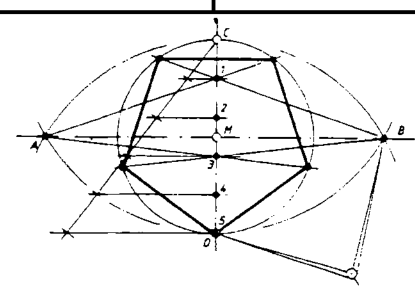


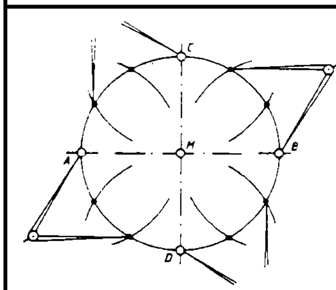


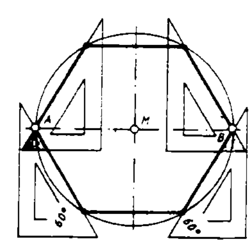






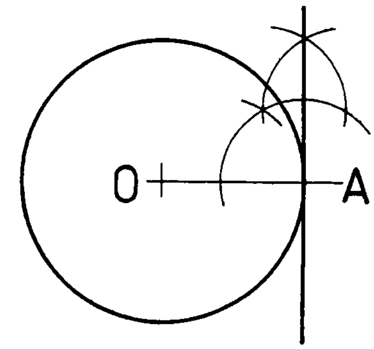




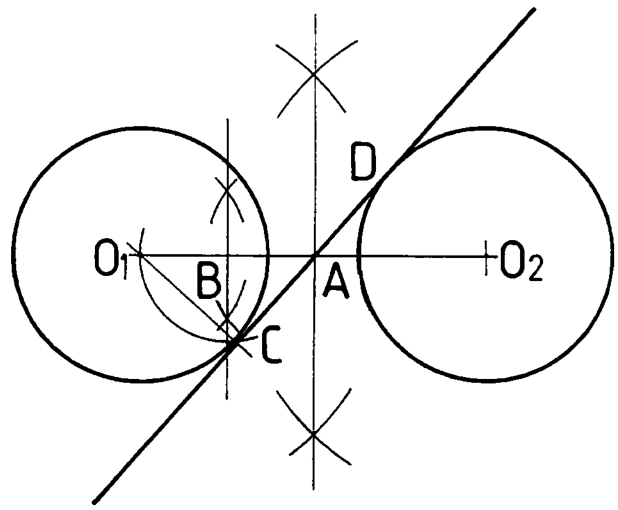


6.3.2 To draw a tangent to a point A on the circumference of a circle centre O

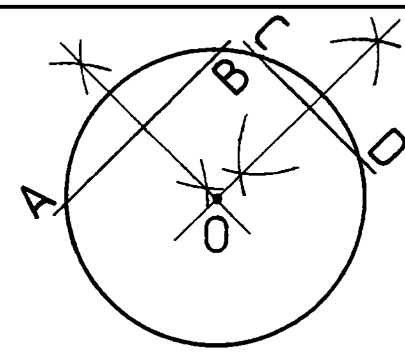
- Join OA
- Erect a perpendicular at point A as shown. The perpendicular is the re- required tangent.



6.3.3 To draw an internal tangent to two circles of equal diameter
- Join the centres of both circles by line O_1O_2
- Bisect the line O_1O_2 to get the point A.
  Then bisect O_1A to geht the point B.
- With radius BO_1 and centre B describe a semi-circle to cut the circumference of one of the given circles at C
- Join CA and estend it to tough the other circle at D. Line CAD is the required tangent. O_1C and O_2D are normals.

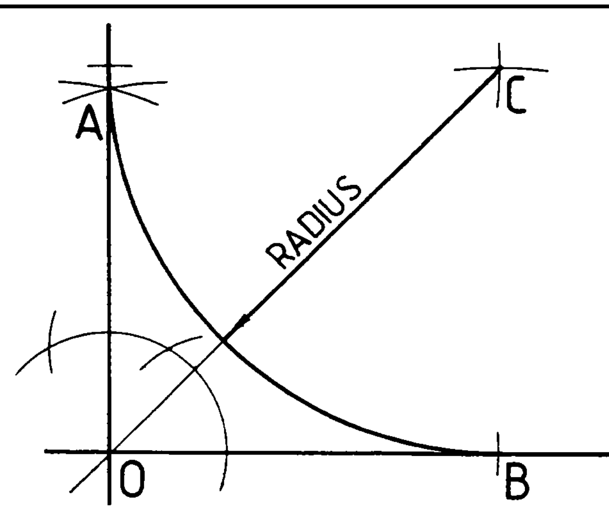


6.3.4 To find the centre of a given circle arc
- Draw any two chords AB and CD
- Draw perpendicular bisectors of AB and CD
- Produce the hisectors to meet at O. O is the required centre of circle.



6.3.5 To join two straight lines at Right Angles to each other by an arc of given radius

- Draw the given straight lines at a right angle to meet at O
- With the centre O and the radius equal to the required radius of the arc, draw arcs to intersect the straight lines at A and B
- With the centres A and B and the same radius draw arcs to intersect at C
- With the centres C and given radius, draw the required arc.



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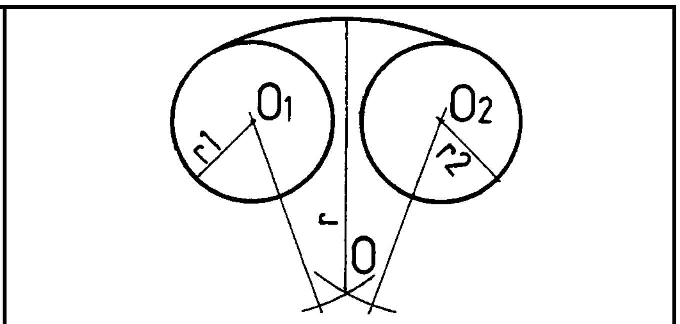
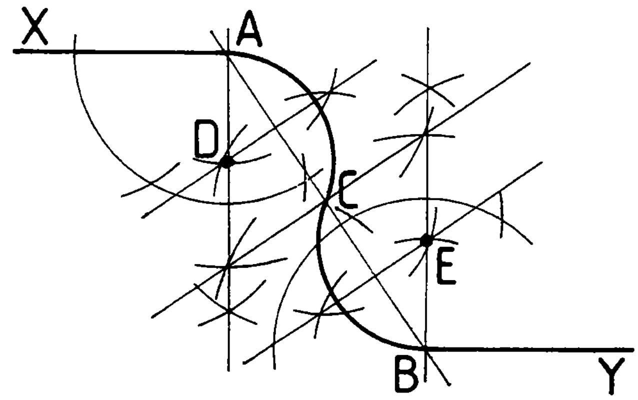
6.3.6 To draw a curve of given radius joining two circles (The circles have to be inside the radius R)

- With centre O and radius T_1 draw an arc,
- With centre O_2 radius T_2 draw an arc to intersect the first arc in O. O is the required centre.

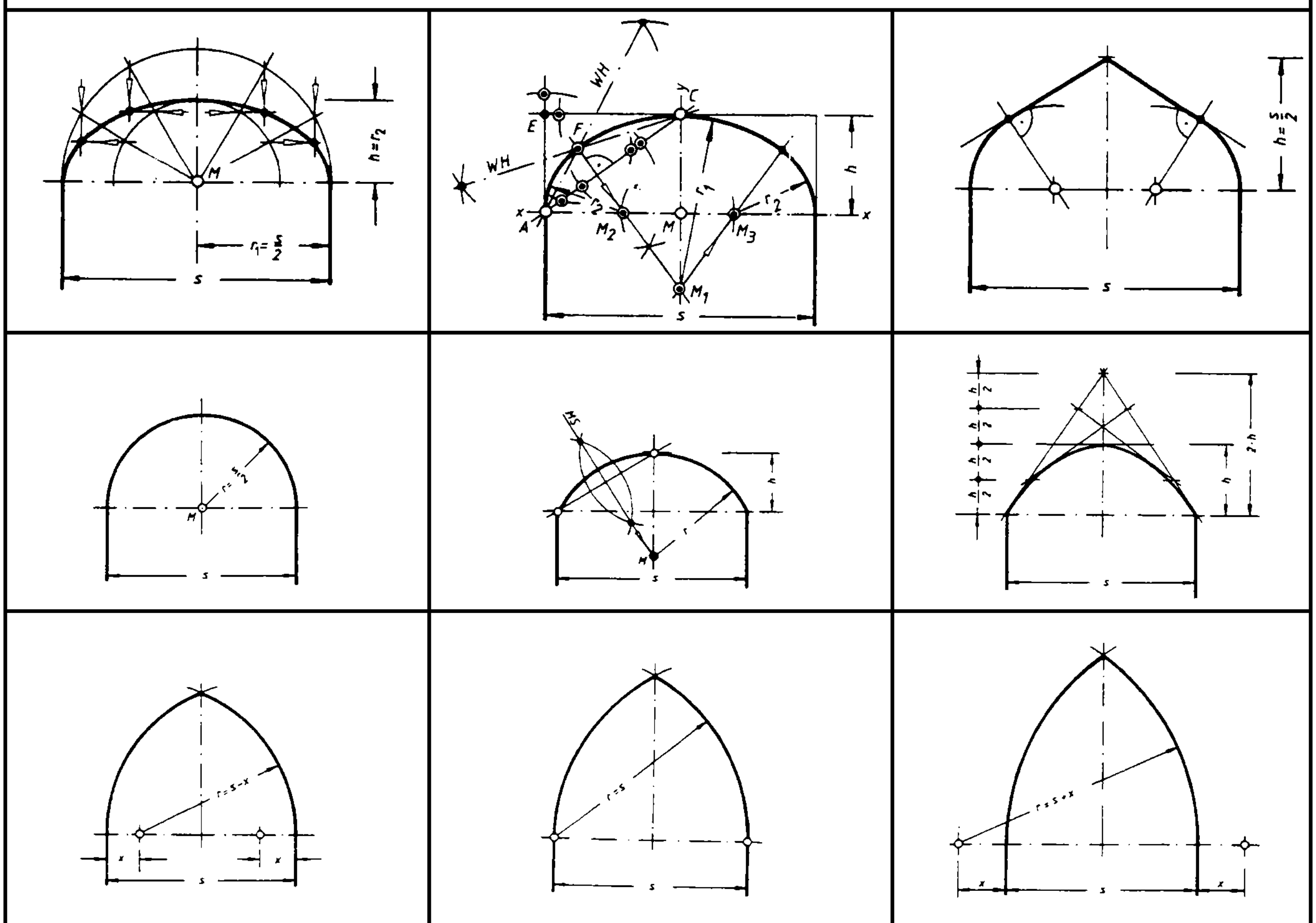


6.3.7 To join two straight lines by two arcs of equal radius

- Draw the two straight lines XA and YB at their correct positions.
- Join AB and bisect it at C
- Bisect AC and CB and estend the two bisectors to meet perpendiculars from A and B at points D and E respectively.
- With centre D and radius AD draw an arc from A to C
- With centre E and radius EB draw an arc from B to C.
  These are the required curves and give a smooth continuous curve ACB.



6.4 BASIC ARCH CONTRUCTIONS



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ARCHITECTURAL DRAWING II

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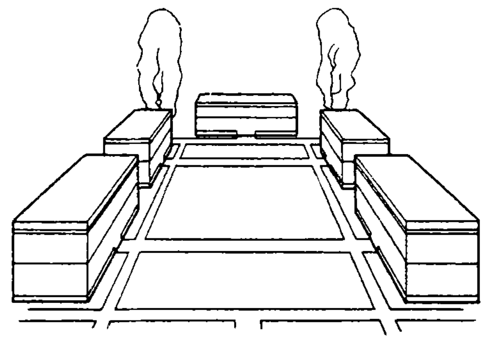

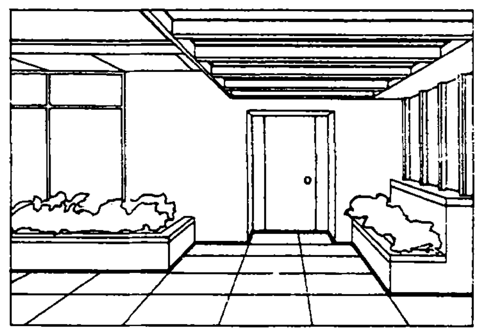

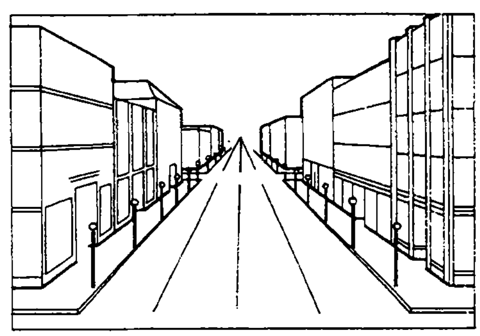

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1.TYPES OF PROJECTIONS

1. TYPES OF PROJECTIONS

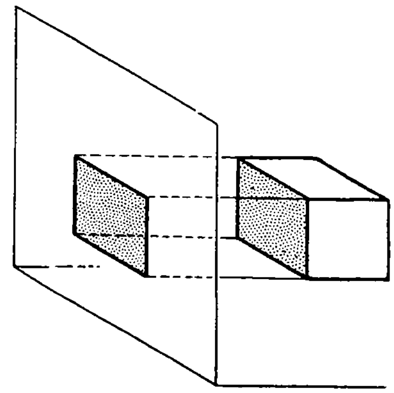
Drawings are a medium through which the draftsman or designer conveys his ideas and instructions to others. Therefore an understanding of all types of drawing is necessary in order to present informations in the clearest and most effective manner.

The theory of any type of projection drawing assumes that the drawing can be made by locating the intersections of lines, which are called PROJECTORS from points on the object with a plane of projection called the PICTURE PLANE:

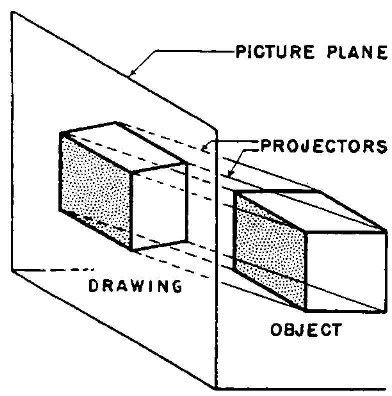
The lines connecting the points thus located on the picture plane make the projected drawing of the object.
The three factors which determine the type of projection drawing are:

1. The relation of the object to the picture plane
2. The relation of the projectors to the picture plane, and
3. The relation of the projectors to each other.

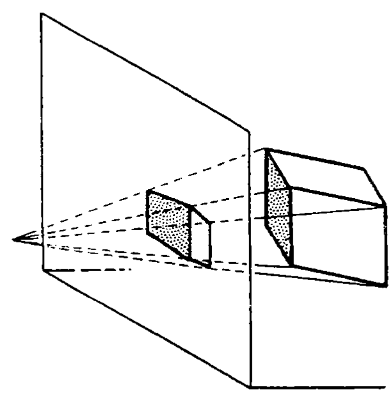
Various types of ORTHOGRAPHIC and PERSPECTIVE PROJECTION are obtained by changing the relation between the object and picture plane. In OBLIQUE PROJECTION the different types are obtained by changing the relative positions of the object and picture plane and by changing the scale of the receding lines. Variations in pictural effect of any type of oblique drawing can also be secured by using different directions for the projectors.
In actual drawing the paper is the picture plane on which the drawing is constructed by drafting methods to conform to the assumed relations of the object, projectors, and picture plane.
PROJECTION DRAWING is the science of constructing drawings of different types by the most efficient and direct drafting methods.



Ⓐ ORTHOGRAPHIC
PROJECTORS PERPENDICULAR TO PICTURE PLANE

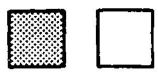
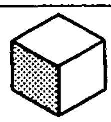
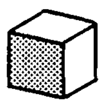
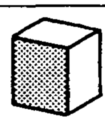
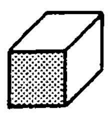
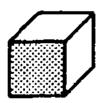
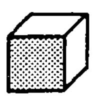
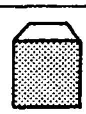
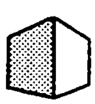
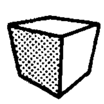


Ⓑ OBLIQUE
PARALLEL PROJECTORS OBLIQUE TO PICTURE PLANE



Ⓒ PERSPECTIVE
PROJECTORS CONVERGE TO A STATION POINT

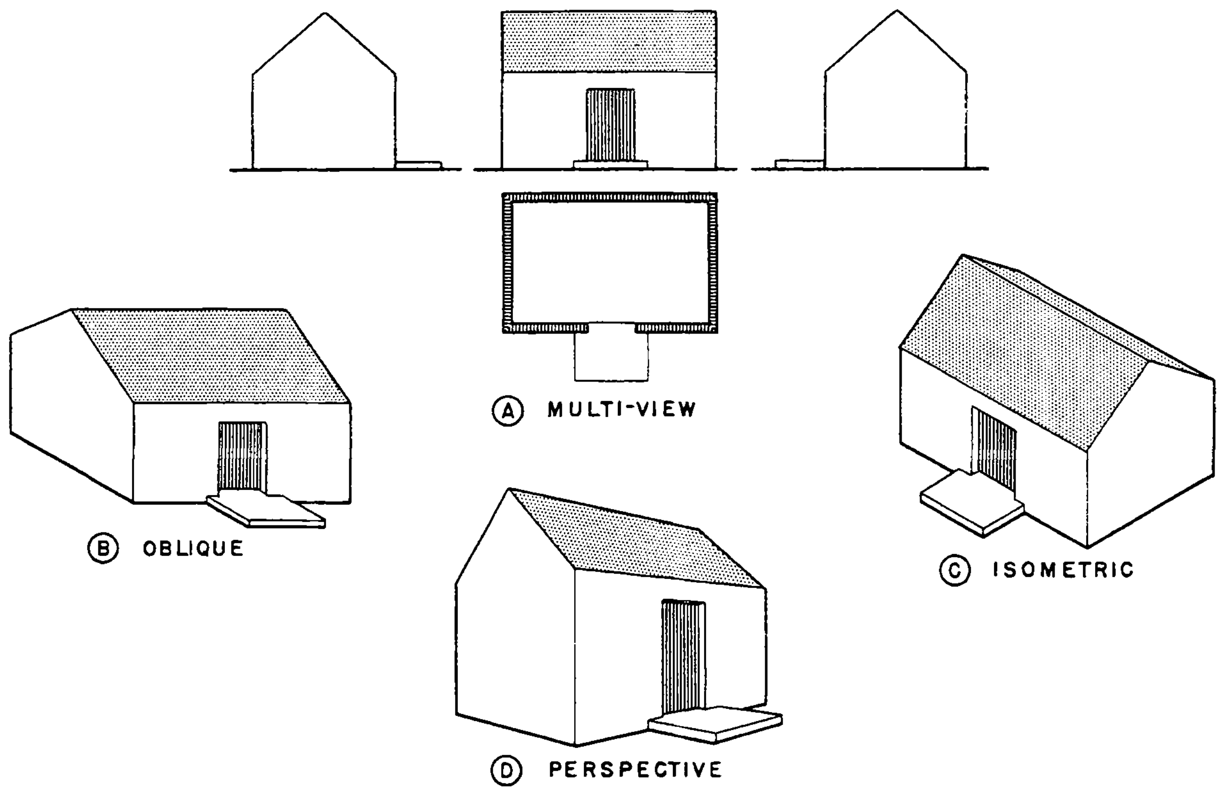
CLASSIFICATION OF TYPES OF PROJECTION DRAWING

TYPE OF DRAWING			RELATION OF		
GENERAL TYPE	GRAPHIC DIAGRAM	SPECIFIC CLASSIFICATION	OBJECT TO PICTURE PL.	PROJECTORS TO EACH OTHER	PROJECTORS TO PICTURE PL.
ORTHOGRAPHIC		MULTI-VIEW	PARALLEL ON ONE FACE	PARALLEL	PERPENDICULAR
AXONOMETRIC		ISOMETRIC	OBLIQUE THREE AXES AT EQUAL ANGLES WITH PICTURE PLANE	PARALLEL	PERPENDICULAR
		DIMETRIC	OBLIQUE TWO AXES AT EQUAL ANGLES WITH PICTURE PLANE	PARALLEL	PERPENDICULAR
		TRIMETRIC	OBLIQUE ALL AXES DIFFERENT ANGLES WITH PICTURE PLANE	PARALLEL	PERPENDICULAR
OBLIQUE		CAVALIER PROJECTION	PARALLEL ON ONE FACE	PARALLEL	OBLIQUE 45°
		GENERAL OBLIQUE	PARALLEL ON ONE FACE	PARALLEL	OBLIQUE AT ANY ANGLE
		CABINET PROJECTION	PARALLEL ON ONE FACE	PARALLEL	OBLIQUE AT 63° APPROX.
PERSPECTIVE		ONE-POINT PERSPECTIVE	PARALLEL ON ONE FACE	CONVERGE TO A POINT	VARIOUS ANGLES
		TWO-POINT PERSPECTIVE	OBLIQUE VERTICAL LINES PARALLEL TO PICTURE PLANE	CONVERGE TO A POINT	VARIOUS ANGLES
		THREE-POINT PERSPECTIVE	OBLIQUE ALL THREE AXES OBLIQUE TO PICTURE PLANE	CONVERGE TO A POINT	VARIOUS ANGLES

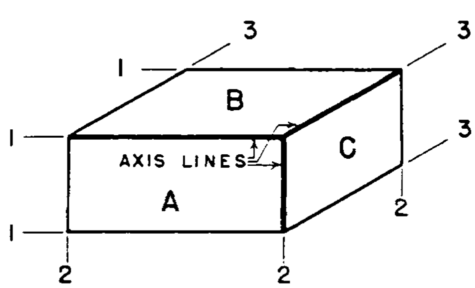
METHODS

The most important types of projection are classified in the chart, typical examples of drawings of the four most widely used divisions of projection drawing are given in the figure.

Most of the objects drawn in architecture have three sets of planes and lines which are mutually perpendicular to each other.



A COMPARISON OF FOUR WIDELY USED TYPES OF DRAWING



TYPICAL LINES AND PLANES

PROJECTION DRAWING METHODS

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2. ORTHOGRAPHIC PROJECTION

2. ORTHOGRAPHIC PROJECTION

In any type of drawing those parts of the object which are parallel to the picture plane are shown in their TRUE SHAPES.

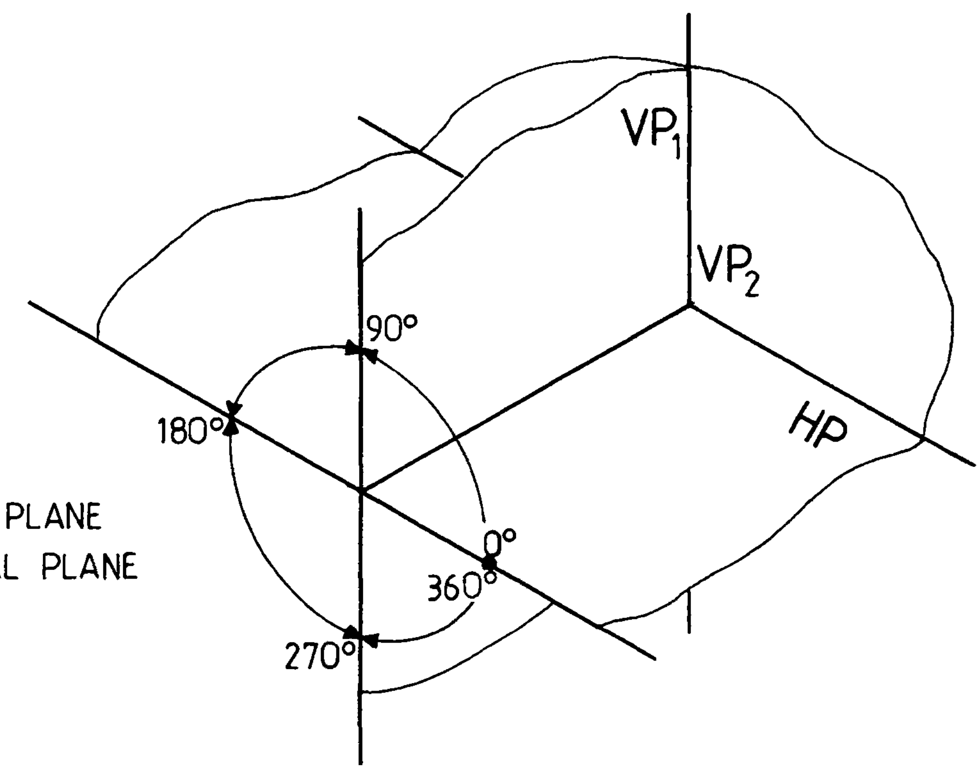
In ORTHOGRAPHIC PROJECTION where the projectors are parallel lines, all parts of the object which are parallel to the picture plane are shown in their correct RELATIVE SIZES, that is, at the same scale - regardless of their distances from the picture plane.

Since only one set of planes of an object can be shown parallel to the picture plane in a single drawing, it is necessary to have a minimum number of three views of an object to give all of its sizes and shapes.
These three basic views are obtained by looking in three mutually perpendicular directions, and these views are drawn on planes perpendicular to each of the three directions respectively.

The basic views, which are drawn true to scale, are taken at 90° to each other and when set on paper are said to be drawn in the principal planes.

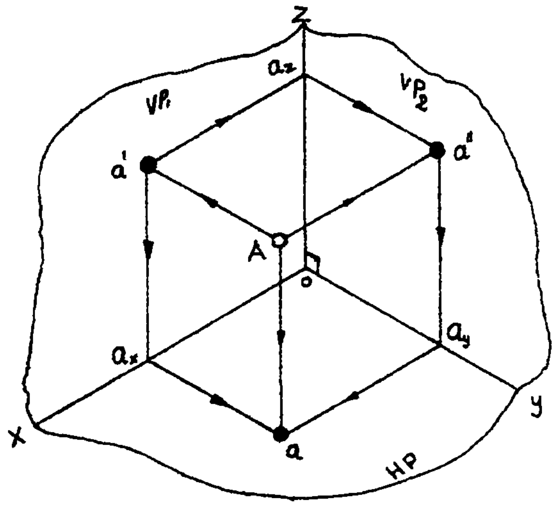
At present there are two methods of relating the principal views to each other, namely FIRST-ANGLE PROJECTION (used in Europe) and THIRD ANGLE PROJECTION (used in Canada and U.S.A.)

These terms FIRST ANGLE and THIRD ANGLE have been derived from the mathematicians convention of annotating the four right angles which make up the 360° of a circle, the first being 0° to 90° and the third angle from 180° to 270°.

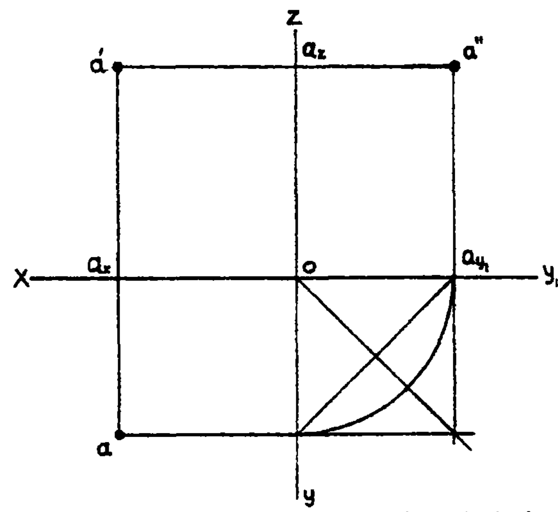


VP = VERTICAL PLANE
HP = HORIZONTAL PLANE

1st ANGLE PROJECTION

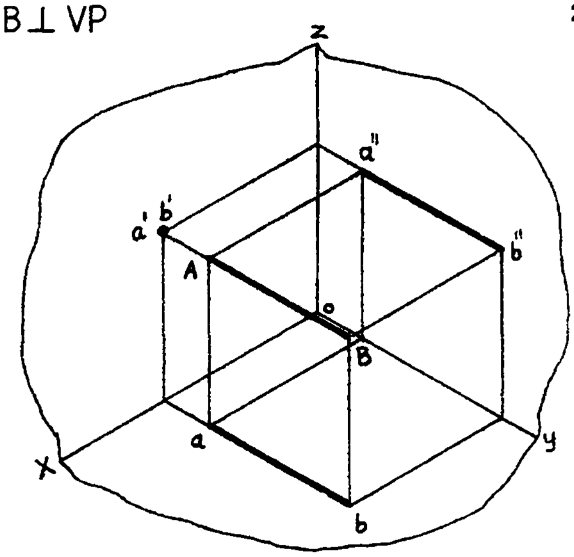


1. **Projection of a Point (A)**

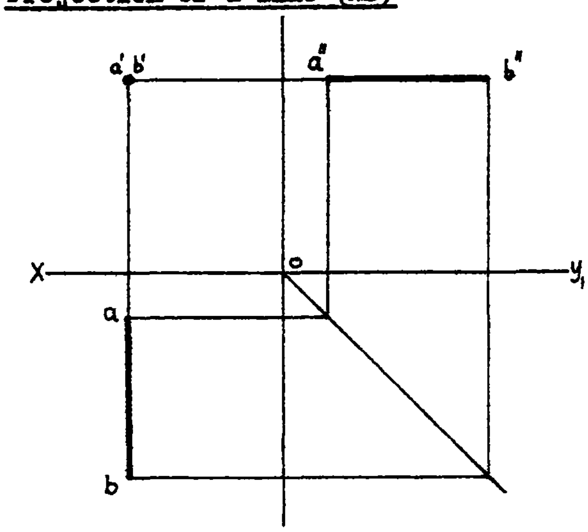


Orthographic projection of point A

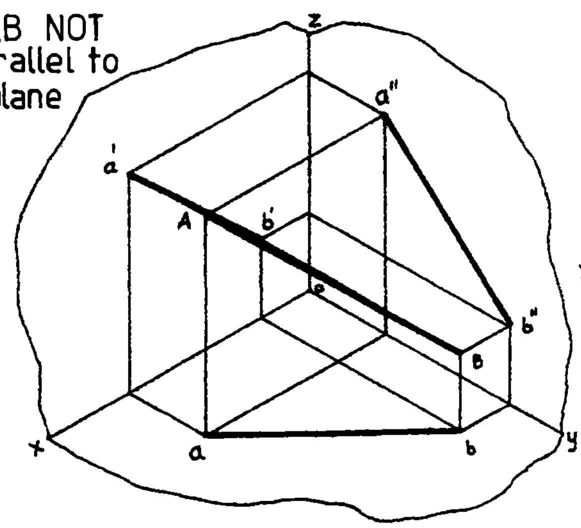
(a)AB ⊥ VP

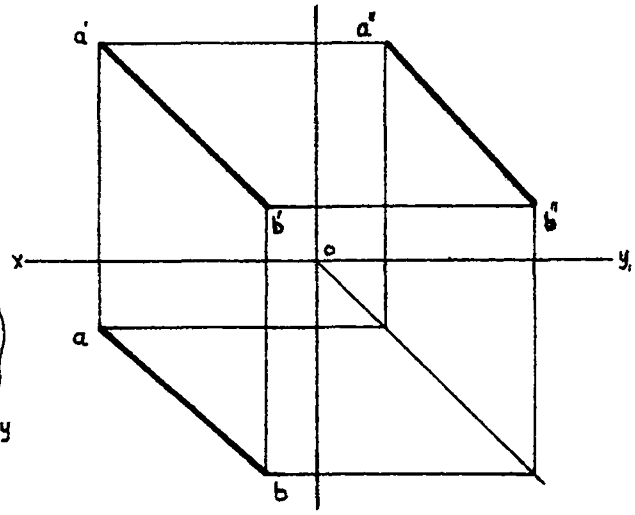


2. **Projection of a line (AB)**



(b) AB NOT
parallel to
any plane





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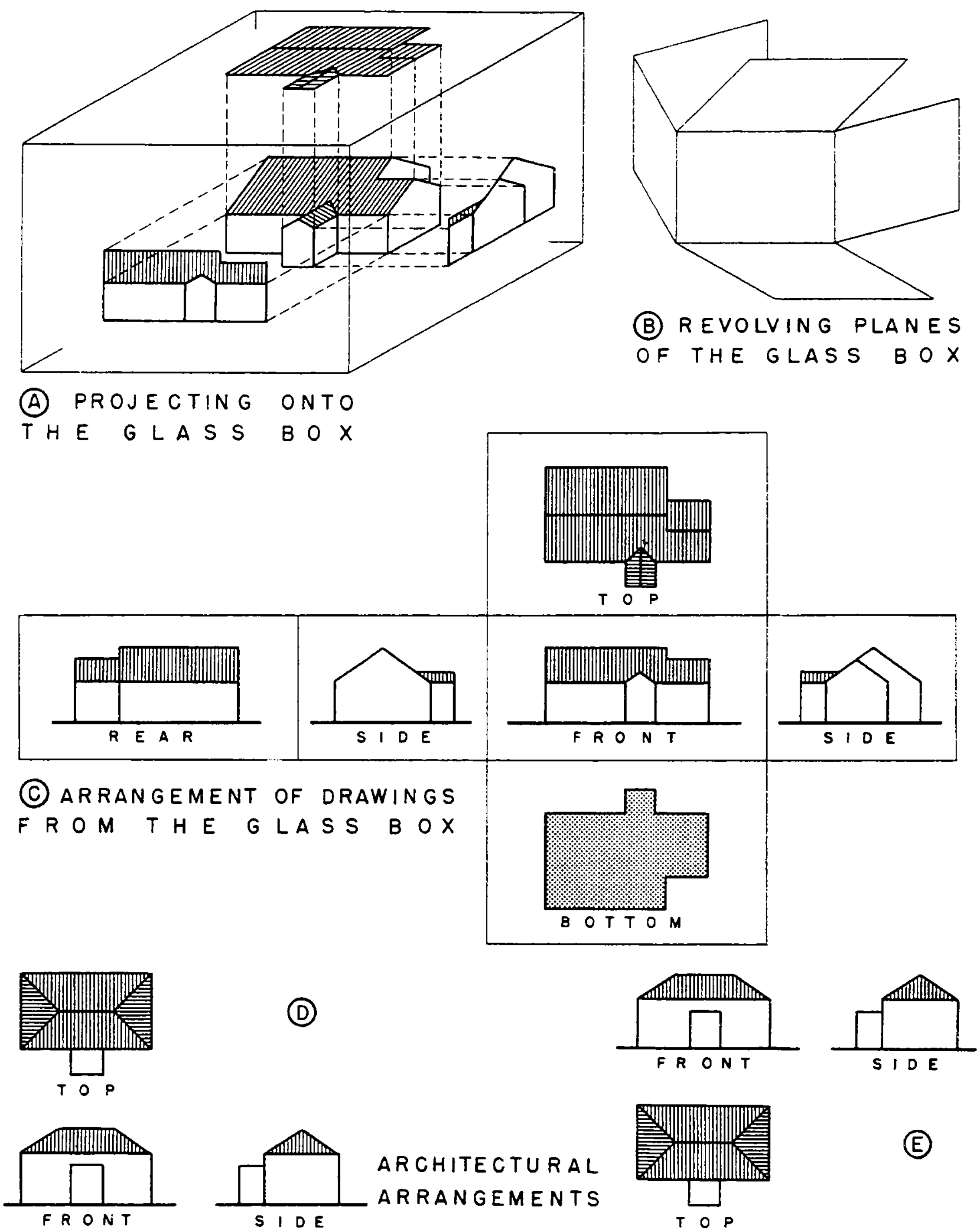

The planes provided by the transparent box - shape of the figure are not always adequate to give TRUE SHAPE VIEWS of all sides of a building. If a wall of the building is not parallel one of the typical planes and consequently one of the faces of the transparent box, its TRUE SHAPE will not be shown by any of the conventional elevations. Picture planes, which are added to the transparent box - shape in order to obtain true shape views of planes of the object not parallel to the original planes of the box, are called AUXILIARY PLANES (see figure A and D) and the projections made on these planes are called AUXILARY VIEWS.

The true shape of any oblique surface, such as a slating roof or wall, can then be obtained by projecting onto an auxiliary plane parallel to the oblique surface.

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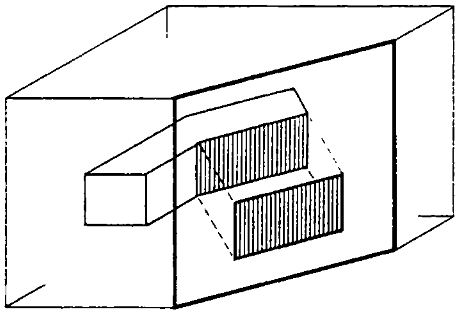
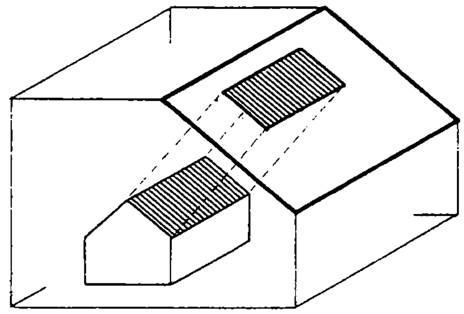
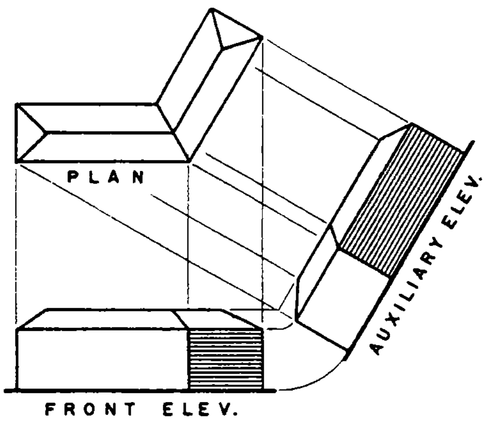
AUXILIARY VIEWS



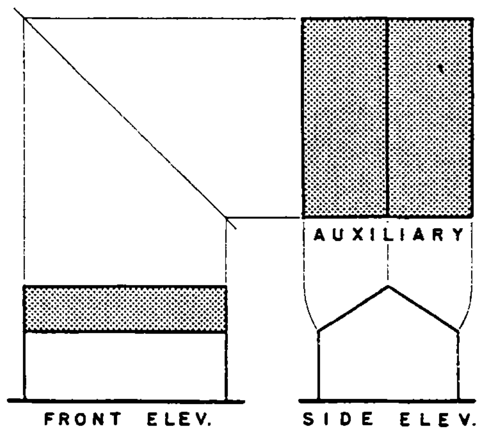
(A) VERTICAL AUXILIARY PLANE



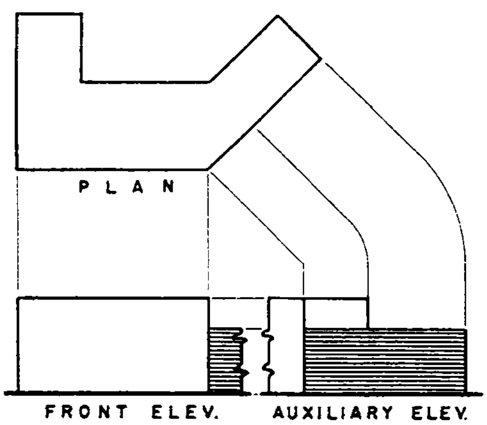
(D) OBLIQUE AUXILIARY PLANE



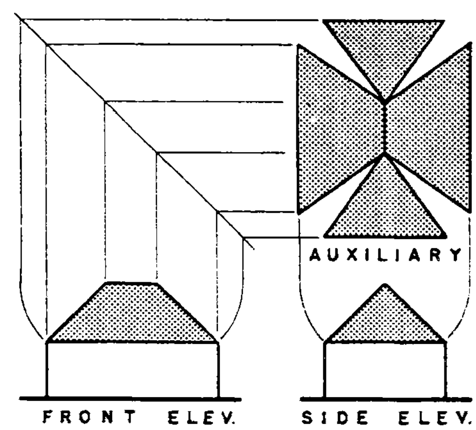
(B) COMPLETE AUXILIARY VIEW



(E) GABLE ROOF AUXILIARY



(C) PART AUXILIARY VIEW



(F) HIP ROOF AUXILIARY

ELEVATION AUXILIARIES

OBLIQUE PLANE AUXILIARIES

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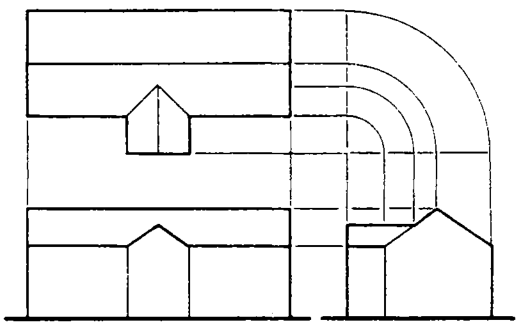
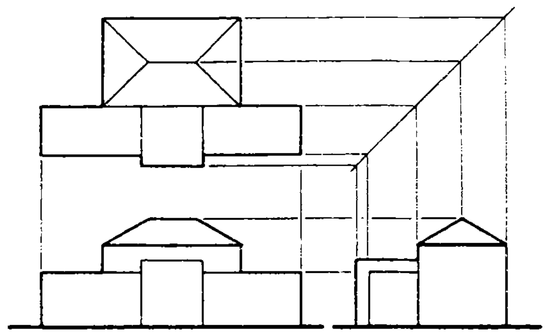
2.1 Construction of Orthographic Projection

In the CONSTRUCTION of orthographic projections, it should be kept in mind that all the different views must check. Drafting methods for the construction of orthographic projections are shown in the figure.

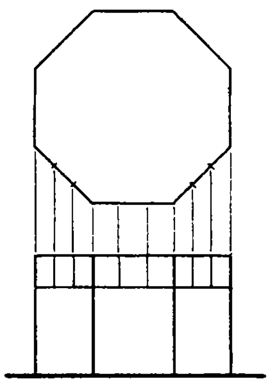
CONSTRUCTION



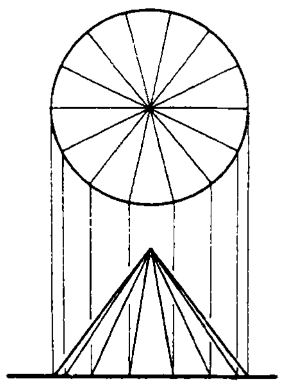
Ⓐ TURNING MEASUREMENTS WITH CIRCULAR ARCS



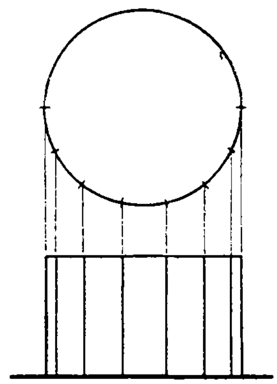
Ⓑ TURNING MEASUREMENTS ON A 45° BISECTOR



Ⓒ OCTAGON

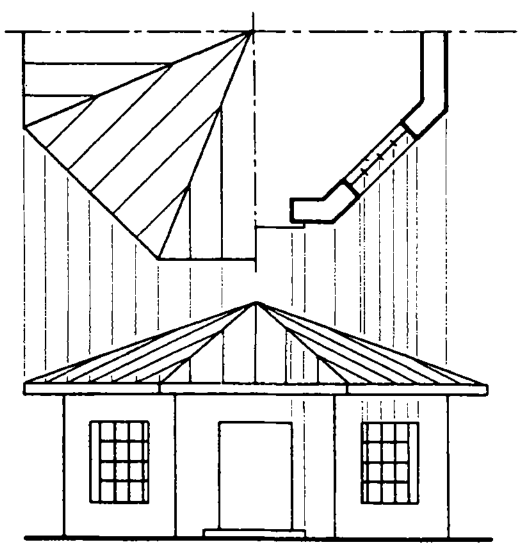


Ⓓ CONE

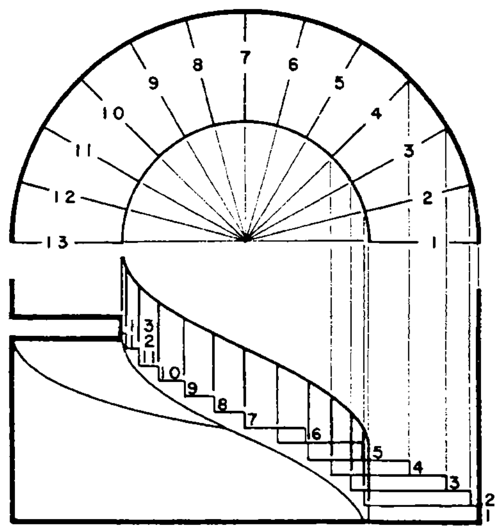


Ⓔ CYLINDER

EQUAL DIVISIONS ON GEOMETRIG SHAPES



Ⓕ OCTAGONAL BUILDING



Ⓖ SPIRAL STAIRS

ELEVATIONS

2.2 Elevations

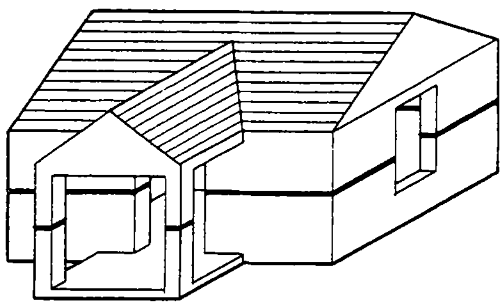
The most common auxiliary views in architecture are ELEVATIONS. The drafting process by which an auxiliary elevation is made may vary in details of construction. However, in all cases the heights may be taken from any other elevation of the building and the horizontal dimensions from plan.

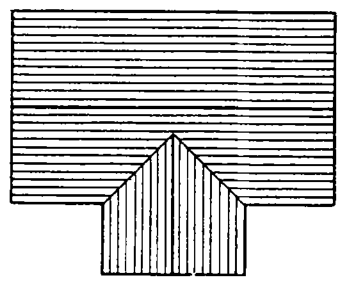
The figure shows two methods of making the auxiliary elevation from a front elevation and plan.
In B the auxiliary drawing is made to show the entire building, as would usually be done in architectural drawing. In C only the part of the building parallel to the picture plane is shown in each elevation.

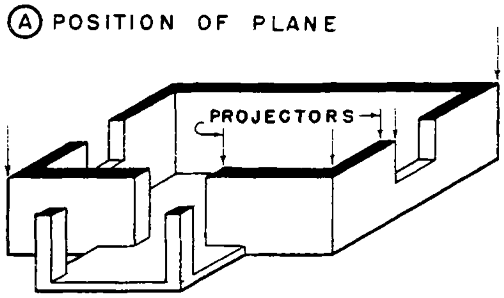
The front roof plane of E is shown by the front elevation to be a rectangle. The length of this roof area is shown in the front view and its true slant-height is shown in the side view. The rectangle made by using these two dimensions is the correct auxiliary view of the front roof plane.

In F all four planes of the simple hip roof are drawn in the auxiliary views. Such drawings are useful to show the true shapes and areas of the roof planes and the true lengths of lines in those planes. The slanting lines in the auxiliary view of F show the true length of the hips. The length of any straight line can be determine graphically by making an auxiliary view on any picture plane parallel to the line

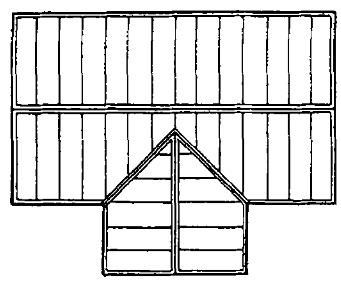
PLANS

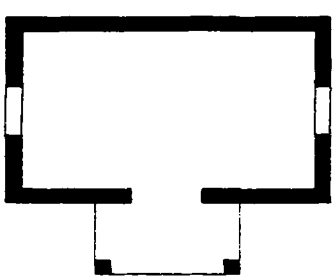

(A) POSITION OF PLANE

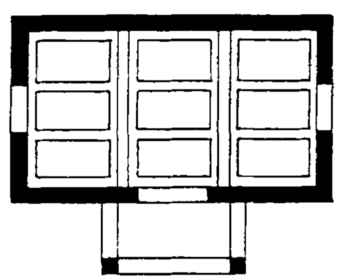

(D) ROOF PLAN



(B) TOP PART REMOVED


(E) FRAMING PLAN


(C) PLAN OF REMAINDER


(F) REFLECTED PLAN

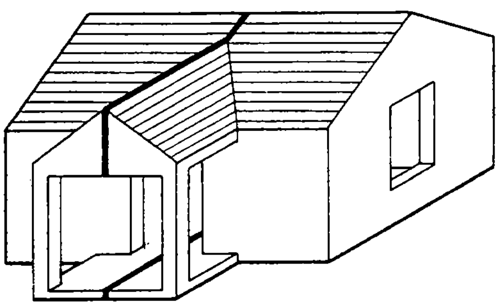
PLANS and SECTIONS

2.3 Plan s and Sections

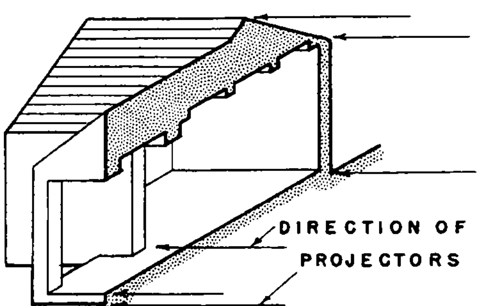
In addition to the exterior views of building it is usually necessary to have one or more views made which CUT through the structure and shows the interior. These views are known as

1. PLAN, which is the term applied to any view on a HORIZONTAL PICTURE PLANE either from the exterior or cut through, and
2. SECTION, which is the name given to any view cutting through the building on a VERTICAL PLANE.

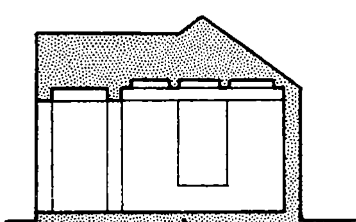
Both, the ARCHITECTURAL PLAN as well as the ARCHITECTURAL SECTION are demonstrated in the figure.



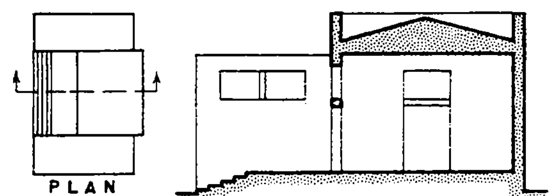
(A) POSITION OF PLANE



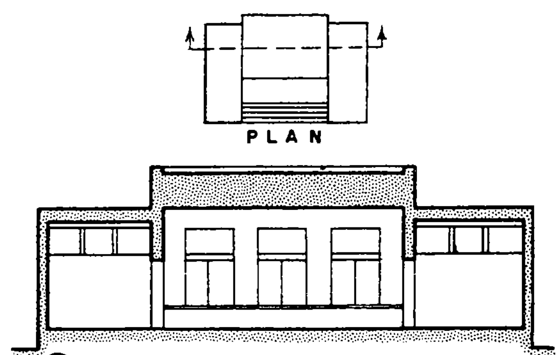
(B) RIGHT SIDE REMOVED



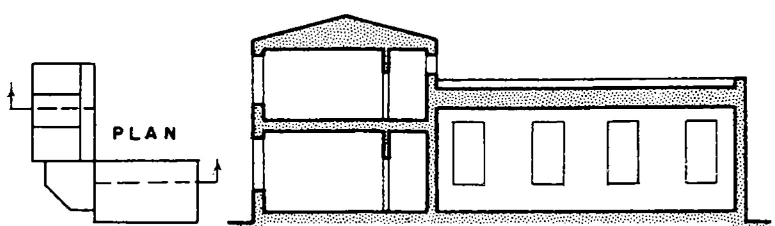
(C) SECTION OF REMAINDER



(D) TRANSVERSE SECTION



(E) LONGITUDINAL SECTION



(F) OFFSET SECTION

3. PICTORIAL DRAWING

AXONOMETRIC

3. PICTORIAL DRAWING

3.1 Axonometric Projection

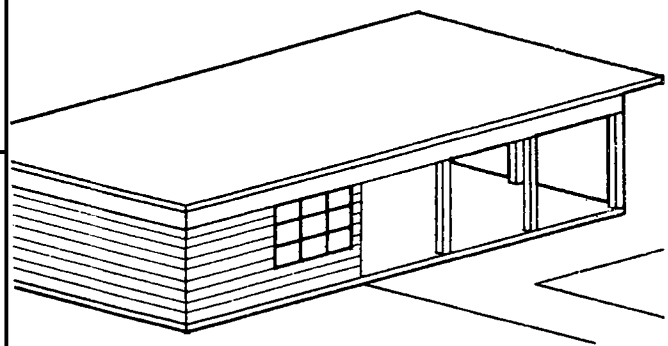
Axonometric and oblique drawings are similar in many respects. Both give views of the object which show all three typical sets of lines and planes in ONE drawing. Both are more easily understood than orthographic drawings because they show all three dimensions in one drawing and indicate the relations of the various parts of the object to each other.

In both axonomic and oblique drawings parallel lines in any direction are drawn parallel. This simplifies construction but causes the more distant parts of the object to appear to be too large. This pictorial defect is the principal criticism of these types of drawings.

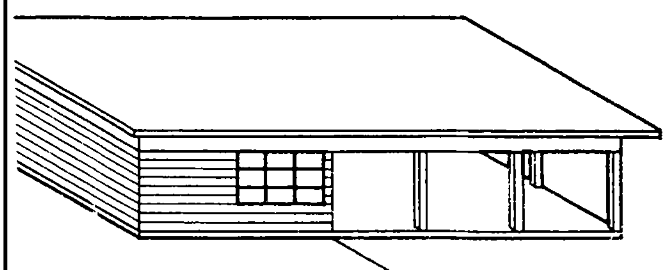
The three typical sets of lines of the object are all measured to scale in axonometric and oblique drawings. Therefore, most of the measuring can usually be done directly on the lines of the drawing itself, and it is practical to give dimensions on the drawings. Simplicity of construction is the chief advantage of these drawings over perspective drawing.

An AXONOMETRIC projection is an orthographic projection in which the object is tilted so that none of the three typical sets of planes, and consequently none of the axes at the intersections of these planes, are parallel to the picture plane.

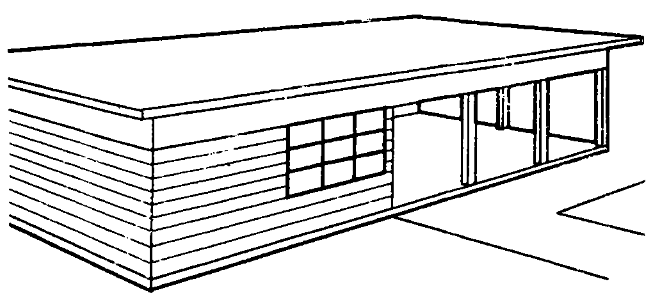
Projectors from the object, perpendicular to the picture plane, locate points on the projected drawing of the object.



(A) AXONOMETRIC



(B) OBLIQUE



(C) PERSPECTIVE

AXONOMETRIC

All axonometric projections may be divided into three classifications:

1. ISOMETRIC projections, in which all three of the axes make equal angles with the plane of projection,

2. DIMETRIC projections, in which two of the axes make equal angles with the plane of projection, and the third axis is at different angle,

3. TRIMETRIC projections, in which all three axes are at different angles with the picture plane.

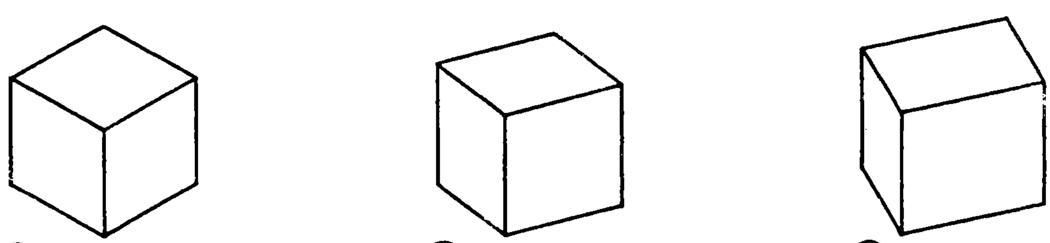
The axonometric drawings of a cube in the figure indicate the relation of the cube to the pictureplane in each case:

- In the isometric drawing all edges of the cube are represented as being of the same length because they are all turned at the same angle to the picture plane

- In the dimetric drawing of the cube two of the sets of edges are the same length and the third set a different length.

- In the trimetric drawing all three sets of edges of the cube are shown at different sizes, because the three sets of lines make different angles with the picture plane.

The relative sizes of the edges of the cube in the dimetric and trimetric drawing can be varied, but the relation is isometric drawing does not allow any variation.



(A) ISOMETRIC (B) DIMETRIC (C) TRIMETRIC

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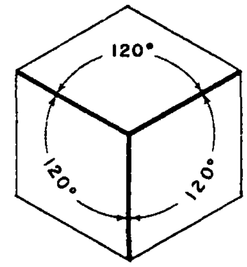
ISOMETRIC

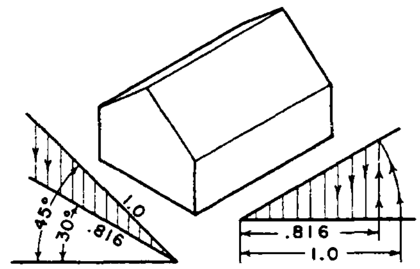
3.2 Isometric Projection.

A scale is assumed for the object and the projected or foreshortened size drawing for that scale is shown in an siometric projection. The projected size of the axis lines is 0.816 of the actual length of the lines. An isometric drawing of an object is measured at any desired scale without considering the scale size of the object represented. The figure shows the difference in size between the isometric projection (B) made with the isometric scale and the isometric drawing (C) measured with the ordinary scale. Although isometric drawings are satisfactory for most practical purposes isometric projections sometimes have advantages.

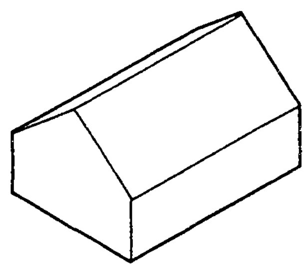
Making an isometric drawing the angle between two adjacent axes of an isometric drawing is 120°. When one axis is vertical the other two are at 30° with the horizontal.
To make an isometric drawing of a simple rectangular object: from a point selected for one of the front corners of the object draw the three axis lines and lay out on these lines their scale sizes. From the ends of the lines draw lines parallel to the axes to complete the drawing.



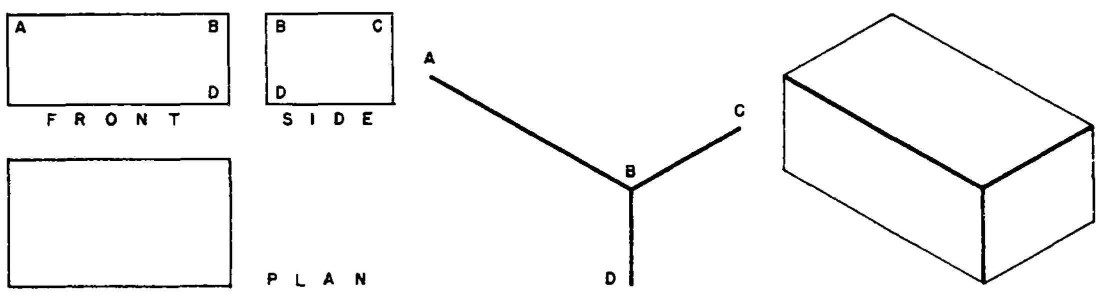
(A) ISOMETRIC AXES



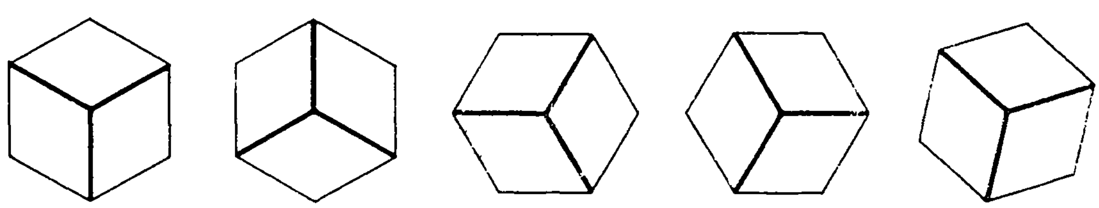
(B) ISOMETRIC PROJECTION



(C) ISOMETRIC DRAWING



(A) MULTI-VIEW DRAWINGS (B) AXES LOCATED (C) OBJECT DRAWN



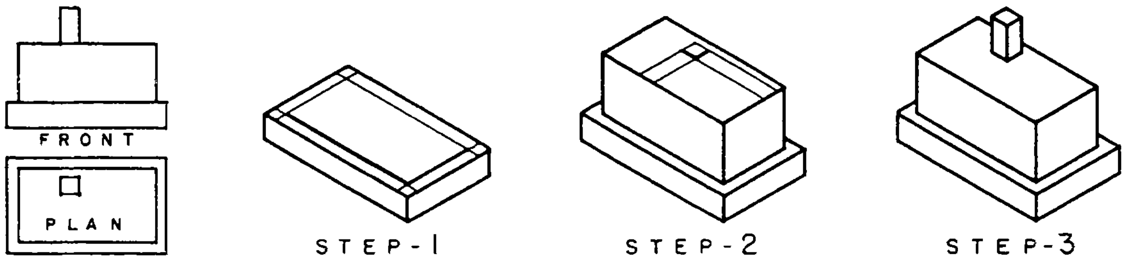
(A) ONE AXIS VERTICAL (B) (C) ONE AXIS HORIZONTAL (D) INCLINED (E)

ISOMETRIC CONSTR.METHODS

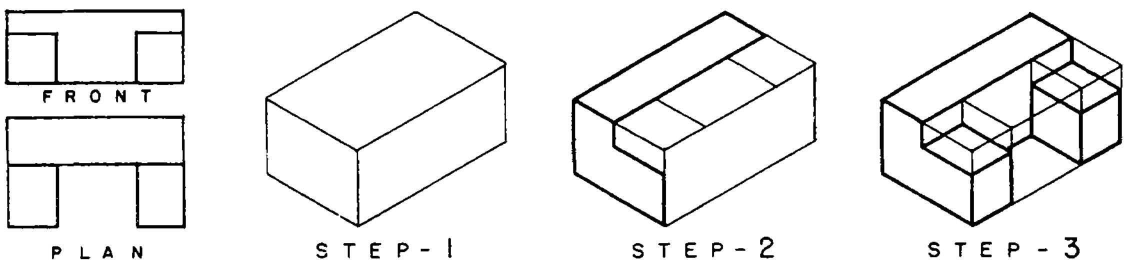
Isometric Contruction Methods:

- Offset method
- Box method
- Section

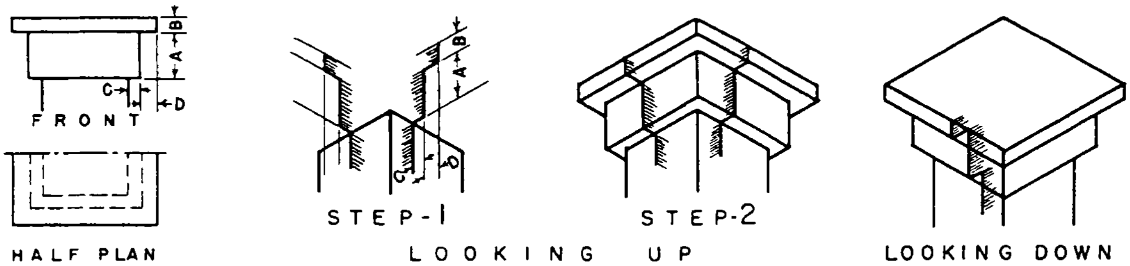
All steps are illustrated in the figure



THE OFFSET METHOD



THE BOX METHOD



THE SECTION METHOD

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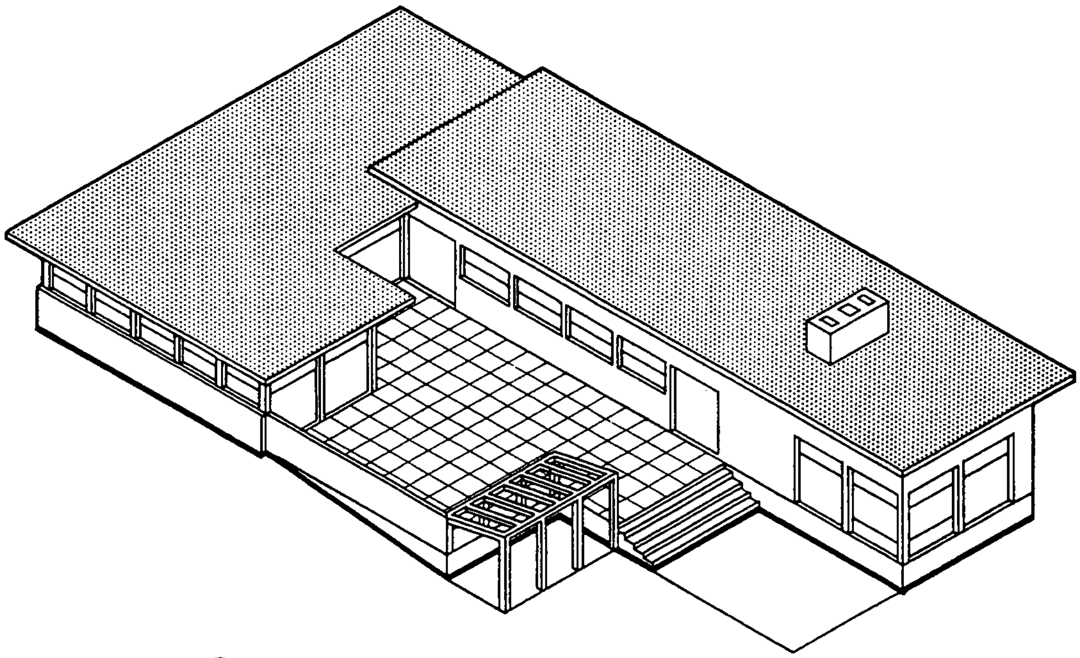
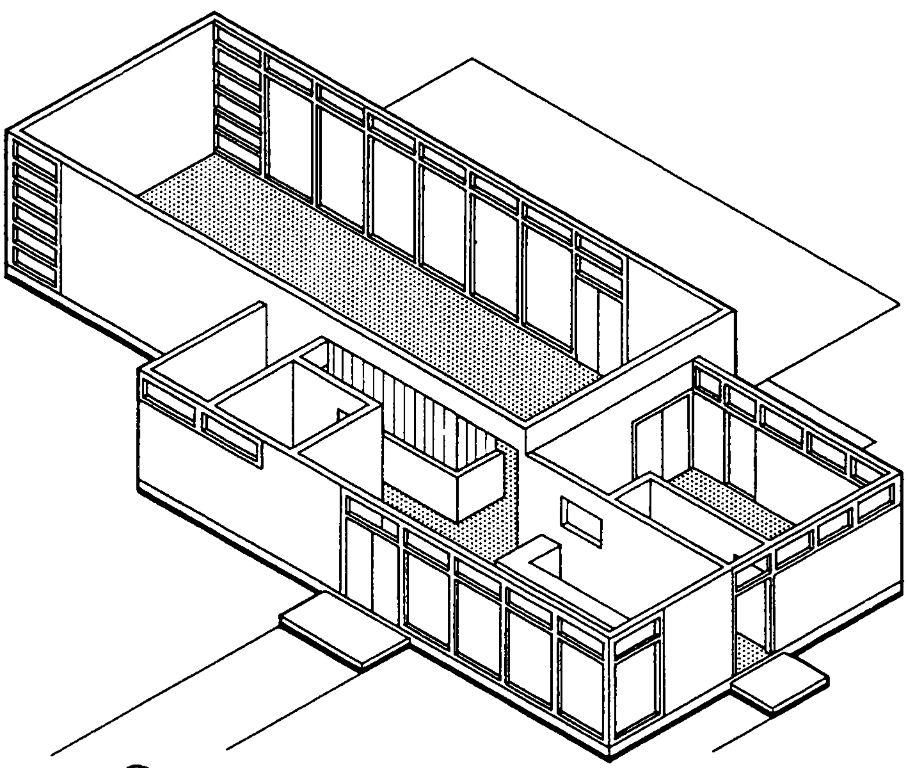
EXAMPLES



Ⓐ EXTERIOR OF BUILDING



Ⓑ VOLUMES BELOW CEILING

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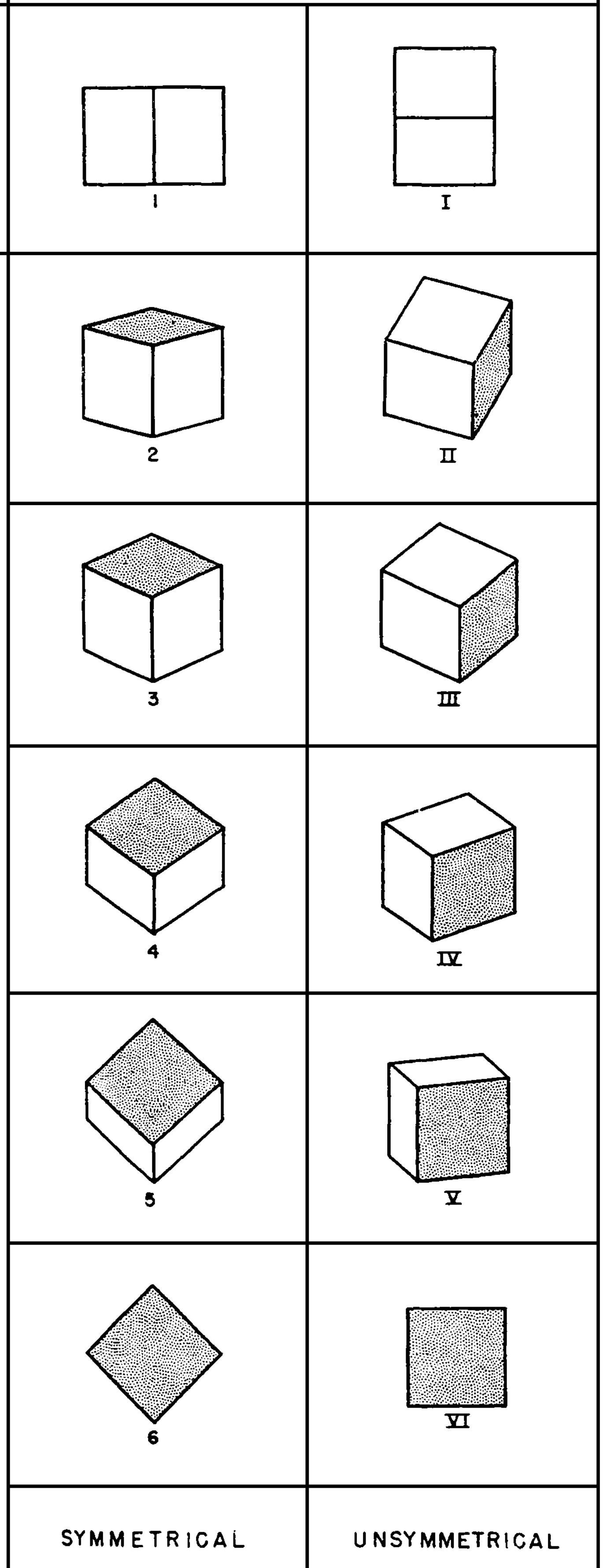
DIMETRIC



3.3. Dimetric Projection

The figure shows a cube placed so that the top and bottom are horizontal and the two visible sides make equal angleswith the picture plane. Imagine the cube to be rotated forward on a horizontal line which is parallel to the picture plane, thus keeping the sides allways at equal angles to the picture plane until the top is in a vertical position.
As the cube was rotated between these two positions the projections of its axes passed through all possible dimetric relations to each other. A few of the infinite number of possible dimetric positions obtained in this manner are illustrated in the figure.
In these illustrations the two equal axes are turned to make equal angles with a horizontal line. If one of these equal axes is turned vertically then the axes to either side will be at different scales and at different angles with a horizontal line.
Thus it is possible to use the same spacings of the axes that are shown in the left column of the figure and twist them to new positions with one of the two equal axes in a vertical position and get a new set of pictorial effects, such as are illustrated in the right column of the figure.
Dimetric drawings can then be made with the angles and scales giving either a symmmetrical or an unsymmetrical arrangement.

Isometric drawing is rigid and inflexible. There is only one possible view of the three typical planes which meet in any corner of the object because the exes must be equally spaced.

Because of its great varety of possible pictoral effects dimetric drawing overcomes the following faults and shortcomings of isometric drawings:

1) The lines of a hip roof and of equal projections of the near corner form parts of continuons vertical line in isometric drawing. This pictorial defect can be avoided in dimetric drawing by using the position of axes, which causes the two sides of the object to be turned at different angles to the picture plane.

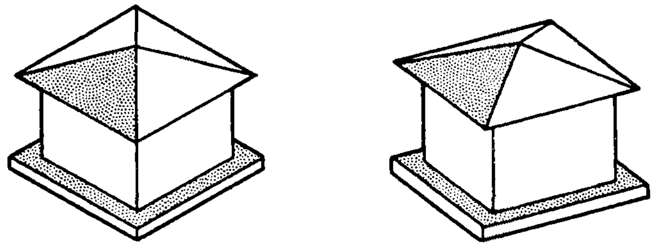
2) One of the three typical planes of the object can be emphasized in dimetric drawing by turning the object so that this plane is seen more directly and consequently occupies a greater proportionate area in the drawing. The emphasis on one plane and subordination of the other two can be in any desired ratio.

3) Two of the planes of the object can be emphasized equally and the third subordinated. Thus, it is possible to subordinate the roof or floor area and emphasize the walls or to subordinate one wall. An example of subordination of roof areas and relatively increased importance of wall areas are shown in the figure. By showing less of the roof it is also possible to see more of the wall under an extending roof.

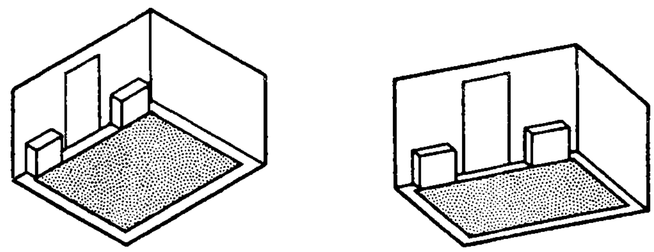
4) The unpleasant effect of wall planes at 45^{o} in isometric projection can be avoided in dimetric drawing.

Dimetric drawing has the advantage of allowing the choice of a symmetrical or unsymmetrical view of the object and emphasis on one or two of the three planes. It permits variation in the pictorial effect obtained, while isometric drawing is rigig and inflexible.

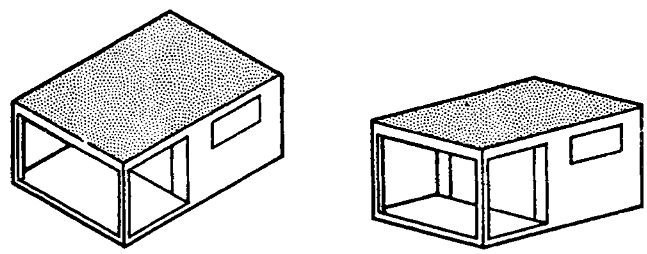
A carefully chosen dimetric drawing usually gives the most pleasing results of any of the usable types of parallel line pictorial drawing. It ranks next to perspective in desirability for presentation work.



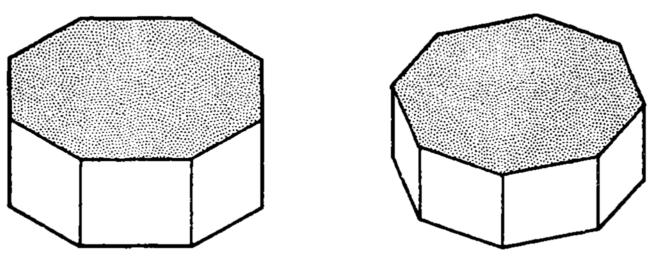
(A) NATURAL APPEARANCE OF CORNERS AND ROOF LINES



(B) EMPHASIS ON IMPORTANT WALL FLOOR AND ONE WALL SUBORDINATED



(C) EMPHASIS ON TWO WALLS ROOF AREA SUBORDINATED



(D) CLEARER REPRESENTATION OF 45° WALL SURFACES

ISOMETRIC DIMETRIC

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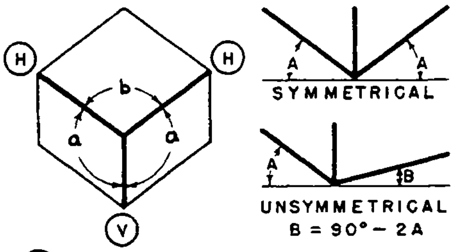
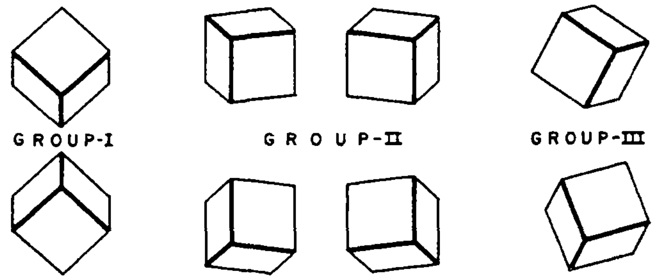
CIVIL ENGINEER. DEPARTMENT

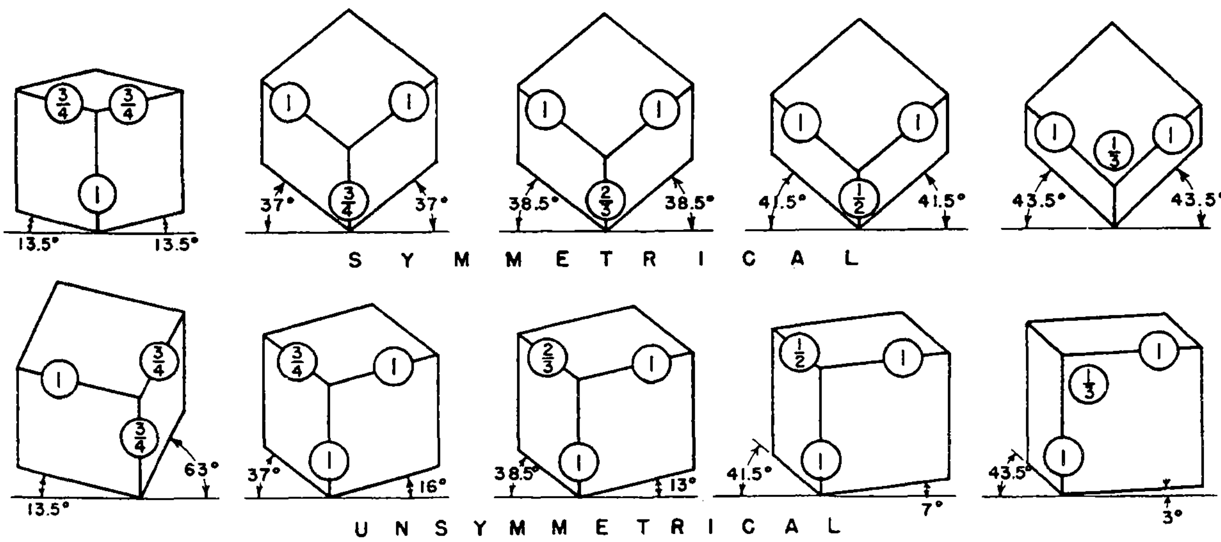
DIMETRIC SCALES & . ANGLES



(A) THE RELATION OF SCALES AND ANGLES

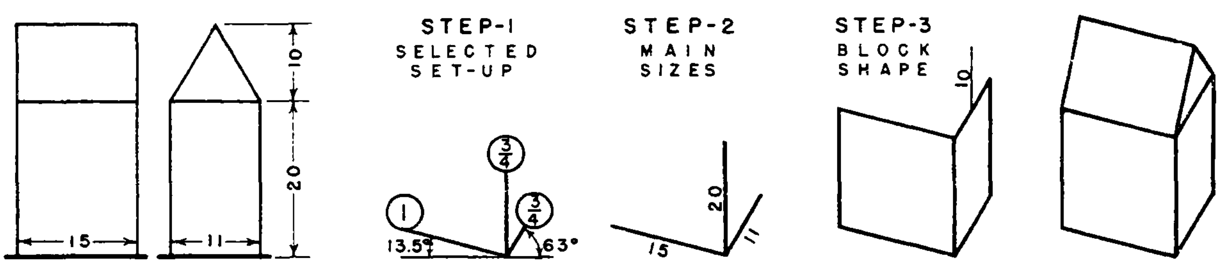


(B) POSITIONS OF THE AXES



(D) SIMPLE FRACTIONAL SCALE RELATIONS

MAKING A DIMETRIC DRAWING



(A) (B) (C) (D) (E)

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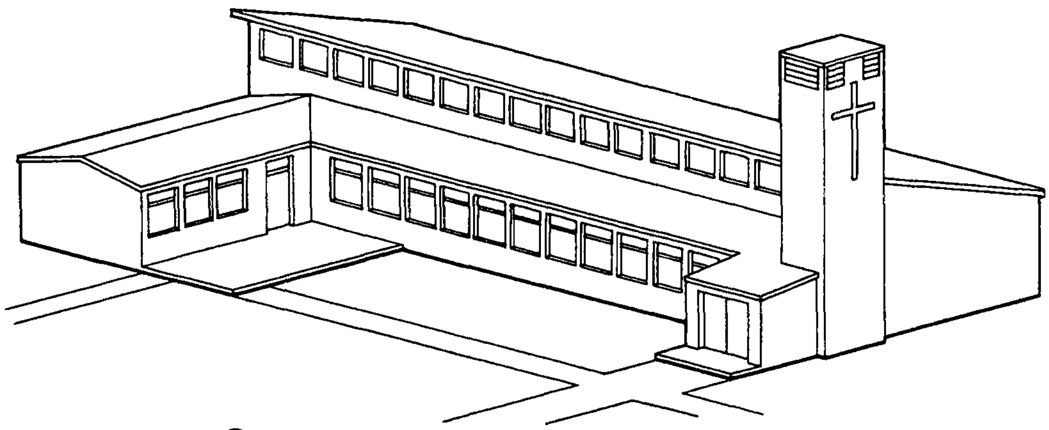
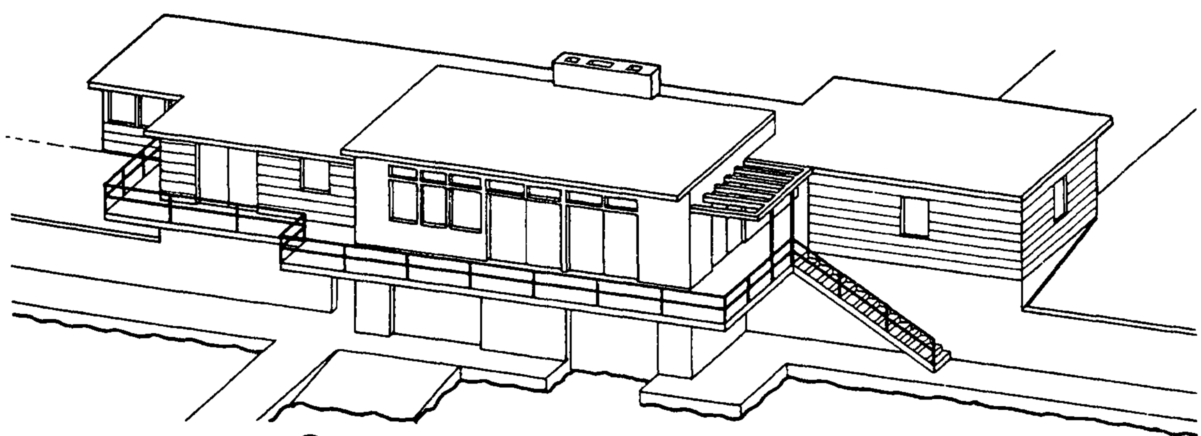
AUG. '83		CET 2043/1 3.3 18

EXAMPLES



Ⓐ A VILLAGE CHURCH



Ⓑ A BOATHOUSE

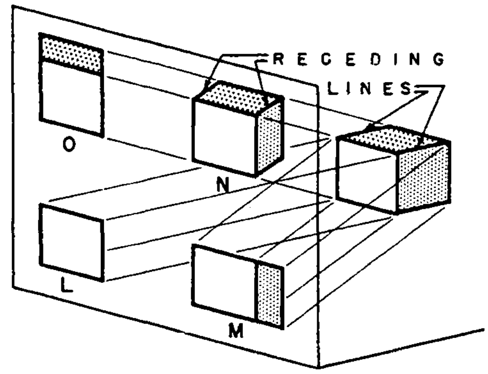
OBLIQUE

3.4 Oblique Projection

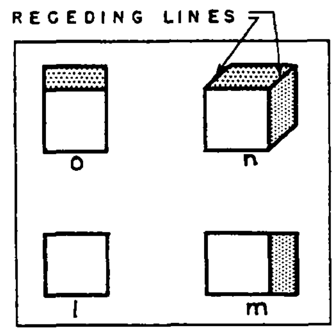
In oblique projection the projectors are oblique to the picture plane and the object is usually turned with one of the typical planes parallel to the picture plan (see fig. A)

In axonometric projection the projectors are perpendicular to the picture plane and the object has all three typical planes oblique to the picture plane. Thus, both the relation of the object to the picture plane and the direction of the projectors in oblique drawing differ from those of axonometric drawing.

Although the drawings M and O of figure A may be considered oblique drawings they are made with the projectors in planes parallel to one of the typical planes of the object and are neither good pictorial drawings nor charcteristic oblique drawings. Drawing N shows the characteristic oblique drawing in which the projectors are oblique to the three typical planes of the object. Fig. B shows these drawings as they would appear from in front of the picture plane.



Ⓐ PICTORIAL VIEW OF OBJECT AND DRAWINGS

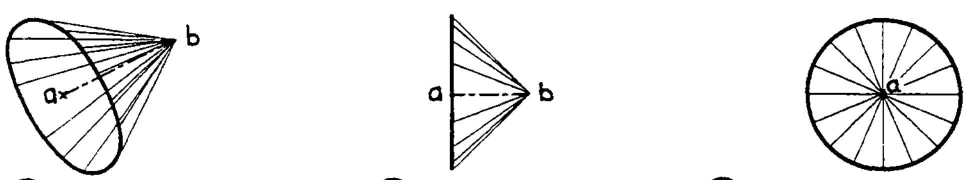


Ⓑ DRAWINGS SEEN ON THE PICTURE PLANE

3.4.1 Length of Receding Lines

The angle of the projectors with the picture plane determines the length of the receding lines of an oblique drawing. If the projectors make an angle of 45^{o} with the picture plane the receding lines will be projected in their true length.

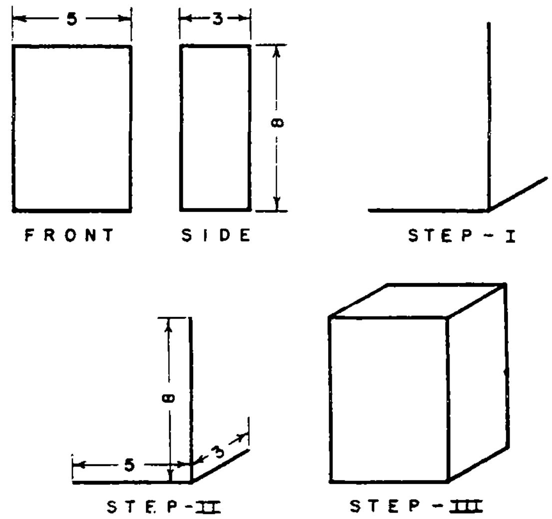
From the end b of a given receding line a - b (fig. C) any number of projectors can be drawn making an angle of 45^{o} with the picture plane. The intersections of these projectors with the picture plane will form a circle with the end ˙a˙ of the line ˙a-b˙ as a centre and the projectors will form a right cone with ˙b˙ at the apex and ˙a˙ at the centre of the base. The possible projections of the receding line ˙a-b˙ radiate in all directions from the end ˙a˙ of the line.



Ⓒ PICTORIAL VIEW Ⓓ SIDE VIEW Ⓔ FRONT VIEW

DIRECTION OF RECEDING LINES

Therefore a line can be drawn at any angle from a (fig. E), to represent the receding line 'a-b' in an oblique drawing, and the projection of the line 'a-b' will be equal to the length of the line itself if the projectors make an angle of 45° with the picture plane. By varying the angle of the projectors with the picture plane the receding lines can be made larger or smaller than scale size.



3.4.2 Construction of Oblique Drawings

The block shape shown in fig. A is drawn in oblique by proceeding as follows:

Step 1: Draw the horizontal and vertical axes and from their intersection lay out the receding axis at any desire angle.

Step 2: Lay out the dimensions of the object on the axis lines

Step 3: Draw lines from the measurements to complete the drawing.

Offset Method: The way of construction is illustrated in fig. B. Usually most measurements on an oblique drawing can be made on lines parallel to the axes. However, the planes of the object which are parallel to the picture plane appear in their true shapes and measurements can be made on them at any angle. Furthermore, any slanting lines which are parallel to the picture plane are drawn in their true directions and lengths.

3.4.3 Rules of Oblique Drawing

There are two rules of oblique drawing which should be followed when it is practical to do so (see fig. C)

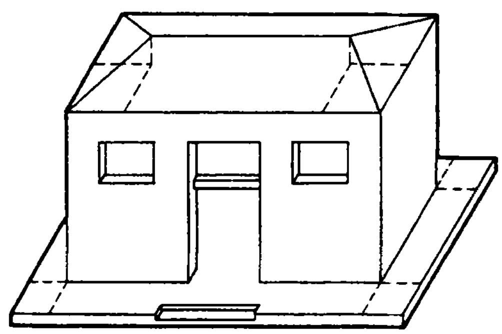
Rule 1: Turn the length of the object parallel to the picture plane

Rule 2: Turn the most complex or characteristic face of the object parallel to the picture plane

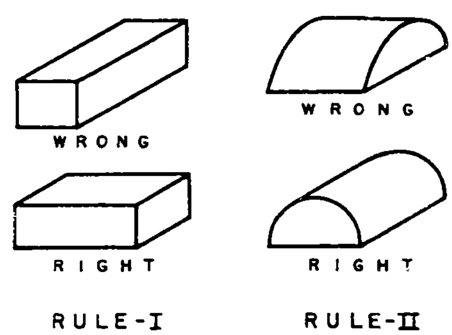
The purpose of the first rule is to decrease the appearance of distortion by making the reciding lines represent the short dimension of the object.

The purpose of the second rule is to show the true shapes of characteristic forms of the object and simplify construction .

CONSTR./RULES



(B) OFFSET CONSTRUCTION



(C) SELECTING THE VIEW

SCALE

3.4.4 Scale of the Receding Lines.

Since the projectors can be at any angle with the picture plane the receding lines of an oblique drawing can be drawn at any scale.

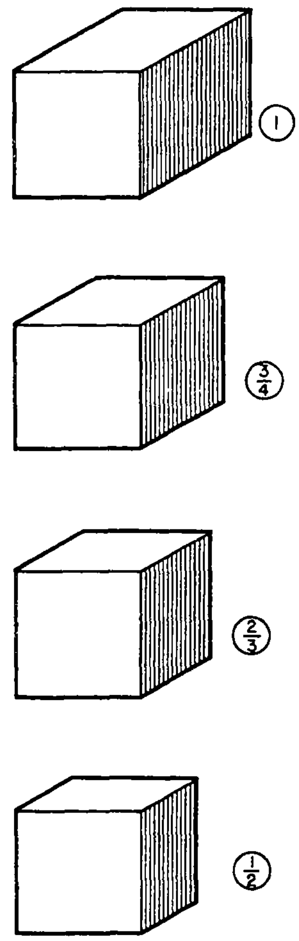
The four drawings of the cube in the figure show the effect of different scales for the receding lines on the proportions of the drawings.

- The receding lines of the CAVALIER-PROJECTION in which the same scale is used on all lines, appear to be too long.
- The CABINET PROJECTION, with half-scale on the receding lines, has gone too far in the other direction, making the receding lines appear too short and the object appear thin.

When the scale of the receding axis is made 3/4 or 2/3 of the scale of the horizontal and vertical axes the proportions of the drawings are better.

Cavalier projection has the advantage of simplicity of contruction. The use of 3/4 or 2/3 scale on the receding lines gives a better pictorial effect.

One of these scales should be used when appearance is an important factor.



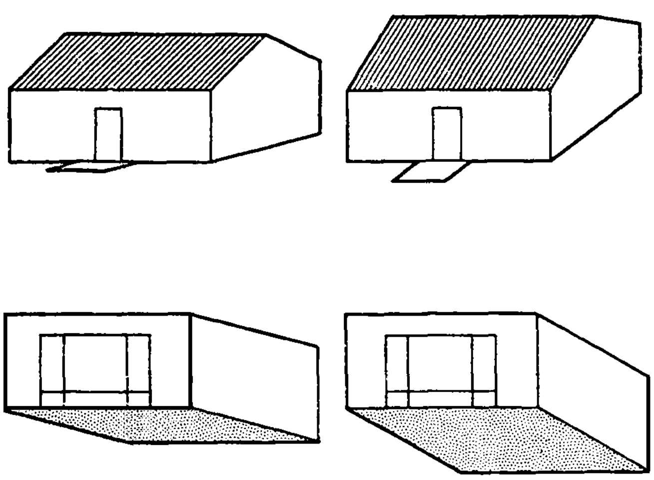
Ⓐ CAVALIER PROJECTION TOO LONG

Ⓑ IMPROVED PICTORIAL PROPORTIONS

Ⓒ IMPROVED PICTORIAL PROPORTIONS

Ⓓ CABINET PROJECTION TOO SHORT

DIRECTION



3.4.5 Direction of Receding Lines

Since the receding axis of an oblique drawing can be drawn in any direction it is possible to secure a great variety of pictorial effects. The figure shows three variations of direction of the receding lines for an exterior and an interior.

POSITION

3.4.6 Position of Axes

In all the preceding illustrations of oblique drawing one axis has been horizontal and another vertical.

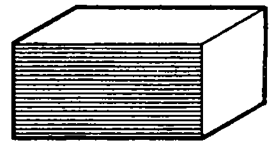
However, the axes may be turned in any position, if two of the three are kept at 90° with each other.

In A: One axis is vertical, another horizontal
In B: The oblique axis is horizontal
In C: None of the axes is vertical or horizontal
In D: The oblique axis is vertical

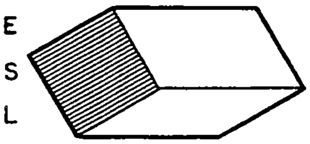
The PLAN OBLIQUE axis position, shown in D, is often used in drawing pictorial views in which it is advantageous to have the picture plane horizontal and parallel to the floor plane. This position of the axis allows all horizontal areas to appear in their true forms.

For either interior or exterior designs having horizontal, circular or other complex forms this arrangement of the axes is to be recommended for simplicity of construction and for clearest representation of the shapes. With the oblique axis vertical, the other axes must remain at 90° with each other but may be turned in any desired relation to the vertical axis. The oblique lines (vertical) should be drawn at 2/3 or 3/4 scale.

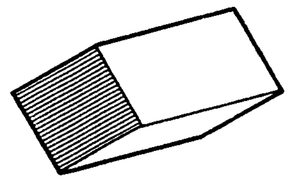
(A) ELEVATION PLANE
TRUE SHAPE
ELEVATION OBLIQUE



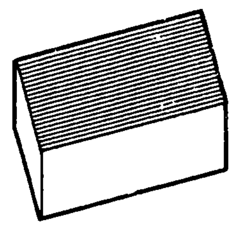
(B) END TRUE SHAPE
RECEDING LINES
HORIZONTAL



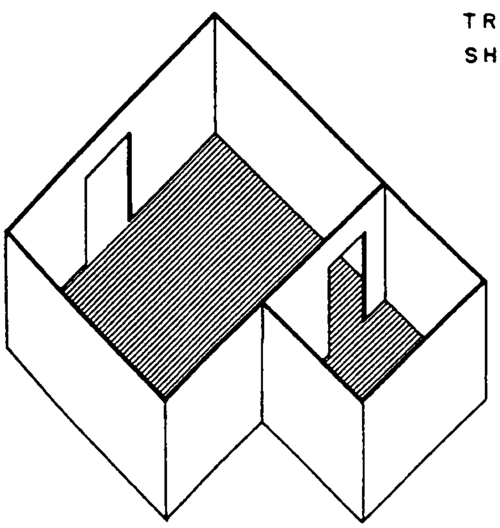
(C) INCLINED OBJECT
ALL OF AXES
OBLIQUE LINES



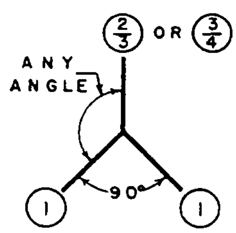
(D) PLAN PLANE
TRUE SHAPE
PLAN OBLIQUE



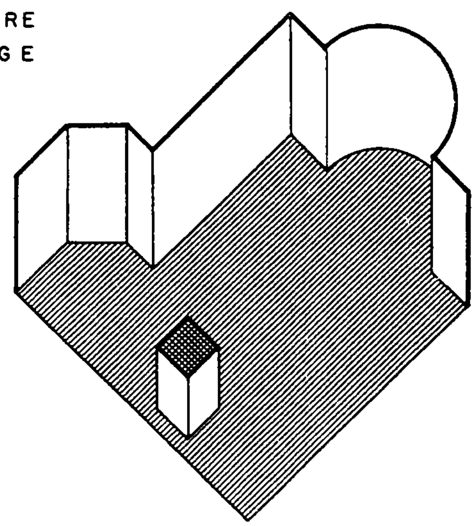
TRUE SHAPE PLANES ARE SHADED ON THIS PAGE



(A) ALL WALLS SHOWN

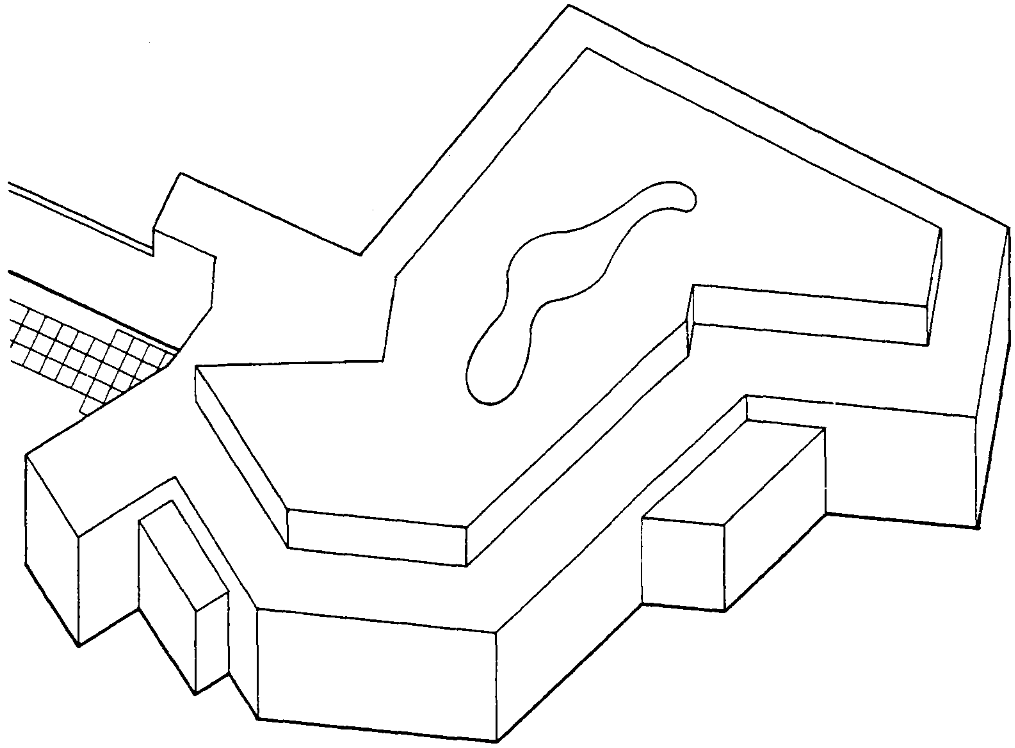


SCALE AND ANGLE DIAGRAM

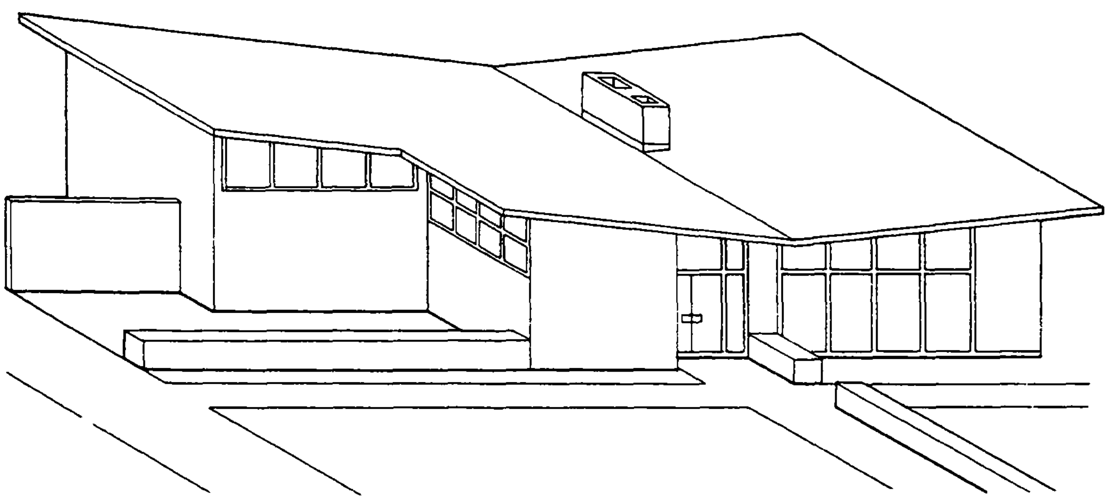


(B) NEAR WALLS OMITTED

EXAMPLES

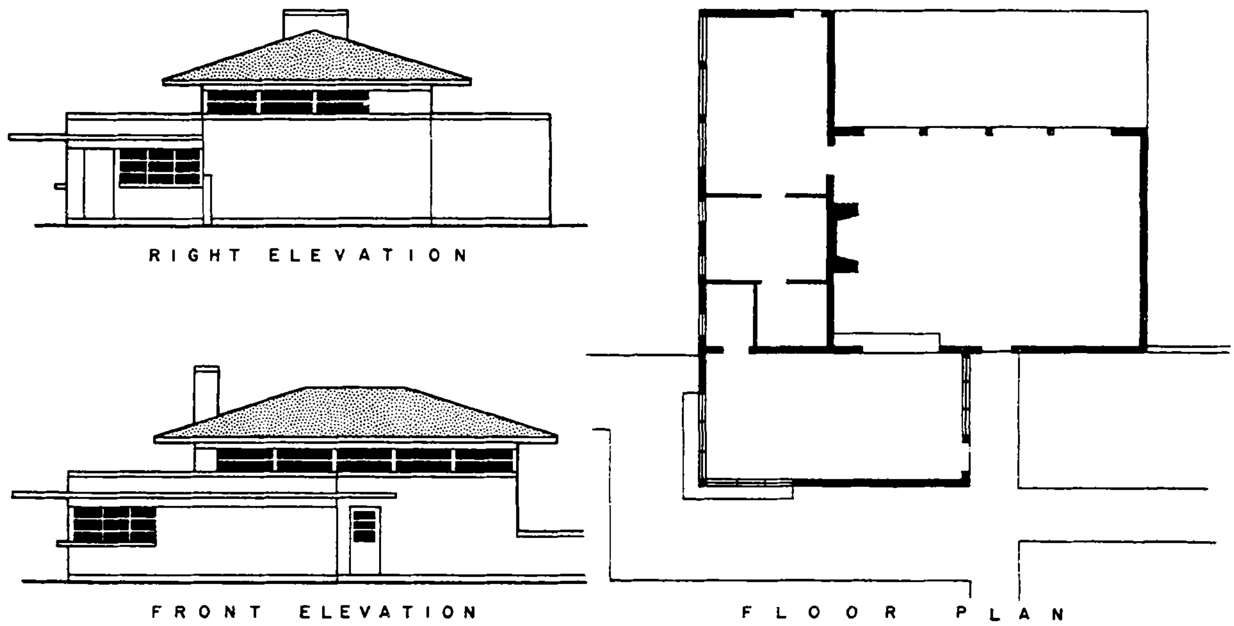


Ⓐ PLAN OBLIQUE OF AN AQUARIU

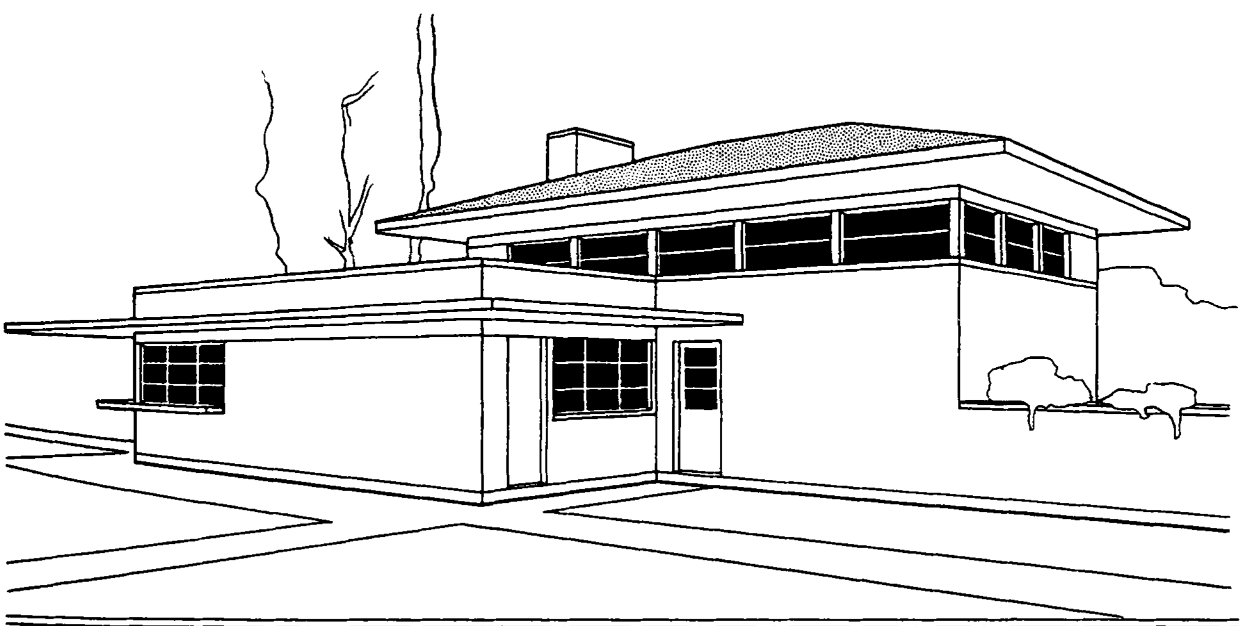


Ⓑ ELEVATION OBLIQUE OF A RESTAURANT

4. PERSPECTIVE DRAWING



(A) MULTI-VIEW DRAWINGS



(B) PERSPECTIVE DRAWING

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4. PERSPECTIVE DRAWING

PERSPECTIVE

Perspective drawing is essential in the work of the architect and designer, because it is the only type of drawing which represents an object in the natural and pleasing way that it would actually appear to the eye. In all other types of pictorial drawing all parallel lines are drawn parallel and produce the unpleasant illusion of becoming farther apart on the more distant parts of the object.

PERSPECTIVE is of value for:

1. drawings which can be easily understood by anyone,
2. an accurate method of studying and perfecting designs, and
3. explanatory sketches and drawings.

TERMS

4.1 Perspective Terms

STAND POINT (S.P.) is the position of the observers eye and is assumed to be the position from which an object is seen.

PROJECTORS. In perspective drawing the projectors converge to a station point instead of being parallel as they are in all other types of drawings.
Perspective projectors are imaginary lines of sight from the eye of the observer to points on the object.

PICTURE PLANE (P.P.) is an imaginary plane which intersect the perspective projectors in order to give points through which the perspective drawing is made, as though drawn on the picture plane.

VANISHING POINT (V.P.) is a point at which lines, not parallel to the P.P. appear to meet on the horizon line.

CENTRE OF SIGHT is the point at which the line of sight meets the P.P. and should be as near as possible to the centre of the object.

GROUND PLAN (G.P.) is the horizontal plane on which the object rests.

GROUND LINE (G.L.) is the intersection of the ground plane and the picture plane.

HORIZON LINE (H.L.) is the line parallel to the ground line and passing through the centre of sight on EYE LEVEL (E.L.).

PHENOMENA

4.2 Phenomena of Perspective Drawing

- Sizes.

In a perspective drawing sizes are shown as they appear to the eye from the position of the station point, NOT as they actually are.
The converging projectors reduce the perspective sizes of distant objects causing them to appear to be smaller than identical objects nearer the picture plane.
Objects in front of the picture plane are enlarged in the size by the projectors.

ONLY THE LINES IN THE PICTURE PLANE ARE DRAWN TO THEIR SCALE SIZES:

- Measurements.

Since lines of equal length on the object may appear in an infinite variety of sizes in a perspective drawing, it is impossible to measure sizes directly on the drawing exept in special cases. The determination of sizes, and especially of heights, is one of the most difficult features of making an perspective drawing.

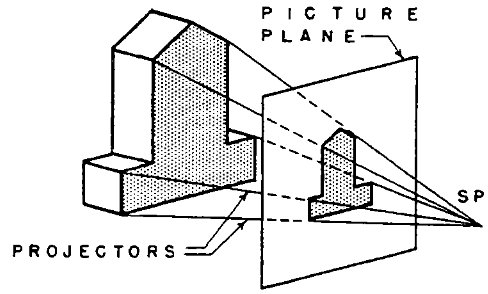
Any lines of the object which lie in the picture plane can be measured to scale.
Parts of the object in front of the P.P. will be larger than scale size.
Parts of the object in the back of the P.P. will be smaller than scale size.

The various methods of perspective drawingobtain this correction of sizes in different ways.

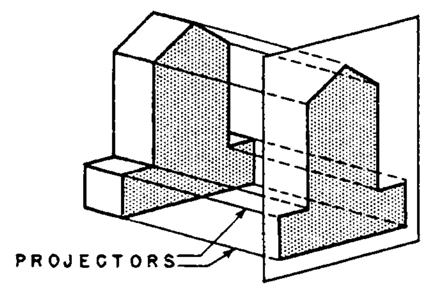
- Shapes.

In perspective drawing the object is represented as it appears to the eye.
Areas and angles usually do not appear in perspective as they really are.

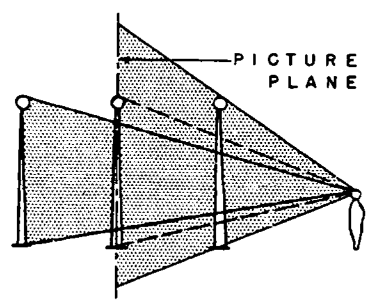
Rectangles and squares are often drawn as irregular quadrilaterals with four unequal sides and four unequal angles.
A right angle seldom appears as such in a perspective but is drawn as an acute or otuse angle. A circle usually appears as an ellipse in perspective.



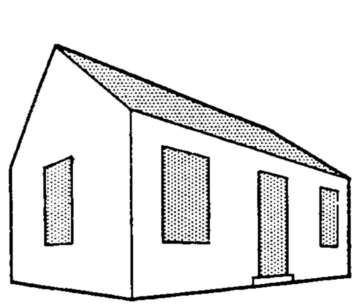
(A) CONVERGING PROJECTORS IN PERSPECTIVE



(B) PARALLEL PROJECTORS IN ALL OTHER DRAWING



(C) EFFECT OF DISTANCE ON PERSPECTIVE



(D) VARIATIONS OF SIZE IN LINES AND AREAS

- Horizontal Surfaces.

The horizon is at the level of the station point in a perspective drawing. The eye looks up at things above the horizon and down on things below the horizon. Horizontal surfaces above the horizon (eye level) are visible from below and horizontal surfaces below the horizon. Such as steps, are visible from above. Thus, both the ceiling and floor of a room may be seen in the same perspective drawing, if the horizon line is located at some position between the floor and ceiling.

The size of a horizontal area in a perspective drawing depends on the distance and angle from which it is seen.

With the area at a constant horizontal distance from the station point, at the level of the horizon, a given horizontal area appears as a line and increases in visible size with its distance above or below the horizon.

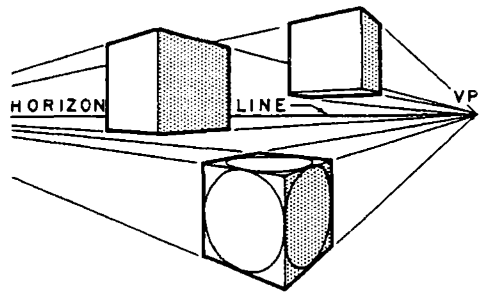
When the height of a horizontal or vertical area is constant, its visible size increases as it approaches the station point and diminishes as it recedes farther from the station point.

Except that, whenever the line of vision passes through the plane of a surface the surface is always seen as a LINE. I.e.: any horizontal plane at the level of the horizon would always appear as a straight line.

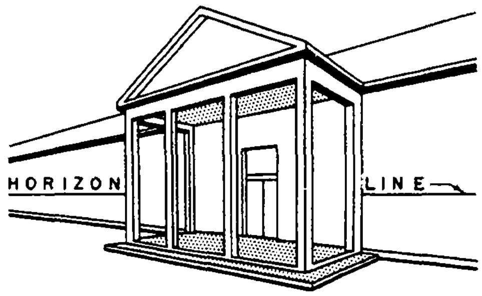
- Lines Parallel to the Picture Plane.

These lines retain their true direction in perspective. Thus, horizontal and vertical lines parallel to the picture plane remain respectively horizontal and vertical. Sets of parallel lines which are parallel to the picture plane remain parallel perspective just as they do in orthographic projection.

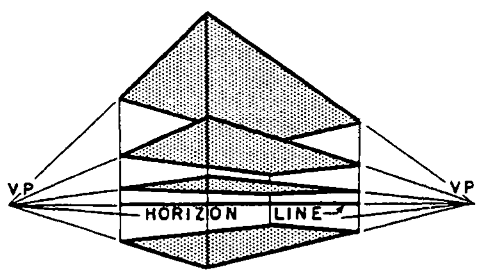
However, the length of the parallel lines in perspective varies with the distance from the picture plane, instead of being projected in actual size relations.



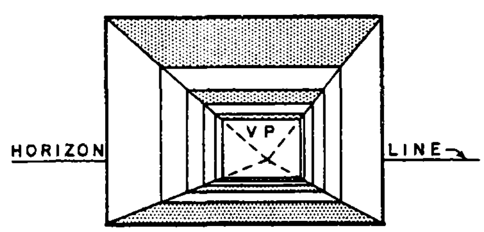
(A) APPEARANCE OF SHAPES OF AREAS AND MASSES



(B) HORIZONTAL AREAS IN PERSPECTIVE



(C) EFFECT OF HEIGHT ON HORIZONTAL AREAS

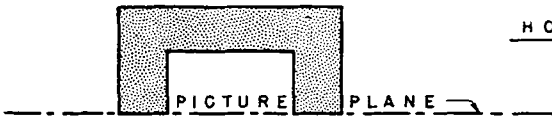


(D) EFFECT OF DISTANCE ON LINES AND AREAS

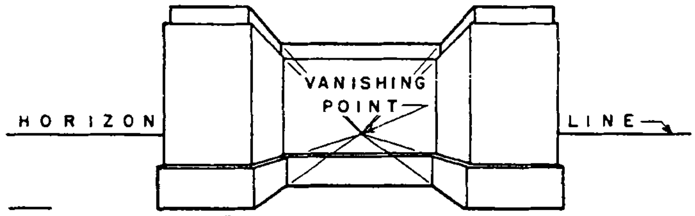
- Lines NOT Parallel to the Picture Plane.

In perspective each set of parallel lines which is not parallel to the picture plane converges to its vanishing point. The vanishing points of all sets of horizontal lines are located on the horizon, which is alsways on a level with the eye of the observer, the Station Point.

PERSPECTIVE SYSTEMS

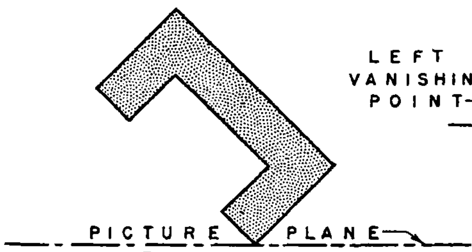


Ⓐ PLAN

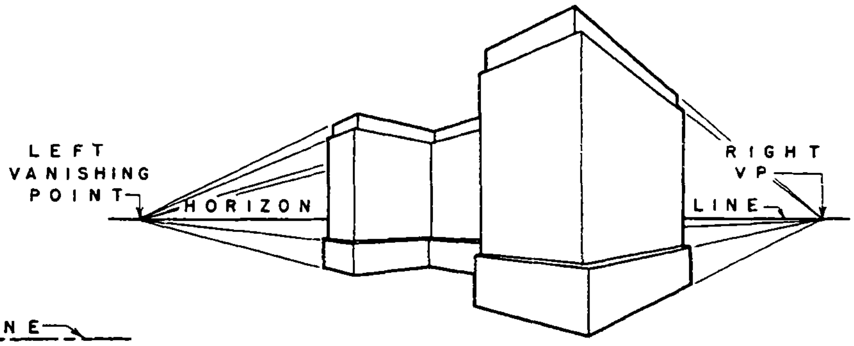


Ⓑ PERSPECTIVE

PARALLEL OR ONE-POINT PERSPECTIVE SYSTEM

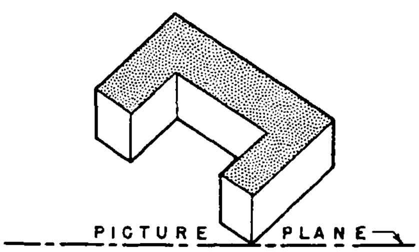


Ⓒ PLAN

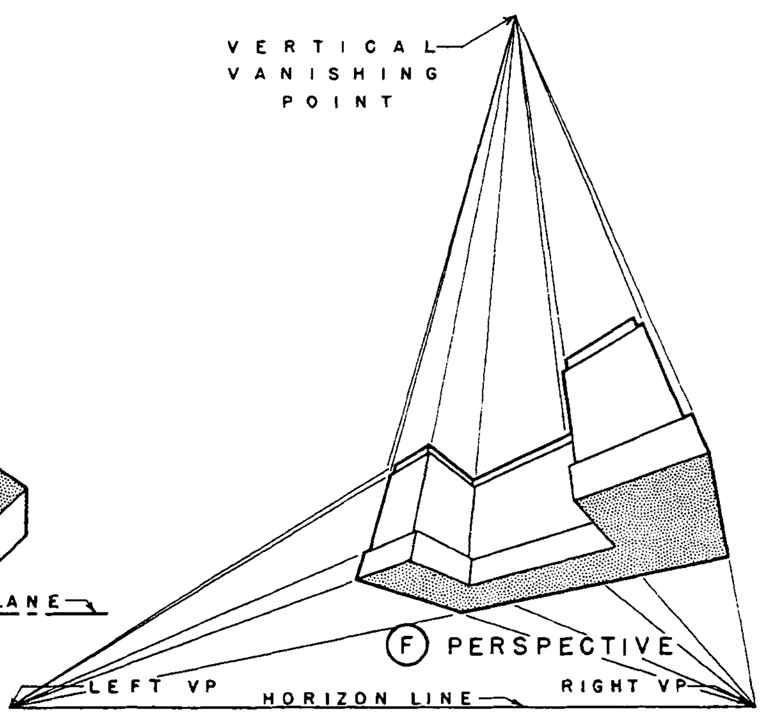


Ⓓ PERSPECTIVE

ANGULAR OR TWO-POINT PERSPECTIVE SYSTEM



Ⓔ PLAN



Ⓕ PERSPECTIVE

OBLIQUE OR THREE-POINT PERSPECTIVE SYSTEM

4.3 Systems of Perspective Drawings.
There are three systems of perspective drawing which are classified according to the relation between the object and the picture plane and the resulting number of vanishing points for the three sets of typical lines.
Most buildings have as important elements three sets of planes which are illustrated by a box.
One of these sets of planes is horizontal (top and bottom). The other two are vertical and at right angles to each other. These planes meet in the three sets of typical lines of which one set is vertical and the other two horizontal and at right angles to each other.
In the PARALLEL or ONE POINT perspective system one set of planes and two sets of lines of the object are parallel to the picture plane, Fig. A. Lines of these two sets remain respectively vertical and horizontal in perspective, Fig. B. The remaining set of horizontal lines is perpendicular to the picture plane and vonverges to a vanishing point.
In the ANGULAR or TWO POINT perspective system the object is turned with both sets of horizontal lines at an angle to the picture plane, as shown in the plan of Fig. C. There are, therefore, two vanishing points, one for each of these sets of horizontal lines, Fig. D. Since the vertical lines are parallel to the picture plane they remain vertical and parallel in the perspective.

In the OBLIQUE or THREE POINT perspective system the object is turned, or the picture plane tilted, so that none of the three sets of typical planes and lines of the object is parallel to the picture plane, plan Fig. E.Since all three sets of lines are at an angle to the picture plane, there are three sets of converging lines and three vanishing points, as shown in Fig. F.
The three vanishing points of the typical sets of lines are the only ones mentioned in this discussion of systems of perspective drawings. However, vanishing points of other sets of parallel lines are sometimes useful. Their location and use will be explaned later.

SYSTEMS

METHODS

4.4 Methods of Perspective Drawings.

A perspective of an existing object can be sketched on a picture plane made of a sheet of glass in the following manner:Place the picture plane at arms length, keep the eye in one position, and draw lines to exactly cover the lines of the object as seen through the stationary picture plane (see fig.). A window glass makes an excellent picture plane for this purpose. Whenever the object ist not conveniently located, when greater accuracy is required, or when there is no existing object but only the drawings of some proposed structure, it is necessary to use some other method of making the perspective. However, the various drafting methods of making perspective drawings are based on this method of sketching the perspective of an existing object on a transparent plane.
A perspective drawing is made by working out by one of the drafting methods the positions of the lines of the object as they would appear on a given picture plane from a given station point. Three of these mechanical methods of constructing perspective drawings:

1) the direct projection method
2) the perspective plan method
3) the common method.

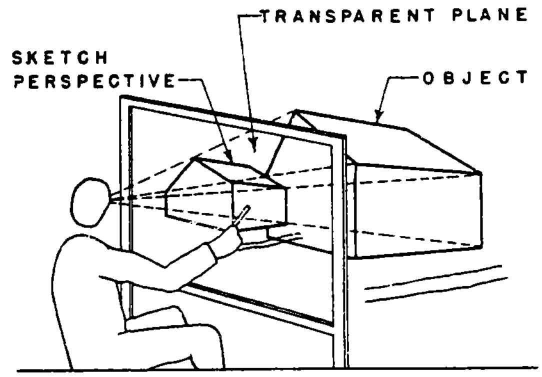
These methods are described in a general way in the following paragraphs and are explained in detail in the chapters on one- and two-point perspective.

METHODS

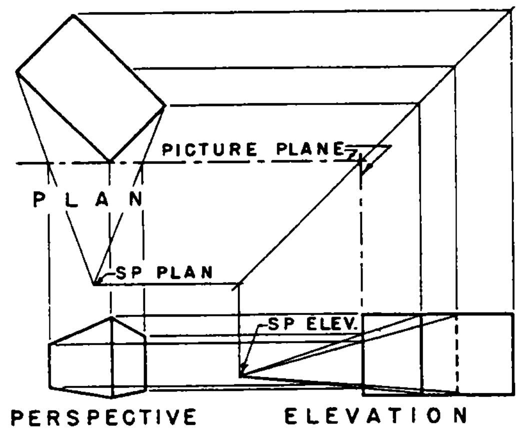
THE DIRECT PROJECTION METHOD has the simplest theory of any method of perspective drawing. Plan and elevation views parallel to the picture plane showing the object, picture plane, and station point are first drawn the fig. The converging projectors are then traced to the picture plane in plan and elevation. Points on the perspective drawing are located from their heights, which are determined from the projectors in plan. The drawings are so arranged that the heights can be carried across horizontally with the T-square and the widths brought down vertically with the triangle to their positions in the perspective from the intersections of the projectors with the picture plane.

The direct projection method is a good method for one-point perspective because the auxiliary drawings used are the plan and elevations, or sections. These drawings are easily understood by the draftsman, and are often available at the correct scale. In two-point perspecktive one or two special drawings are required for the direct projection method. These drawings are auxiliary elevations or sections from a corner (parallel to the picture plane) and are more difficult to construct and understand than the ordinary elevations and sections. If this method is used without vanishing points very slight inaccuracies will change the directions of short lines and produce a warped effect. This method requires a great deal of space on the drafting board and many construction lines. Although vanishing points are not required their use will simplify the construction and make the drawing more accurate.

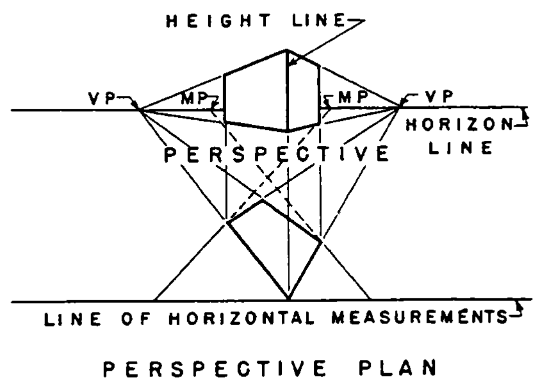
THE PERSPECTIVE PLAN METHODallows the entire perspective to be constructed from measurements made in the picture plane and broght into correct perspective sizes and positions by tracing line to their vanishing points. The plan is first drawn in perspective. The vertical lines of the perspective drawing are then obtained by drawing



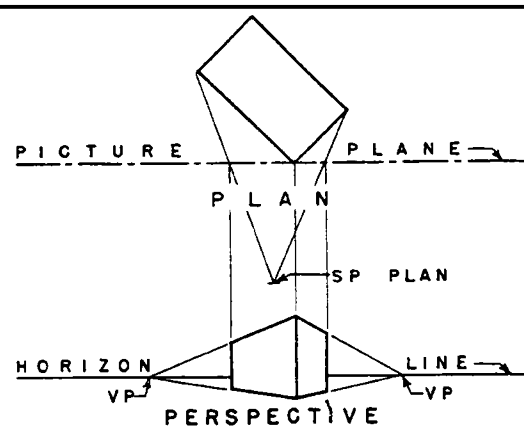
SKETCHING A PERSPECTIVE



DIRECT PROJECTION METHOD



PERSPECTIVE PLAN METHOD



COMMON OR OFFICE METHOD

vertically from the perspective plan. The scale heights are laid out on any convenient vertical line in the picture plane from which they can be traced by lines toward the vanishing points into their correct perspective positions.

Since this method divides the construction into two steps, the construction lines are easier to trace to the perspective. In addition to the vanishing points of the sets of typical lines not parallel to the picture plane, the perspective plan method requires one or more measuring points to be used in drawing the perspective plan. A measuring point is the vanishing point for the set of parallel lines , which transfers scale measurements of horizontal dimensions from the horizontal measuring line to a base line of the perspective plan. The location and use of measuring points is explained under one- and two-point perspective.

The perspective plan can be drawn at any convenient height either above or below the perspective drawing. It can be placed on an important plane of the perspective, such as the floor of an interior or ground plane of an exterior. It is practical and sometimes very convenient to use more than one perspective plan for tall buildings. The perspective plan method requires less space on the drawing board than any other widely used method and is considered the best method by some expert draftsmen.

METHODS

THE COMMON METHOD is also called the OFFICE METHOD and the MIXED METHOD. It combines the plan construction for horizontal spacing of vertical lines of the direct projection method and the height contruction of the perspective plan method.(Fig.) It is widely used in offices and schools. One reason for its popularity is that plans and elevations which are available at the correct scale may be attached to the drawing board and used as auxiliary drawings from which the perspective is made.

CHOOSING A METHOD Each of these methods of making perspective drawings has advantags and disadvantages. Som problems are more easily solved by one method, some by another. This is partly due to the varying nature of designs, and partly because of the information furnished by available drawings of the object of which the perspective is to be made. All accomplish the same result - a true picture of the object from some chosen position.

TWO-POINT PERSPECTIVE

4.5 TWO-POINT PERSPECTIVE

Two - point perspective is the most widely used of the three perspective systems. It is typical of the way in which buildings are usually seen and of photographs of buildings. It is, therefore, of greatest importance to the architect and draftsman. When only one kind of perspective is to be learned twopoint perspective is in most cases the one.

THE COMMON METHOD. The most popular and most widely used method of two-point perspective is called the common method. In this method the plan of the object, picture plane, and station point is used to work out the horizontal spacing of points, and vertical lines for the perspective. The plan is turned with the line of the picture plane horizontal. It is convenient to have an elevation at one side of and below the plan. From this elevation the heights can be carried across with the T-square to the construction for the correct heights for the perspective. Any elevation, or section, or part of either drawing which gives all of the heights necessary to construct the perspective drawing will serve for this purpose. Although it is not necessary to have an elevation or section included in the construction its use makes the construction more easily understood, decreases the chance of error in working out heights, and makes the checking of construction easier.

THE CONSTRUCTION OF A SIMPLE TWO-POINT PERSPECTIVE.
The construction by the common method has been divided into a series of steps, illustrated in fig. A,B, and C, These steps are typical of the procedure followed in this method of two-point perspective.

- THE AUXILIARY DRAWINGSare a plan and elevation. The plan of the object, picture p lane, and station point is drawn with the picture plane line horizonal (fig. A). The elevation is drawn and the horizon line and ground line placed to suit it.

The horizon line is at the height of the eye of the observer. The ground line is drawn at the bottom of the elevation. The station point should be approximately on a line perpendicular to the picture plane through the center of the plan.

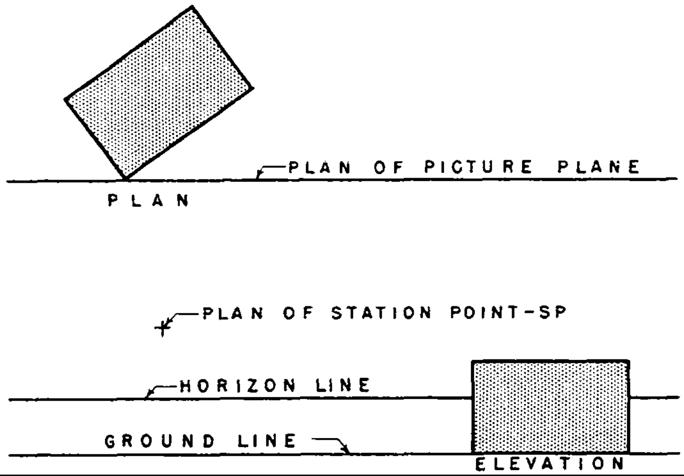
- THE VANISHING POINTS are located on the horizon line in the following manner (fig. B). From the station point SP lines are drawn parallel to the two typical sets of horizontal lines of the plan to meet the picture plane. From these intersections A and B vertical lines are drawn to the horizon to locate the two vanishing points, VL and VR. All of the horizontal lines of the object which are parallel to the line SP-B in plan vanish in VR in the perspective drawing. Likewise, all of the horizontal lines of the object which are parallel to the line SP-A in plan vanish in VL in the perspective drawing.

- MAKING THE PERSPECTIVE requires the use of a plan and elevation. The horizontal spacing of all points and vertical lines of the perspective drawing are obtained from the plan. This is done by drawing lines from the necessary points on the plan toward the station point to meet the picture plane, then drawing vertical lines from these intersections to the perspective (Fig. C.).

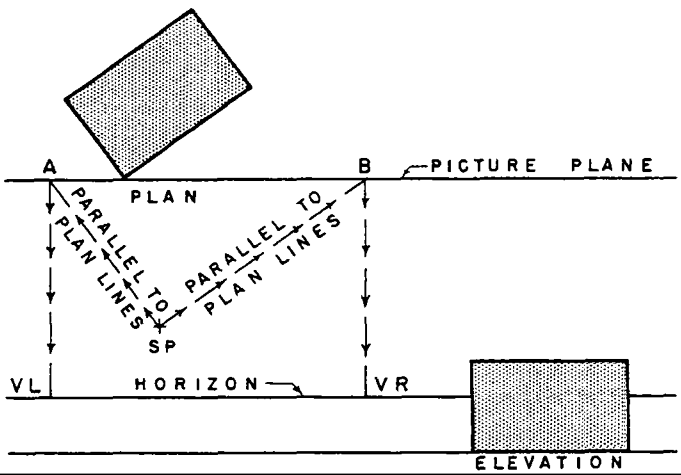
Since the nearest corner of the wall is in the picture plane its height is laid out to scale by drawing horizontal lines from the top and bottom of the wall in elevation to the line of the corner in the perspective. From these height measurements lines are drawn to VR to locate the top and bottom of the right side. Likewise, lines are drawn to VL to locate the top and bottom lines of the left side.
The illustrations of Fig. A, B, and C show the elementary principles of two - point perspective by the common method.

THE COMMON METHOD

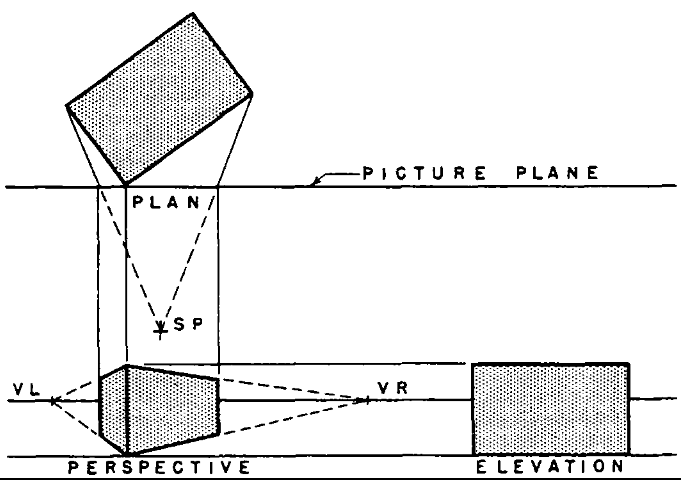
(A) STEP ONE
THE AUXILIARY DRAWINGS

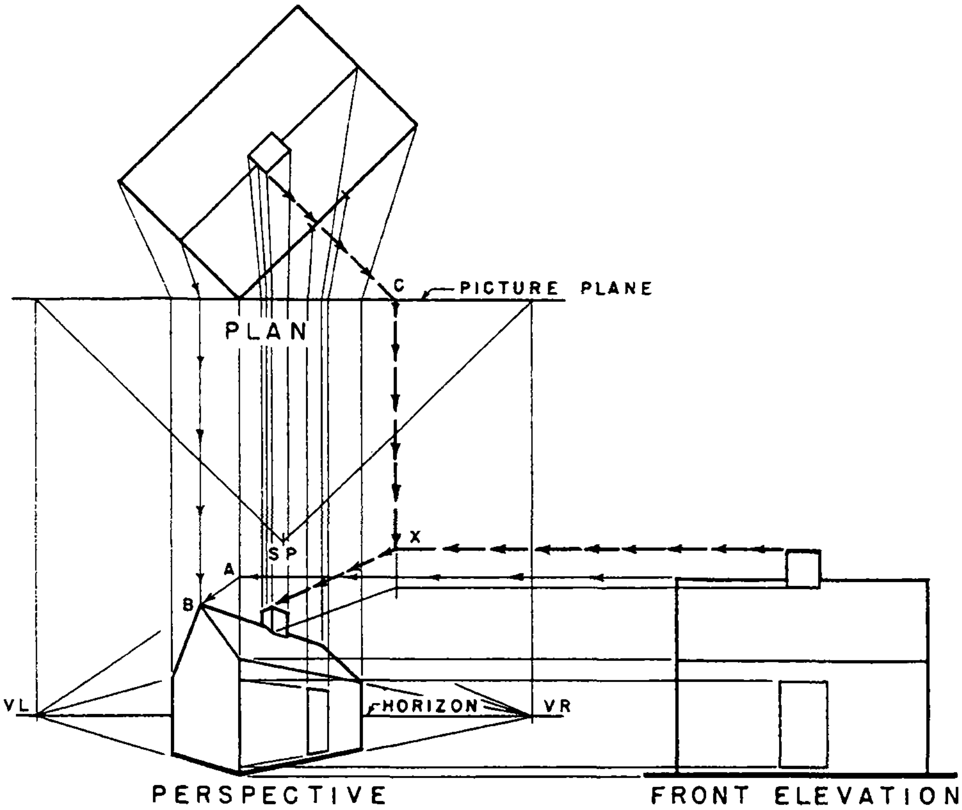


(B) STEP TWO
LOCATING THE VANISHING POINTS



(C) STEP THREE
MAKING THE PERSPECTIVE





TWO-POINT PERSPECTIVE OF A SIMPLE EXTERIOR

- THE DETERMINATION OF HEIGHTS.

Two important facts should be kept in mind while studying the following illustrations:

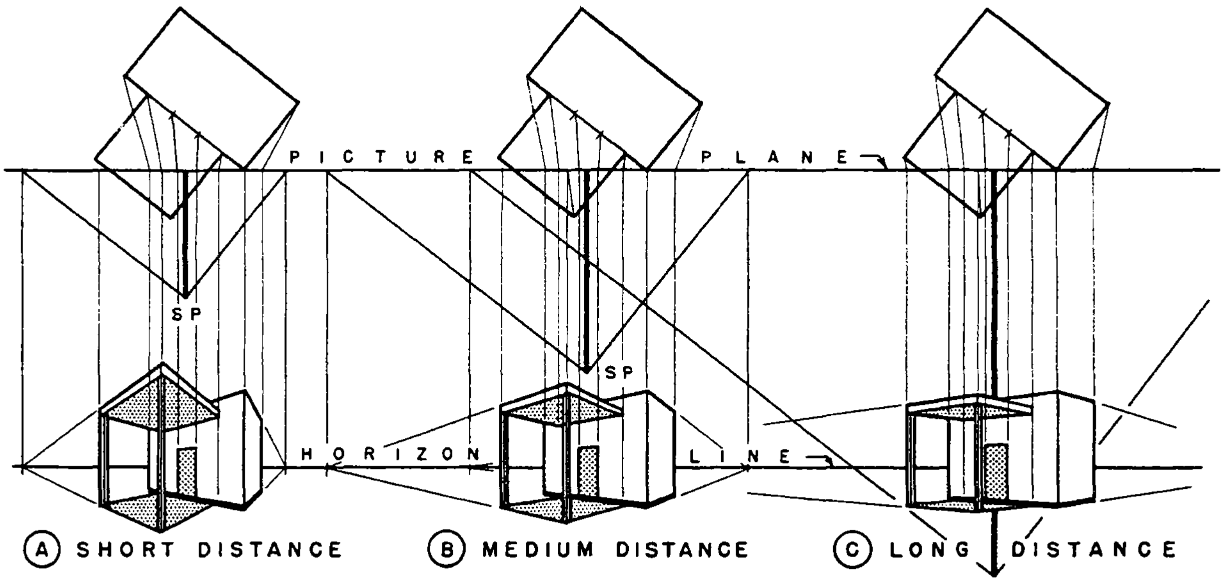
1. All heights are laid out to scale in the picture plane only,
2. Heights are carried from their scale sizes in the picture plane into correct perspective positions by tracing them along lines which vanish in the vanishing points and lead to the on the object where the heights are used.

- THE LOCATION OF THE STATION POINT.

The pictorial effect obtained in a perspective drawing is determined by the position of the station point. Since it would be possible to have the eye of the observer in any one of an infinite number of positions in viewing an object it is possible to have an infinite number of different perspective drawings of the object.

The location of the station point can be varied in three ways:
1. distance from the object
2. height
3. angle of view.

These variations and their effects on the perspective are discussed in the following paragraphs. The general theory applies to interiors as well as exteriors.



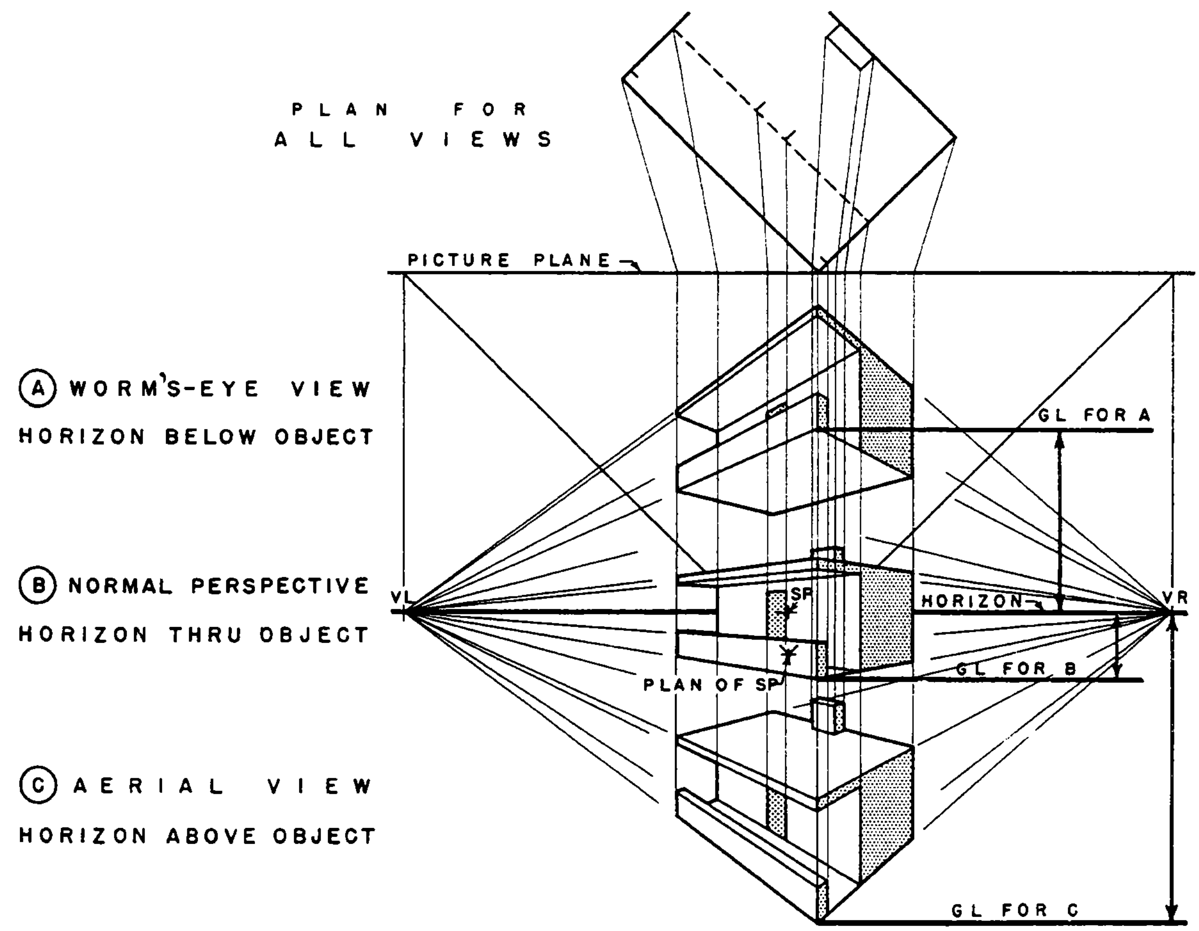
DISTANCE FROM STATION POINT TO OBJECT

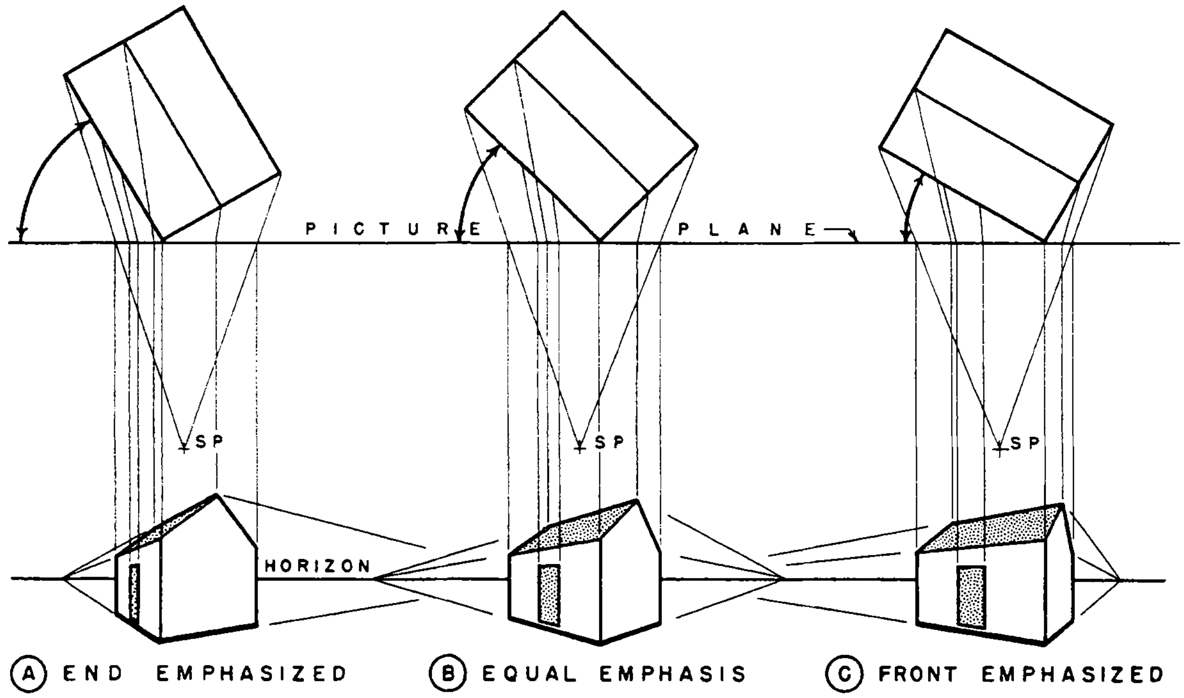
THE DISTANCE FROM THE STATION POINT TO THE OBJECT influences the pictorial effect and size of the perspective. When the station point is near the object the horizontal lines not parallel to the picture plane slant sharply (Fig. A). As the distance from the object is increased the horizontal lines flatten out and the perspective approaches the form of an elevation perpendicular to the picture plane in which all horizontal lines are parallel and horizontal (Fig. B and C). Parts of the object which are in front of the picture plane become smaller as the distance from the object to the station point increases, and parts behind the picture plane become larger. Both approach scale size as the distance increases and conversely, both vary more from scale size as the distance diminishes. When the station point is near the object the bottoms of horizontal surfaces above the horizon are large, as are the top surfaces of horizontal areas below the horizon. As the station point moves farther away these areas become smaller and disappear from view when the station point is at infinity (Fig. A,B, and C).

The maximum angle of vision of the eye is usually assumed to be 45° or 60°. This angle should include everything shown in the perspective. When the height of the object is greater than its width the height will determine the angle of vision. In one-point perspective the limit of vision is considered to be a cone of rays from the eye, thus avoiding the distorted effect sometimes found in the corners of one-point perspectives. To avoid excessive distortion in perspectives of spheres and circles, these shapes should be kept within a 30° cone of vision in any type of perspective.

As a practical consideration the farther the station point is located from the object, the greater the distance from the drawings to the various centers of converging lines. It is usually desired that these centers be in reach of the T-square for drawing lines and that they be on the area of the board. When the picture effect of the perspective is entirely satisfactory it is more convenient to keep all centers of converging lines on the board.

THE HEIGHT OF THE STATION POINT determines whether the object is seen from above, below, or from its own level in the perspective drawing. The relation of the station point, vanishing points, and horizon is constant for varying heights of the station point if the distance from the picture plane to the station point and the angle between the object and picture plane are constant. The perspective position of the station point is always on the horizon when the picture plane is vertical. The picture plane is alsmost always vertical in one- and two point perspective. The vanishing points of horizontal lines are always found on the horizon. When the eye of the observer (SP) moves up or down, the horizon and VP`s of the horizontal lines move with it. The distance from the horizon to the ground line is the height of the eye of the observer above or below the base of the building. Fig. A, B, and C uses the same position of the horizon, SP and VP`s but uses three different distances to the ground line, so that the view in the center has the SP opposite the center of the object, while the other two have the SP above or below the object. The relation of the horizon and ground line then determines whether the perspective is a view from below (A), normal perspective (B) or an aerial view (C).





THE ANGLE OF VIEW determines which sides of the object are seen and their relative widths in the perspective. When a photographer takes a picture of a free standing building he walks around it to find the best position for his camera. The draftsman can get similar information in two dimensions from a plan of the building of which the pespective is to be made. He can choose a trial station point and, by turning a straight-edge on this point as a pivot, he can determine which wall areas will be visible in a perspective made from this point. Furthermore, he can determine the relative perspective widths and importance of these areas and whether there is any unfortunate alignment of corners in an irregular plan. From these observations he may be able to select a more satisfactory station point. The experienced draftsman develops the ability to visualize the perspective effect from different positions around the plan of the object and thus choose the station point best suited to his purpose. The relative importance of the sides shown in the perspective has probably the areatest influence on the angle of view. Ordinarily it is desirable to look more directly at the imprtant side and less directly at the unimportant one. In most perspectives of exteriors the entrance to the building is considered as an essential. A reasonable amount of the entrance should be visible when the shape of the building does not allow all of it to be shown from the chosen direction. When a model of the proposed building is available it is very useful in selecting a station point. All three of the variables can be considered with a model. The figure shows three views of the same object from different angles.

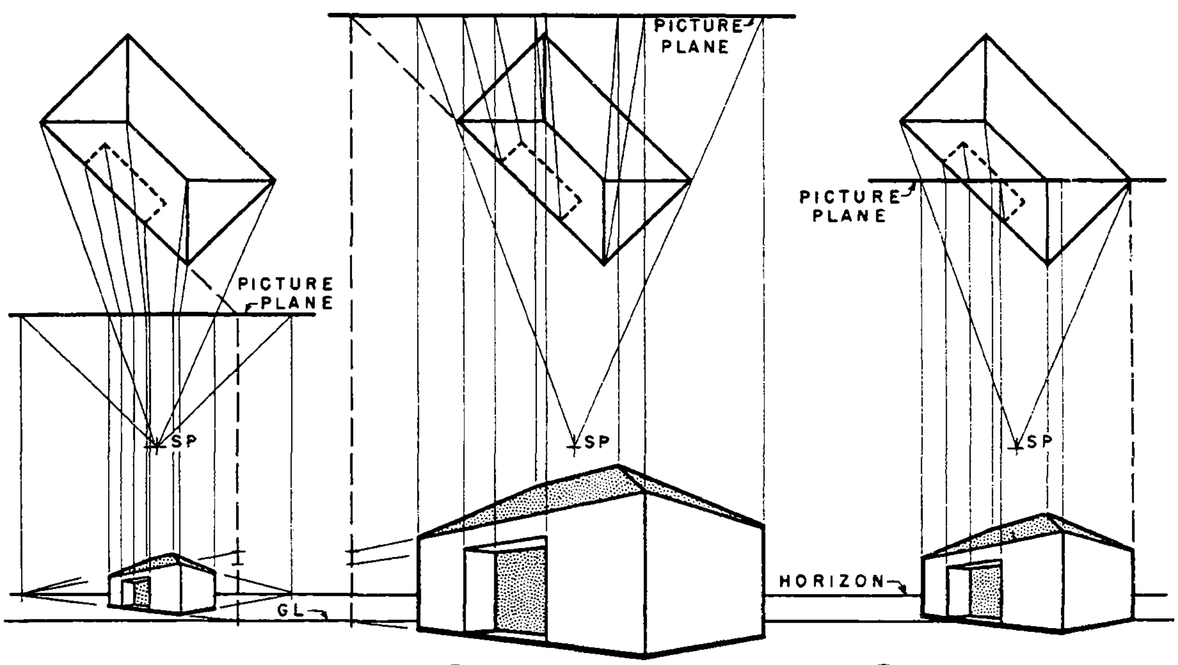
Regardless of the angle from which the object is seen, the station point should always be located approximately on a line through the center of the plan and perpendicular to the picture plane. The perspective is distorted when the station point is located very far to one side of this line. It is a great temptation where the plan is set up and the correctly located station point does not give satisfactory results, to take the easy way out and push the station point to one side. However, such a procedure causes the perpendicular to the picture plane to be off center on the plan and perspective. It will, therefore, cause the perspective to be out of proportion.

THE POSITION OF THE PICTURE PLANE.
The size of the perspective drawing obtained with a given object, given scale, and given relation between station point and object, can be varied by changing the position of the picture plane (fig. A, B, and C) The nearer the picture plane to the station point the smaller the perspective, the farther the picture plane from the station point the larger the perspective. If all positions of the picture plane are parallel the resulting perspective drawings will be identical in all respects except size.

The shifting of the position of the picture plane is a very helpful device for obtaining any size perspective desired. However, there are limits to its use. Extreme enlargements may be lacking in accuracy, while extreme reductions in size require space for the construction which is out of proportion to the size of the resulting perspective drawing.

The most common position of the picture plane is through the nearest main corner of the object. Simplicity and directness of construction are the principal advantages of this location of the picture plane. However, similar advantages are secured by having the picture plane pass through any visible corner of the object.

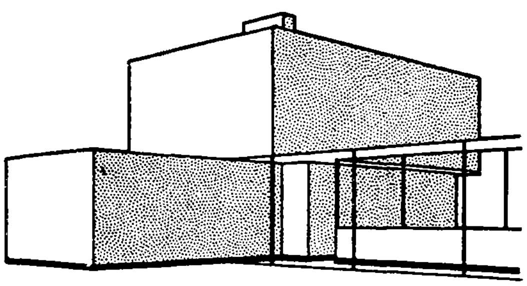
Other positions of the picture plane can be used to increase or diminish the size of the drawing without greatly complicating the construction. The constructions for points in front of and behind the picture plane have been given in the preceding pages.

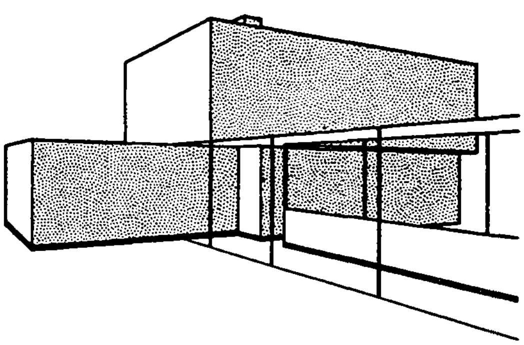


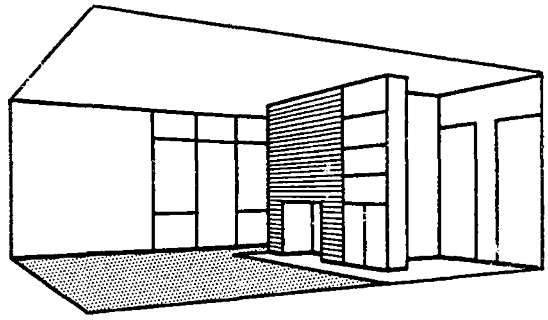
(A) BEFORE OBJECT (B) BEHIND OBJECT (C) THROUGH OBJECT

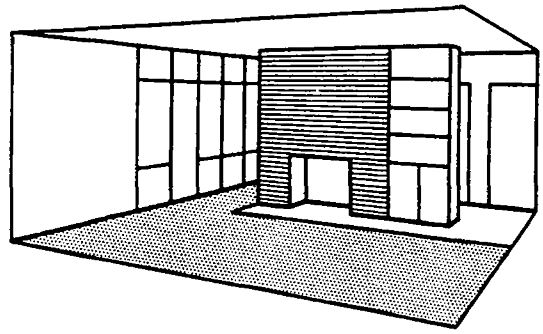
VARIATIONS OF THE PICTORIAL EFFECT IN PERSPECTIVE are obtained by changing the height, distance, and angle of view through manipulation of the station point. Variations in size of the perspective drawing can be obtained by change of scale of the auxiliary drawings, and by varying the position of the picture plane. An active imagination and the ability to visualize final results are as important to the draftsman as to the photographer in obtaining interesting pictures. The draftsman who understands the effect of the variables in perspective should be able to get the exact view that he wishes and make it the size best suited to his purpose.

When several perspective studies are made from a given design and none of them looks well, the designer may be reluctantly forced to the conclusion that he has not designed a beautiful building. It is even more difficult for the draftsman to make a dramatic perspecktive of a mediocre design than for the photographer to make a glamorous photograph of a homely person. Furthermore, the architect must prove the design in the actual building, and there is a question of professional integrity involved.



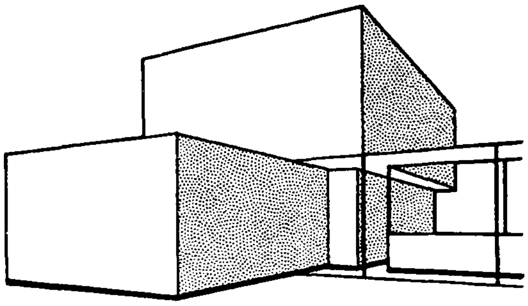




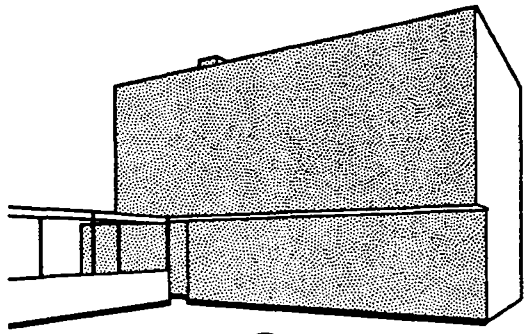


BLOCK STUDIES AT SMALL SCALE, which show only the masses and principal features of the object, can be made very quickly. They are of great value in choosing a station point for a larger and more detailed perspective drawing. They often save time because the large perspective can be made correctly the first time. With several possible variations considered in block form a better pictorial effect can be secured. These simple preliminary studies may be compared to the proofs furnished by a photographer. One of the proofs is selected for the final pictures or perspective.

While the beginner in perspective drawing needs the information from a number of block studies, he is usually not as willing to make them as the expert draftsman who appreciates their value from experience. On these speedy drawings the designer feels free to try arrangements which he would be very unlikely to try for a single large perspective.
There is, therefore, a psychological advantage in a number of block studies which leads to greater imaginative freedom, and often to more dramatic results. Freehand studies are used by many designers for ideas for perspectives.

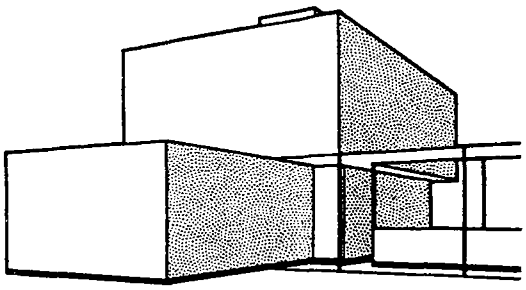


(A)

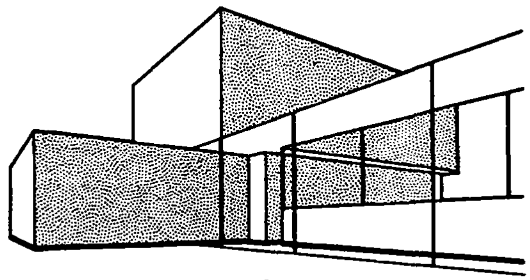


(B)

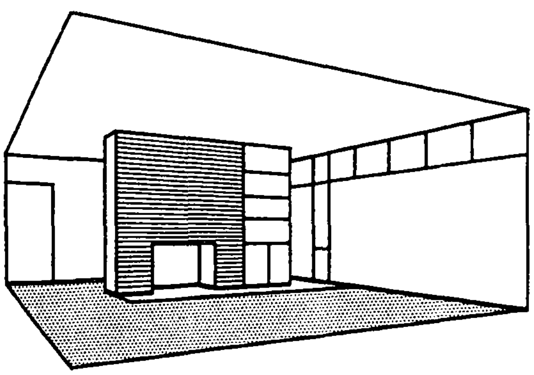
EXTERIOR BLOCK STUDIES



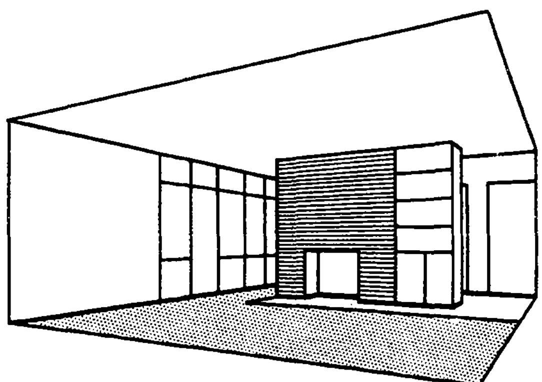
(C)



(D)

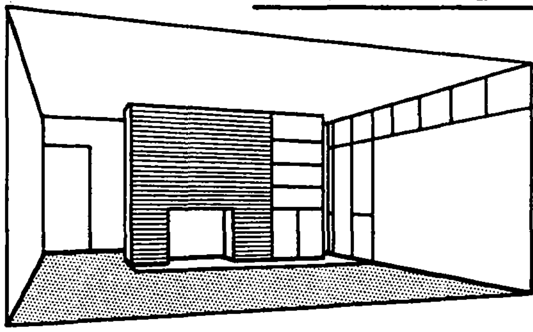


(A)

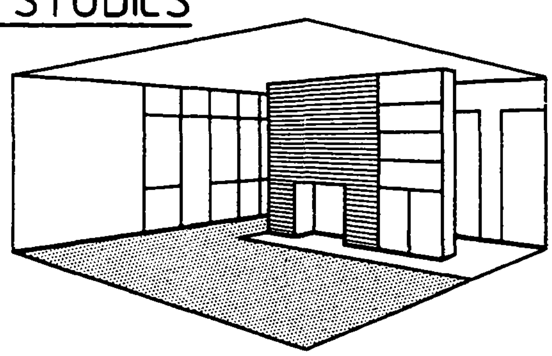


(B)

INTERIOR BLOCK STUDIES



(C)



(D)

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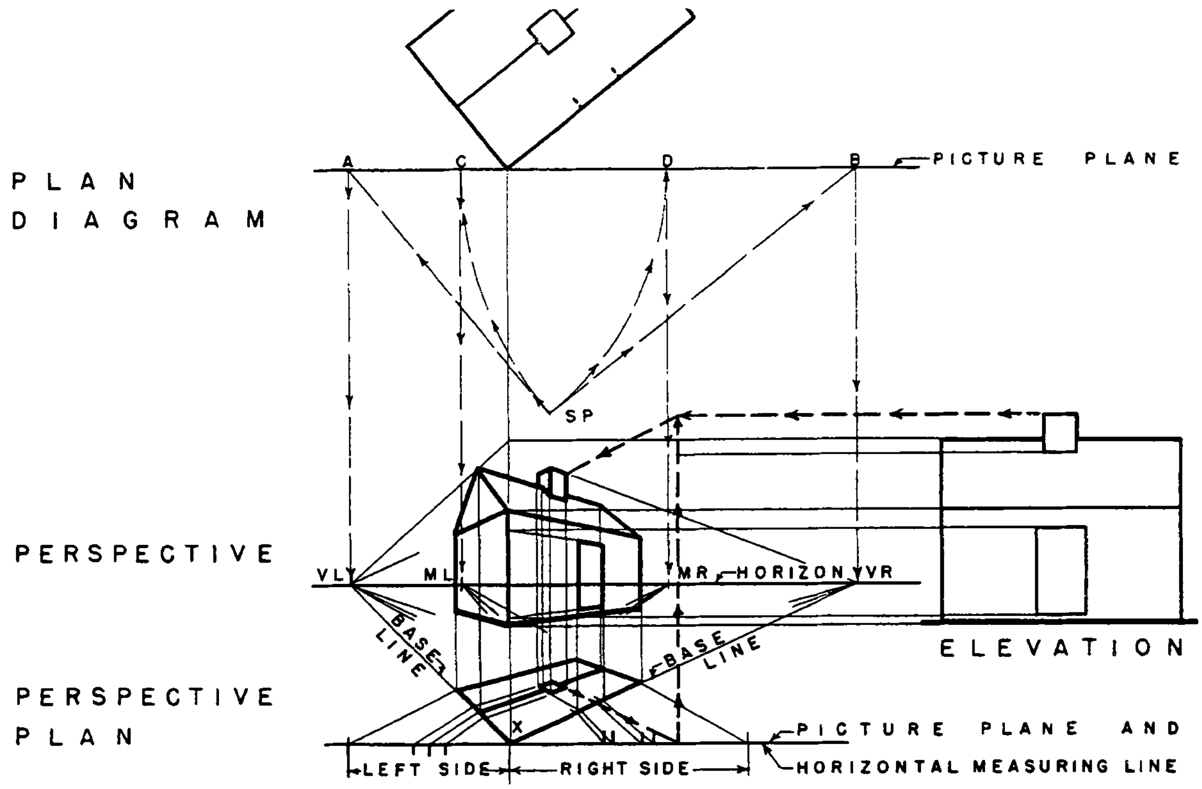
THE PERSPECTIVE PLAN METHOD



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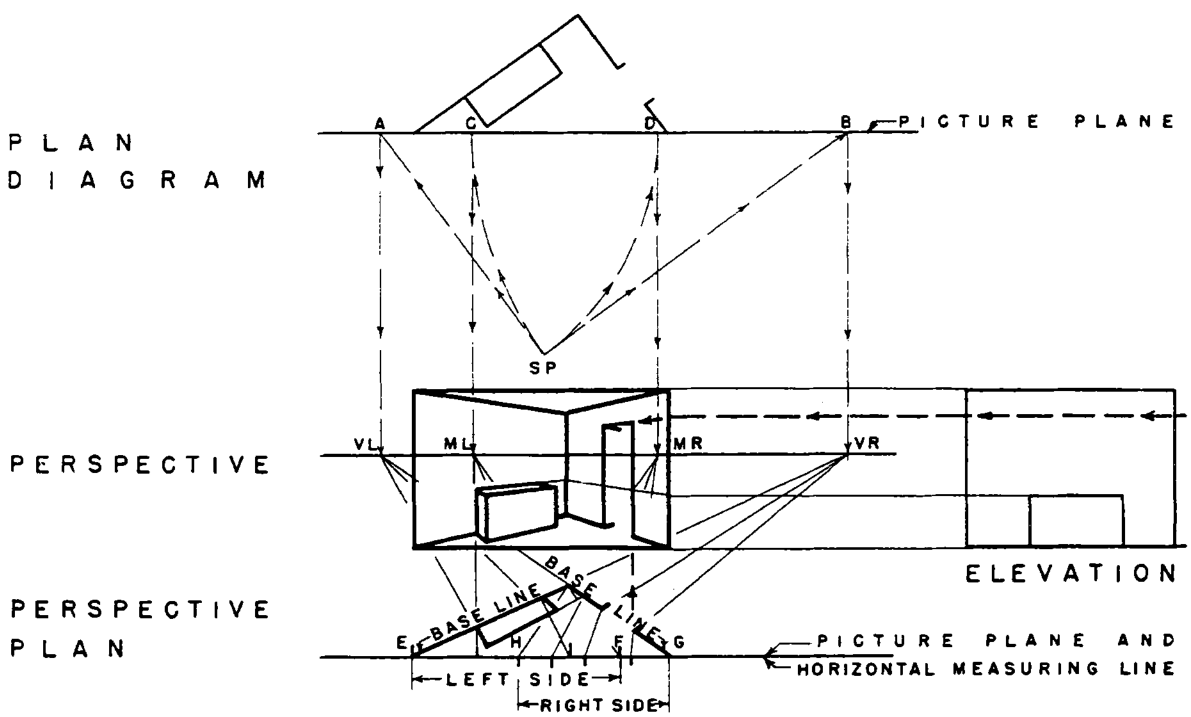

S I M P L E   I N T E R I O R

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ONE POINT PERSPECTIVE

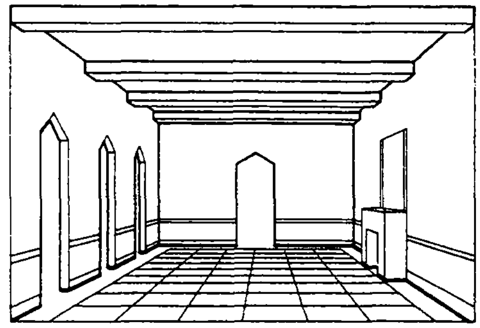
4.6 ONE — POINT PERSPECTIVE

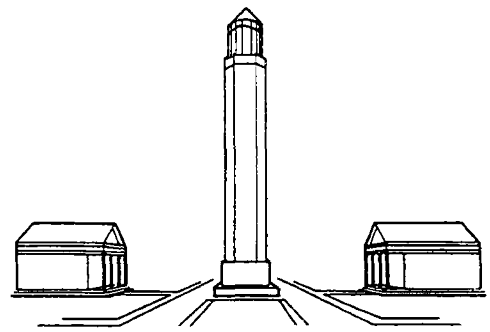
The most striking and characteristic views of streets, landscape garden scenes, groups of buildings, single buildings, and parts of buildings both exterior and interior, often show them as they would appear in one-point perspective. One-point perspective is therefore important to the architect and draftsman, because it is frequently more suitable for the subject to be drawn or gives a more characteristic view than could be obtained with two - point perspective.

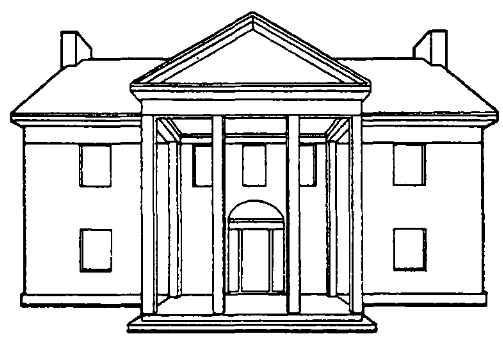
One-point perspective is so named because only one of the three typical sets of lines converges to a vanishing point. The remaining two sets of lines are parallel to the picture plane. Since lines which are parallel to the picture plane retain their true directions, the lines of each of these two sets remain parallel in perspective. In most one-point perspectives the picture plane is vertical. The vertical lines and one set of horizontal lines of the object are parallel to the picture plane, and remain respectively vertical and horizontal in the perspective drawing. The remaining set of horizontal lines is perpendicular to the picture plane and converges to a vanishing point.

One-point perspective can be used appropriately and effectively whenever the object presents a good appearance with the line of the center of vision of the observer perpendicular to one set of planes of the object, and consequently parallel to one set of lines; that is, when the conditions under which the object is naturally seen are those of one-point perspective.

Typical subjects for one-point perspectives are shown in the illustrations of the figure.







Although one-point perspective is not as widely used as two-point perspective it is extremely useful for both exterior and interior subjects and deserves the careful study and consideration of the person who wishes to become proficient in perspective drawing. Some of the most striking photographs used in illustrations of architectural magazines are one-point perspective views. Since the photographer usually has a wide range of choice of views, the one-point perspective position is chosen in most cases because of its pictorial merits and not from necessity.

THE COMMON METHOD OF ONE-POINT PERSPECTIVE. The use of a plan showing the object, picture plane, and station point is required for the construction of the perspective drawing.

Step I of the figure shows the location of the plan and elevation as the first step in making the perspective. The elevation is in this example located below the station point of the plan and to the right of the edge of the plan to leave a clear area for the perspective drawing. The horizon has been located near the center of the height of the elevation.

In Step II vertical lines are drawn from plan and horizontal lines from the elevation to give the intersection of walls, floor, and ceiling of the room with the picture plane. This line of intersection is at scale size since it lies in the picture plane. The vanishing point is located by drawing a vertical line from the plan of the station point to meet the horizon. When the position of one end of a line perpendicular to the picture plane has been located in the perspective drawing the line can then be drawn through this point toward or away from the vanishing point.

Step III shows how the plan is used to determine the correct horizontal spacing of vertical lines for the perspective drawing. The projectors are drawn from the two rear corners of the plan toward the station point to meet the picture plane. From these intersections with the picture plane vertical lines are drawn to the perspective locating the two vertical corners at the rear of the room. The lines of the intersections of walls with floor and ceiling are drawn from the corners A,B, C, D toward the vanishing point to meet the rear corners of the room. Horizontal lines from the two rear corners complete the simple perspective.

Step IV shows how lines can be traced around the walls and along the floor and ceiling from their correct scale positions on the lines in the picture plane.

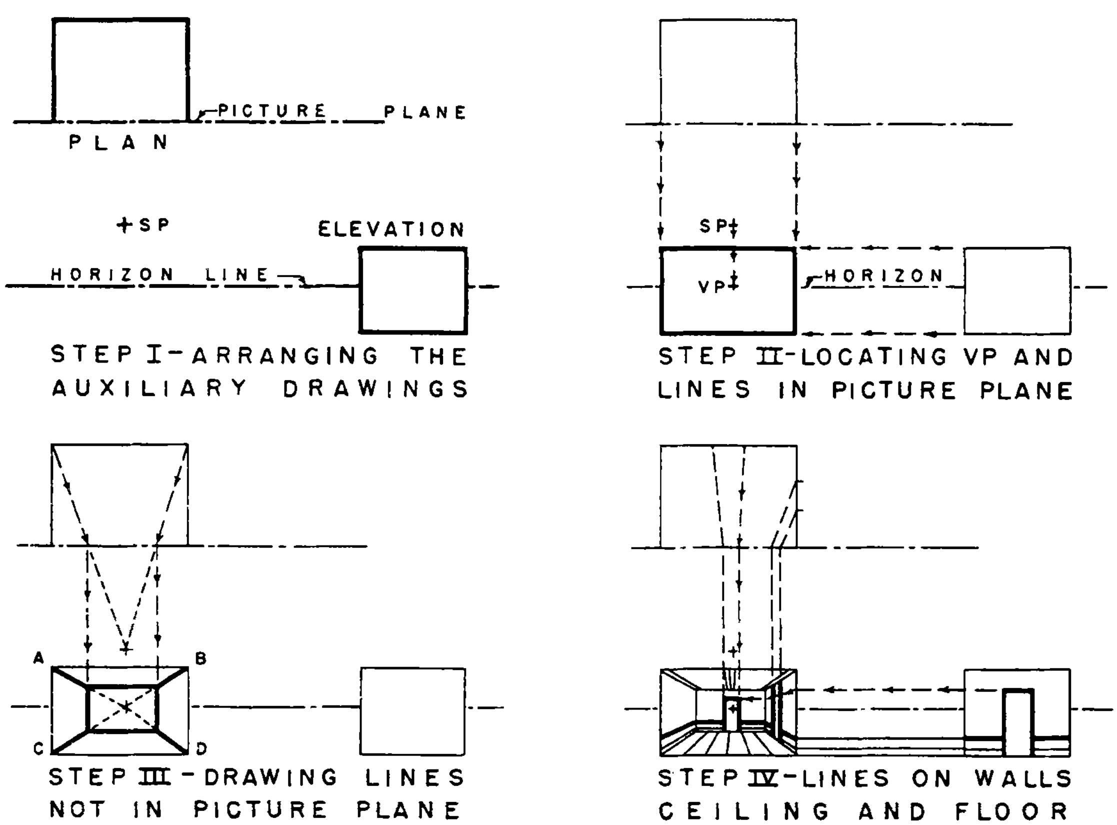


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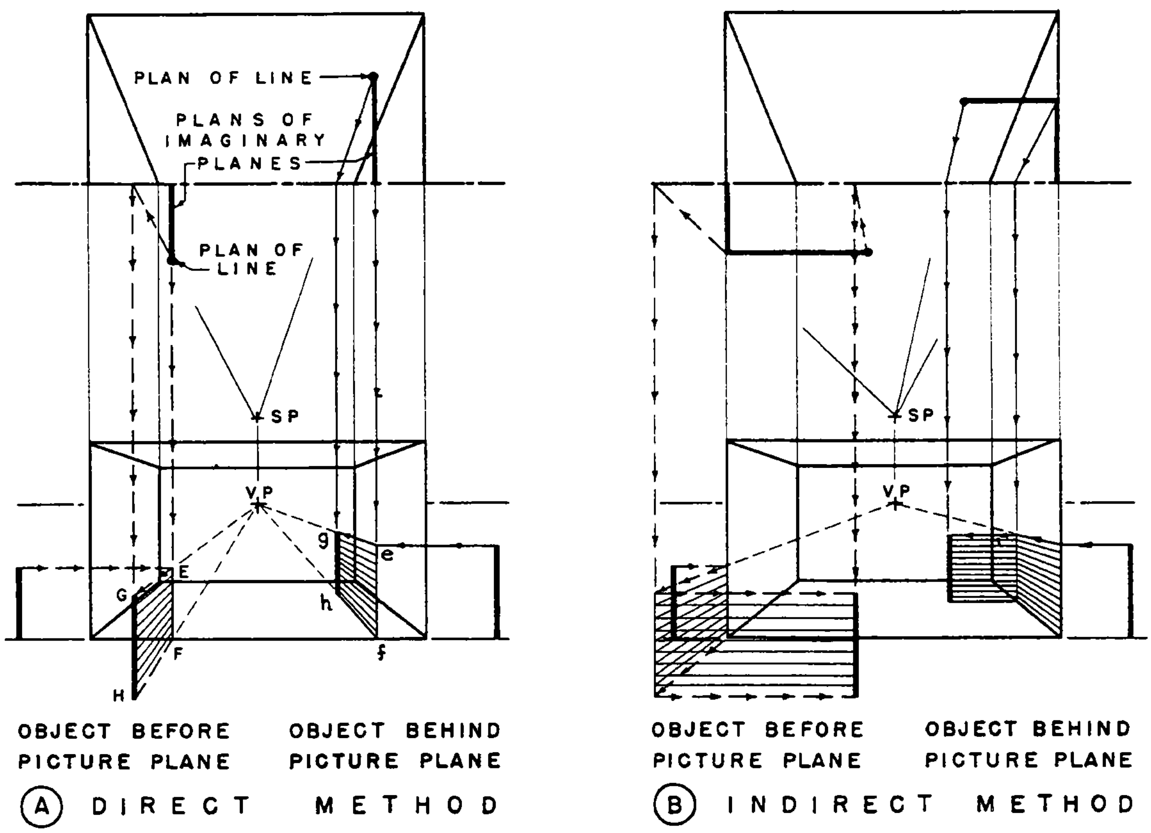
Fig. A and B shows two methods of determining heights of objects which do not lie in or touch the wall surfaces or picture plane of a one-point perspective drawing. In these examples the freestanding objects are vertical lines which rest on the floor.

In each example there are two freestanding lines. The line object on the right of each example is behind the picture plane and the one on the left is in front of the picture plane. When the object is a solid, the method shown can be repeated as many times as necessary for different parts of the object to obtain a number of points which can be connected to make the drawing.



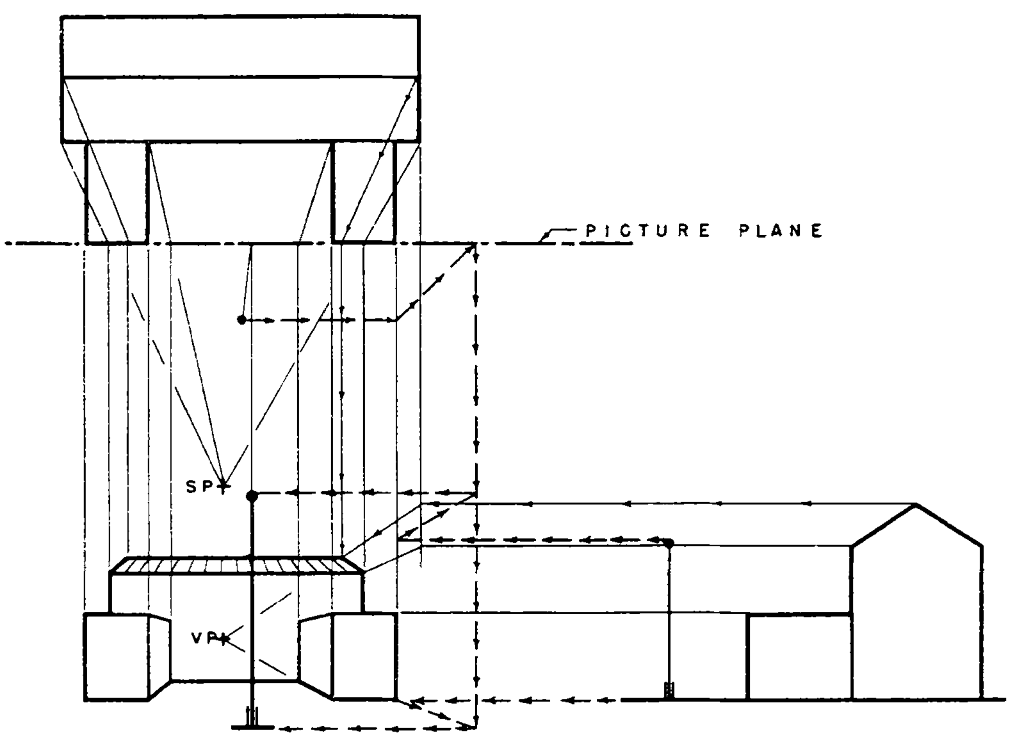
IN THE DIRECT METHOD, Fig., an imaginary plane which is parallel to the side walls of the perspective drawing and perpendicular to the picture plane is extended through the point plan of the freestanding line to meet the picture plane in plan. The height of the line is laid out to scale on the line E-F of intersection of the imaginary plane and picture plane in the perspective drawing. The height is then traced directly along the imaginary plane by lines through the vanishing point and brought to correct perspective position at G-H as shown. This is the most convenient and simple method of determining most heights of freestanding objects. However, in the special case when the freestanding line is on a vertical through the vanishing point this method cannot be used, because the line from the vanishing point is a vertical line and will not intersect vertical lines brought down from plan to establish heights. Furthermore, the lines from the vanishing point must be at a sufficient angle, so that their intersections with vertical lines can be accurately located. Objects which are very near a vertical line through the vanishing point cannot be accurately located by this method.

THE INDIRECT METHOD carries the heights along the walls or other planes perpendicular to the picture plane to the required distance, then along imaginary planes parallel to the picture plane to the correct perspective position. In the two examples of Fig. the wall serves as the plane perpendicular to the picture plane for the object behing the picture plan. An extension of the wall has been used for the object in front of the picture plane.

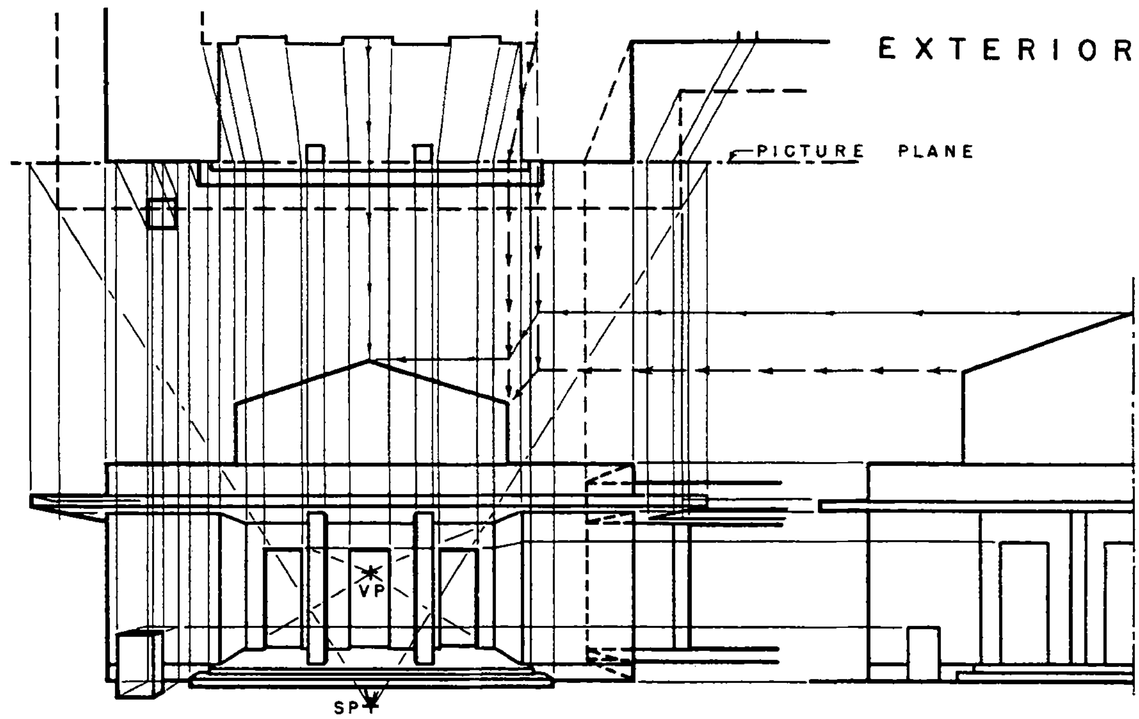
The three examples of one-point perspective by the common method (see figures) show the application of principles previously explained to more detailed subjects. An elevation or section has been drawn in each example in order to make the methods of determining heights as clear as possible. It is not necessary to draw the elevation or section as a part of the construction of a perspective by the common method.

The heights and widths of the parts of the object in the picture plane are drawn to scale size.

In the figure the ends of the projecting wings of the building lie in the picture plane and are drawn to scale size by dropping verticals from plan to meet horizontals from elevation. The top and bottom lines of the wings, which are perpendicular to the picture plane, are drawn to the vanishing point to meet the construction lines broght down from the junction of the wings and main building in plan. The indirect method is used to determine the height of the flagpole since it is too nearly on a vertical line throgh the vanishing point to use the direct method accurately. These construction lines are heavy dotted lines. The height of the roof is traced back into position by the direct method using an extension of the end wall to the picture plane for the height construction.

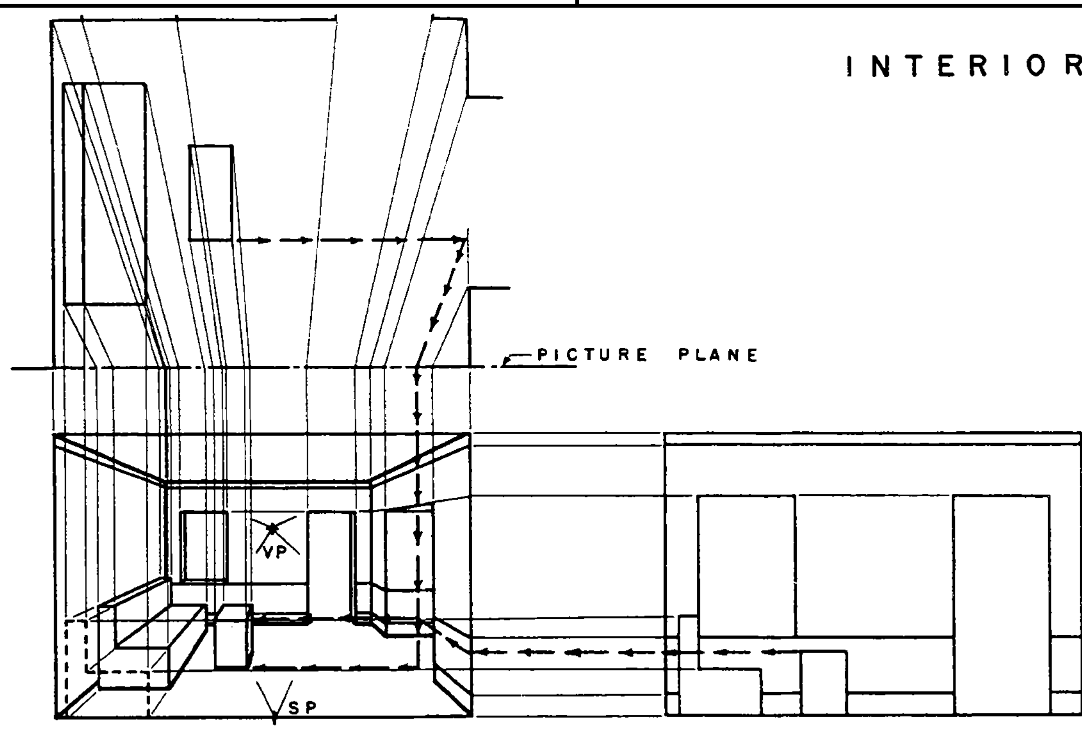


ELEMENTS OF ONE-POINT PERSPECTIVE - COMMON METHOD

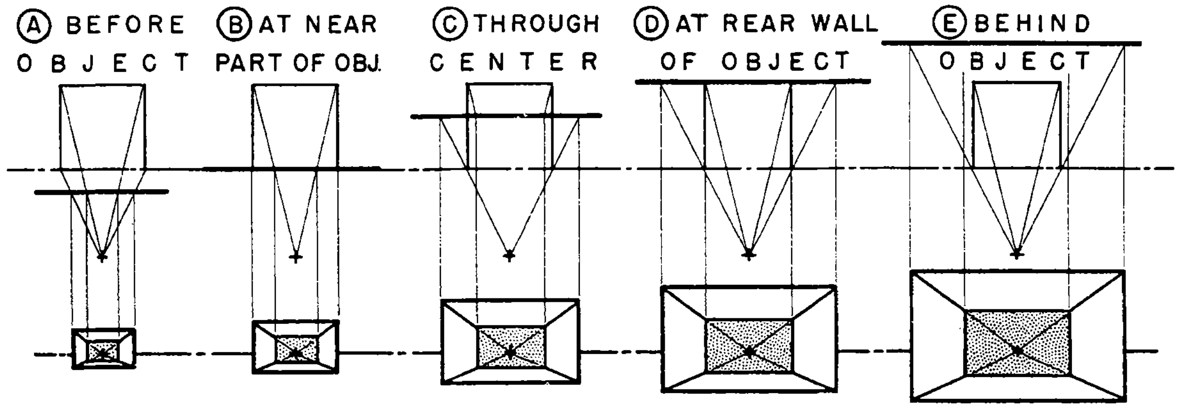


In the figure the lines made of short dots on the right side of the perspective show the construction of heights by tracing around hidden surfaces. The lines with longer dots and arrows in this example show the construction of a height, by the direct method, around one imaginary corner. The indirect method is used to determine the height of the highest point of the building.

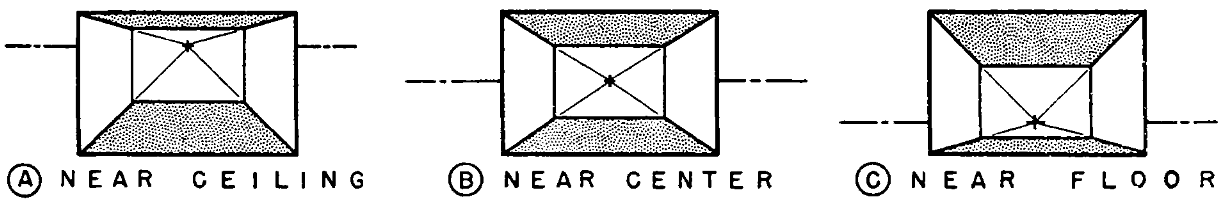
The figure illustrates the tracing of heights around visible wall surfaces for the wainscoting, windows, and ceiling line. The height of the rectangular box is found by the indirect method, using an imaginary extension of a plane of the box to meet the wall. The lines of the sofa are projected directly from the scale profile (drawn in dotted lines) in the picture plane to position in the perspective drawing.



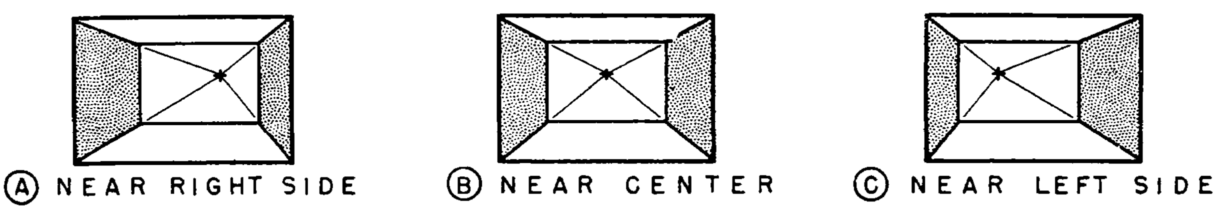
VARIABLES



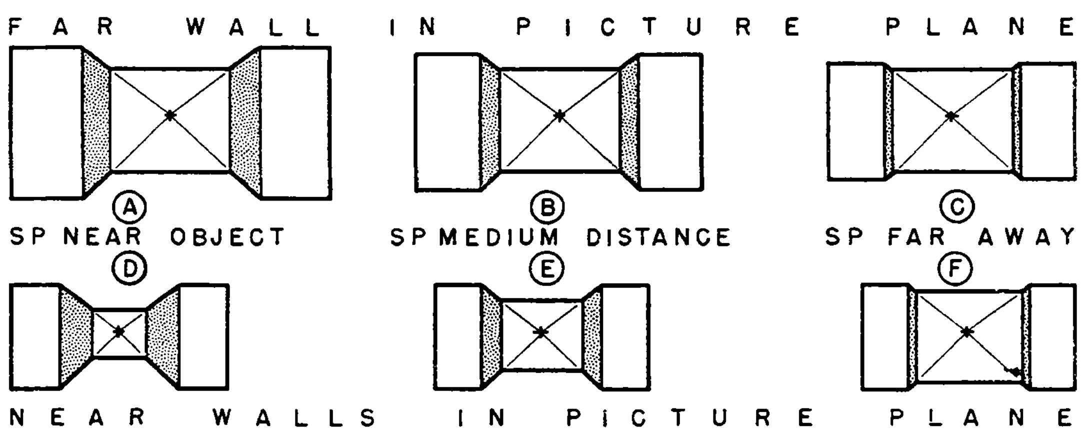
LOCATION OF THE PICTURE PLANE



HEIGHT OF STATION POINT

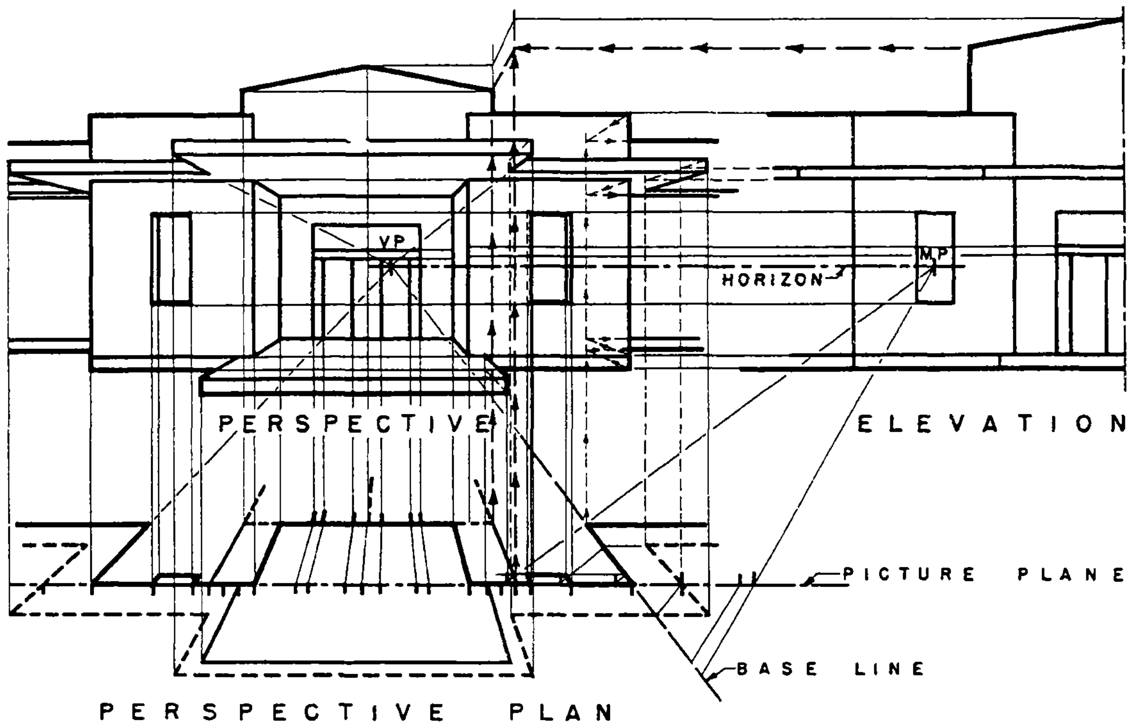


HORIZONTAL POSITION OF STATION POINT

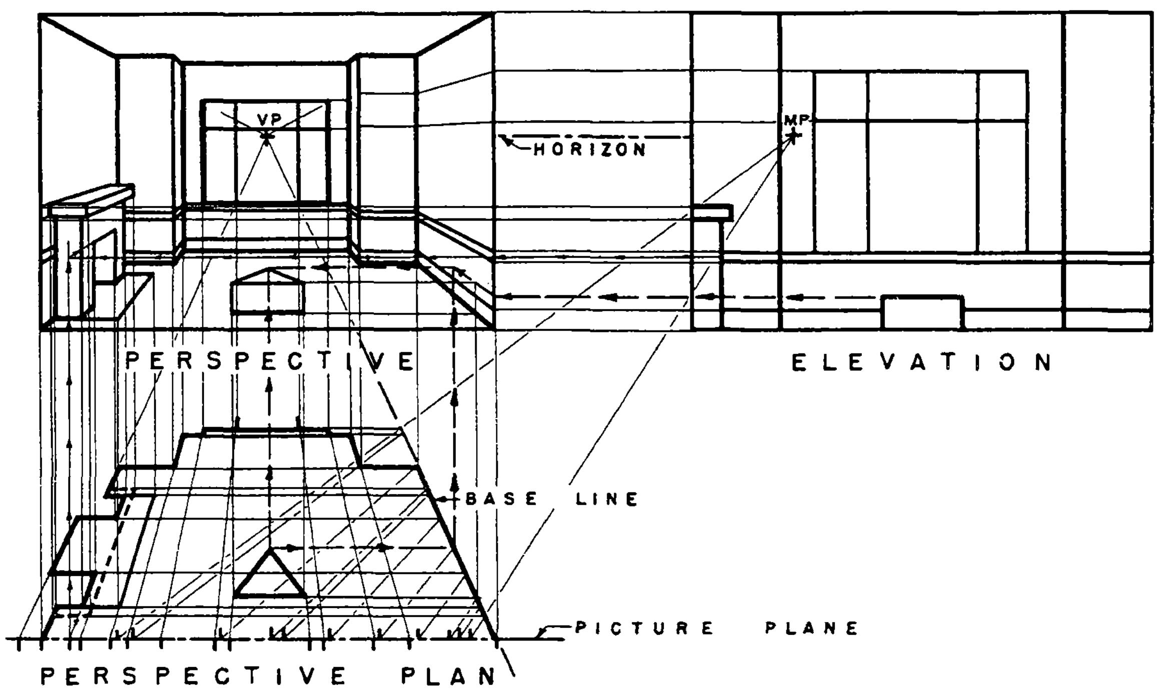


DISTANCE OF STATION POINT FROM OBJECT

EXAMPLES



EXTERIOR ONE-POINT PERSPECTIVE



INTERIOR ONE-POINT PERSPECTIVE

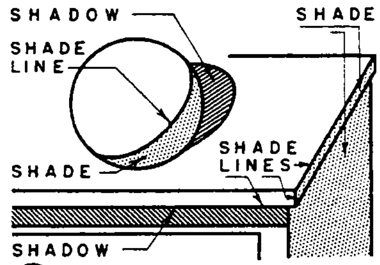
5. SHADES and SHADOWS

5. SHADES AND SHADOWS

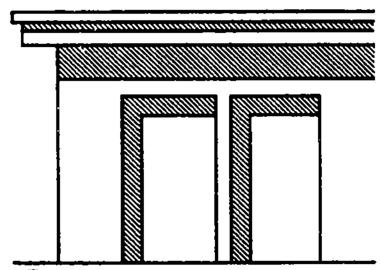
Wherever there are buildings, clouds, trees, rocks, or other objects extending above the surface of land or water there are shadows when the sun shine. These shadows form an essential part of the pattern of a landscape, a piece of pottery, or a building. Since shadows are inevitably a part of any object which is to be placed in the light, their forms and masses must be considered in studying a design if that design is to be completely successful.
A knowledge of shadow shapes and of the methods by which they are correctly and accurately constructed on various types of drawings is an essential part of the training of any draftsman or designer of objects in three dimensions.

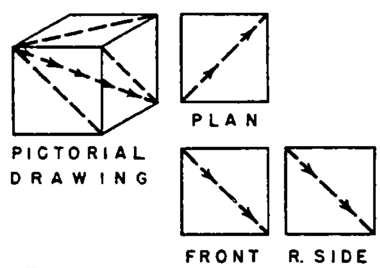
5.1 THE USE OF SHADOWS. Shadows are especially useful in architectural drawing and design because they make the drawings more easily understood. The shades and shadows express the shapes of surfaces, showing whether they are curved or flat, slanting or vertical. In drawings shadows are especially valuable because they bring out the third dimension; the distance back, in what would otherwise be a two-dimension drawing. The lines and masses of shadows form an important part of an architectural design and should be a part of the studies made in the development of the design. When the correctly drawn shadows are unpleasant or disturbing there is something wrong with the design and it should be revised to produce a more harmonious effect.

Shadows are almost indispensable on rendered presentation drawings. They add to the picture effect of drawings, making them much more easily understood by the client. The rendered shadows give even the designer a clearer conception of the appearance of the projected building and aid him in perfecting its design.

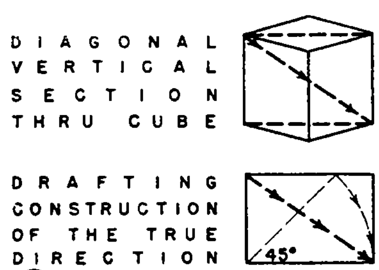


(A) DISTINCTION BETWEEN SHADE AND SHADOW


(B) SHADOW WIDTHS MAY EQUAL PROJECTIONS



(C) THE CONVENTIONAL DIRECTION OF LIGHT

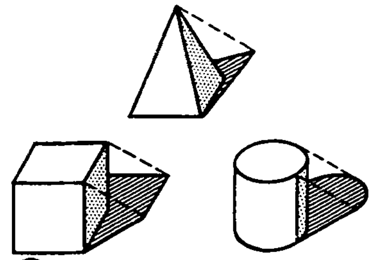


(D) TRUE DIRECTION OF A CONVENTIONAL RAY

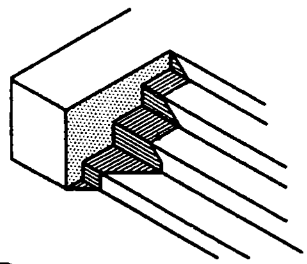
DEFINITION OF SHADOW TERMS

5.2 SHADES AND SHADOWS.

A shade occurs when the shape of the object excludes the light rays from part of its surface (Fig. A) The lines between the areas of light and shade are called shade lines. On a curving surface, such as that of a sphere, the shade line is the line of tangency of light rays to the curving surface. On objects made up of plane surfaces a shade line is the edge where a surface in light meets a surface in shade. A shadow travels through the air from one object to another, or from one part of an object to another part of the same object.



(I) THE SHADE LINES CAST SHADOW OUTLINES

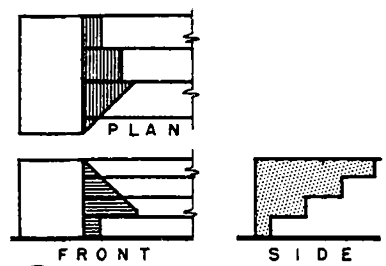


(II) SHADOW SEEN IN A PICTORIAL DRAWING

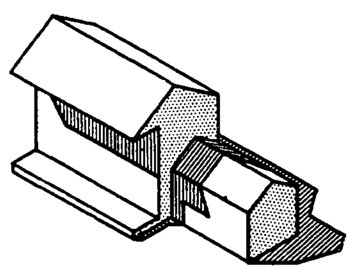
5.3 THE CONVENTIONAL DIRECTION OF LIGHT.

In casting shadows it is necessary to assume a source and direction of light. The source of light is usually assumed to be the sun and the rays of light are considered to be parallel The direction of light used in practically all shadow-casting gives shadow widths which are equal to the projections from wall surfaces of vertical and horizontal shade lines which are parallel to the picture plane and the wall. Characteristic examples of shadows which are equal to the projections making them are those of the cornice and window shown in fig. B.

If a cube is placed so that its sides are parallel to the three coordinate planes of elevation, plan, and side elevation, then its diagonal from the top left front corner to the lower right rear corner gives the conventional direction of light and the three views of the cube give the apparent directions of light in the three typical drawings (fig. C).



(III) SHADOW SEEN IN THE MULTI-VIEW DRAWINGS



(IV) SIMPLE MODELS HELP TO EXPLAIN SHADOWS

5.4 THE 45° DIRECTION.

Since the direction of light in front elevation, plan, and side elevation views is the diagonal of a square it is a 45° line in all three drawings. Therefore, shadows may be traced by using the 45° triangle on these drawings. A ray of light travels equally in three directions:

1. to the right
2. down, and
3. back,

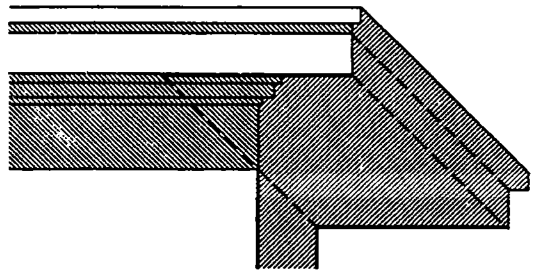
as shown by edges of the cube.

The 45^0 triangle should be regarded as a tool for measuring equal distances in two directions, in front elevation down and to the right, in side elevation down and back, and in plan back and to the right. It is usually the most convenient way to measure shadow widths, but any means of measuring equal distances such as dividers, scale, or paper strips may be used if more convenient.

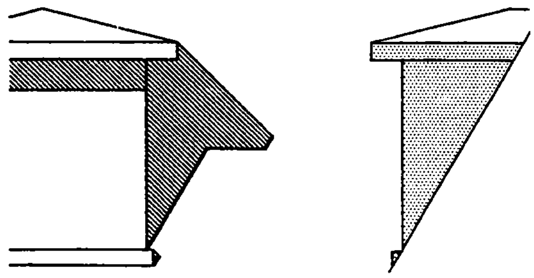
5.5 THE TRUE DIRECTION OF LIGHT.
Since the light rays are at an angle to all the planes of projection the true direction of light is not seen in any of the multi-view drawings. In order to see the true direction of the conventional ray of light it is necessary to use an auxiliary plane perpendicular to plan and parallel to the direction of light. The true direction of a ray of light is represented by the diagonal of a cube, which is the diagonal of a rectangle, of which the short sides are edges of the cube and the long sides the diagonals of the top and bottom of the cube. The true direction of light may readily be constructed as shown in the bottom drawing of fig. D, and will be found useful in constructing some shadows.

5.6 SHADOWS OF SOLIDS
Architecture is made up of volumes and masses which are usually the shapes of the simple geometric solids used either singly or incombinations. Shadows on architectural drawings are the shadow of solids or of hollow masses.

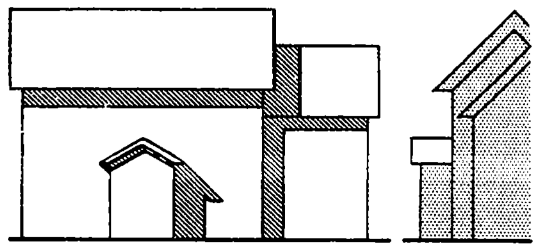
The shadow of any solid is bounded by the shadows of the shade lines of the object.
Only those lines which mark the divisions between light and shade on an object can cast shadows. There fore, if the shade lines on the drawings of an object can be located by inspection, the shadows of these shade lines can then be determined to give the outline of the shadow of the object.



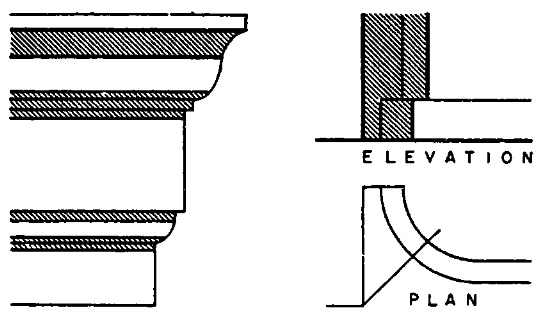
(A) LINES WHICH CAST SHADOWS



(B) SHADOWS OF PARALLEL LINES



(C) SHADE LINES PARALLEL TO SURFACE RECEIVING SHADOW



(D) SHADE LINES PARALLEL TO LINES IN SHADOW SURFACE

PRINCIPLES OF SHADES AND SHADOWS

AD II compiled : D.VOLKE AUG. '83	SHADES &. SHADOWS	ARCH. DRWNG. LECTURE CET 3o43/15.6 52

5.7 PLANES OF SHADOW

The straight shade lines of an object make planes of shadow. Therefore the shadows of these straight lines are the intersections of their planes of shadow with the surfaces on which the shadows fall.

1. The position of the shade line
2. the location of the eye of the observer
3. the direction of light, and
4. the shape of the surface on which the plane of shadow ends are the factors which determine the shape of the shadow as shown on the drawing.

5.8 PRINCIPLES OF SHADOW-CASTING

A knowledge of some of the simple geometric and self-evident principles used in casting shadows will make the problems of working out shadows more easily understood. Several of these helpful principles are described in the numbered paragraphs, and illustrated on this and the following page. The use of a light and a simple model will help the reader to verify and understand these principles.

I - A LINE IN SHADE OR SHADOW CANNOT CAST A SHADOW because light does not strike it. The lines of the moldings underneath the cornice in fig. A are entirely in shadow and do not cast shadows. When part of a line is a shade line in light and part of the line is in shadow, then only the part of the line which is in light will cast a shadow. The corner of the wall in fig. A is an example of a line which is partly in light and partly in shadow. By first determining which parts of the object are in shadow it is possible to locate the shadow of the object without wasting time finding the shadows of lines which do not make parts of the shadow outlines.

2-SHADOWS OF PARALLEL LINES ARE PARALLEL when they fall on the same plane or on parallel planes (fig. B). This is true regardless of the relation of the parallel lines to the plane receiving the shadow and of the direction of the plane receiving the shadow. This principle can often be applied to problems to simplify the working out of shadows of parallel lines and to secure greater accuracy. In the case of slanting shadow lines such as those from the dormer onto the roof the direction can be determined most accurately from the longest shadow; then the others can be drawn parallel to it. When the direction of a shadow line is known the construction of the shadow is simplified.

3-THE SHADOW IS PARALLEL TO THE LINE MAKING THE SHADOW when

1. the line is parallel to the plane receiving the shadow, or
2. the line is parallel to the straight lines in the surface receiving the shadow.

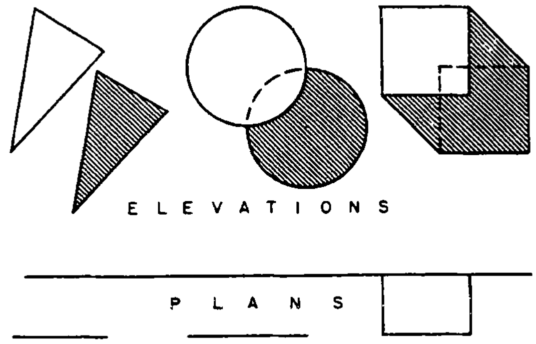
The shadows on the house of Fig. C illustrate the first condition. The shadow of the cornice onto the wall below, the shadow of the vertical corner of the wall onto the second wall surface and the shadow of the right edge of the main roof onto the parallel lower roof surface are all illustrations of this principle. The second condition is illustrated by the molding and the shadow of the vertical line onto a vertical cylinder in Fig. D.

4-THE SHADOW OF ANY PLANE FIGURE ON A PARALLEL PLANE is identical in shape size, and direction with the figure. This relation is true regardless of the angle at which the area and the parallel plane are turned (fig.). When part of the shadow is behind the plane figure making the shadow, as in the center example, the visible part of the shadow is identical with the part of the figure which makes the shadow. When the plane figure is part of a solid, as in the case of the example of the block on the right of Fig. I, then the part of the shadow made by the end of the block follows this rule since it is parallel to the plane receiving the shadow.

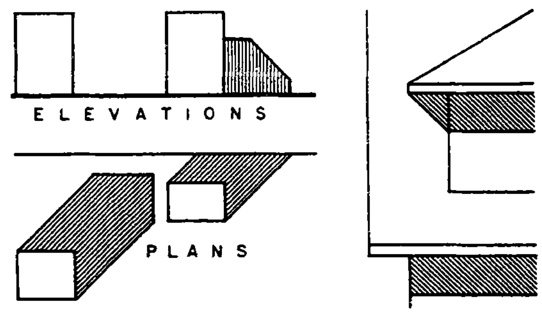
5-A SHADOW IS VISIBLE only where it falls on a visible surface which is in light. The triangular shadow below the left edge of the dormer roof in Fig. II is visible because it falls on the main roof. There is no similar visible shadow at the left edge of the main roof because there is no visible surface receiving the shadow. The block at the left of Fig. II is set out from the wall so far that none of its shadow is visible in elevation. All of the shadow falls on the floor plane. The distance of the block on the right side is such that part of the shadow is visible in elevation and part in plan.

6-ANY LINE ON A PLANE SURFACE APPEARS TO BE A STRAIGHT LINE WHEN THE OBSERVER LOOKS PARALLEL TO THE PLANE SURFACE. (Fig. III) Since the entire plane surface will be seen as a line when the observer looks parallel to the plane, then any line in the plane will appear to be straight. Objects, areas, and lines are shown in drawings as they would appear from a certain viewpoint.

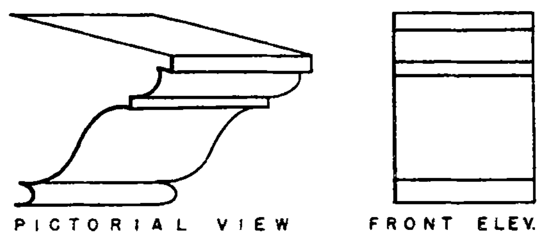
7-WHEN THE OBSERVER LOOKS AT THE END OF ANY STRAIGHT LINE, so that the line is seen as a point, then the shadow of the line will appear to be straight regardless of the shape of the surface receiving the shadow. The line makes a plane of shadow. Since the observer is looking parallel to the line he is also looking parallel to the plane of shadow made by the line and any line in the plane of shadow appears to be straight. The shadow line lies in the plane of shadow and therefore appears to be a straight line when seen parallel to the plane, as illustrted in the elevation of fig. IV. Any line seen in end view in elevation, plan, perspective, or any other drawing will cast a straight line shadow in that view where it is seen as a point. A simple model made of boxes and cans with either sunlight or a single artificial light will help the reader understand this type of shadow.



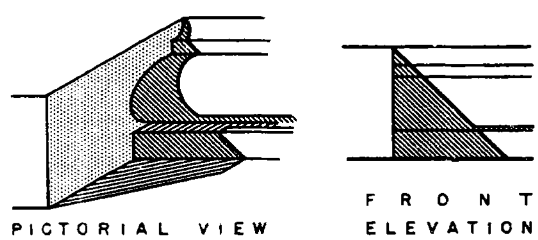
(I) SHADOWS OF PLANE FIGURES



(II) VISIBILITY OF SHADOWS



(III) APPEARANCE OF LINES IN PLANE SURFACES

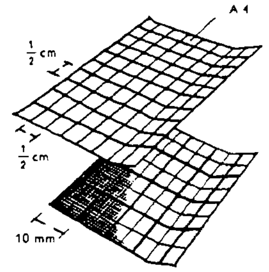


(IV) SHADOWS OF LINES WHICH ARE SEEN AS POINTS

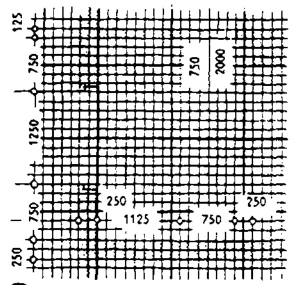
PRINCIPLES OF SHADES AND SHADOWS

6.DRAWING PRACTICE

The designer's language is the drawing. It formulates his statements clearly and is internationally readable: factually, by geometrical drawings; attractively, by perspectives. A drawing helps to present ideas and to convince the client. The architect's production drawings and perspectives are only a way of presenting the proposed building clearly, not an end in themselves as are paintings.



(1)



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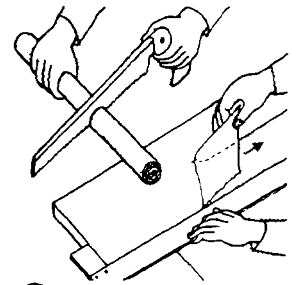
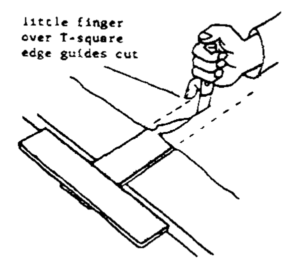
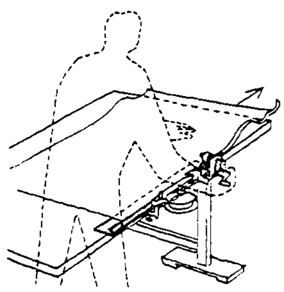


(3)



(4)

Sketch pads (A4 size) with 5 mm (¼ in) squared paper are convenient for freehand designing to scale; for more exact sketches, mm squared paper with bold 10 mm and less bold 5 mm division lines, → (1), (2). For sketching with soft pencil, thin transparent paper; roll is cut to required sizes and single pieces torn off along T-square, → (3), or cut on T-square, → (4). Plans on good translucent, unglazed tracing paper in standard sizes, → p. 2, to be used with edge protection, → (5). For ink and water colour drawings, tracing



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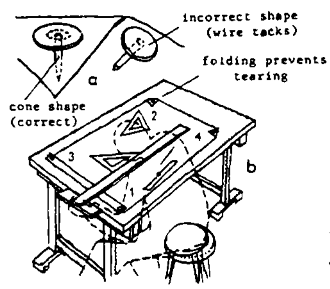

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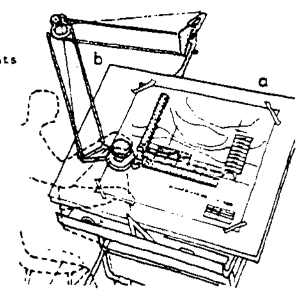

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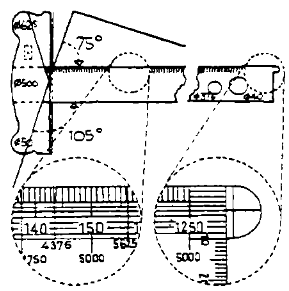
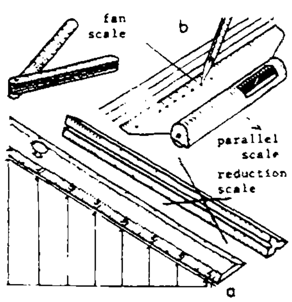


(8)

linen is best; for painting and perspectives, special papers. Fix paper to drawing board or table with clips or drawing pins, not wire tacks which leave holes, →(6a). First, fold 20 mm (¾ in) wide edge of the paper which later becomes the fastener hem and lifts T-square slightly off paper to avoid blurred lines (for same reason draw from top to bottom). Then fold remaining corners 2 and 4 of



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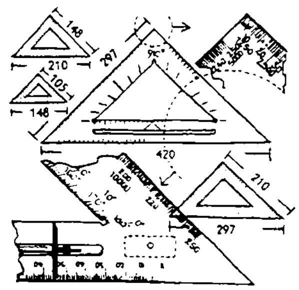
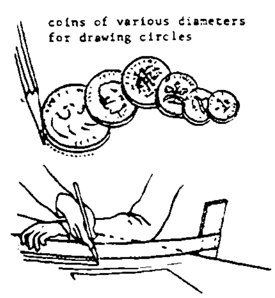


(10)



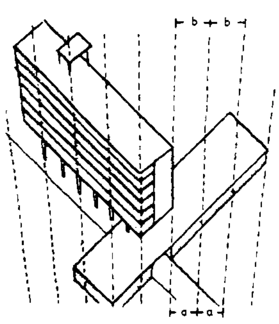
(11)

(12)

sheet, → (6b); pin corner in 1, smooth sheet in direction 2; after fixing this corner, repeat the action from corner 3 to 4. Instead of drawing pins, clips or adhesive tape may be used, → (7a). Mechanical drawing equipment originally used only by engineers is finding its way into architects' offices, → (7b). In addition to ordinary T-square, special (Patent Neufert) T-square, which makes it possible to apply various angles; has octameter and centimetre scale, → (8).

DRAWING PRACTICE

Scale with 1 mm divisions is best, $\frac{1}{2}$ mm markings are confusing. For sketching to scale and drawing lines at set distances, parallel rules or rolling parallel rules are useful, → (9b). Use of triangle rules is discouraged, → (9). Best set squares are transparent uncoloured plastic with mm division, sometimes degrees, → (10), (rigid or adjustable). Various aids to drawing circles and curves,



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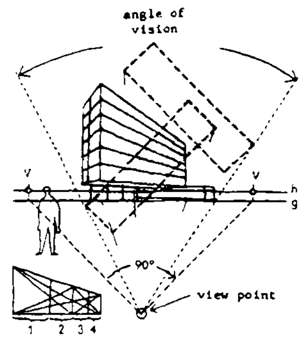
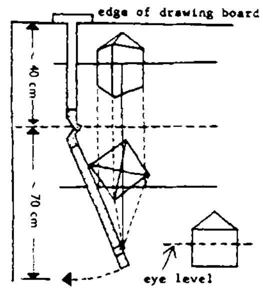


⑭



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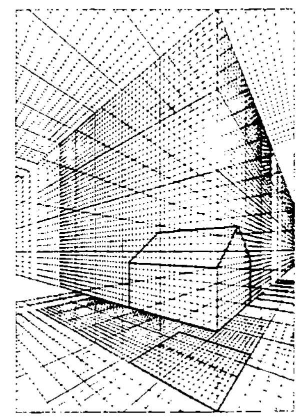
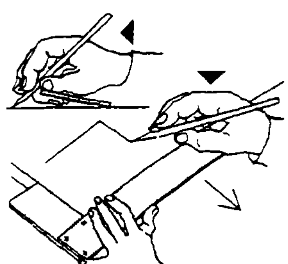


⑯

→ (11) (improvised) and (12) (manufactured). Perspectives and models clarify the ideas of the designer and usually convince better than words. Perspective should be constructed to give an exact picture of the real building. Isometric projections can replace perspective birds-eye view if they are drawn to sc. 1:500, → (13). Easy method to set up perspective, → (14). Perspective apparatus, → (15). Perspective screen which may also be used for interiors, → (16). Drawing tricks: fast and exact drawing of rectangular



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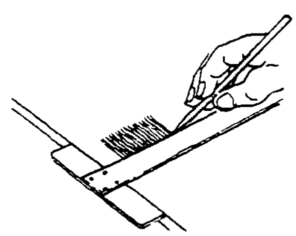

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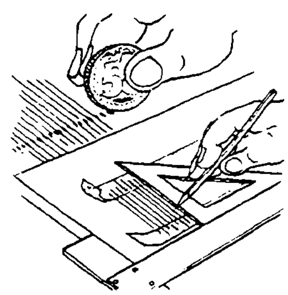

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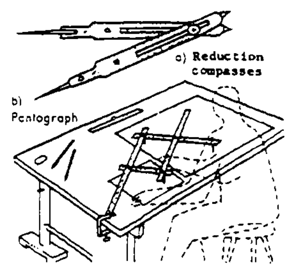
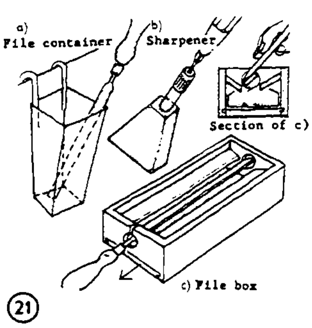


⑳

diagrams with T-square only, without set square, → (17); correct holding of T-square and much practice essential to success. Division of line into equal parts facilitated by putting a scale rule at slant, → (9). Various aids, → (18), (19). Enlargement of drawings to scale through pantograph, → (20). Reduction compasses facilitate drawing of fixed lines in adjusted relation to original, → (20).



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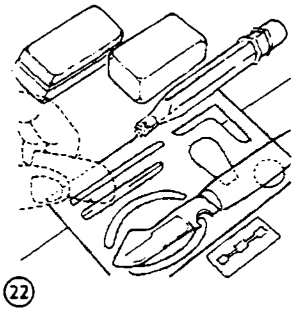

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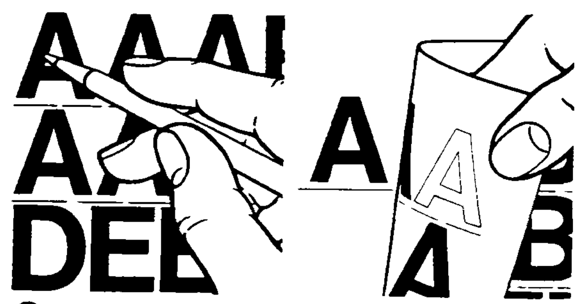


㉓

Retractable pencil suitable for 2 mm dia leads of all grades 6B-9H. When sharpening leads, graphite catcher essential, → (21). To erase indian ink; glass eraser, erasing knife or razor blade; to erase pencil lead: non-smearing india rubbers. In drawing with many lines use erasing shields, → (22). Lettering best unaided; for technical drawings stencil with pen or brush, or use instant dry transfer system such as 'Letraset' which also provides architectural symbols, → (23).

6.1 DRAWING SHEETS

(→ BS 1192: 1969)

Standard sizes

A0 841 x 1 189 mm (33 $\frac{1}{8}$ x 46 $\frac{3}{4}$ in)
A1 594 x 841 mm (23 $\frac{3}{8}$ x 33 $\frac{1}{8}$ in)
A2 420 x 594 mm (16 $\frac{1}{2}$ x 23 $\frac{3}{8}$ in)
A3 297 x 420 mm (11 $\frac{5}{8}$ x 16 $\frac{1}{2}$ in)
A4 210 x 297 mm (8 $\frac{1}{4}$ x 11 $\frac{5}{8}$ in)

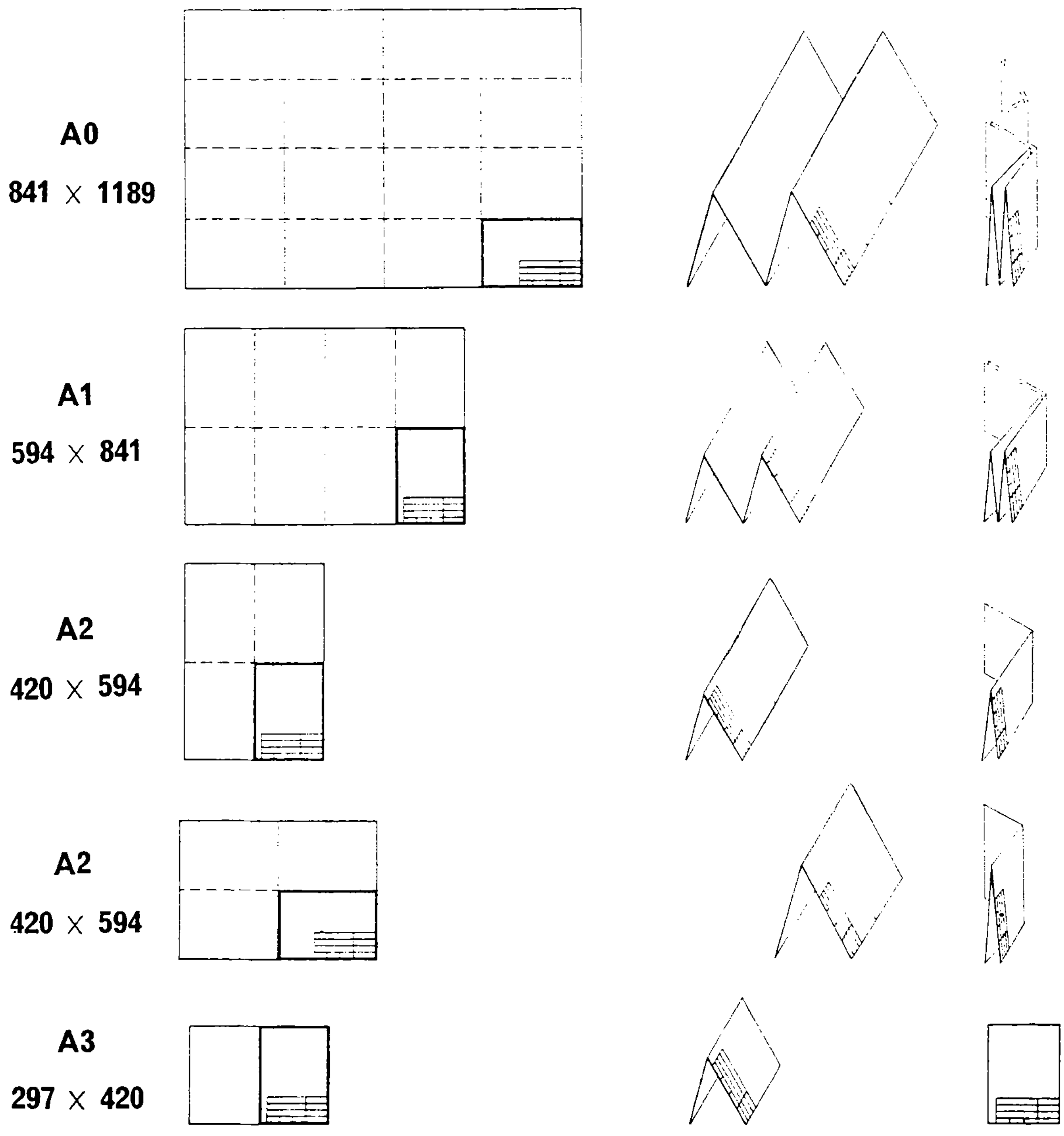
These sizes are all proportional, leading to simple reduction and enlargement and sheets may be easily folded for filing and despatch. The relatively small sizes should lead to easier handling in the drawing office and on site. Keep the number of sizes to minimum, to facilitate binding and reference.

Original drawings and contact copies should both be of standard sizes, therefore trimming of sheets that makes them less than A sizes should be avoided.

Folding

Prints may be folded to A4 size quite easily from any larger A size.

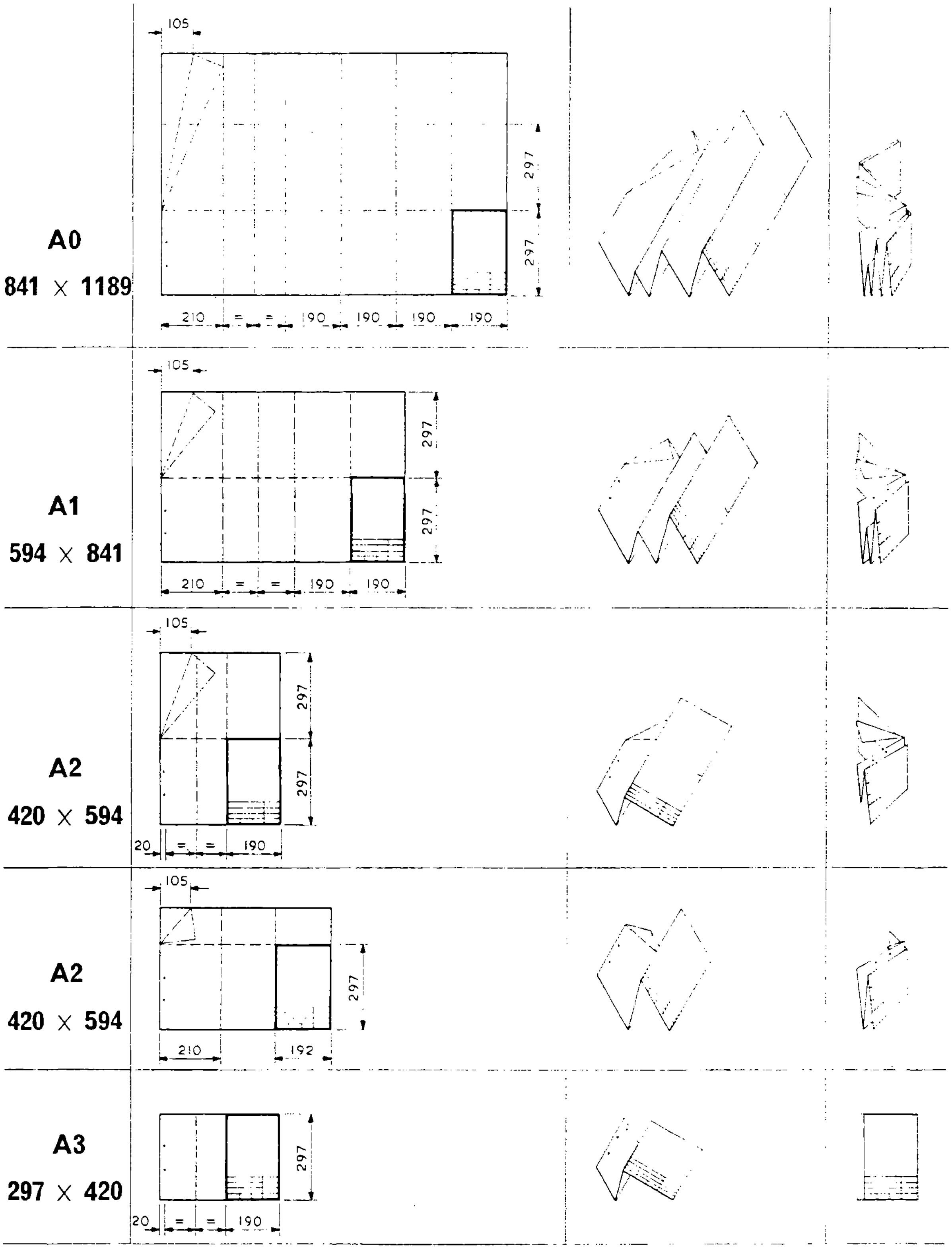
When prints are to be filed it is necessary to fold them in such a way that the punch holes penetrate only one layer. Methods of folding, → (1) and p. 3.



(1) Simple folding of drawings

DRAWING SHEETS

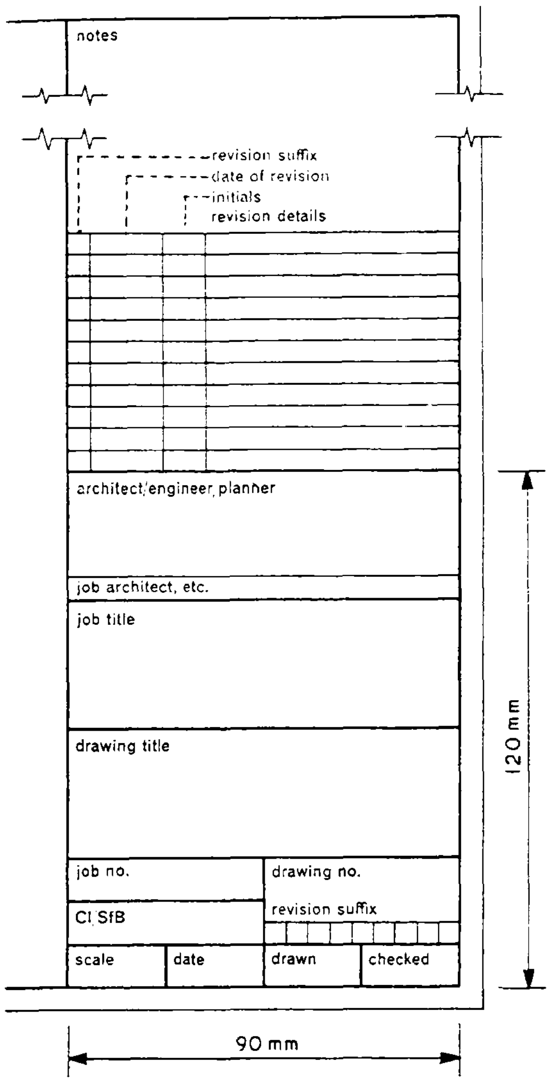
(→ BS 1192: 1969)



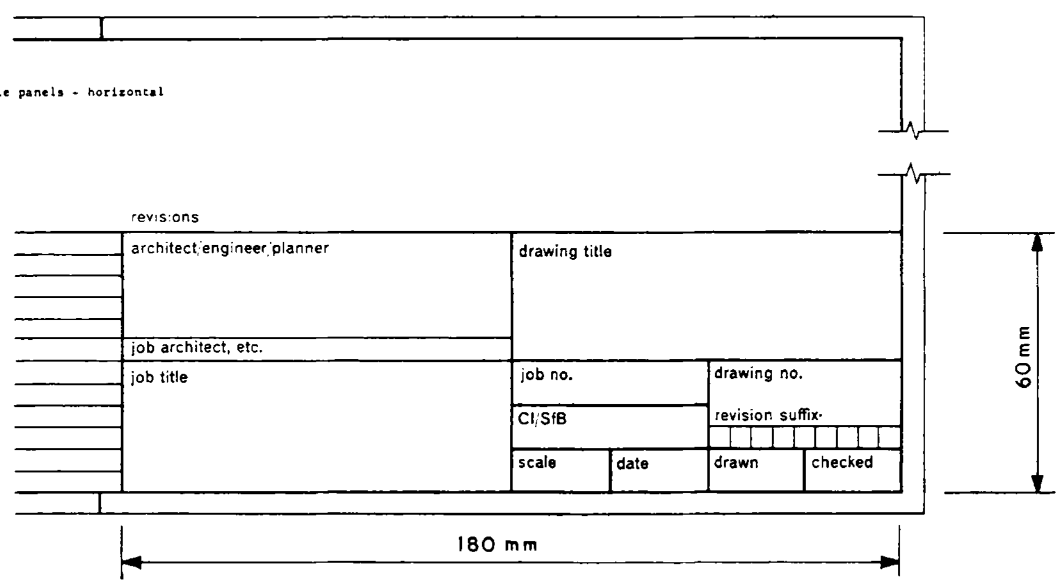
(1) Folding of drawings for filing

AD II	DRAWING PRACTICE	ARCH. DRWNG.
compiled : D.VOLKE		—— LECTURE ——
AUG. '83		CET 3o43/16.158

LAYOUT and IDENTIFICATION



(1) Typical title panels - vertical



(2) Typical title panels - horizontal

Layout and identification

(→ BS 1192: 1969)

Layout: every sheet should have filing margin, title and identification panel.

Filing margin: at left hand edge ≥ 20 mm ($\frac{7}{8}$in) wide. Filing **punch marks** and **fold marks** printed as ticks at edges of sheet. Where microfilming likely, → BS 4210.

Title panel: place in bottom right hand corner of sheet to aid reference when prints are filed or folded, → (1), (2).
Include: job title; subject of drawing; scale; date of drawing; job number; SfB and UDC reference if appropriate; name of architect, etc. Panel may also give initials of person drawing, tracing and checking sheet.

Revision suffix should be changed each time drawing is issued after revision.

Printed blank title panels or use of stencils, transfers or rubber stamps save time and labour.

Information panel: note nature and date of each revision, with architect's initials; start at bottom of panel and work upwards. When general notes included, start at top and work down.

Key: on large projects give key diagram showing continuous drawing sheets, with appropriate part blacked in on each relevant drawing.

Orientation: show north point on every plan. When practicable all plans should have same orientation, except for site location plan. For latter, draw with north at top of sheet to aid identification with Ordnance Survey maps.

TITLE PANEL

NOTES

REVISIONS

SUFF.	DATE	INICIALS	REVISION DETAILS

TCA TECHNICAL COLLEGE CHUO CHA UFUNDI ARUSHA

JOB TITLE	DRWG. TITLE		
JOB ARCHITECT	REVISION SUFFIX		
CLIENT	JOB No.	DRWG No.	
SIGNATURE	SCALE	DATE	DRAWN / CHECKED

AD II	DRAWING PRACTICE	ARCH. DRWNG.
compiled : D.VOLKE		LECTURE
AUG. '83		CET 3043/16.160

TCA TECHNICAL COLLEGE ARUSHA CHUO CHA UFUNDI ARUSHA — CIVIL ENGINEER. DEPARTMENT

6.2 LEVELS

(→BS 1192: 1969)

Levels

General
Levels record distance of a position above or below a defined datum.

Datum
A suitable fixed point should be taken as TBM (temporary bench mark) such that all other levels are positive (minus sign is easily misread). This datum should be clearly indicated or described on drawings, and all levels and vertical dimensions related to it. Vertical dimensions in metres to three decimal places (or in feet and decimals of a foot) above this datum. On large jobs, particularly, it is usually necessary to relate job datum to OS datum (OS levels at present in feet). State clearly whether Newlyn or Liverpool Ordnance Datum is used.

OS are preparing bench mark lists giving heights in metres to two places of decimals.

Levels on plan
It is important to differentiate on site layout drawings between existing levels and intended levels:

existing level: x 58.210

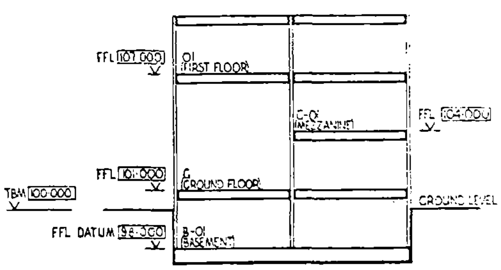
intended level: x [60.255]

Exact position to which level applies should be indicated by 'X'

Finished floor levels should be indicated by letters FFL followed by figures of level:

FFL [12.335]

Levels on section and elevation
Use same method as for levels on plan except that level should be projected beyond drawing with arrowhead indicating appropriate line, → (1).



(1) Levels on section and elevation

6.3 REFERENCING

Referencing

Classification and coding of building components and elements shown on drawings may be achieved through use of SfB system (UK application known as CI/SfB; → 'Construction Indexing Manual', published by RIBA, for details of system and its tables).

SfB enables information contained within different kinds of documents, such as bills of quantity, drawings, specifications, texts, trade literature, etc, to be co-ordinated and correlated for maximum benefit of user.

SfB system is a facet system of alpha-numerical symbols forming three tables which may be used individually or in combination to indicate concepts and terms required. Three tables of SfB system cover building elements, components/products, and materials.

Each type of component or element shown on a drawing may be identified by appropriate SfB notation, e.g.:

concrete blocks	Ff2
concrete lintels	Gf2
aluminium sections	Hh4
hardwood sections	Hi3
manholes	(52)
external walls	(21)
windows	(31)
doors	(32)
radiators	(56)

Notations may be combined, e.g.:

external walls, concrete block	(21) Ff2
windows, aluminium	(31) Hh4
doors, hardwood	(32) Hi3

Number and length of component and element notations should be kept to minimum compatible with a rational system of identification for each particular job.

A specific component within any range may be identified by a suffix giving nominal sizes for length, width, height, etc:

concrete block Ff2 400 mm x 100 mm x 200 mm
Ff2 1 ft 4 in x 4 in x 8 in

Alternatively, where principles of modular coordination are applied, such a suffix may give nominal sizes for a component or element in multiples of 100 mm or 4 in (M), e.g.:

concrete block Ff2 4M x 1M x 2M

6.4 ABBREVIAT.

Abbreviations

(→ BS 1192:1969)

Term	Abbreviation
Aggregate	agg
Air brick	AB
Aluminium	al
Asbestos	abs
Asbestos cement	abs ct
Asphalt	asph
Bitumen	bit
Boarding	bdg
Brickwork	bwk
BS Universal beam	BSUB
BS Channel	BSC
BS equal angle	BSEA
BS unequal angle	BSUA
BS tee	BST
Bronze metal antique	BMA
Building	bldg
Cast iron	CI
Cement	ct
Chromium plate	CP
Cleaning eye	CE
Column	col
Concrete	conc
Convector	conv
Copper	cu copp
Cupboard	cpd
Damp proof course	DPC
Damp proof membrane	DPM
Discharge pipe	DP
Drawing	dwg
Expanded metal lathing	EML
Foundation	fdn
Fresh air inlet	FAI
Glazed pipe	GP
Granolithic	grano
Hardcore	hc
Hardboard	hdt
Hardwood	hwc
Inspection chamber	IC
Insulation	insul
Invert	inv
Joist	jst
Lighting	ltg
Mild steel	MS
Pitch fibre	PF
Plasterboard	pbd
Polyvinyl acetate	PVA
Polyvinyl chloride	PVC
Radiator	rad
Rainwater head	RWH
Rainwater pipe	RWP
Reinforced concrete	RC
Rodding eye	RE
Satin chrome	SC
Sewers foul	FS
Sewers surface water	SWS
Satin anodised aluminium	SAA
Softwood	swd
Stainless steel	SS
Tongue and groove	T&G
Unglazed pipe	UGP
Vent pipe	VP
Wrought iron	WI

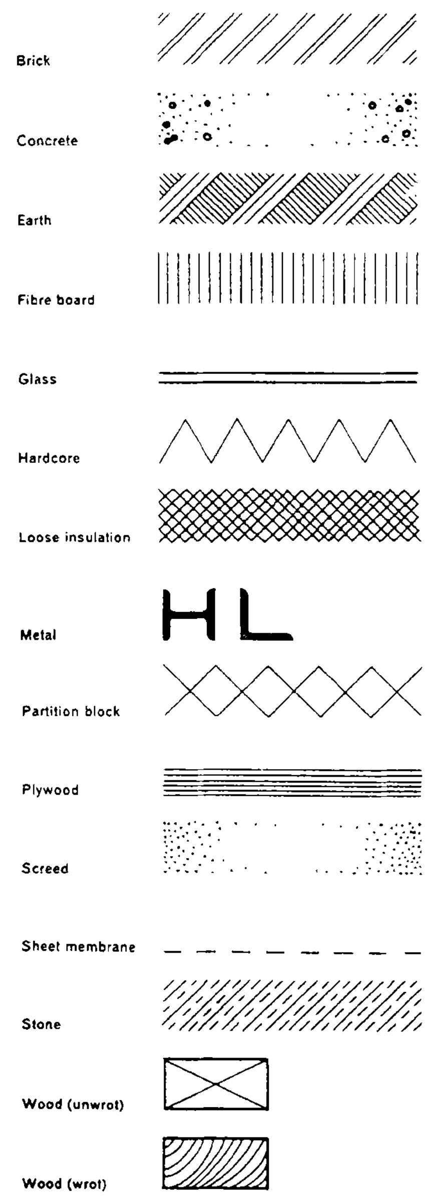
6.5 REPRESENT.

Representation of materials

(→ BS 1192:1969)

Table shows recommended methods of indicating materials on drawings. These methods should only be used where confusion is likely to occur in interpretation of drawings, but in all cases they should be accompanied by a descriptive note, stating type of material, thickness, etc. Existing and proposed work should be clearly indicated. Spacing of hatching lines should be adapted to scale of drawing and should not normally be used on small scale drawings.

Colouring is costly, laborious and conducive to error and consequently to be avoided. Hatching is preferable where it is necessary to show different materials.



6.6 GRAPHICAL SYMBOLS

(→ BS 1192:1969)

A drawing is a symbolic representation of a real or imagined object. Aspects or parts of a drawing may themselves be symbolically represented. Symbols for this purpose are termed graphical symbols, use of which enables maximum information to be contained within the drawing, clearly and legibly, with minimum effort.

Types of symbols
Principal types used in building drawing practice are graphical. Many of these, as well as other kinds of symbols such as letters, numbers and signs, are covered by British Standards, of which the following are relevant:

BS 108 Graphical symbols for general electrical purposes (power and lighting).

BS 1553 Graphical symbols for engineering:
Part 1 Pipes and valves
Part 4 Heating and ventilating systems.

BS 1635 Graphical symbols for fire protection drawings.

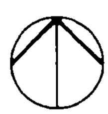
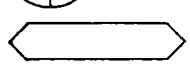
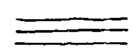
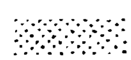
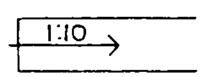
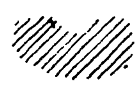
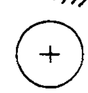
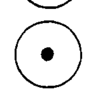
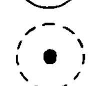
BS 1991 Letter symbols, signs and abbreviations
Part 1 General
Part 4 Structures, materials and soil mechanics.

BS 3939 Graphical symbols for electrical power, telecommunications and electronics diagrams.

Graphical symbols
Building drawing practice requires use of graphical symbols on drawings which are additional to those covered in above British Standards. Examples of most commonly used graphical symbols are given below

GRAPHICAL SYMBOLS AND REPRESENTATION

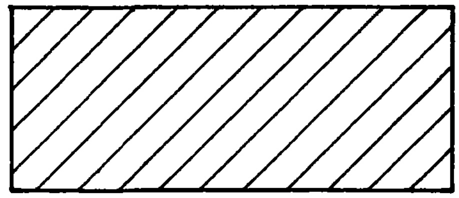
Draughtsmanship

Description	Symbol	Description	Symbol
Centre to centre	c/c	Existing level on section	⊻ 0·000
Centre line	℄	Finished floor level	FFL
Direction of view	⟶	Ground level	GL
External	ext	Required level on plan	× [0·000]
Internal	int	Required level on section	⊻ [0·000]
North point		Temporary bench mark	TBM
Modular space		Paved area	
Rise of stair		Grass area	
Rise of ramp		Planted area	
Bench mark	BM	New trees	
Existing level on plan	× 0·000	Existing trees	
		Existing trees removed	

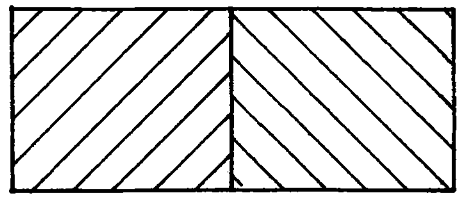
6.7 HATCHING

HATCHING RULES

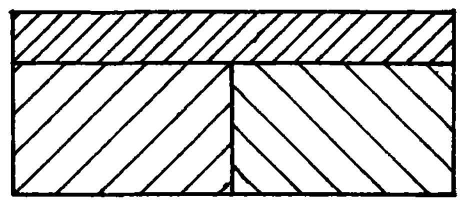
1. Draw HATCHING LINES preferably at 45° as thin lines with a spacing of - preferably - not less than 4 mm.



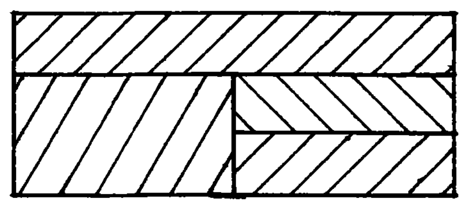
2. If two adjacent parts to be hatched, draw the HATCHING LINES in opposite directions.



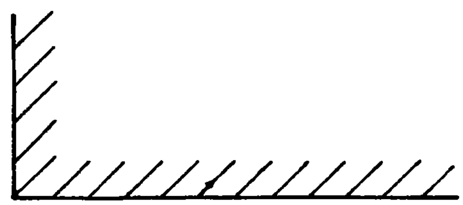
3. Where more than two adjacent parts to be hatched, draw the HATCHING LINES of one area - preferably the smallest - closer together.



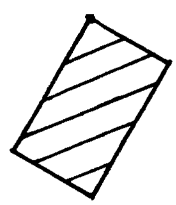
4. In order to simplify distinguishing between more than two adjacent parts, HATCHING LINES drawn at 60° and/or 30° my be used additionaly.



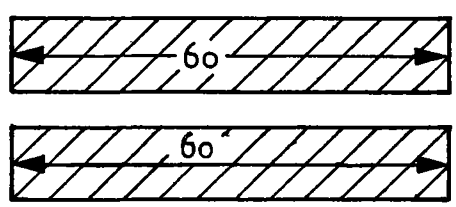
5. Large areas may be hatched along the borderline only.



6. If a part is drawn at such an angle that the HATCHING LINES become parallel to one edge of the part, the angle of hatching may be chaused.



7. Interrupt HATCHING LINES to give space for dimensioning figures, words etc.



7.APPLICATION for BUILD.PERMIT

7.1 PROCEDURE OF APPLYING FOR PERMISSION TO ERECT A BUILDING

Application for and Allocation of a plot:

a) Request to the (District) Land Officier
b) Land Officier submit all applications to the Urban Planning Committee
c) Plots are allocated by the Urban Planning Committee
d) Right of Occupancy of the plot is issued through the Land - Officier.

Application for Permission to erect a Building

a) Submission of the Application to the Town Council Authority
The application includes:
- A properly filled Form of Application for Permission to erect a Building
- A properly filled Form of Application for Planning Consent.
- 4 sets of drawings:

Blockplan	scale 1:2500 (better 1:1000)
Siteplan	scale 1: 500
All floor plans	scale 1: 100
Sections	scale 1: 100
Elevations	scale 1: 100
R.C. Details	scale 1: 20 - 1: 5

- Schedule of doors, windows, opening arrangements.
- Details of the Drainage system including septic tank and soakage, pit, inspection chambers, gully traps, vent. pipes, etc.

b) Before submitting the Application to the Urban Planning Committe, forms and plans will be checked by:

- the Land Officier
- the Health Officier
- the Town Engineer
- the Town Planning Officier
- the Fire Master

In case the application does not comply with the technical requirements of the Authority the Application may be disapproved and send backs for amendments resubmission to the applicant. After the technical approval, the application will be submitted to the Urban Planning Committee. The Committee approves or disapproves the application and issues the Building Permit.

c) The Building Permit will be sent to the applicant together with one set of plans (with stamp and signature of the Authority) and one set of proceed sheets.

Form of Application for Permission to Erect a Building

FOR OFFICE USE ONLY
Plan submitted ....
Registered No. of Plan ....
Date of Registration ....

To, TOWN DIRECTOR
ARUSHA TOWN COUNCIL
P. O. Box 3013, Arusha

.... 19..

I beg to submit herewith Plans, Sections and Elevations for ....

....
(State here if New Building, Alteration or Addition or Sanitary Reconstruction)

....

to be used as ....
(Insert whether a Domestic Building or for what purpose the building will be used)

to be executed by me on Plot No. ....

such plot having frontage to ....

I also submit the following proposed means of construction and other particulars:

External walls to be built of ....

Internal walls to be built of ....

Mortar in walls to be composed of ....

Dampcourse to be of ....

Foundations to be of .... Mortar in foundation composed of ....

Roof to be constructed of ....

Water supply from ....

Drainage to sewer/permeable cesspit/impermeable septic/tank (erase words which do not apply). In the

of septic tanks state how the effluent will be disposed of ....

Material of drain pipes ....

Closet accommodation — (state type)

Indoor ....

....

Outdoor ....

Name of Architect or Draughtsman ....

Address of above ....

Name of Builder (if known) ....

Signature of Owner or Agent ....

Address of Owner or Agent ....

SUBMISSION OF PLANS

All Plans to be submitted to the ....

One set of Plans to be made on cloth (paper on cloth is not accepted)

All Drawings to be signed by owner or his agent.

All Drawings to be accompanied by application form duly completed as required by the ....

....

All Drawings to be submitted in duplicate and to be of a quality approved by the ....

....

DRAWINGS REQUIRED

Scale 1:100 — Plans of each floor or level; having thickness of wall shown in figures. Section through Building (more than one if building is large or if required by Authority).

Scale 1:50 — Sections are required of Floors and Roofs, Verandas, and Balconies, Stairs, iron or steel Beams, Pillar and Principal Timbers, Pavements, Openings, etc., on public Streets

Colours — The above drawings are to be coloured thus:

Brick, stone or concrete	Red
Fire-proofing, damp-proofing or impervious floors of stables, closets, etc.	Thick black line
Work to be removed	Dotted line
Steel or iron	Blue lines, in skeleton
Work existing	Natural Colour

Scale 1:500 — Block plan as follows:

To show plot on which buildings are to be erected.

To show plots immediately adjoining and names of the proprietors thereof.

To show buildings, existing or proposed. on all these plots.

To show numbers of plots, names of streets, and township.

To indicate of what materials existing buildings are composed, i.e. bricks wood and iron, or stone, etc.

To show lines of drainage, giving size and fall of drains.

To show level and width of the steet or streets upon which the proposed buildings will abut with reference to their ground-floor level.

FORMULARS

for office

Date	Application No.	Zone	Category

FORM 'A

APPLICATION FOR PLANNING CONSENT

The Town and Country Planning Ordinance

(All development other then Use classes A (d), A (e) and A (f)

This form should be submitted in duplicate

To: The TOWN DIRECTOR

1. I hereby make application to the ________________ Area
   Planning Committee for planning consent to the following development –
   ____
2. Location and planning zone of proposed development ________________
   ____
   ____
3. Development (delete as necessary).
   (a) Category I (Sub division and layout of land)
   Number of plots proposed and proposed use of any buildings to be erected thereon
   ____
   (b) Category II (Change of use of land or premises).
   Number of buildings effected (if any) and changes of use proposed ________________
   ____
   ____
   (c) Category III (any building, engineering or mining work in, on under or over any land or premises)
   ____
   (d) Previous use: purpose for which building or land was last used
   ____
   (e) Details of plot or land . Area ________________
   acres/sq feet Frontage to road ________________
   feet. Width of street opposite ________________
   feet. Building line or set back adjoining building ________________
   ________________ feet.
4. My interest in land is ________________
   ____
5. I enclose three copies of plans illustrating the proposals

.... Signature of Applicant

Address

P. O. Box 3013
Phone: 3631/2

ARUSHA TOWN COUNCIL
TOWN HALL

BUILDING PERMIT

The Township (Building) Rules 1930

Permission is hereby given to ________________ to

erect a building as a ________________

____

on ________________

____

In accordance with the plan (No. ________________) attached hereto and with all conditions imposed by the above Rules.

________________ 197____ TOWN DIRECTOR

N. B.:- Your attention is invited to the Electricity Rules, 1953, which require you to notify The Tanganyika Electric Supply Company, Limited, as well as the Electrical Engineer, General Post Office, before Commencing to erect a building; should the electric wires in the street be accessible from any portion of such building where erected or from the scaffolding required during its construction.

Building Rules 5 (6). This permit is subject to the fulfilment of the covenants entered into

between ________________ **lessee of the above mentioned plot and the Authority, concerning connection of the building (s) to the main sewerage system when this is applicable.**

Building Rule 5 (6), (G. N. 45/1955). The prescribed number of occupants permitted to reside in the building to which this Permit refers is:

____

____

(Note—Two children may be counted as one adult person)

YOU ARE HEREBY WARNED THAT APPROVAL OF PLANS BY THE AUTHORITY DOES NOT IMPLY THAT ERECTION OF BUILDINGS IN ACCORDANCE WITH THESE PLANS WILL NECESSARILY BE IN ACCORDANCE WITH THE CONDITIONS OF THE RIGHT OF OCCUPANCY UNDER WHICH YOU HOLD THE LAND.

FORMULARS

E

This form MUST be submitted in its proper sequence prior to any rther work proceeding.

o. 1885

.... Date............................

....

Plot No. Block No. Area

I hereby give notice that the work of construction has now roceeded to wall plate level.

lan No. **Refers**

Signed.......................................

WO DAYS NOTICE REQUIRED

F

This form MUST be submitted in its proper sequence prior to any rther work proceeding.

o. 1885

.... Date............................

....

Plot No. Block No. Area

I hereby give notice that all the roofing timbers in the building re in position and are ready for examination.

lan No. **Refers**

Signed.......................................

WO DAYS NOTICE REQUIRED

G

This form MUST be submitted in its proper sequence prior to any further work proceeding.

No 1885

.... Date............................

....

Plot No. Block No. Area

I hereby give notice that the drainage and sanitary work are ready for testing.

Plan No. **Refers**

Signed.......................................

TWO DAYS NOTICE REQUIRED

H

This form MUST be submitted in its proper sequence prior to any further work proceeding.

No. 1885

.... Date............................

....

Plot No. Block No. Area

I hereby give notice that the whole of the work has been completed and I hereby apply for a certificate of occupation in respect of the premises.

Plan No. **Refers**

Signed.......................................

SEVEN DAYS NOTICE REQUIRED

A

This form MUST be submitted in its proper sequence prior to any further work proceeding.

No. 1885

.... Date............................

....

Plot No. Block No. Area

I hereby give notice that I intend commence the work approved in

Plan No. ....on.......................197......

Signed.......................................

TWO DAYS NOTICE REQUIRED

B

This form MUST be submitted in its proper sequence prior to any further work proceeding.

No. 1885

.... Date............................

....

Plot No. Block No. Area

I hereby give notice that the foundation trenches are now ready. for inspection.

Plan No. **Refers**

Signed.......................................

TWO DAYS NOTICE REQUIRED

C

This form MUST be submitted in its proper sequence prior to any further work proceeding.

No. 1885

.... Date............................

....

Plot No. Block No. Area

I hereby give notice that the foundation concrete in now ready for inspection.

Plan No. **Refers**

Signed.......................................

TWO DAYS NOTICE REQUIRED

D

This form MUST be submitted in its proper sequence prior to any further work proceeding.

No. 1885

.... Date............................

....

Plot No. Block No. Area

I hereby give notice that the ground floor concrete and damp proof course are ready for inspection.

Plan No. **Refers**

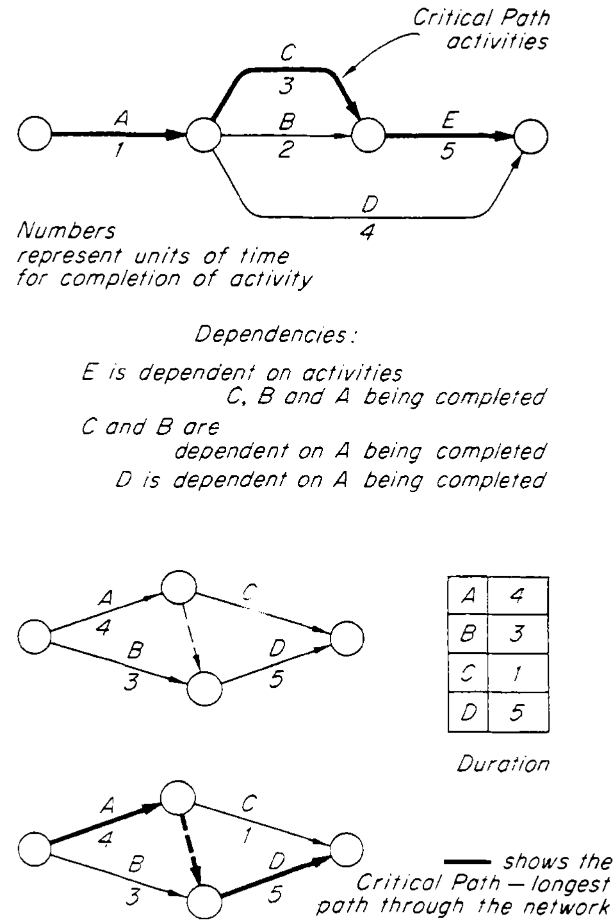
Signed.......................................

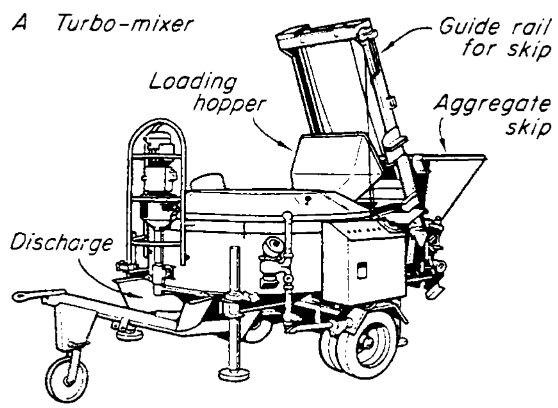
TWO DAYS NOTICE REQUIRED

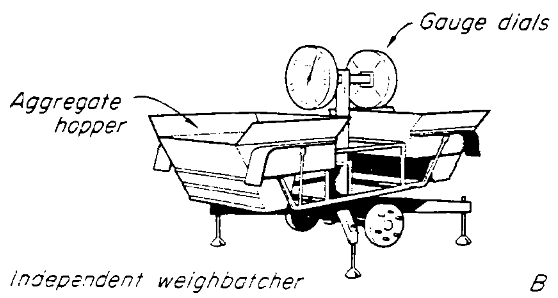
AD II compiled : D.VOLKE AUG. '83	BUILDING PERMIT	ARCH. DRWNG. LECTURE CET 3o43/17.168
TCA TECHNICAL COLLEGE ARUSHA CHUO CHA UFUNDI ARUSHA	CIVIL ENGINEER. DEPARTMENT	68

4. CONTRACT PLANNING and SITE ORGANISATION

CONTENTS :







REFERENCES:

1. Jack Stroud Foster
   MITCHELL`S BUILDING CONSTRUCTION
   "Structure and Fabric"
   Part 1 and 2

2. W. G. Nash
   "Brickwork 3 "

3. R. Chudley
   "Construction technology"
   Volume 2 and 4

4. R. L. Fullerton
   "Building Construction in Warm Climates"
   Volume 1 and 2

4. CONTRACT PLANNING and SITE ORGANISATION

4. CONTRACT PLANNING AND SITE ORGANIZATION

Buildings, and consequently their construction, have become more and more complex and the proper management of a contract as well as the control of cost (on the part of the architect at design stage and the contracter during erection) are more than essential.
Because mechanisation of building operations and the use of expensive plant has increased, the contractor must obtain maximum use of the plant and speed the construction of the job in order to keep his costs to a minimum. The design/erection continuum must be seen as a production process from inception to completion and there must be a programme on which the job may be organized, against which performance may be assessed and within which control may be exercised.

Contract planning and site organization, together with general control are the construction aspects of production management which itself is a part of overall management in building.

PLANNING makes efficient and economical use of labour, machines and materials.

ORGANIZATION is the means of delegating tasks

CONTROL enables planning and organization to be effective.

4.1 CONTRACT PLANNING

4.1 CONTRACT PLANNING

Contract Planning involves working out a PLAN OF COMPAIGN or PROGRAMME for the contract as a whole and assembling the necessary data.

Such a programme is to promote the flow of the various building operarions during the course of erection, by planning in advance
- the times and sequences of all operations
- the requirements in labour
- the requirements in materials
- the requirements in equipment.

The BUILDING RESEARCH STATION DIGEST 91 states that such a programme should:
a) show the quickest and cheapest method of carrying out the work consistent with the available recources of the builder.
b) by the proper phasing of operations with balanced labour gangs in all trades, ensure continous productive work for all the operatives employed and reduce unproductive time to a minimum.

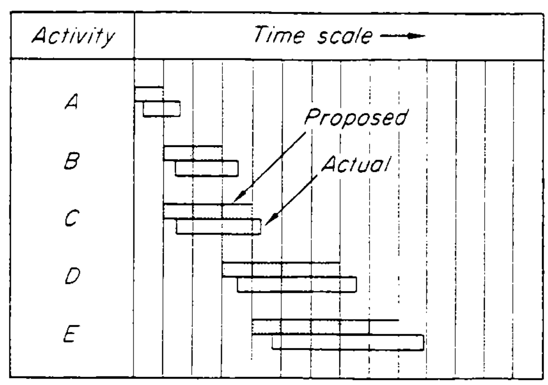
c) provide an assessment of the level of productivityin all trades
d) determine attandance dates, and periods for all subcontractor´s work
e) provide information on material quantities and essential delivery dates, the quantity and capacity of the plant required and the periods it will be on site.
f) provide, at any time during the contract, a simple and rapid method of measuring progress for the builders information for the architect´s periodical, for the valuation of work for accounting purposes.

If a builders tender is to be realistic, planning must start at the estimating stage.
The following considerations should be taken into account:
- use of the most economic methods for each operation
- sequence and timing of the operations
- resources at the contractors disposal
- use of hand or mechanical methods, type of plant
- space available and best positions for the various machines to be used.
- the best methods of handling material and most suitable places on the site for the storage of materials and for the placing of hut
- suitable points of access to the site for lorries and machines.

4.1.1 BAR CHART

4.1.1 BAR CHART

A typical site orientated control device is the GANTT CHART or BAR CHART which allows a fairly simple and easily read plan of perations to be made available to all site personnel against which may be plotted actual performances. However, this device only takes into account one of the resources - TIME - and unless further schedules of the recources needed for each operation are also available (adjacent ot the BAR CHART) it does not inform on the critical relationships between the various activities nor does it enable procedures involving a number of variables to be optimised since the complex interrelationships affecting the outcome of any plan (or alteration of plan) are not readily evident or quantifiale. (see fig.)
This can be achieved by means of a technique known as NETWORK ANALYSIS.



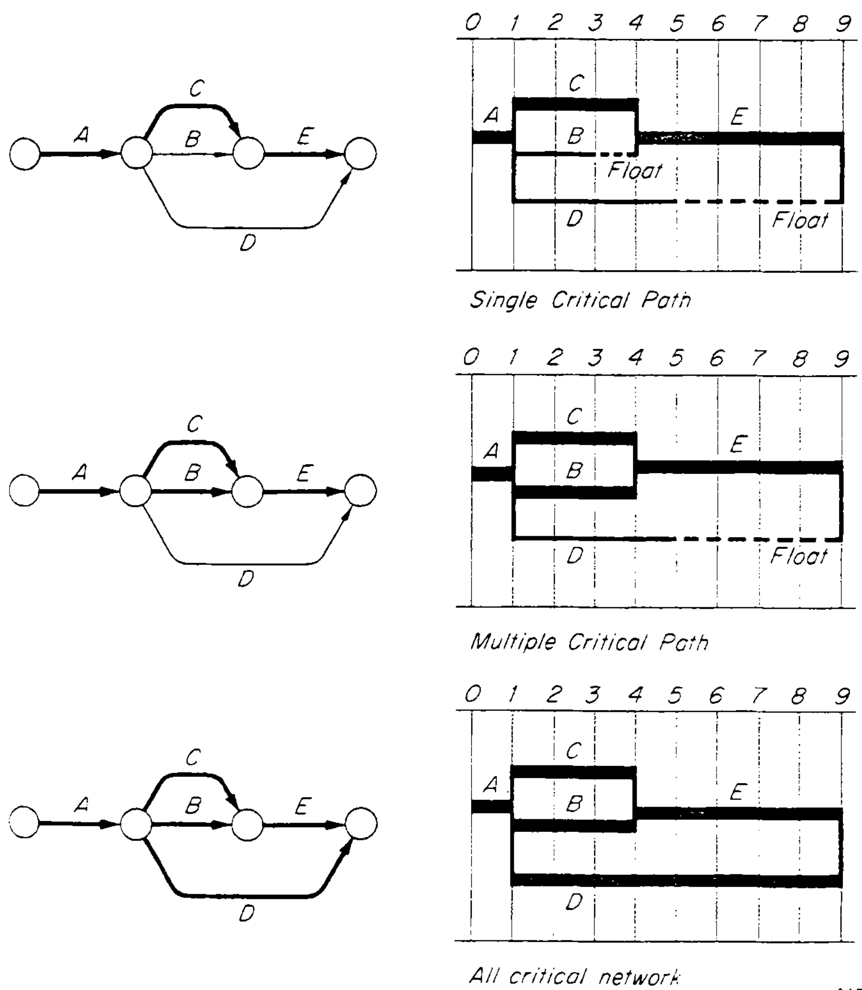
4.1.2 NETWORK ANALYSIS

4.1.2 NETWORK ANALYSIS

The essential difference between analysing a production problem by NETWORK and LINEAR or PARALLEL LINEAR methods lies in the identification of the dependency between operation.

This approach leads to interelated networks through which certain sequences can be seen to be 'critical' to the anticipated outcome in that they occupy the longes and irreducible time necessary to execute the project (or parts of the project). to which they are necessary.

The fig. shows this in a simple set of 5 intorelated activities A,B,C, D,E of time values 1,2,3,4 and 5 days.



	D	F
A	1	0
B	2	1
C	3	0
D	4	4
E	5	0

D = duration
F = float

	D	F
A	1	0
B	3	0
C	3	0
D	4	4
E	5	0

	D	F
A	1	0
B	3	0
C	3	0
D	8	0
E	5	0

(Rows: Activities; values: Units of time)

NB Activities on Critical Path have zero "float"

Network or Critical Path diagrams

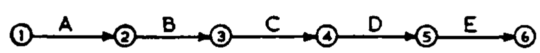
ARROW DIAGRAM

The way how to prepare a NETWORK in the form of an ARROW DIAGRAM is described in the following:

1) Project to be broken down into a series of stages (or elements of work) called
ACTIVITIES
represented by ARROWS (Length not important)
Head of arrow = finish of activity

2) Any junctions of activities are called
EVENTS
represented by CIRCLES.
An event indicates the completion of one activity and the start of the next (except first and last!)

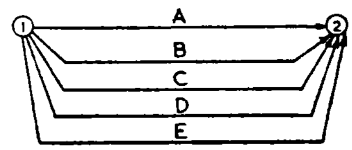
3) Example: 5 operations carried out continuously:



4) Each activity may be identified by the numbers of the beginning and end as follows:

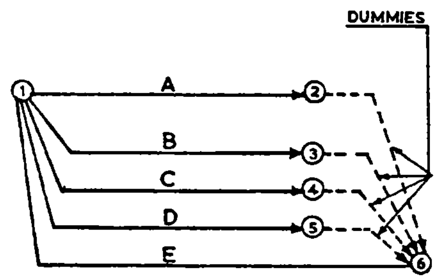
Activity	*Identity*
A	1–2
B	2–3
C	3–4
D	4–5
E	5–6

5) If these 5 operations had been started and finished at the same time, it is not convenient to show them as follows:



because each has the same identity.

Therefore, to give each a seperate identity, DUMMY ACTIVITIES must be introduced (dotted lines)

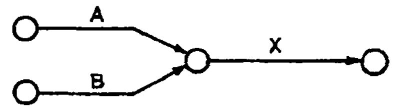
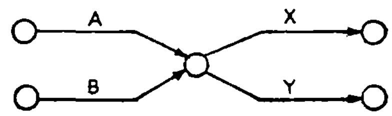
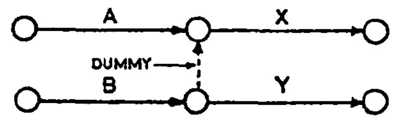
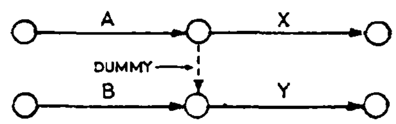
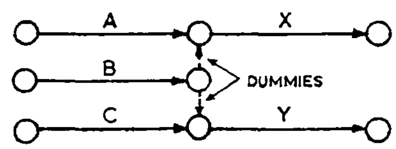
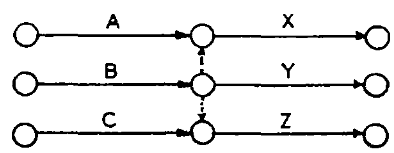
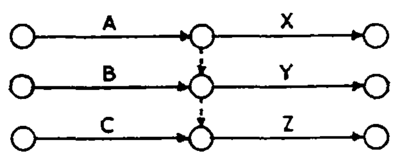
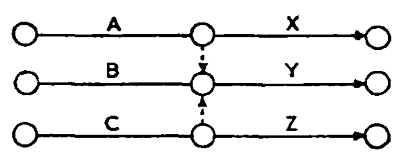
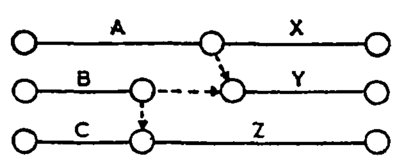


ACTIVITY	INDENTITY
A	1 - 2
B	1 - 3
C	1 - 4
D	1 - 5
E	1 - 6
DUMMY	2 - 6
DUMMY	3 - 6
DUMMY	4 - 6
DUMMY	5 - 6

A dummy arrow has no duration and shows only the logical relationship which cannot be shown by activity arrows (no time, no recources, they have only transfer information from one event to another)
Arrows should always be identified by ascending order of numbers (lower number: the tail, higher number : the head).

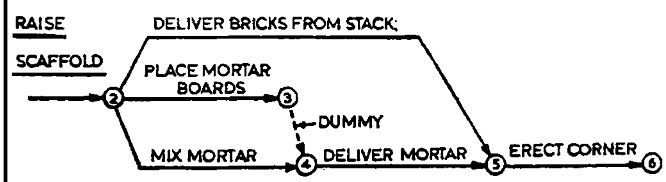
6) Which questions should be asked, when setting out an arrow diagram for a project?

a) what controls the start of each activity?
b) what controls its finish or end?
c) what job or jobs must be done before the next activity can be started?
d) what jobs must follow the activity?
e) what jobs can run concurrently?

7) Examples (should be thoroughly understood)	# EXAMPLES
1 Activity X depends upon activity	
2 Activity X and Y depend upon activities A and B	
3 Activity X depends upon activities A and B and activity Y depends upon B only	
4 Activity Y depends upon activities A and B and activity X depends upon A only	
5 Activity X depends upon A and B and activity Y depends upon B and C	
6 Activity X depends upon activities A and B, activity Z depends upon activities B and C and activity Y depends upon B only	
7 Activity Z depends upon activities A,B,C, activity X upon A only and activity Y upon A and B	
8 Activity Y depends upon activities A,B,C, activity X depends upon A only and activity Z depends upon activity C only	
9 Activity X depends upon activity A, activity Y depends upon activities A and B and activity Z depends upon activities B and C	

8) Example: Errecting a corner

Activities:
1 raise scaffold
2 deliver bricks from stack to scaffold
3 place mortar boards
4 mix mortar
5 deliver mortar to scaffold
6 build corner

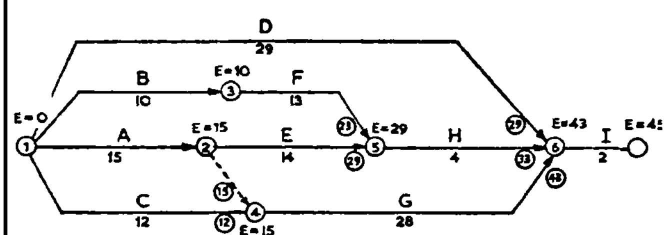


9) The time element
We have so far been concerned only with the placing of the activities in a logical order.

Now the time element has to be considered, and to be applied to the network, in order to obtain the EVENT IMES and the TOTAL PROJECT TIME.
- The duration of the activities should be written under each arrow.
  these items must be very carefully estimated (according to the work content contained within each activity) otherwise the network would not be of any value.

TIME ELEMENT

10) Earliest starting times
When the durations of the activities have been entered, the times of starting and finishing the events can be calculated. The earliest times for starting and finishing activities can be found by adding the duration of each activity to the finishing time of the previous activity. Begin at 0 with the first activity and calculate each path separately. Where two ore more paths meet at an event or node, the longer or longest total time must be taken as the earliest starting time to the next activity.



E = Earliest starting time

	ACTIVITY	DURATION	EARLIEST START	EARLIEST FINISH
A	1–2	15 days	0	15
B	1–3	10 days	0	10
C	1–4	12 days	0	12
D	1–6	29 days	0	29
	2–4	dummy	15	15
E	2–5	14 days	15	29
F	3–5	13 days	10	23
G	4–6	28 days	15	43
H	5–6	4 days	29	33
I	6–7	2 days	43	45

11) Latest starting times
This is a similar analysis carried out only in a reverse direction, which means beginning at the last event time and working backwards by deducting the activity time from the end event time. Where two or more paths meet at an event, the shorter or shortest time is adopted for the calculation of the latest starting time. The total times for each path have been indicated by the figures in circles, and it will be seen that the highest figures have been taken in each case.

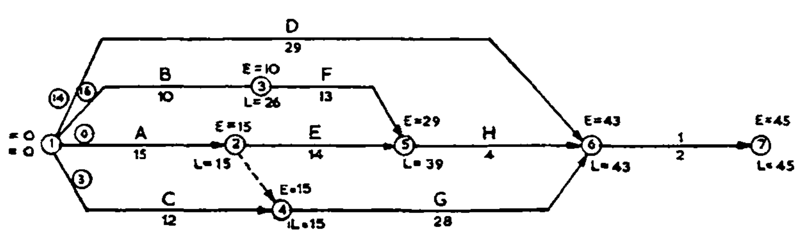
12) Latest finishing times
The times for each path have been shown in circles as before, but this time the lowest figure have been used in each case.
It is most important that the dummy activity is taken into account when calculating the earliest starting and latest finishing times. These times could have been analysed as before, but in this case the calculating is started at the bottom of the table and the durations are deducted from the latest finishing times.

	ACTIVITY	DURATION	LATEST START	LATEST FINISH
A	1–2	15 days	0	15
B	1–3	10 days	16	26
C	1–4	12 days	3	15
D	1–6	29 days	14	43
	2–4	dummy	15	15
E	2–5	14 days	25	39
F	3–5	13 days	26	39
G	4–6	28 days	15	43
H	5–6	4 days	39	43
I	6–7	2 days	43	45

start here

The two tables can now be combined as follows

	ACTIVITY	DURATION	EARLIEST START	EARLIEST FINISH	LATEST START	LATEST FINISH
A	1–2	15 days	0	15	0	15
B	1–3	10 days	0	10	16	26
C	1–4	12 days	0	12	3	15
D	1–6	29 days	0	29	14	43
	2–4	dummy	15	15	15	15
E	2–5	14 days	15	29	25	39
F	3–5	13 days	10	23	26	39
G	4–6	28 days	15	43	15	43
H	5–6	4 days	29	33	39	43
I	6–7	2 days	43	45	43	45



L = Latest finishing times

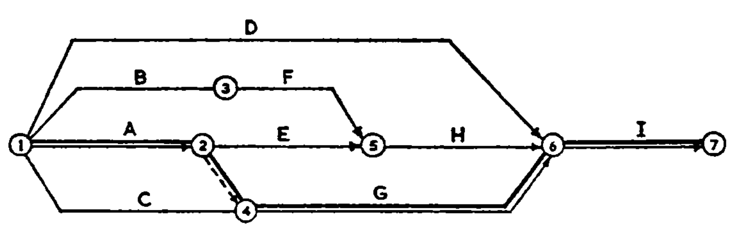
13) Floating times
From the diagrams and the analyses it will be seen that, if the earliest starting times are deducted from the latest finishing times, some activities have a greater length of time available for carrying out the activity then the work content requires. The spare time in each case is called the total float.
The total float for each activity is calculated as follows:
Latest finishing time - earliest starting time - duration of the activity.

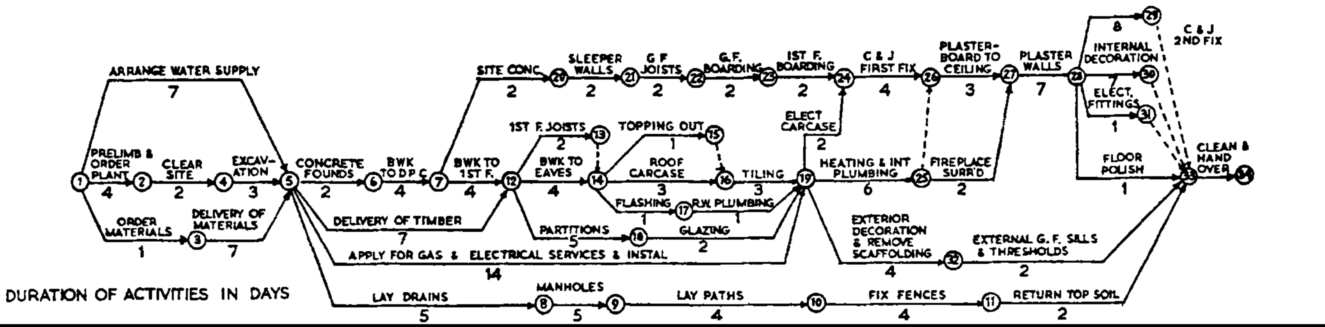
14) Critical path
Where there is a zero float against an activity, this activity will be a critical item. This means that such an item must not be delayed otherwise it will delay the whole project.
These activities will form a continous chain through the network, and this chain is called CRITICAL PATH in a network.

The critical path includes the dummy activity. All of the other activities have longer times than the durations need.

Besides TIME (as the main planner´s parameter) other factors such as COST, LABOUR and MATERIAL AVAILABILITY, the DEMAND of other Projects under the planner´s control will affect the final assesment of times to be ascribed to the constituent activities of network.

			EARLIEST		LATEST		TOTAL
ACTIVITY		DURATION	START	FINISH	START	FINISH	FLOAT
A	1–2	15 days	0	15	0	15	0
B	1–3	10 days	0	10	16	26	16
C	1–4	12 days	0	12	3	15	3
D	1–6	29 days	0	29	14	43	14
	2–4	dummy	15	15	15	15	0
E	2–5	14 days	15	29	25	39	10
F	3–5	13 days	10	23	26	39	16
G	4–6	28 days	15	43	15	43	0
H	5–6	4 days	29	33	39	43	10
I	6–7	2 days	43	45	43	45	0





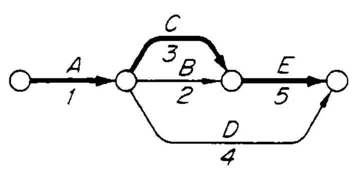
ACTIVITY	NO.	DURATION	EARLIEST START	EARLIEST FINISH	LATEST START	LATEST FINISH	TOTAL FLOAT
Prelims and order plant	1–2	4 days	0	4	0	4	0*
Order material	1–3	1 day	0	1	1	2	1
Arrange water supply	1–5	7 days	0	7	2	9	2
Clear site	2–4	2 days	4	6	4	6	0*
Delivery of materials	3–5	7 days	1	8	2	9	1
Excavation	4–5	3 days	6	9	6	9	0*
Concrete foundations	5–6	2 days	9	11	9	11	0*
Lay drains	5–8	5 days	9	14	32	37	23
Delivery of timber	5–12	7 days	9	16	12	19	3
Gas and electrical services	5–19	14 days	9	23	15	29	6
Bwk up to d.p.c.	6–7	4 days	11	15	11	15	0*
Bwk to 1st floor level	7–12	4 days	15	19	15	19	0*
Site concrete	7–20	2 days	15	17	21	23	6
Manholes	8–9	5 days	14	19	37	42	23
Lay paths	9–10	4 days	19	23	42	47	23
Fix fences	10–11	4 days	23	27	47	51	24
Return top-soil	11–33	2 days	27	29	51	53	24
1st floor joists	12–13	2 days	19	21	25	27	6
Bwk to eaves	12–14	4 days	19	23	19	23	0*
Partitions	12–18	5 days	19	24	22	27	3
Dummy	13–14		21	21	27	27	6
Topping out	14–15	1 day	23	24	25	26	2
Roof carcase	14–16	3 days	23	26	23	26	0*
Flashings	14–17	1 day	23	24	27	28	4
Dummy	15–16		24	24	26	26	2
Tiling	16–19	3 days	26	29	26	29	0*
R.W. plumbing	17–19	1 day	24	25	28	29	4
Glazing	18–19	2 days	24	26	27	29	3
Electrical carcase	19–24	2 days	29	31	29	31	0*
Heating and internal plumbing	19–25	6 days	29	35	29	35	0*
External decorate, etc.	19–32	4 days	29	33	47	51	18
Sleeper walls	20–21	2 days	17	19	23	25	6
G.F. floor joists	21–22	2 days	19	21	25	27	6
G.F. floor boards	22–23	2 days	21	23	27	29	6
1st F. floor boards	23–24	2 days	23	25	29	31	6
C & J 1st fixing	24–26	4 days	31	35	31	35	0*
Dummy	25–26		35	35	35	35	0*
Fireplace surround	25–27	2 days	35	37	36	38	1
Plasterboard to ceilings	26–27	3 days	35	38	35	38	0*
Plaster to walls	27–28	7 days	38	45	38	45	0*
C & J 2nd fixing and fittings	28–29	8 days	45	53	45	53	0*
Internal decoration	28–30	7 days	45	52	46	53	1
Electrical fittings	28–31	1 day	45	46	52	53	7
Polish floors	28–33	1 day	45	46	52	53	7
Dummy	29–33		53	53	53	53	0*
Dummy	30–33		52	52	53	53	1
Dummy	31–33		46	46	53	53	7
Ext. G.F. sills and thresholds	32–33	2 days	33	35	51	53	18
Clean and hand over	33–34	2 days	53	55	53	55	0*

A DETAILED NETWORK FOR THE CONSTRUCTION OF A HOUSE

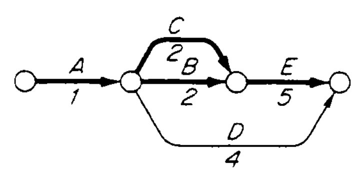
15) Time/cost optimisation
This technique explores the possibilities of altering production time in order to optimise the costs.
In building work:
increased speed of production leads to increased cost (due to having to use more operatives, and /or machinery, or to pay high rates).

Any reduction of the activity times on the critical path will reduce the overall production time, but will probably reduce the 'float' on other activities to the point that they also become critical
(case 1) Activities A,B,C,D,E are given to be carried out in 'normal' times shown in column X. Activities A,C, and E are capable of being carried out by different means at 'crash' times for increased rates shown in column Y.
It is then possible to define three basic outcomes from the application of these figures:
- normal cost programme (case 1)
- all 'crash'programme (case 5)
- best time/least cost programme (case 4)

Case 1



9 days



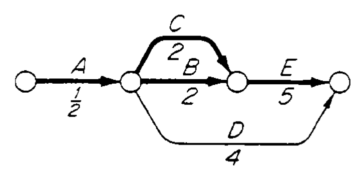
8 days

Case 2

Cost data — X: Dur'n, Cost; Y: Dur'n, Cost

Activity	Dur'n (X)	Cost (X)	Dur'n (Y)	Cost (Y)	
A	1	120	$\frac{1}{2}$	200	CC
B	2	80	2	80	
C	3	100	2	150	CC
D	4	60	4	60	
E	5	200	3	300	CC

CC = crash costs



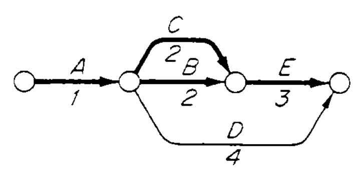
$7\frac{1}{2}$ days

Case 3

I.C. = rate of Indirect Costs — 70 00 per day

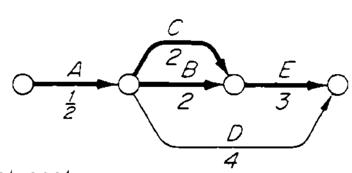
Activity	Duration (days)				
	9	8	$7\frac{1}{2}$	6	$5\frac{1}{2}$
A	120	120	200	120	200
B	80	80	80	80	80
C	100	150	150	150	150
D	60	60	60	60	60
E	200	200	200	300	300
I.C	630	560	525	420	385
Totals	1190	1170	1215	1130	1175

Summary of cases 1–5 — Best time for least cost (6 days)



6 days

Case 4



$5\frac{1}{2}$ days

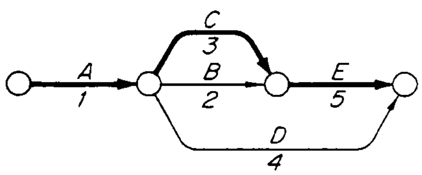
Case 5

Time-cost optimisation

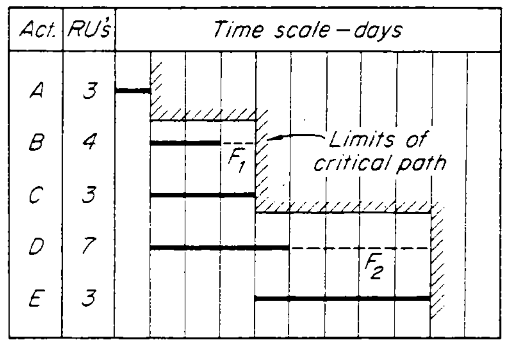
16) Resource levelling and control
This technique enables a planner to assess the requirements of varous resources to serve any given network of activities and to utilise 'float' in uncritical activities to optimise his use of resources or to reduce imbalances of resource demand.

- The technique ascribes the various resources to each activity and by comparison with established norms identifies excessive demands.
- It is possible to reposition activities requiring excessive use of resources and to balance the total requirements within the resources available or at least to reduce the time of excessive demand.
- The repositioning of certain activities will often render them critical when they are taken together with fixed waiting periods necessary to the planned use of resources.

A (i)

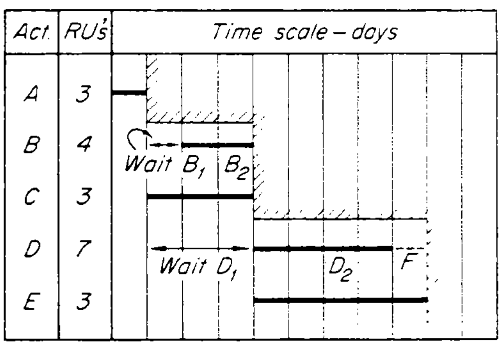


Network with Normal times (N)

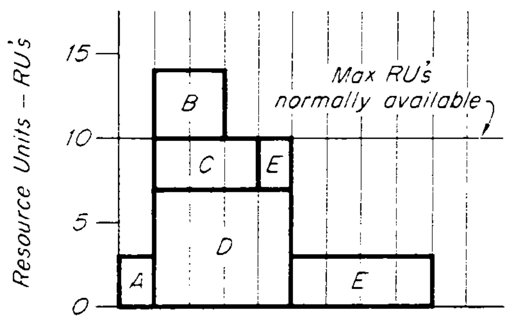


A (ii) Bar Chart based on Network (N)

Re-plan due to overload exposed by A (iii)

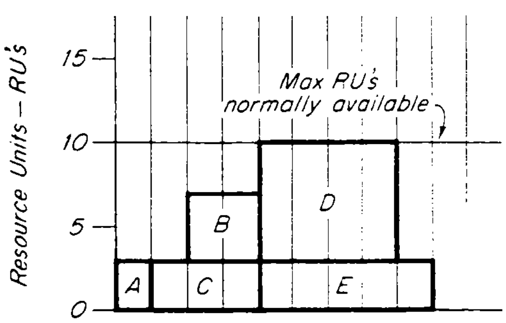


B (i) Bar Chart still based on Network (N), but activities B and D moved within time spaces available (F_1 and F_2)

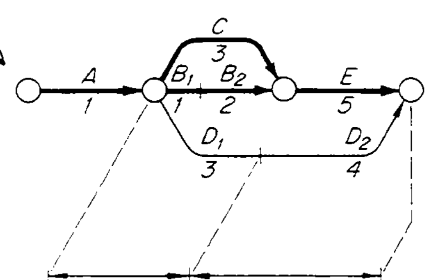


A (iii) Resource Loading Chart for A (ii)

Re-check Network as to new critical activities



B (ii) Resource Loading Chart for B (i)

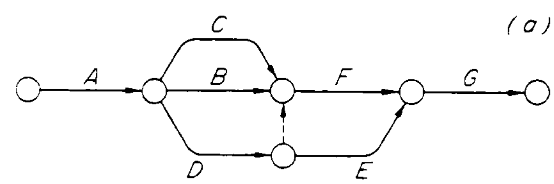


C

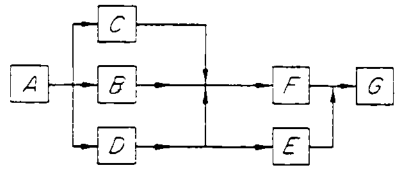
This technique is illustrated in fig.
The network A (i) yields the scaled network in bar chart form A(ii)
By allocating the resource units - RU's - for each activity, a resource loading diagram (A(iii) can be prepared.
In this case it shows an excetive demand of four RU's above the resource units normally available during the second and third days, due to activities B and D coming together.
B (i) shows the repositioning of activities B and D in the excess times available for their execution and a resulting 'levelling' of the loading diagram to bring the requirements for resources within the limits of normal availibility as in B (ii).
This manoeuvre involves specific positioning of waiting periods B_1 and D_1 and examination of the resulting network at C shows that these constrains on the commencement of activities B_2 and D_2 leads to the former becoming critical and reduces the float of the latter to one day only.

The foregoing brief description of some of the uses of network analysis has been based on a simplified description of the network involved. For further informations one of the many books dealing specially with these techniques should be consulted.

The most useful aspect of network analysis lies in exercising the logic used to set up the basic network of activities since the planner has a full knowledge of the practical consequences of any sequence of activities and the importance of their relationships. This aspect of a network approach to planning is illustrated in the method of presentation of the logic known as a Precedence Diagram. The fig. shows a typical network restated in this form which eliminates the need for dummy activities normally used in conventional networks to indicate dependency.



Dependencies:
C, B and D depend on A being completed
F depends on B, C and D being completed
E depends on D being completed
G depends on F and E being completed



Precedence diagram (b)

4.1.3 The OVERALL PROGRAMME

On acceptance of the tender a WORKING or OVERALL PROGRAMME is prepared by the contractor's planning staff together with the plant engineers and the site agent or foreman for the job. This will be used as a guide for:
- site activities
- detailed planning
- purchasing and delivering of materials
- coordination of sub-contractors and main contractors work
- assessing job progress

At this point it is essential to have full information from the architect in the form of
- site survey
- a full set of wirking drawings
- specifications
- bills of quantities and
- a full list of all nominated subcontractors.

The preparation of the overall programme consists broadly of
- breaking the job down into a series of basic operations involving only one trade.
- establishing the quantities of work in each operation and the time content of each in terms of men and machines.
- arranging the operations in a sequence and balancing the size of gangs to give a maximum continuity of work for each trade
- breaking down a large job into phases so that several operations may proceed simultaneously.

The programme is usually expressed in the form of a chart, covering
- all main operations throughout the contract
- the phasing of the work
- the duration of each operation

Together with this chart a written report or schedule has to be prepared including
- the methos to be used
- a schedule of plants
- the labour requirements
- informations regarding site offices, storage huts, equipment, and small tolls.

Besides the overall programme, showing the major operations and phasing of a job, a detailed short - term planning at regular intervals on the site is necessary:
1) a reasonably detailed programme is prepared at mothly intervals, to cover four weeks ahead,
2) a detailed programme is prepared each week. This indicates in detail the materials/labour requirement/ and operational methods to be used.

4.1.3.1 Break down of job

Smaller jobs are commonly divided into the following stages:
1) foundations and walling up to DPC
2) carcase to completion of roofing in
3) finishes and all services
4) drains and site works

In large jobs and multi - storey work the break - down stages can be.
1) sub-structure, or foundation work
2) frame, or basic structure
3) cladding, infilling, weather - proofing etc.
4) drains and site works.

Each stage is planned separately rist.
Compenstion for any variations from the programme arising within the stages can be made by increasing the gang sizes to speed up certain operations or, at times when productivity is greater than that assumed at the planning stage, labour can be put on to isolated jobs which can be carried out at any time without interfering with the sequence of other operations.

4.1.3.2 Quantities of work and time content.

In order to relate the various operations throughout the job a schedule of basic quantities has to be worked out from which the number of MAN HOURS and MACHINE HOURS required to complete the job can be obtained. (so-called LABOUR and PLANT standards.)
These standards in each case are established on the basis of information fed back from
- previous contracts or
- work studies, having regard to the type of labour which will be available and the likely demand on plant.

The work content for each operation is inserted on a schedule of basic operations which can be in the form of a series of DATA SHEETS.
These sheets form a detailed analysis of the complete work and give informations to all planning activities during the course of the contract.

4.1.3.3 Plant and Labour outputs
As soon as the probable availability of resources has been estimated, the outputs of men and machines must be evaluated, so that the times for elements of work can be determined These LABOUR CONSTANTS must be realistic and allowances must be made for rests, bad weather, tea breaks and other interferences with normal output.

An element of work on site is 1,ooom^2 of 1-brick internal walling. If the firm's estimated labour constant for this work is 1.50 men/h/m^2 then the number of men/h required for this work will be:

$1{,}ooo\,m^2 \times 1.50\ men/h/m^2$
$= 1{,}5oo\ men\ /h$

If 10 bricklayers are available in a gang, the time to be taken will be

$\frac{1{,}500\ men/h}{10\ men}$
$= 150\ h$

If an 8 hour day is worked on site, this element will take 18 3/4 days to complete.

The following examples are typical of reasonable standard times for various operations, but these should be carefully checked and verified, and, if necessary, adjusted to suit any special conditions before aplying them to actual work on site.

MACHINE EXCAVATION

Machine excavation	cbm/h
Surface excavation not exceeding 300 mm deep 0.375 m^3 bucket	11
Surface excavation not exceeding 300 mm deep 0.625 m2 bucket	21
Surface excavation not exceeding 300 mm deep 0.375 m3 bucket	12
Surface excavation not exceeding 300 mm deep 0.625 m3 bucket	24
Excavate foundation trenches not exceeding 1.5 m deep 0.375 m3 bucket	6
Excavate foundation trenches not exceeding 1.5 m deep 0. 625 m3 bucket	12
Excavate basements not exceeding 1.5 m deep 0.375 m3 bucket	9
Excavate basements not exceeding 1.5m deep 0.625 m3 bucket	18
Excavate basements exceeding 1.5 m and not exceeding 3 m 0.375 m3 bucket	7 1/2
Excavate basements exceeding 1.5 m and not exceeding 3 m 0.625 m3 bucket	15
Add for each additional 1.5 m depth	1.25
Excavate spoil from heap and load into barrow	0.5
Wheel 20 m	0.25
Load excavated material into lorries	0.6
Spread and level in layers not exceeding 300 mm thick	0.3
Return fill and ram	0.85
Level and ram bottoms	0.06/m2

Planking and strutting	Hours per square metre
excavations not exceeding 1.5 m deep:	
poling boards and struts	0.075
open boarding	0.2
close boarding	0.4
excavations exceeding 1.5 m and not exceeding 3 m deep:	
open boarding	0.3
close boarding	0.8

HARDCORE FILLING

Hardcore filling	h/cbm
Filling in making up levels	0.5
Concolidated in 150 mm layers	1.0

HAND EXCAVATION

Hand excavation	h/cbm
Surface excavation not exceeding 1.5 m deep	2.0
Add for each additional 1.5 m of depth	0.75
Excavate trenches not exceeding 1.5 m deep	2.5
Add for each additional 1.5 m of depth	1.0
Excavate pits not exceeding 1.5 m deep	3.0

CONCRETE WORK

Concrete work	h/cbm
Mixing	
By hand for small quantities	4 to 6

By machine allow 4 to 5 minutes per batch according to type of mixer

TRANSPORTING

Transporting	h/cbm
By hand in barrows and wheel not exceeding 18 m or raise not exceeding 3 m	1.5
By machine plant and labour to suit required output and placing conditions	

PLACING &.COMPACTION

Placing and compaction	h/cbm
Foundations in trenches over 300 mm thick	0.5
Foundations in trenches not exceeding 300 mm thick	0.7
Isolated pier holes	1.0
Beds over 300 mm thick	0.75
Beds over 150 mm thick not exceeding 300 mm thick	1.0
Beds not exceeding 150 mm thick	1.25
Add to the above for working around reinforcement	1.0

SURFACE TREATMENT

Surface treatment	h/square metre
Grading to falls	0.3
Tamping	0.2
Trowelling	0.25

BRICKWORK

Brickwork
(The following outputs are based on the ratio of 2 bricklayers to 1 labourer).

	Men/h per unit
General brickwork in plasticised or gauged mortar 60 bricks	1.0
General brickwork in cement mortar 60 bricks	1.1
General brickwork overhand in gauged mortar 60 bricks	1.1
Walling curved on plan ex 15 m n.e. 22 m rad 60 bricks	1.5
Walling curved on plan ex 7.5 m n.e. 15 m rad 60 bricks	1.66
Walling curved on plan ex 4.5 m n.e. 7.5 m rad 60 bricks	1.75
Walling curved on plan exceeding 3 m rad	
Underpinning 60 bricks	2.00
Rough arches 60 bricks	3.0
Form cavity inc. laying wall ties, and keeping cavity clean per m2	0.25
Rough cutting per m2	0.7
Close cavity per m	0.3
Cut chase for small pipe per m	0.6
Eaves filling per m	0.3
Engineering bricks per 60	1.50

FACE BRICKWORK

Face brickwork	men/h per unit
General facing bricks per m2	1.25
Fair faced walling / m2	1.10
Rake out joints and point on completion per m2	0.75
Fair straight cutting per lin.m.	0.3
Fair raking cutting per lin.m	0.4
Fair curved cutting per lin.m	0.5

ARCHES

Arches	men/h per unit
Soldier arches or brick lintels per m2	3.6
Fair axed arches per m2	5.5
Rubbed and gauged per m2	12.25

COPINGS &. SILLS

Copings and sills	men/h per unit
Brick on edge coping including pointing per lin.m	0.4
Two courses of tile creasing per lin. m.	0.6
Brick on edge per lin. m.	0.75

PARTITIONS

Partitions	men/h
Clinker, concrete and hollow clay 50 mm thick per m2	0.5
Clinker, concrete and hollow clay 75 mm thick per m2	0.6
Clinker, concrete and hollow clay 100 mm thick per m2	0.7
Lightweight blocks 50 mm thick per m2	0.4
Lightweight blocks 75 mm thick per m2	0.5
Lightweight blocks 100mm thick per m2	0.6
Bonding to brickwork per lin. m	0.2
Rough cutting at irregular angles and soffits per lin. m.	0.15

	men/h
Air bricks each	0.2
Flue linings per lin. m.	0.6
Set chimney pot and flaunch each	1.0

D.P.C.

Damp-proof courses	men/h
Two courses of slates horizontal per m2	0.9
Two courses of slates vertical per m2	1.35
Bituminous felt per m2	0.3

SUNDRIES

Sundries	men/h
Bed plates and sills per lin. m.	0.1
Bed frame and point one side per lin. m.	0.25
Bed frame and point two sides per lin m	0.35
Rake out joints and point flashings per lin. m.	0.3
Cut groove for asphalt skirting and point per lin.m	0.45
Fix metal windows including cut and pin lugs to brickwork not exceeding 0.4 m2 each	0.5
Fix metal windows including cut and pin lugs to brickwork not exceeding 0.8 m2 each	0.75
Fix metal windows including cut and pin lugs to brickwork not exceeding 1.6 m2 each	1.0
Add for pointing one side per lin. m.	0.08

SCAFFOLDING

Scaffolding	men/h per 100 m2 erect and dismantle
Putlog scaffold up to 6 m high	25
Putlog scaffold 6 to 9 m high	30
Putlog scaffold 9 to 18 m high	35
Putlog scaffold over 18 m high	40
Independent scaffolds add 25 per cent to the above	

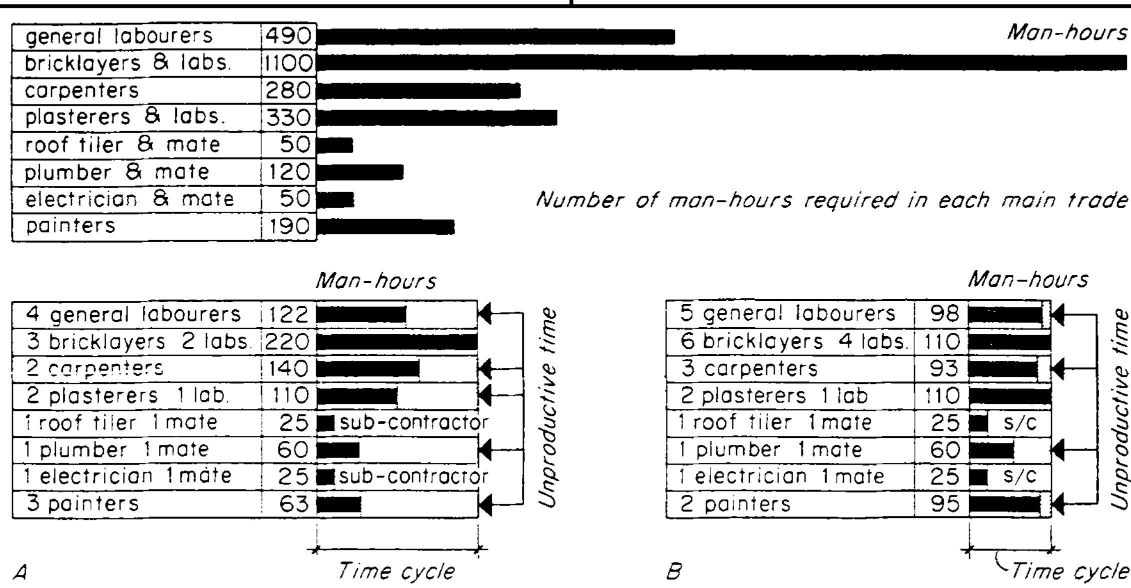
DRAINAGE

Drainage	men/h			
Stoneware drain pipes	100 mm	150 mm	225 mm	
Lay and joint 600 mm pipes per lin. m.	0.45	0.6	0.75	
Lay and joint 900 mm pipes per lin. m.	0.35	0.45	0.6	
Extra for bends each	0.1	0.12	0.15	
Extra for junctions each	0.2	0.25	0.3	
Gulleys each	0.5	0.66	-	
Interceptors each	0.66	0.75	-	
Concrete drain pipes	225mm	300 mm	375 mm	450 mm
Lay and joint per lin.m.	0.8	0.9	1.1	1.25
Extra for bends each	0.2	0.25	0.3	0.35
Manholes	100 mm	150 mm	225 mm	
Channels each	0.2	0.3	0.4	
Three-quarter section channels each	0.3	0.5	0.7	
Covers and frames bedding and fixing each	0.75			
Step irons each	0.1			

4.1.3.4 Sequence and timing of operations

In each stage into which a job may be divided, there will be one operation or a group of related operations governing the production time of the complete stage. This KEY OPERATION takes the longest time, when the time cycles of all the operations are based on the use of the optimum size of gang for each.

The largest of the key operations in each stage is termed the MASTER OPERATION. The speed of the master operation is governed by:
- the time, in which the work has to be completed
- the size of the gang or
- the amount of labour available(in which case the size of the gang which can be put on it will fix the time required to complete the operation)



It is necessary to bring all other operations into phase with the master operation, in order to ensure continuity of productive work for each trade or gang and to minimize unproductive time.

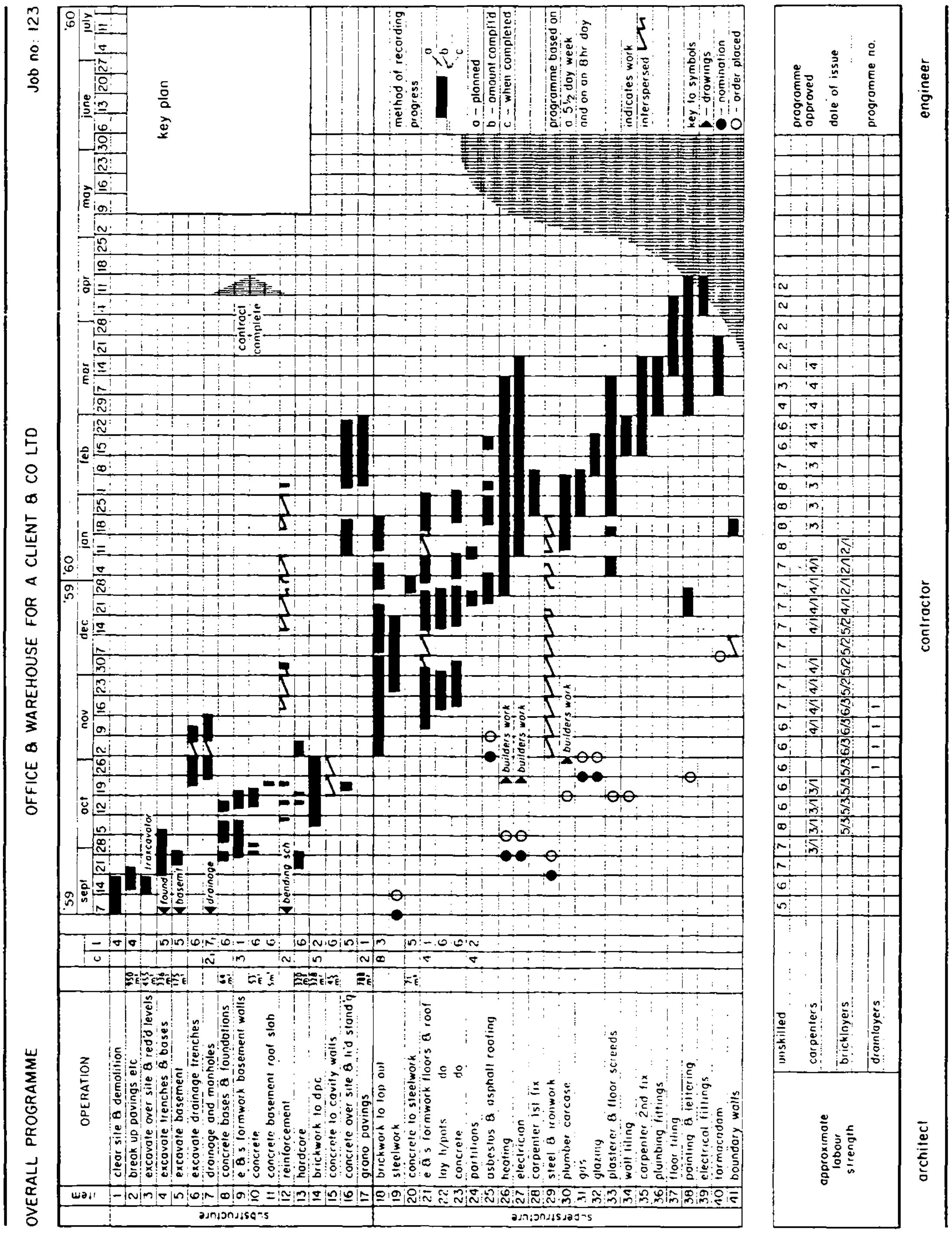
The time cycles of the operations in each stage are brought into phase by adjusting the size of the gangs, so that the working time of each gang is (as far as possible) the same as that of the key operation. Figure illustrates the effect of the balancing of trade gangs.

4.1.3.5 The programme chart

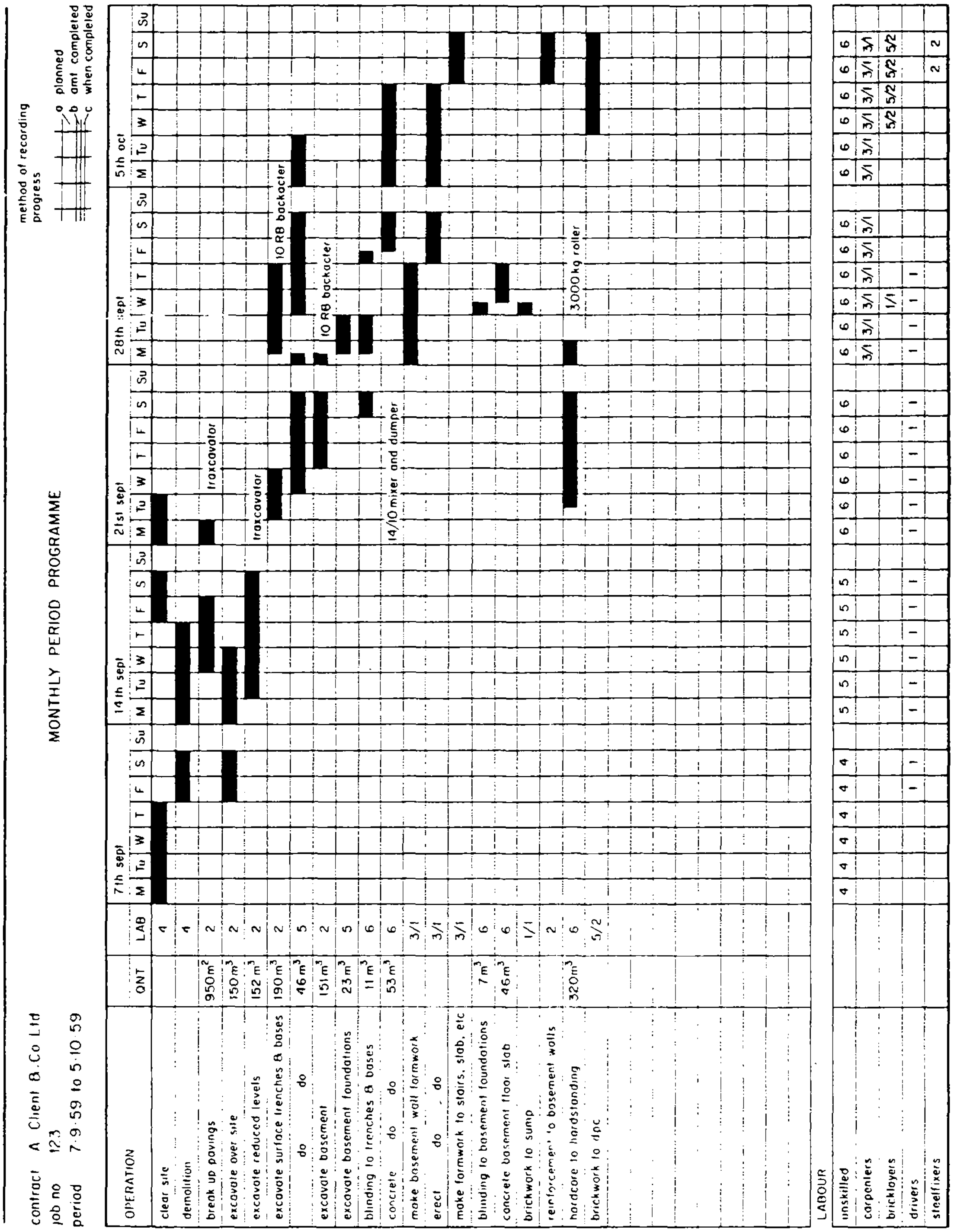
The final step is to prepare a working schedule an the basis of the balanced production in each stage, from which programmes for the various stages are drawn up.
The stage programmes are combined to give the final overall programme.
(A short intervall may be left between the stages to provide for delays due to bad weather or other causes).
A typical overall programme chart is shown in fig.
In addition to the data sheets and the overall programme, a SCHEDULE of CONTRACT INFORMATION is prepared giving
- the recommended labour force for each stage of the contract under trades
- details regarding the sequence of operations given on the data sheets
- details of equipment and methods of construction to be used.
- full details concerning all sub contractors

A site layout plan and a site preparation programme will also be prepared at this stage as well as the detailed programme for the first four week period of the contract.
(ref. to 'site organisation')

OVERALL PROGRAMME



MONTHLY PERIOD PROGRAMME



4.1.4 PLANNING CONSIDERATIONS
A number of factors which have a bearing on the decisions made during the contract planning stage are briefly considered here.

4.1.4.1 Site conditions and access
Site conditions will limit the type of plant that may be used:
- on wet sites it will be necessary to use tracked machines in the case of excavators and mobile cranes, and dempers for transport
- sloping sites may make the use of rail mounted cranes unsuitable or uneconomical.
- on confined sites there may be insufficient room for a mixer or mixing plant and it may be necessary to use truck mixed concrete.
- Limitations of access may fix the maximum size of plant which can be brought on the site.

4.1.4.2 Nature of job
The type of structure, the general form, size and detailing of the building will all have an effect upon the way in which the contract is planned.
The contractor has to consider the nature of the structure in relation to the site so that he can decide where best to place his equipment and materials. All plant should be so placed on the site that the structure can be erected without moving the plant until most of it is completed. Plant should also be so placed that it can be removed easyly at the completion of the job.
In some circumstances the contractor may request the adjustment of the structure in some way, in order to permit the most efficient planning of the contract. It may be desirable to enlarge a lift shaft slightly in order that a climbing crane may be accomodated within it.
OR : For certain parts designed originally as in situ cast work to be carried out as precast work in order fully to utilize a crane on the job etc.

4.1.4.3 Plant
The choice of the most suitable plant for any particular operation necessiates a consideration of the capabilities, limitations, and outputs of different types of plant.

- EXCAVATION can be carried out either mechanically by a number of different types of plant or by hand.
  The SPOIL can be transported in various types of vehicle and the length of haul to tip will vary with the job, so that many combinations of excavator and transporting machines are posibble.

The method adopted for excavating operations will depend upon
a) the type of excavation to be carried out
b) the nature of the soil to be excavated
c) the volume of soil to be excavated
d) the length of haul to tip and the terrain over which the machinery has to dig and travel
e) the type of plant available for the contractor

For small quantities, handexcavation is cheaper than mechanical excavation and the type of transport will depend on the distance to be hauled, the nature of the ground to be traversed and the cost of temporary roads, where necessary.

- HANDLING of structural units and materials in fabrication and erection can be carried out by crane or forklift truck.
  If a crane is used the work must be planned round the crane. Consideration must be given to the quantity and nature of materials to be handled and whether or not there is sufficient to keep a crane fully accupied throughout the working day.

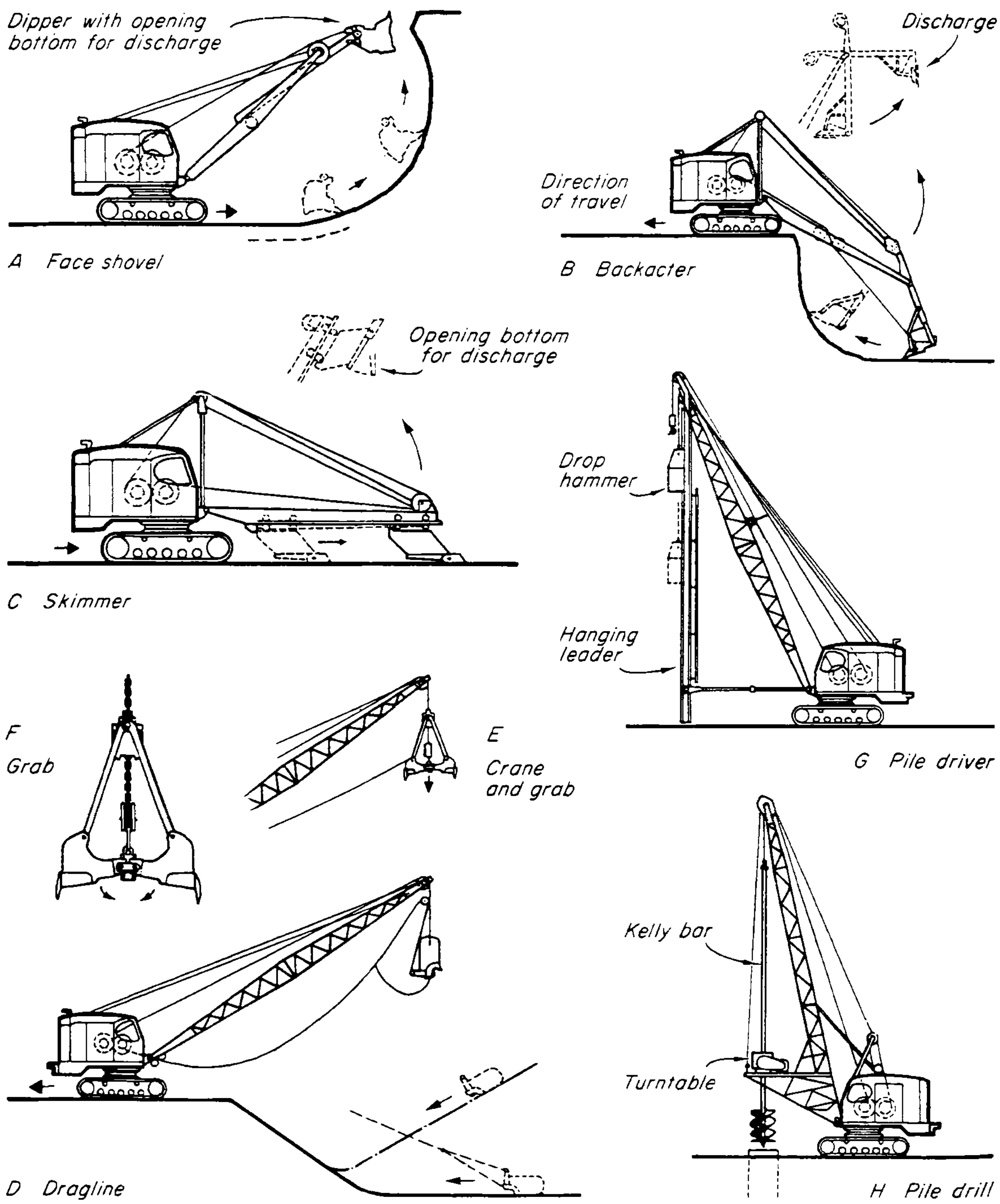
  The careful timing of materials as near as possible to the point at which they will be used, together with the correct siting of hoisting plant, materials dumps and mixing plant in relation to the building and to each other is an important factor in planning for high productivity and for the reduction of double-handling.

- MIXING Type and size of concrete mixer are dictated to a large extent by the quality and quantity of concrete required.
  When small to medium quantities (say up to 20 m3/day)are required a mixer together with hand loading of the aggregate skip, some form of weight batching and hand barrow delivery can be economical.
  When steady outputs of not less than 30m3 per day are required, complete mechanisation (with a mechanical scoop ar gravity loading of the mixer skip, gravity fed bulk cement and - for delivery - a crane carrying a full batch skip or, alternatively, a pneumatic concrete placer) is best.

- CONTRACTORS MECHANICAL PLANT
  In its widest sense 'contractors plant' implies the machinery, tools and other equipment used in the contractor's yard and workshop, and on the site.
  The machines and power tools are divided into three classes according to their degree of mobility:
  - fixed (operating from a fixed position on site)
  - portable (being moved about by pulling, pushing or carrying by hand)
  - mobile (moving from one place to another under their own power)

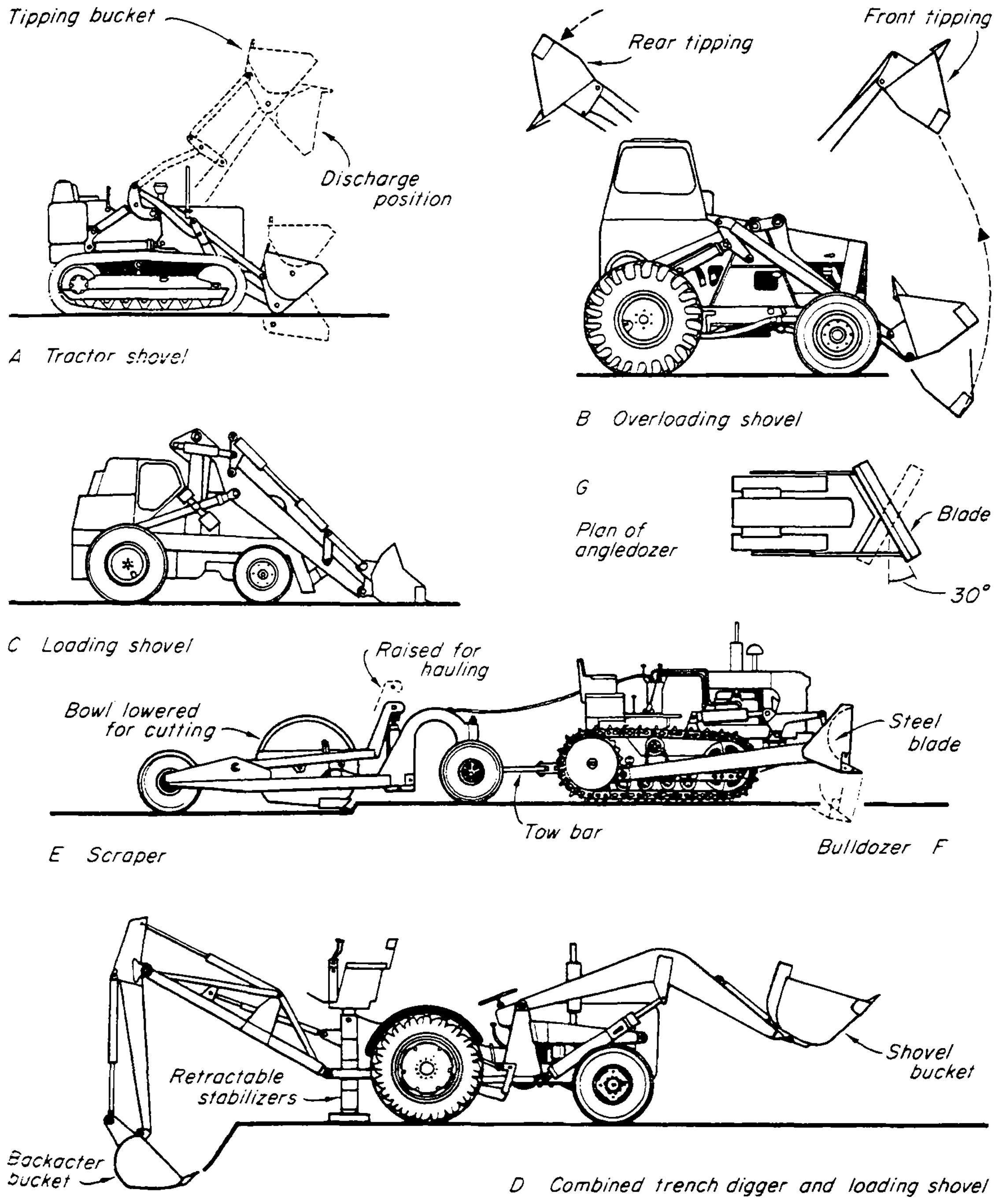
  They may further be devided into classes according to their function.
  The following figures show a collection of mechanical plant and power tools used on the building site only.

EXCAVATING



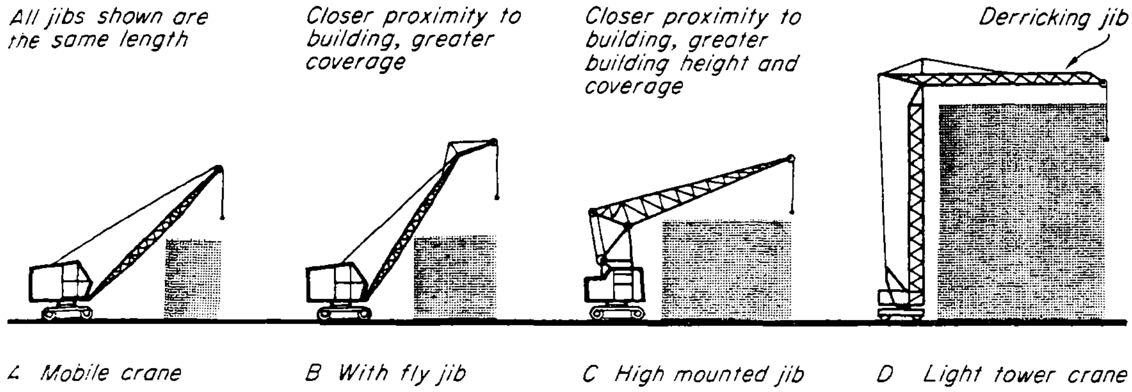
Excavator equipment

EXCAVATING

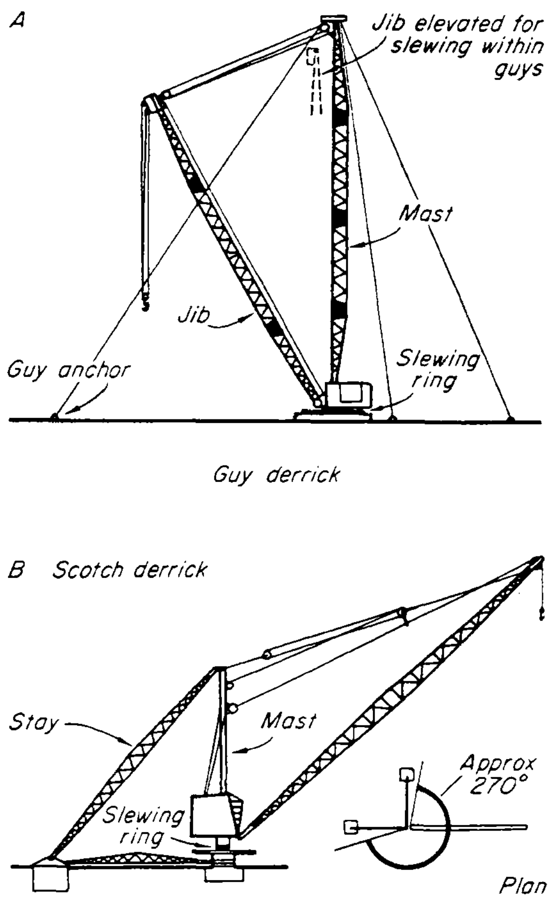


Tractor based equipment

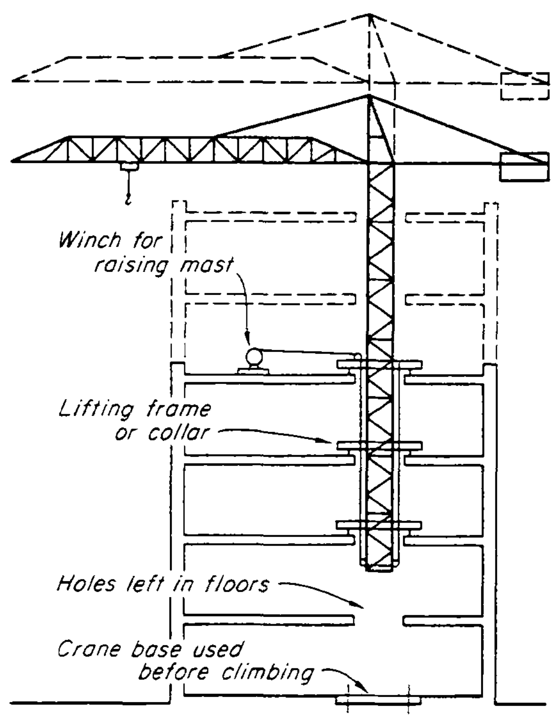
CRANES



Cranes – relative amount of working areas and coverage



Derrick cranes



Climbing crane

4. CONTR. PLANNING	CONTRACT PLANNING	BUILDING CONSTR.
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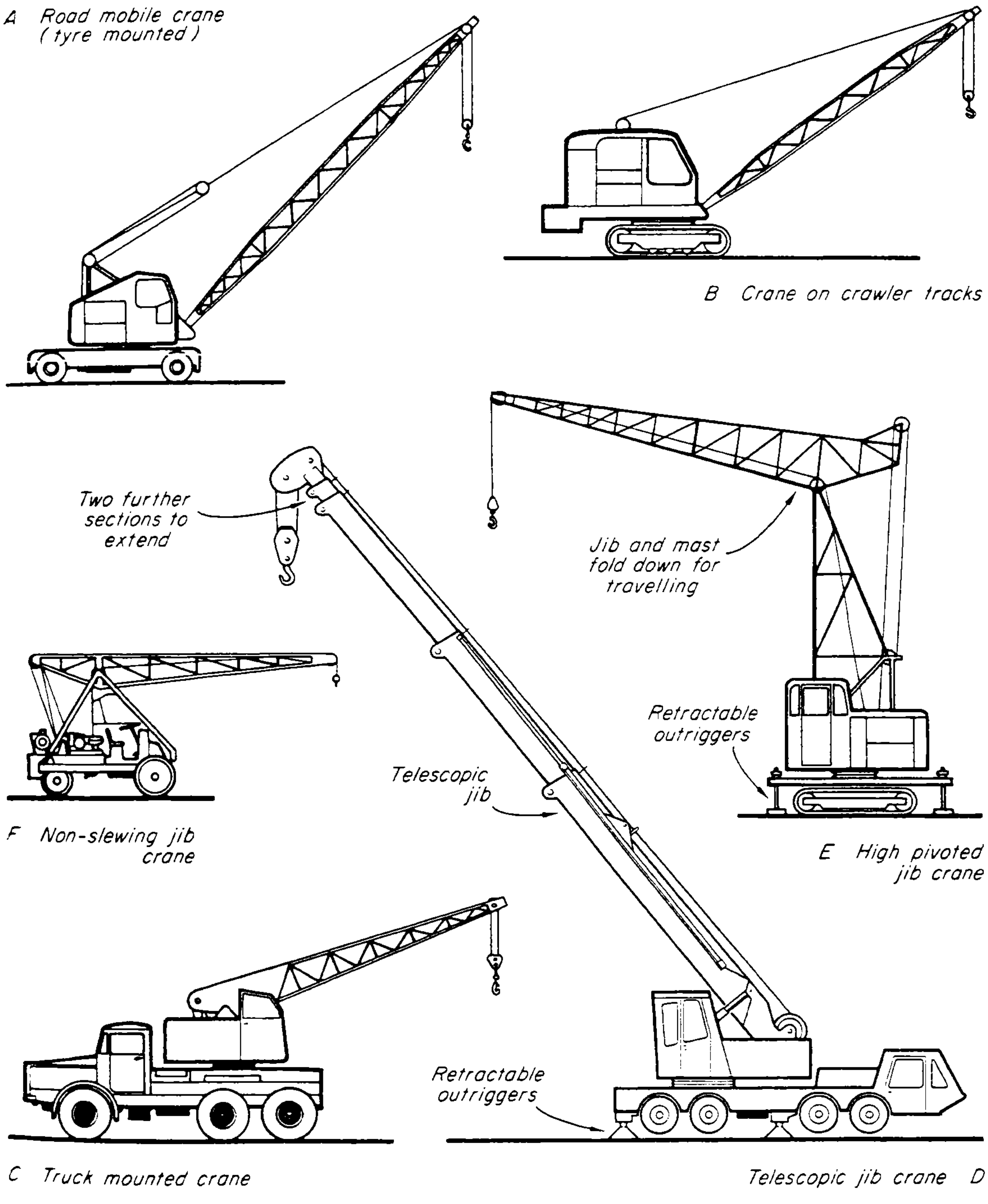
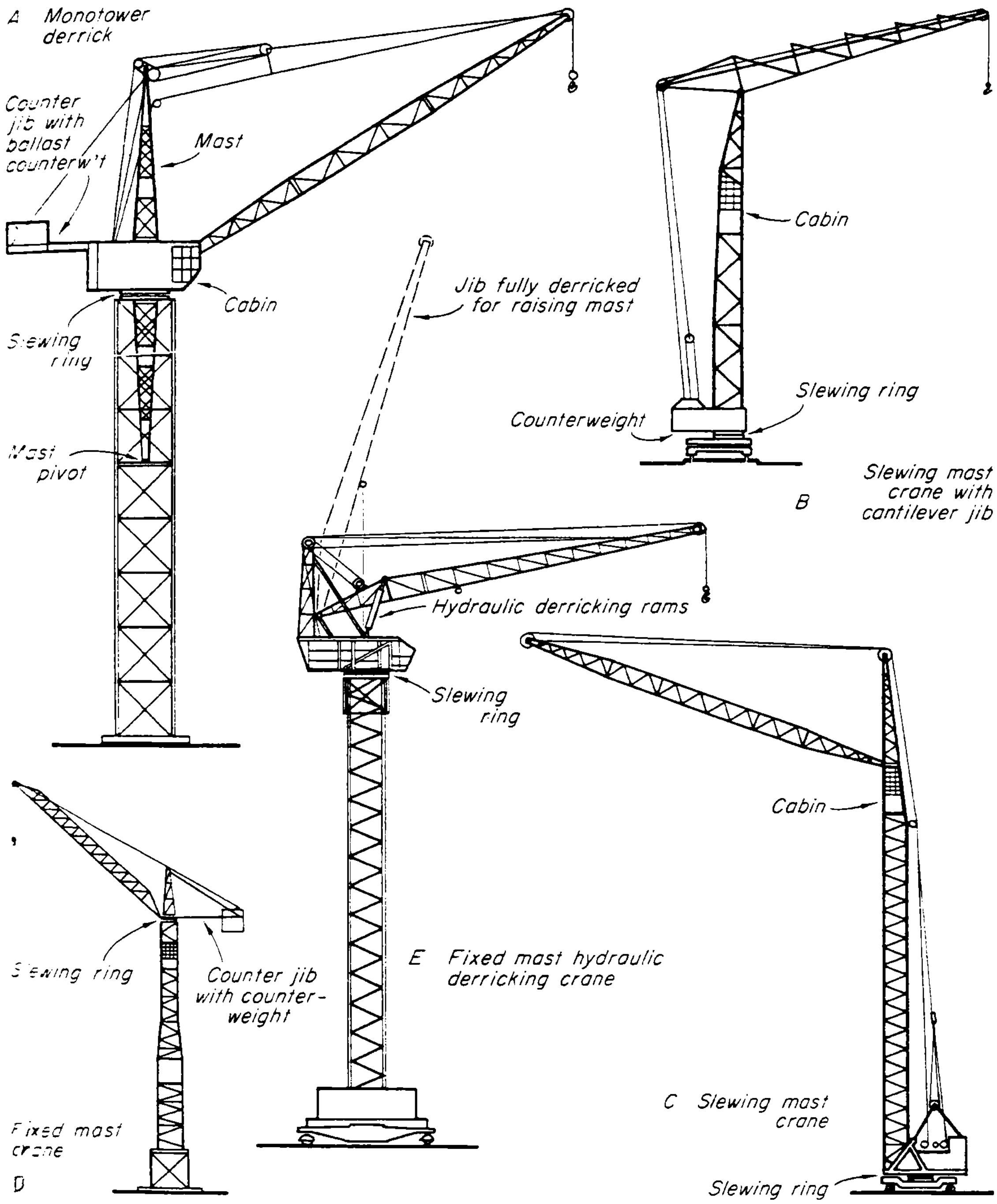
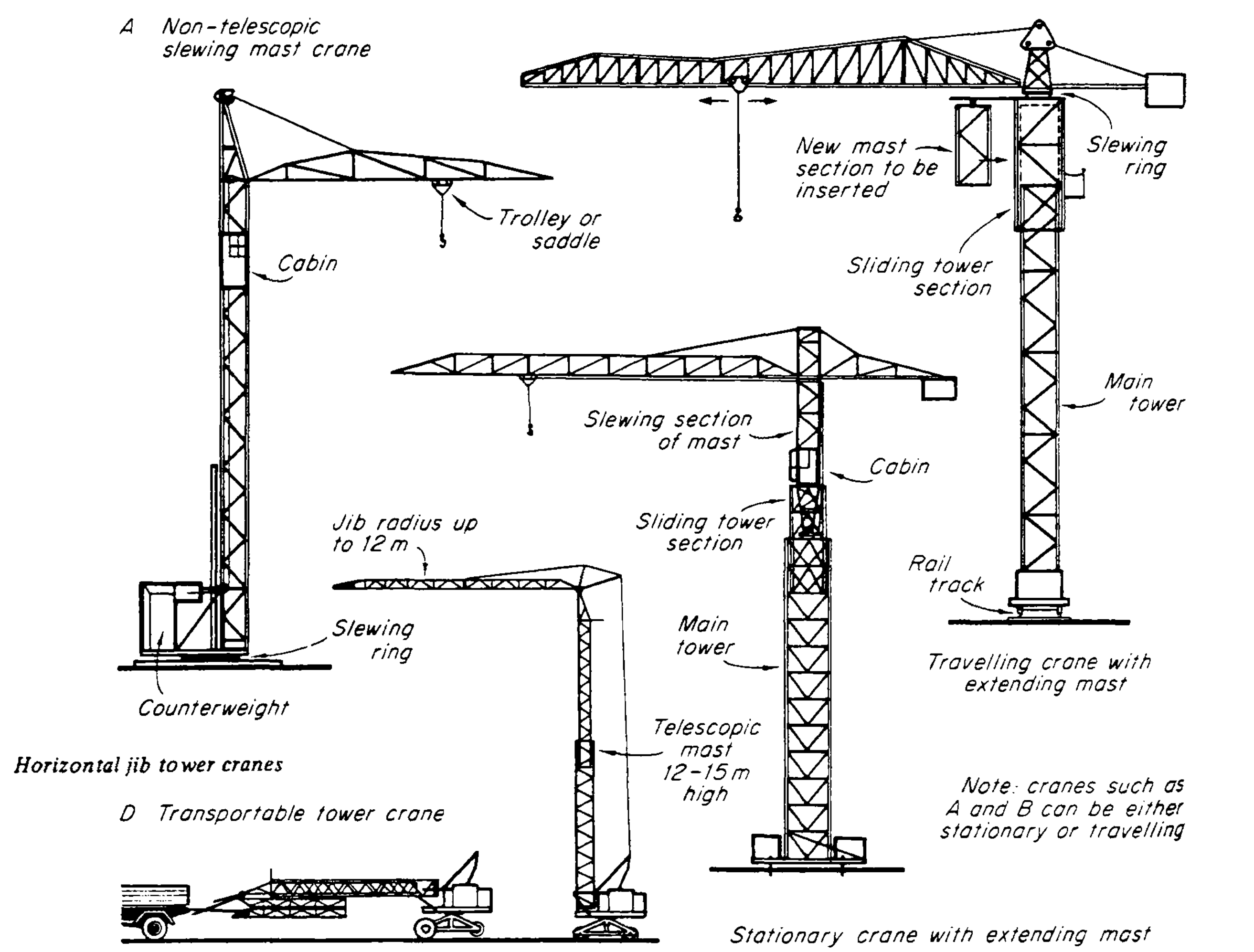
CRANES



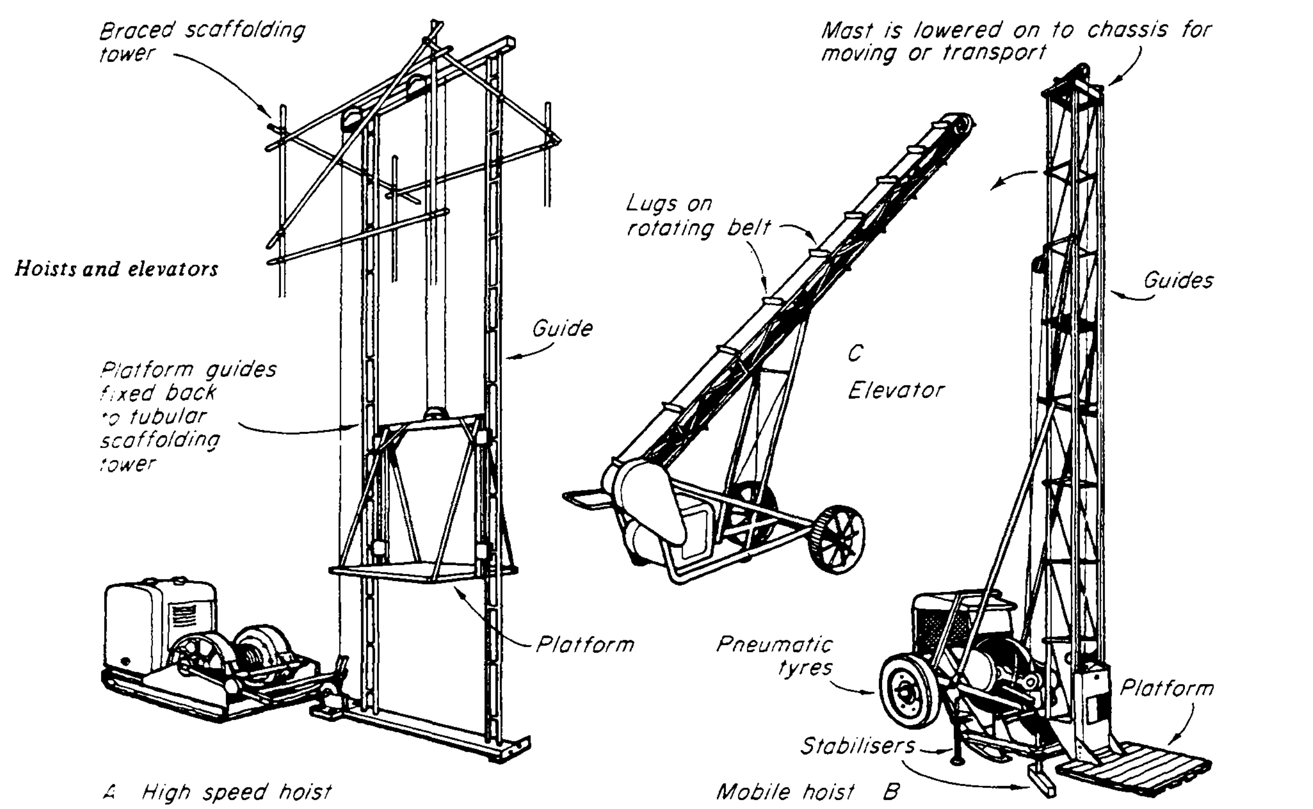
Mobile cranes



Derricking jib tower cranes



Horizontal jib tower cranes



Hoists and elevators

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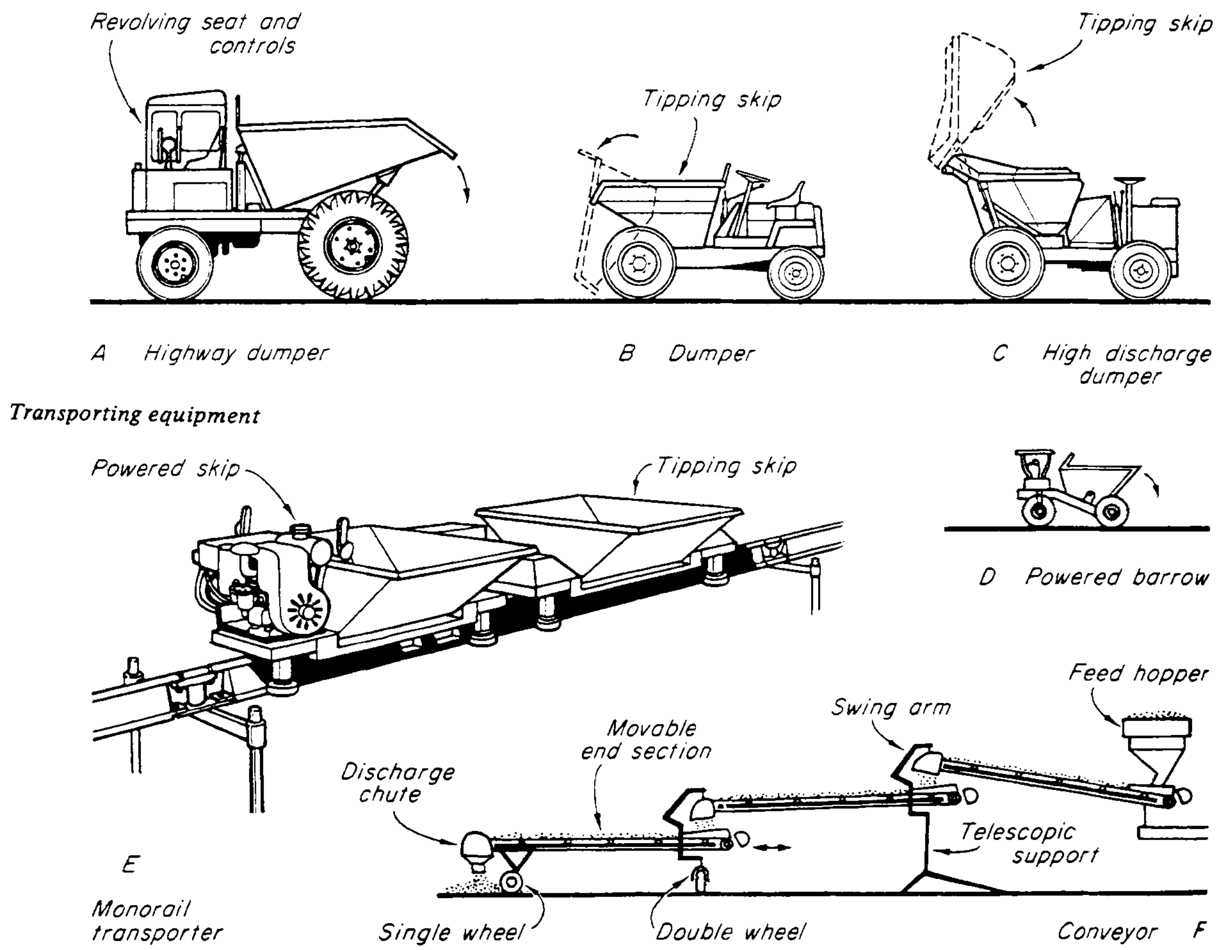
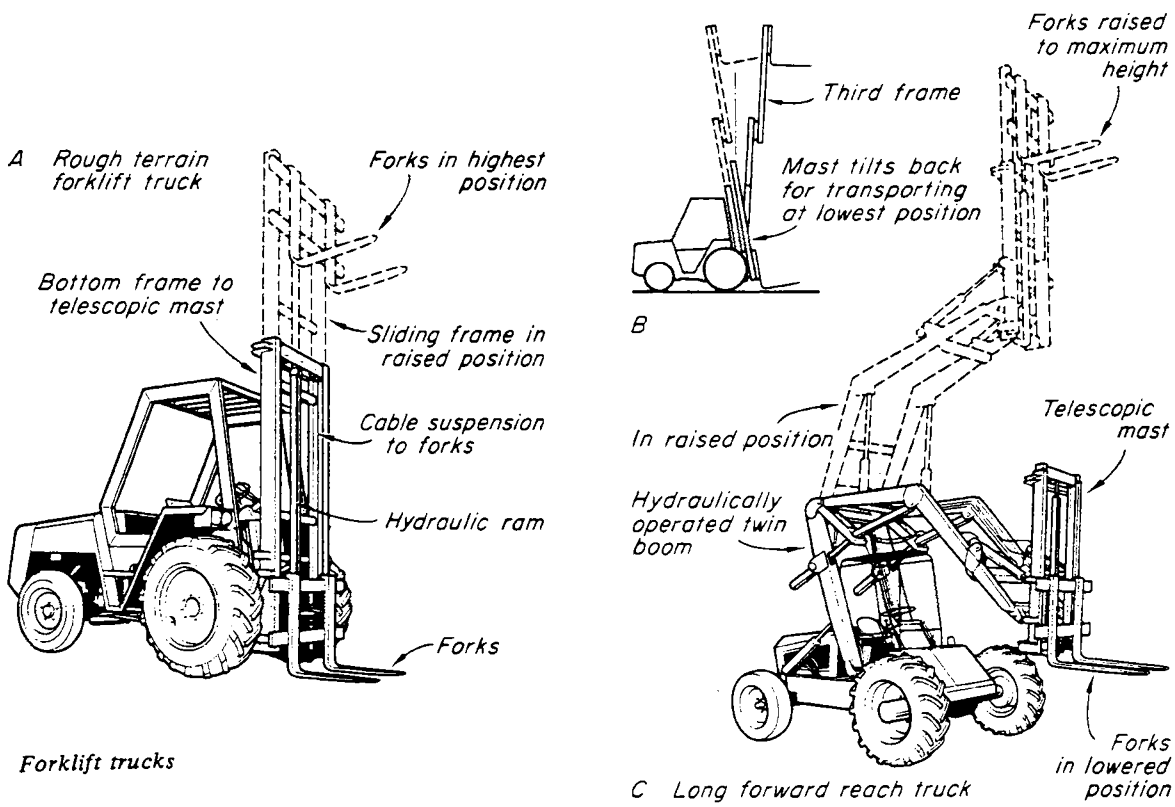
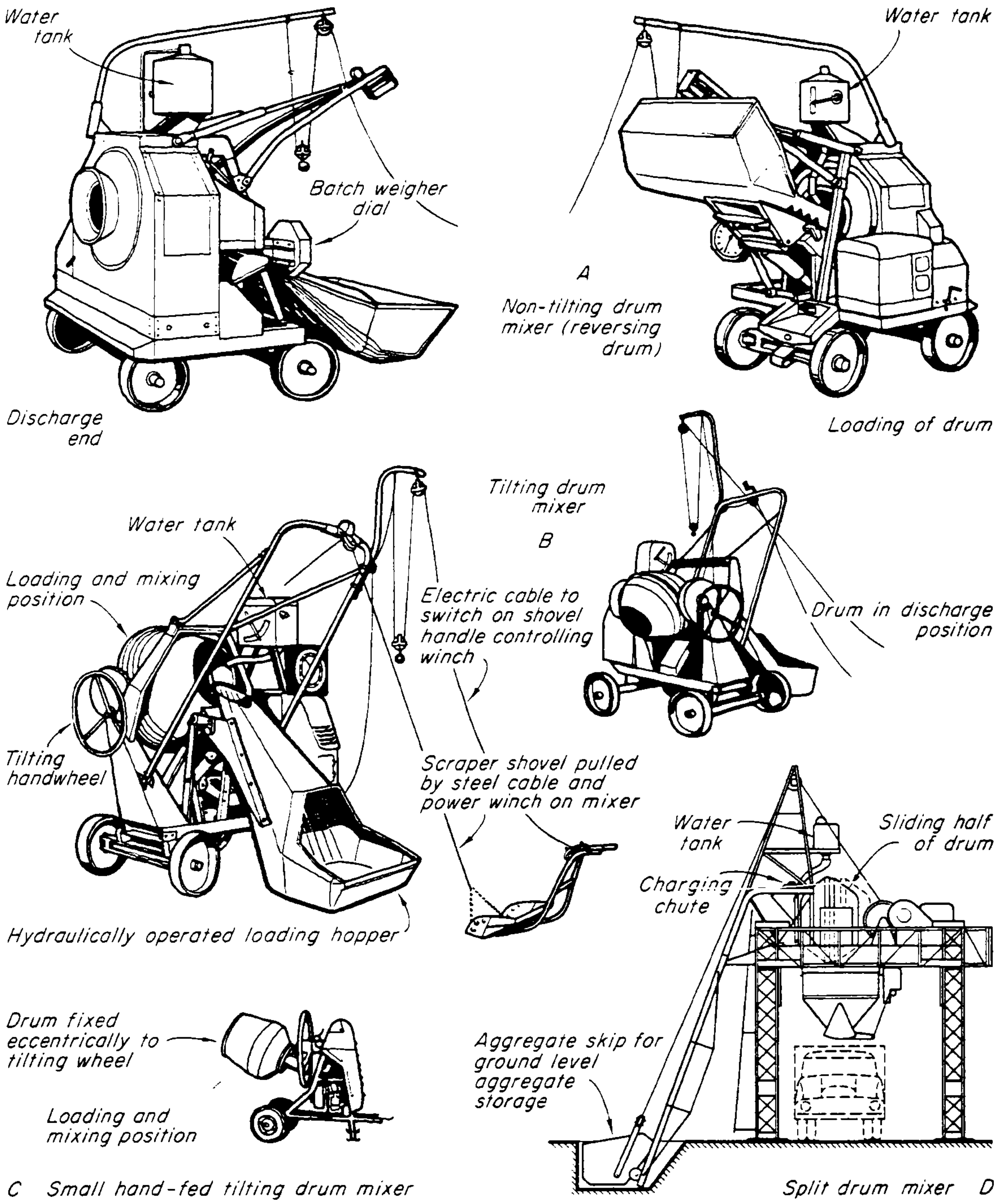


Transporting equipment

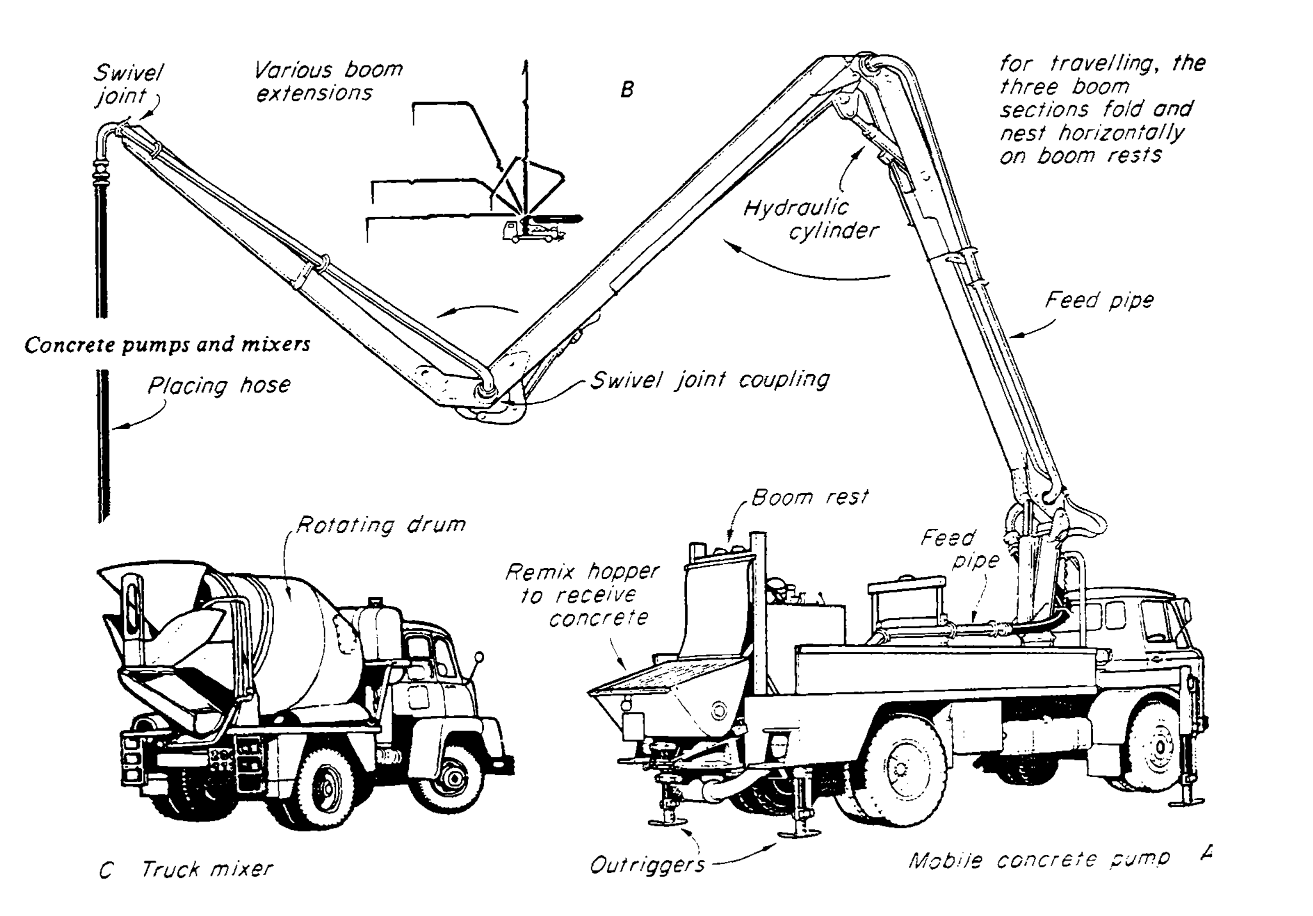


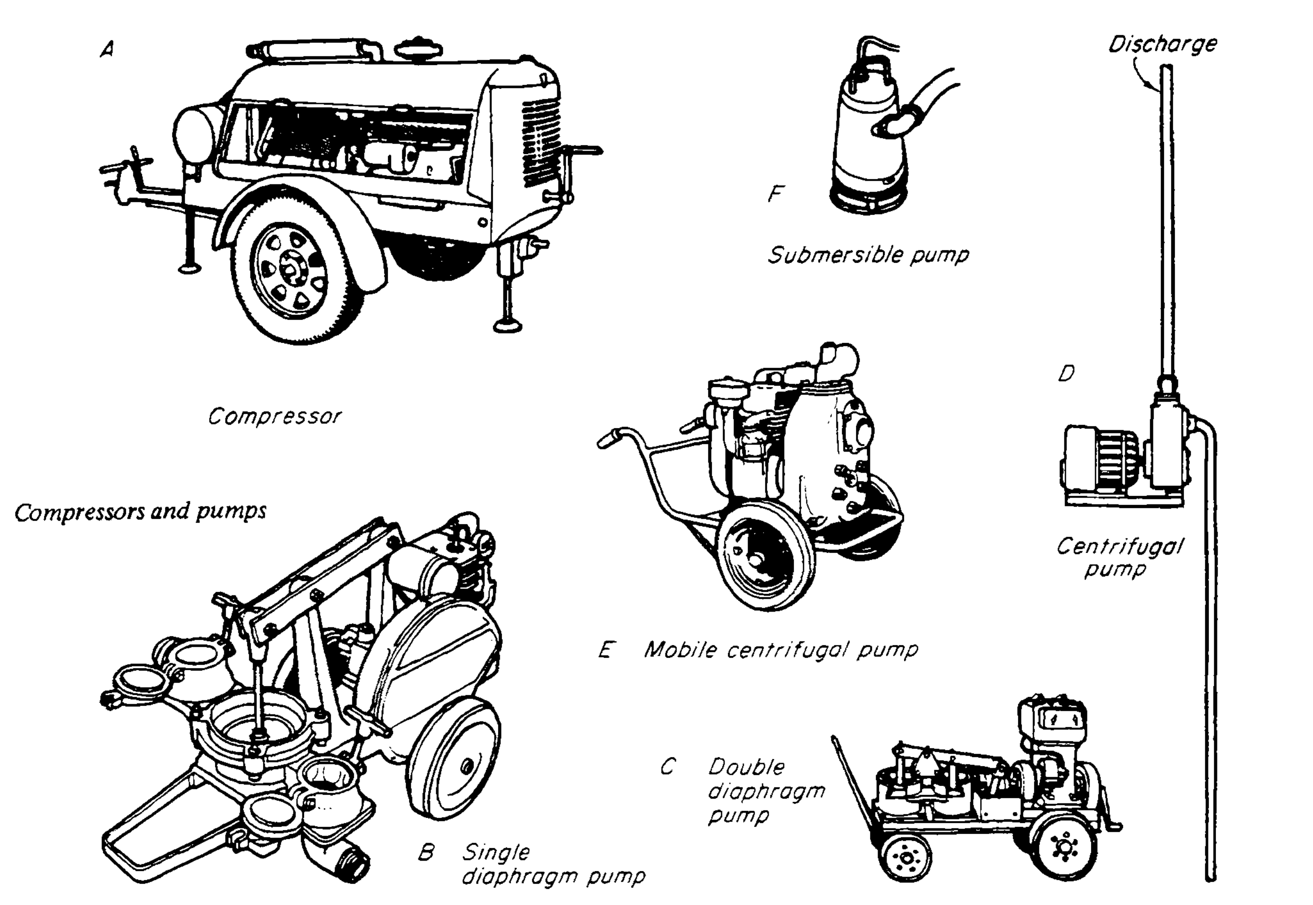
Forklift trucks

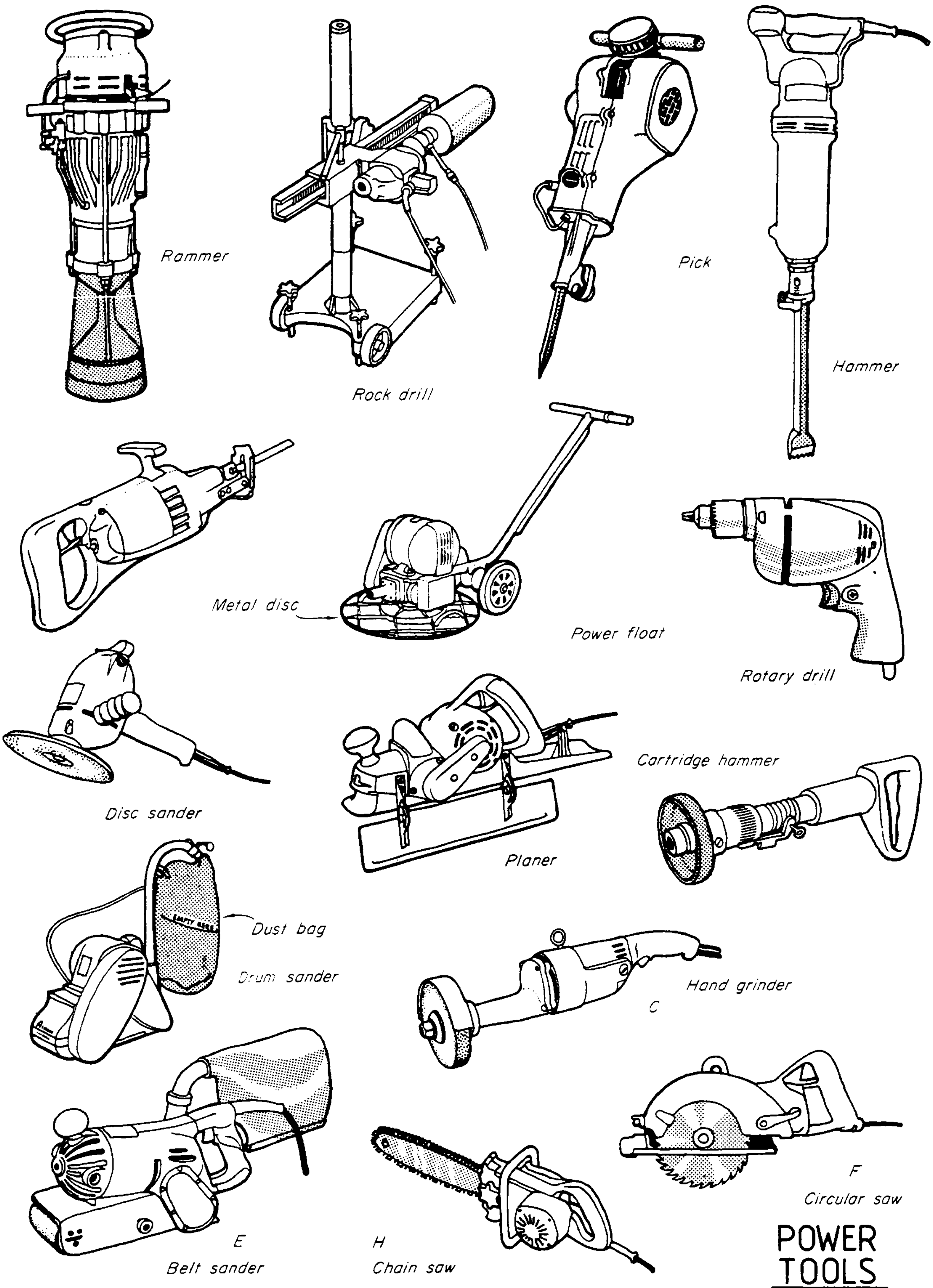
CONCRETE MIXERS



Concrete mixers


Concrete pumps and mixers
Swivel joint
Various boom extensions
B
for travelling, the three boom sections fold and nest horizontally on boom rests
Hydraulic cylinder
Feed pipe
Placing hose
Swivel joint coupling
Boom rest
Rotating drum
Feed pipe
Remix hopper to receive concrete
C Truck mixer
Outriggers
Mobile concrete pump A


Compressors and pumps
A
Compressor
F
Submersible pump
Discharge
D
Centrifugal pump
E Mobile centrifugal pump
C Double diaphragm pump
B Single diaphragm pump



POWER TOOLS

4.CONTR. PLANNING	CONTRACT PLANNING	BUILDING CONSTR.
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CHUO CHA UFUNDI ARUSHA
CIVIL ENGINEER DEPARTMENT

SCAFFOLDING

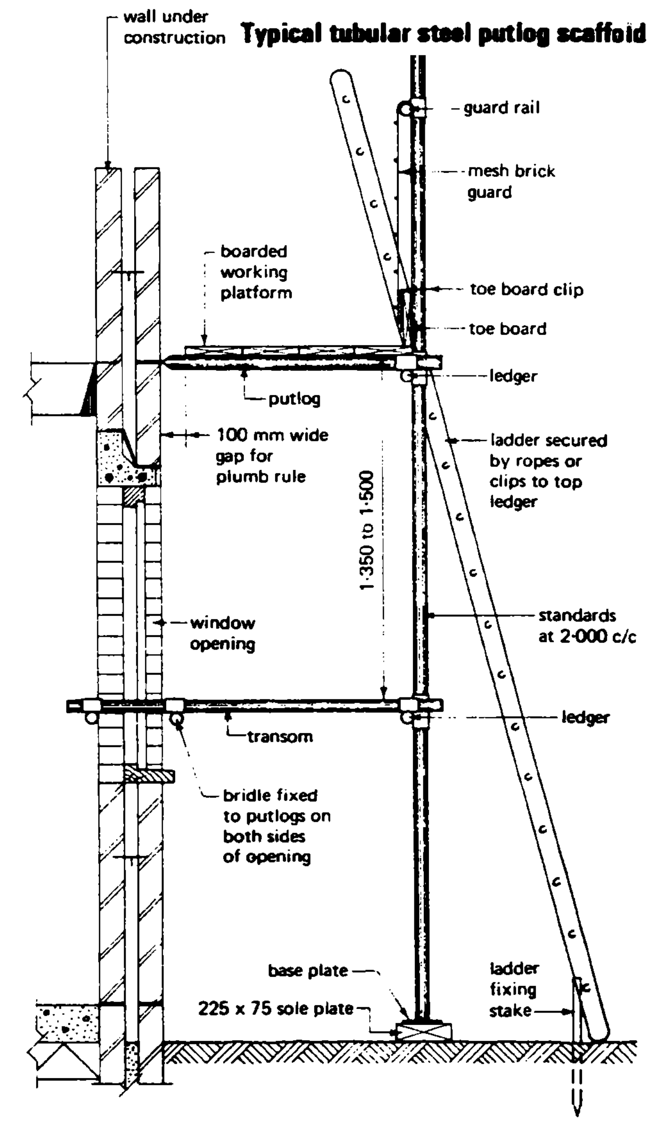
4.1.4.4 SCAFFOLDING
A scaffold is a temporary structure from which persons cangain access to a place of work in order to carry out building operations, it includes any working platforms, ladders and guard rails. Baically there are two forms of scaffolding:
1) Putlog scaffolds.
2) Independent scaffolds.

PUTLOG SCAFFOLDS This form of scaffolding consists of a single row of uprights or standards set a-way from the wall at a distance which will accommodate the required width of the working platform. The standards are joined together with horizontal members called ledgers and are tied to the building with cross members called putlogs. The scaffold is erected as the building rises and is mostly used for buildings of traditional brick construction (see Fig.).

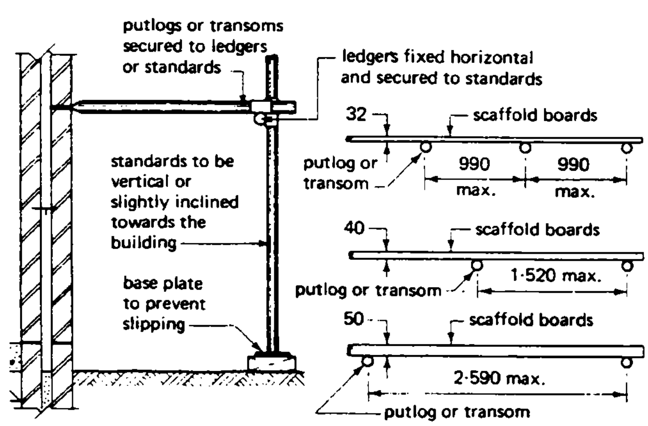
INDEPENDENT SCAFFOLDS An independet scaffold has two rows of standards which are tied by cross members called transoms. This form of scaffold does not rely upon the building for support and is therefore suitable for use in conjunction with framed structures (see Fig.).
Every scaffold should be securely tied to the building at intervals of approximately 3.600 m vertically and 6.000 m horizontally. This can be achieved by using a horizontal tube called a bridle bearing on the inside of the wall and across a window opening with cross members connected to it (see Fig.); alternatively a tube with a reveal pin in the opening can provide a connection point for the cross members (see Fig.). If suitable openings are not available then the scaffold should be strutted from the ground using raking tubes inclined towards the building.

MATERIALS Scaffolding can be of:
1) Tubular steel
2) Tubular aluminium alloy
3) Timber

Typical tubular steel putlog scaffold



Scaffolds and Construction Regulations



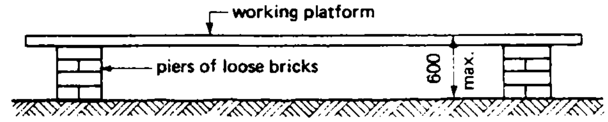
Regulation 13 ~ Standards, putlogs and transoms

TUBULAR STEEL British Standard 1139 gives recommendations for both welded and seamless steel tubes of 48mm outside diameter with a nominal 38 mm bore diameter. Steel tubes can be obtained galvanised (to guard against corrosion); ungalvanised tubes will require special care such as painting, varnishing or an oil bath after use. Steel tubes are nearly three times heavier than comparable aluminium alloy tubes but are far stronger and since their deflection is approximately one third of aluminium alloy tubes, longer spans can be used.

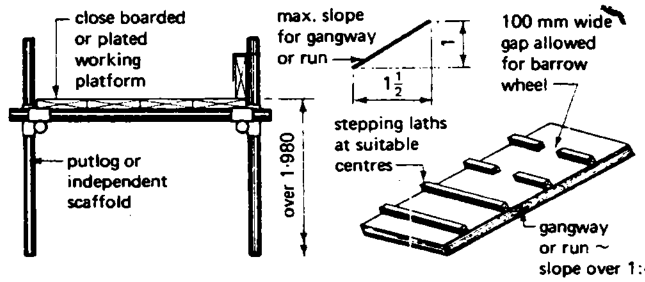
ALUMINIUM ALLOY Seamless tubes of aluminium alloy with a 48 mm outside diameter are specified in BS 1139 for metal scaffolding. No protective treatment is required unless they are to be used in contact with materials such as damp lime, wet cement and sea water, which can cause corrosion of the aluminium alloy tubes. A suitable protective treatment would be to coat the tubes with bitumastic paint before use.

TIMBER The use of timber as a temporary structure in the form of a scaffold is now rarely encountered in this country, although it is still used extensively in other countries. The timber used is fir of structural quality in either putlog or independent format, the members being lashed together with wire or rope instead of the coupling fittings used with metal scaffolds.

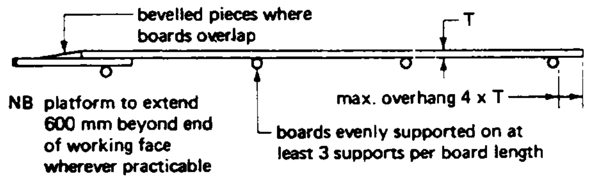
SCAFFOLD BOARDS These are usually boards of softwood timber complying with the recommendations of BS 2482 used to form the working platform at the required level. They should be formed out of specified softwoods of 225 x 38 section and not exceeding 4.800 m in length. To prevent the ends from splitting they should be end bound with not less than 25 mm wide x 0.9 mm galvanised hoop iron extending at least 150 mm along each edge and fixed with a minimum of two fixings to each end. The strength of the boards should be such that they can support a uniformity distributed load of 6.7 kN/M2 when supported at 1.2oom centres.



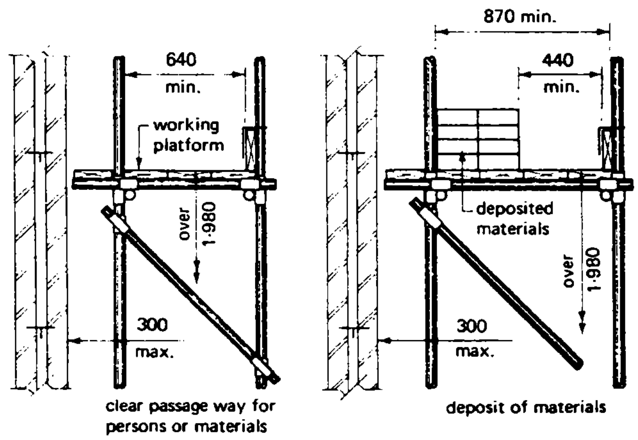
Regulation 15 ~ Stability of scaffolds



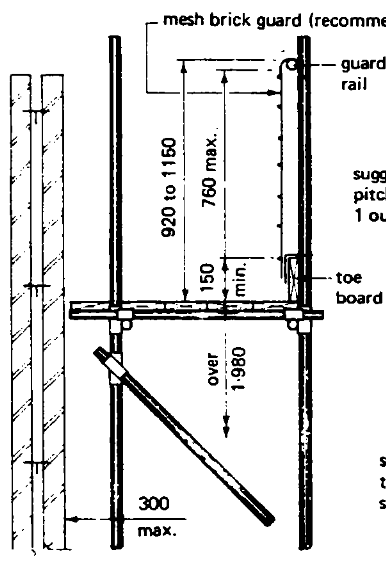
Regulation 24 ~ Platforms, gangways and runs



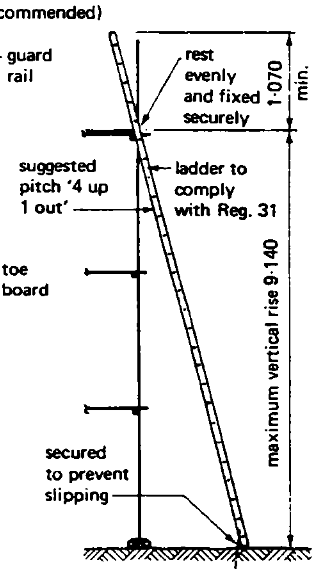
Regulation 25 ~ Boards in working platforms



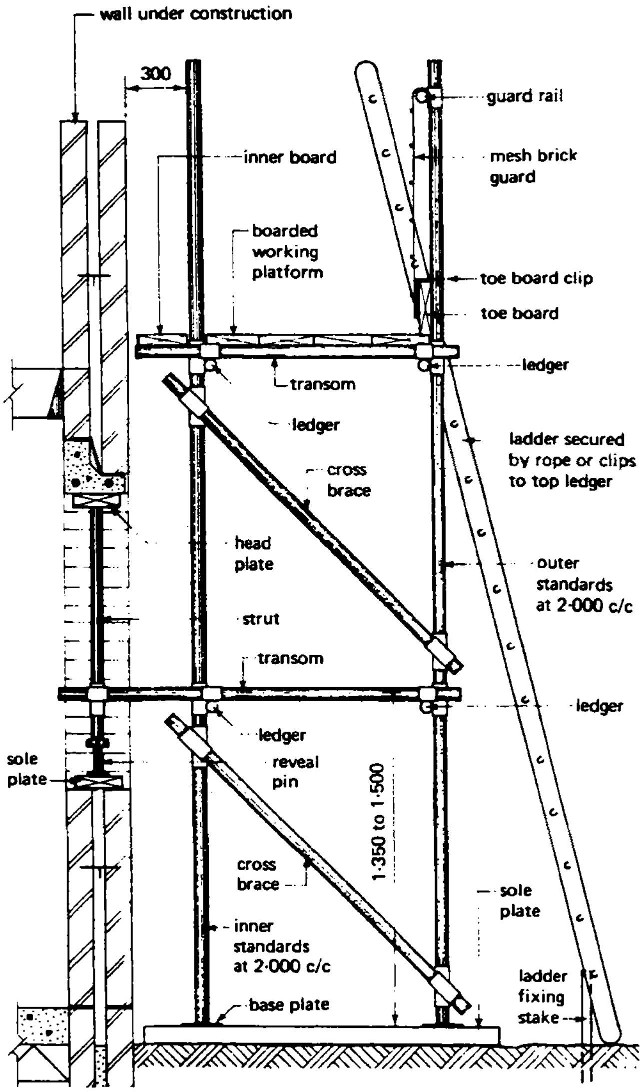
Regulation 26 ~ Widths of working platforms for putlog and independent scaffolds



Regulation 28 ~ Guard rails and toe boards for putlog and independent scaffolds



Regulation 32 ~ Use of ladders



Base plate: a square plate with a central locating spigot used to distribute the load from the foot of a standard on to a sole plate or firm ground. Base plates can also be obtained with a threaded spigot and nut for use on sloping sites to make up variations in levels.

Split joint pin: a connection fitting used to joint scaffold tubes and to end. A centre bolt expands the two segments which grip on the bore of the tubes.

Reveal pin: fits into the end of a tube to form an adjustable strut.

Putlog end: a flat plate which fits on the end of a scaffold tube to convert it into a putlog.

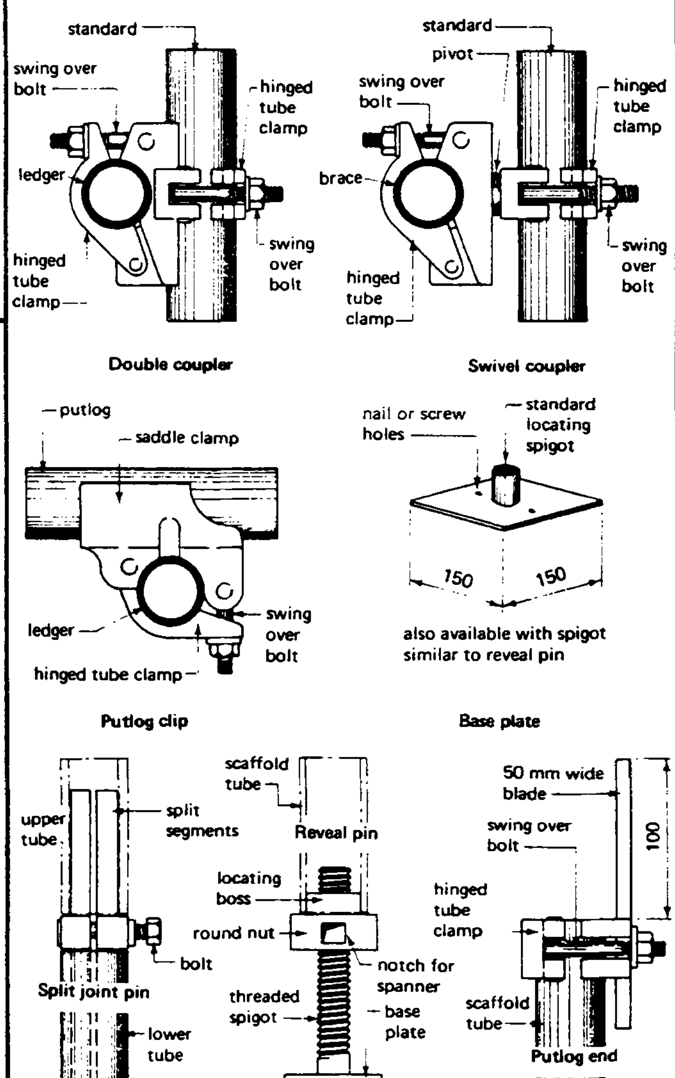
Typical examples of the above fittings are shown in the Fig.

SCAFFOLD FITTINGS Fittings of either steel or aluminium alloy are covered by the same British Standard as quoted above for the tubes. They can usually be used in conjunction with either tubular metal unless specified differently by the manufacturer. The major fittings used in metal scaffolding are:

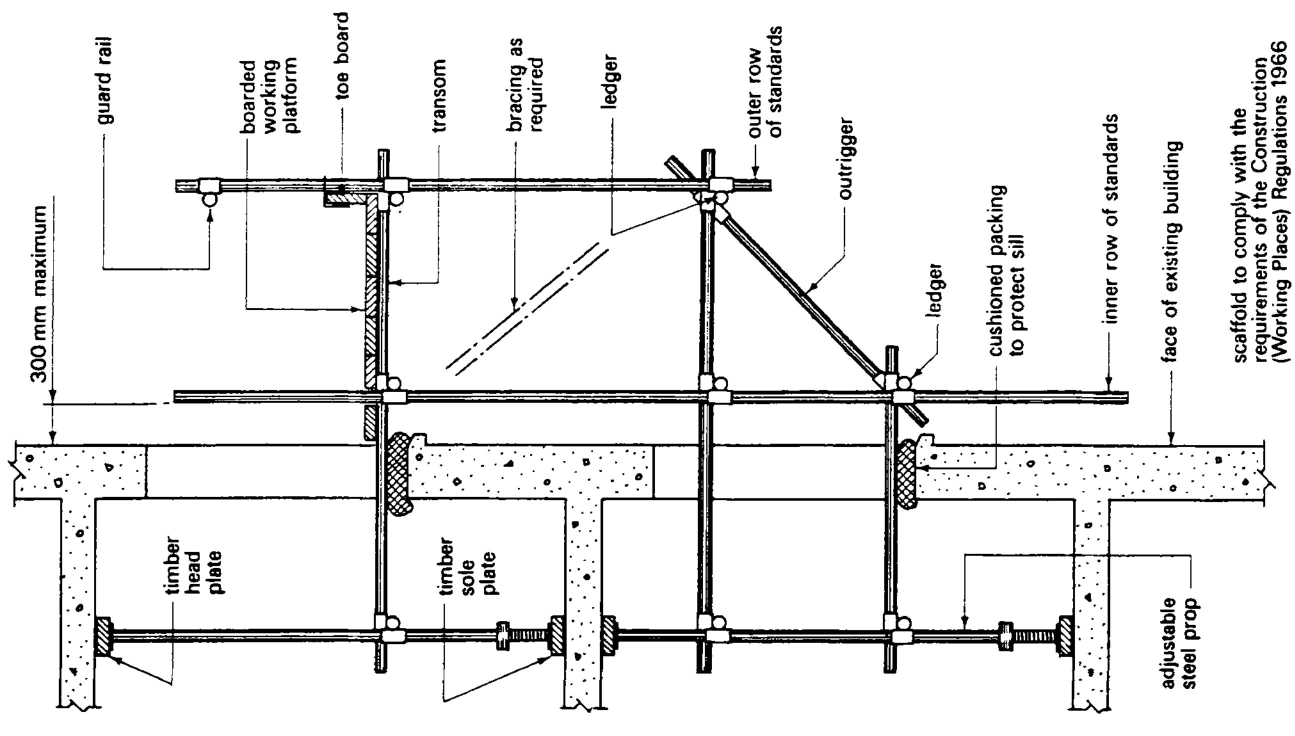
Double coupler: the only real load bearing fitting used in scaffolding and is used to join ledgers to standards.

Swivel coupler: composed of two single couplers riveted together so that it is possible to rotate them and use them for connecting two scaffold tubes at any angle.

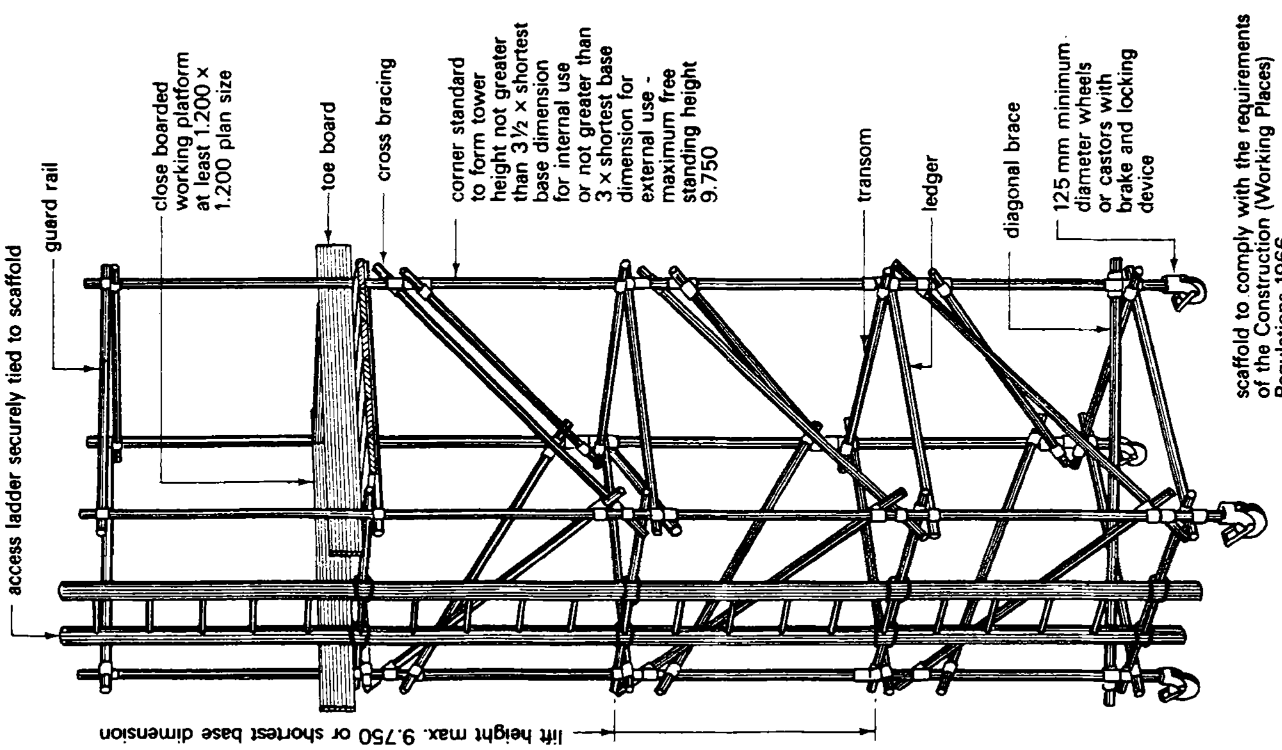
Putlog coupler: used solely for fixing putlogs or transoms to the horizontal ledgers.



TRUSS-OUT SCAFFOLD
MOBILE TOWER SCAFFOLD



Typical truss-out scaffold details



Typical mobile tower scaffold

4.2 SITE ORGANIZATION

4.2.1 Preliminary work

Before site work begins, a PERMISSION to erect a building has to be obtained from the local Authorities. For the procedure of application as well as for the contents of all necessary documents to be submitted refer to 'ARCHITECTURAL DRAWING, Vol II'

The general foreman should visit the site at the earliest opportunity to note such details as:
rainfall / humidity / prevailing wind / orientation / contours.
These factors will influence the site layout plan as far as drainage, shade storage of materials, etc. are concerned.

The following items will also require his attention:
- Adjacent buildings
- Ground surface
- Soil
- Site surround
- Access road
- Water supply
- Electric power
- Transport
- Existing services, etc.

4.2.2 SITE PLANNING

A PROGRAMME covering operations during the first four weeks will have been drawn up at planning stage, in the preparation of which, where possible, the general foreman will have assisted, so that he is in agreement with the proposals lad down.
This programme will be generally in two parts:

a) Site preparation programme, which will cover the demolishing of any existing buildings the setting out of the site and marking out of starage areas, the erection of huts and the construction of temporary access roads where necessary
b) Period 1 programme, on the lines of that shown in the fig., which will cover work during the first four weeks or so of the contract.

Together with these will be provided site layout plans to show a) traffic routes, on which will be indicated any areas requiring particular attention, such as levelling-off or covering with temporary Summerfield track, and any direction signs required; b) the location of offices, huts and stores; c) the position of bulk storage areas both during and after excavation together with the location of any equipment.
The general foreman will in addition also be provided with copies of the:
- overall programme
- schedule of contract information
- data sheets

as well as all other necessary documents such as
- bills of quantities
- specifi cation
- set of contract drawings
- details of all material orders placed and to be placed at various dates during the contract
- details of the type and quantity of equipment to be used and the approximate periods when they will be required on the site.

compiled : D.VOLKE MAY '83

4.2.2.1 PERIOD PLANNING

Work on the site will commence on the basis of the first monthly programme and during the third week of this period, and all subsequent stages, the next monthly programme will be prepared on the basis of the overall plan and data sheets. In the preparation of the monthly plan consideration must be given to the labour force desirable and practicable in the circumstances at the time, to plant requirements and availability, to the phasing and overlapping of operations to ensure completion of the work in the minimum time and to the planning of labour to maintain group identities. Steps must be taken to give adequate warning to all su-contractors when they will be reauired on site.

4.2.2.2 WEEKLY PLANNING

Towards the end of each week progress will be reviewed and the next week's planned progress confirmed or modified if necessary. The following week's planned labour requirements will be reviewed and an stimate made of materials required for the next week but one and of any action required to be taken regarding equipment. This weekly review will be prepared by the general foreman in consultation with his trade foremen and any sub-contractors' foremen, and a written report will be submitted to the contractor,s planning department.

In certain cases where close integration of fully mechanized operations is required over a short period, particularly in the case of reinforced concrete structures, a weekly programme would be drawn up in chart form by the planning department. Such a chart is illustrated in the Fig. In addition to weekly planning, the general foreman will hold a brief meeting each day with his trade foremen and sub-contractor foremen to review the next day's work and to make the necessary preparations in regard to the placing of materials and equipment in readiness for the next day's operations.

The general foreman will, at the beginning of the job whenever possible, indicate to the local employment office his anticipated 'build up'of labour force during the course of the contract.

4.2.2.3 PROGRESS CONTROL

Good site planning is a prior necessity to smooth and effective progress in construction work, but a regular review of the progress of all perations and its comparison with the programme or plan is essential.
Progress is maintained by the foreman, or on larger jobs by a progress engineer, by the proper organization of the delivery and placing of materials, by ensuring that all equipment and plant is in its correct position at the right time, and by adjusting the size of labour gangs when progress is likely to fall behind the programme because of unforeseen circumstances.
Progress is checked during weekly planning by estimating or measuring the work completed, the percentage of each operation or group of operations completed being established and compared with the programme.
Progress is marked on the charts as indicated in the fugure. When progress varies appreciably from the overall programme and where for this and any other reason it is considered desirable to alter the planned sequence of operations, the general foreman would consult the planning department beforemaking such changes.

Close co-operation between the site staff and the planning department is often maintained by means of regular and formal site production meetings between the general foreman and the planning engineer responsible for the job.

When considering any changes, the effect on the supply of materials must be borne in mind, and when progress is faster than planned, the supply of materials in time for the work becomes the predominating factor. All subcontractors must be notified immediately of any changes in the planned programme of work.

The general foreman should maintain a record of current and planned labour strength in the form of a schedule or chart on which the following week's planned labour requirements will be entered during weekly planning. In addition, all incoming material will be recorded on a form, one for each main item, which should show amongst other information dates of order and receipt, quantity delivered ant the balance of material outstanding.

As an aid to progress control on a job of any size, regular site meetings should be held at which should be present
- the contract manager
- site agent or general foreman
- architect
- clerk of works
- quantity surveyor and
- any subcontractors (when necessary)

At these meetings all aspects of the job requiring attention are discussed and decisions for future action made.

4.2.3 SITE LAYOUT

The layout of every site may be divided into an administrative area and a construction area. In the former will be located stores, offices, subcontractors'huts and canteen and similar accommodation if this is provided, and in the latter, which will be the actual site of the buildings being constructed, will be located consumable stores adjacent to the various buildings and all equipment required for construction purposes.

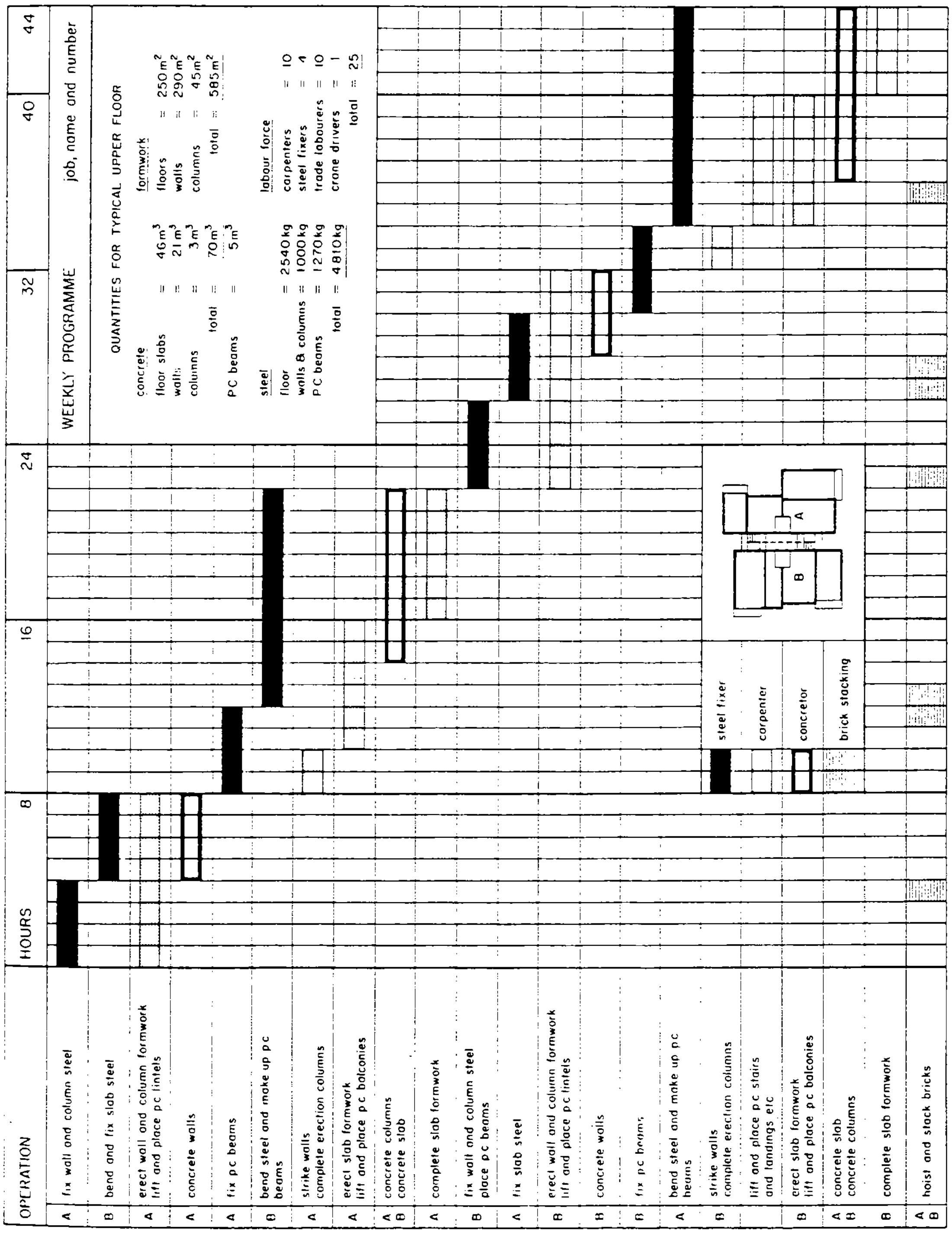
Proper access and departure routes for lorries should be provided and these should be clearly signposted. In determining the traffic routes attention must be paid to the position of all main services, such as water, gas and electricity, and to drains and excavations. Temporary roads must be positioned with sufficient distance between them and future buildings to allow for the movement or positioning of all mechanical plant.

The administrative area should be located to give quick access to that area of the site which will require maximum labour controll and the main storage area, sub-contractors' huts and canteen, should be so located that accessibility for unloading materials is good and so that they are a minimum distance from the construction areas. The site office should be sited on the route into the administrative area and with as good a view as possible of the construction areas.
All contracts of bigger size require adequate telephone facilities for communication, electricity for power, and lighting facilities for office huts.

The stores area should be situated near the site office and will consist of covered huts for valuable or non-weatherproof stores, such as paint and iron-mongery, and a locked pen for larger valuable stores which are weatherproof, such as metal window frames and pipes. Areas for sub-contractors'stores will be located near the sub-contractors'huts and sometimes they will be situated within the main stores area.

The construction area should contain the minimum practical quantities of materials and of necessary equipment and these should be so positioned that handling and movement is kept to a minimum. As the position of equipment, particularly mixers, hoists and cranes, will influence the position of materials such as sand, aggregates and bricks, the position of all plant should be planned before that of the materials.
Materials arrive on the site in the order decided at planning stage, or in accordance with instructions issued from the site, and sufficient area must be provided to accommodate the size of batch ordered. In addition, overflow areas should be allocated. In planning the layout of the site, consideration must be given to the excavation stages as these may seriously restrict proposed storage areas.
Standardized materials, such as bricks, tiles and drainpipes, should be stacked in unit dumps, the numbers in which remain constant although the length, breadth and height may be varied to suit site conditions.

PERIOD PLANNING



4. CONTR. PLANNING	SITE ORGANIZATION	BUILDING CONSTR.
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MAY '83		CET 2031/14.241

•REPETITION•• exercises ••REPETITION•

Try to answer the following questions and use sketches for illustration

1. CONTRACT PLANNING

- Which considerations should be taken into account in 'Contract Planning';

- Explain the function of a 'Bar Chart'

- What is the difference between analysing a production problem by 'Network' and by a 'Linear Method';

- Describe step by step the way how to prepare a 'Network'in the form of an ARROW DIAGRAM

- Explain the terms:
  - Earliest starting time
  - Latest starting time
  - latest finishing time
  - Floating time
  - Critical path
  - Time /cost optimisation
  - Resource levelling and control

- Who prepares the OVERALL PROGRAMME and where will it be used for;

- Where does the OVERALL PROGRAMME consist of, and in which form is it usually expressed;

- Explain and write notes on the following headings:
  - Break down of job
  - Quantities of work and time content
  - Plant and Labour outputs
  - Sequence and timing of operations
  - Programme chart

- List and describe factors which have a bearing on the decisions made during the contract planning stage.

- Write notes on contractors mechanical plant

- Explain different types of SCAFFOLD refering to their form as well as to the materials and fittings used for construction.

2. SITE ORGANIZATION

- What has to be obtained before site work begins ?

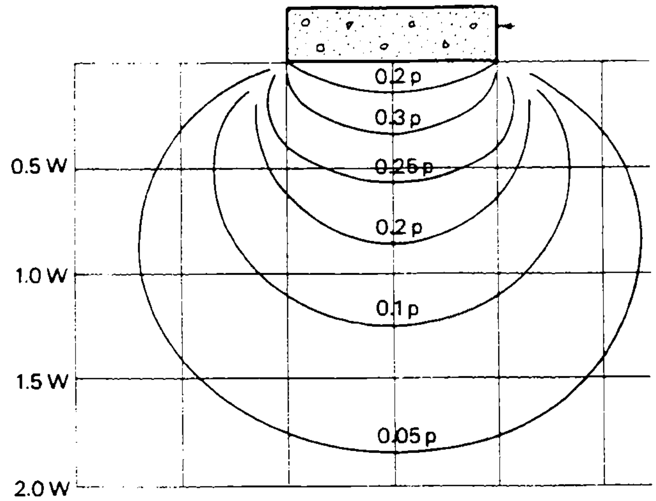
- List items which should require the attention of the general foreman during his first site visit

- What is the contents of the 'site planning programme' ?

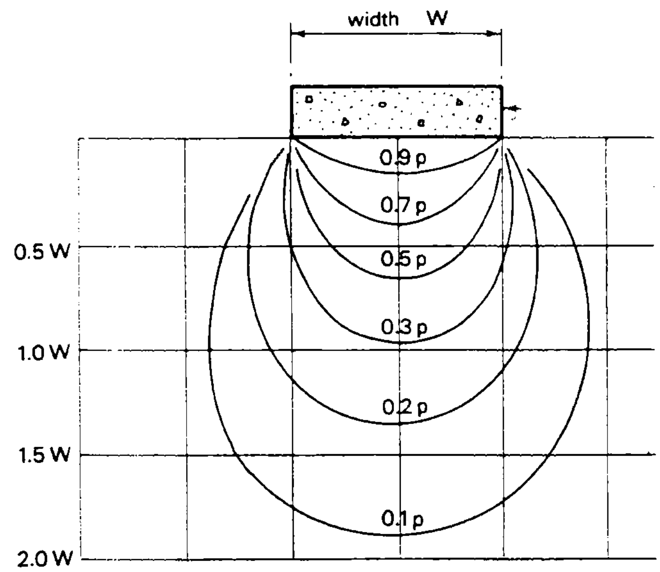
- What are the two areas of the 'site layout' ? Write notes and explain the requirements of these areas.

5.FOUNDATIONS

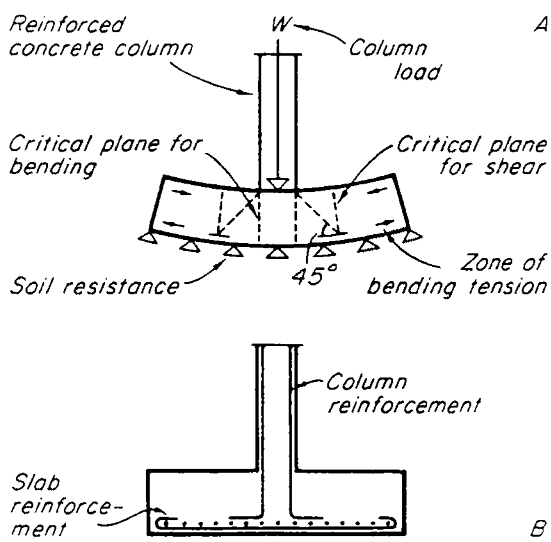
CONTENTS:



Pressure bulb for shear stress



Pressure bulb for vertical stress



Pad or slab foundation

REFERENCES:

1. Jack Stroud Foster
   MITCHELL'S BUILDING CONSTRUCTION
   " Structure and Fabric "
   Part 1 + 2

2. R. Chudley
   "Construction technology "
   Volume 1,3,4

3. R. L. Fullerton
   "Bu ilding Construction in
   warm climates"
   Volume 1,3

4. W. G. Nash
   "Brickwork 2"

5. FOUNDATIONS

A FOUNDATION is the BASE on which a building rests and its purpose is to safely transfer the load of a building to a suitable subsoil.

Apart from solid rocks all soils are compressible in varying degrees, so that under the building load foundations will - to some extent - move in a downward direction. This is known as SETTLEMENT and is due mainly to the consolidation of the soil particles.

Excessive settlement will result from overloading the soil to such an extent that the loaded area of soil SHEARS past the surrounding soil in what is known as PLASTIC FAILURE of the soil.

In addition, settlement may be caused by a reduction in the MOISTURE CONTENT of certail soils which shring on drying out or by a general movement of the earth due to various causes.

Provided the settlement is UNIFORM over the whole area of the building and is not excessive, the movement does little damage.
If the amount of settlement VARIES at different points under the building (known as realtive or differential settlement) distortion of the structure will occure which, if too great, may result in damages or possible failure of the structure.

Such differential movements must be kept within limits which avoid harmful distortion. These limits will vary with the type of structure and its ability safely to withstand differential movements.

5.1.1 Site exploration

Tall, wide-span or heavily loaded buildings exert greater pressures on the soil resulting in greater settlements, and lead to greater possibility of shear failure of the soil than do small-scale buildings. To overcome this, types of foundations may be required which affect the soil and to considerable depths. In such cases the various soil characteristics take on greater significance and a closer consideration of the soil and its properties is required than is often necessary for small-scale buildings.

This may require an extensive examination of the subsoils involving boring to considerable depths and carrying out field and laboratory tests on the soils.

An extensive investigation of the soil is not usually necessary in the case of small-scale buildings on soils of adequate strength, where (by means of simple stripe or pad foundations near the surface) the pressure on the soil can be kept well within the known SAFE BEARING CAPACITY of a particular soil type. What is required is a simple method of establishing the TYP OF SOIL to a sufficient depth and a means of determining its bearing capacity.

The bearing capacity can be found from standard tables and the soil type can be established by exposing the soil to view for the shallow depths by digging holes- known as TRIAL HOLES (or PITS) - and using simple visual and tactile means of identification.

5.1.1.1 Trial holes

- Should not be further apart than about 30 m and not less than one per 900 m2 of site.

- Should be large enough to accomodate a man (say 1.20 m x 1.00 m or larger if timpering is required.

- Depth: Usually up to 3.oo m, it rarely exceeds 6.oo m.

- The soil should be inspected at all levels as soon as possible after excavation.

- As a check on the possible existance of a very weak layer of soil below the trial hole, a probe of about 1 m may be made by means of a hand anger. This can also be used when the presence of ground water makes the completion of the trial hole difficult.

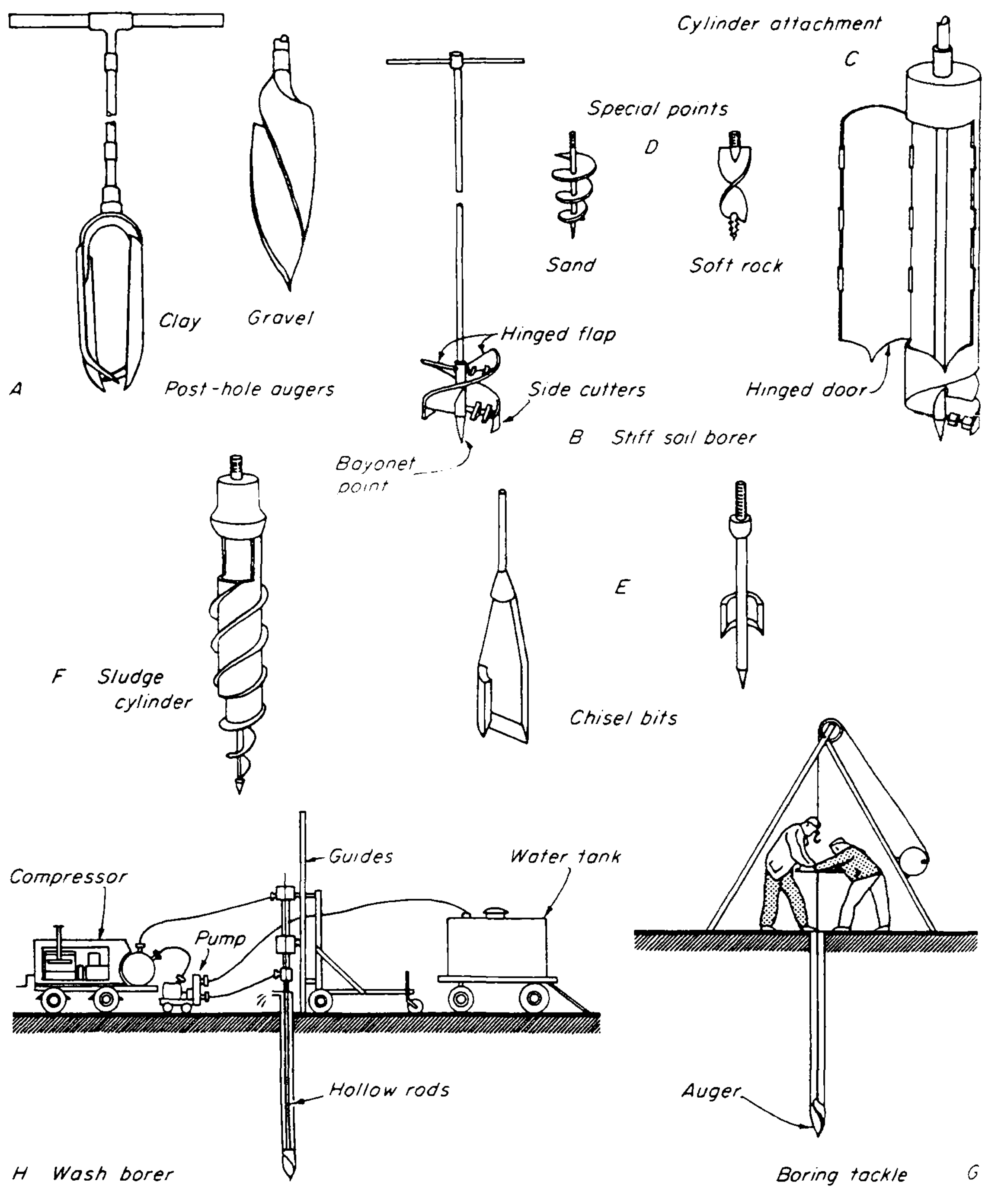
- The soils excavated and exposed in the trial holes can be identified within broad types by simple field tests.

- Foundations are invariably formed in concrete. The durability can be affected by sulphate salts in the soil, particularly in the ground water.
  The nature of any groundwater should be checked and where sulphate salts are known to be present precautions must be taken (e.g. by use of suitable cement).

- A trial hole also gives to the contractor valuable informations affecting labour costs (ease of excavation) and amount of timbering, underground water (pumping, dewatering).

- Excavations should not be carried out too close to the proposed foundations, they may be a source of weakness, and the should be filled and consolidated ofertwards.

SOIL BORING METHODS



5.FOUDATIONS compiled : D.VOLKE MAY '83	SOIL INVESTIGATIONS	BUILDING CONSTR. LECTURE CET 2031/15.1o3
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BORE HOLES

5.1.1.2 Bore holes

- Are fomed as required on site for the purpose of raising samples of soil for examination.

- Tools:
  a) post-hole anger (simple) having arod with crosshead, it is capable of forming holes in clay or soft soils up to about 6 m deep and Ø 150 mm or more.
  b) for cleeper borings or where rock is expected, either the
     - percussion or the
     - rotary
     method is employed.

A hole is formed by percussion method with a chipsel-shaped steel bit, screwed to a rod;
this is driven vertically in to the ground, lifted, partly rotated and again driven. It has to be repeated rapidly until the desired depth is obtained.
Samples of the soil are obtained during the process.

The rotary method is usually applied to rock formations.
A small hole (Ø 50 mm) is drilled with a rotating bit (having diamonds set round the cutting edge) jointed to a hollow rod.
The cylindrical core of rock thus formed within the tool is broken off at intervals and removed for inspection and testing.

SAMPLING

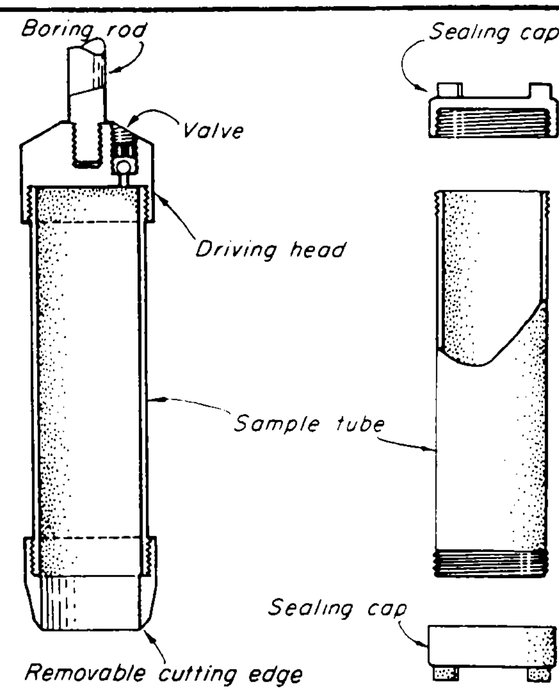
5.1.1.3 Sampling

The form of samples depends upon the
- nature of the soil
and whether it was
- disturbed or
- undisturbed.

e.g. an undistrubed sample of rock can be obtained if such stratum has been exposed in a trial pit.
It has to be dressed to a cube (at least 75 mm each side).
When it can be tested for
- compression
- permeability etc.
and slides prepared from it can be exmamined.

An undisturbed sample of clay from a trial hole is cut by a knife in the form of a cube, coated with paraffin wax to prevent loss of moisture, placed in an airtight container and labelled ready for testing.

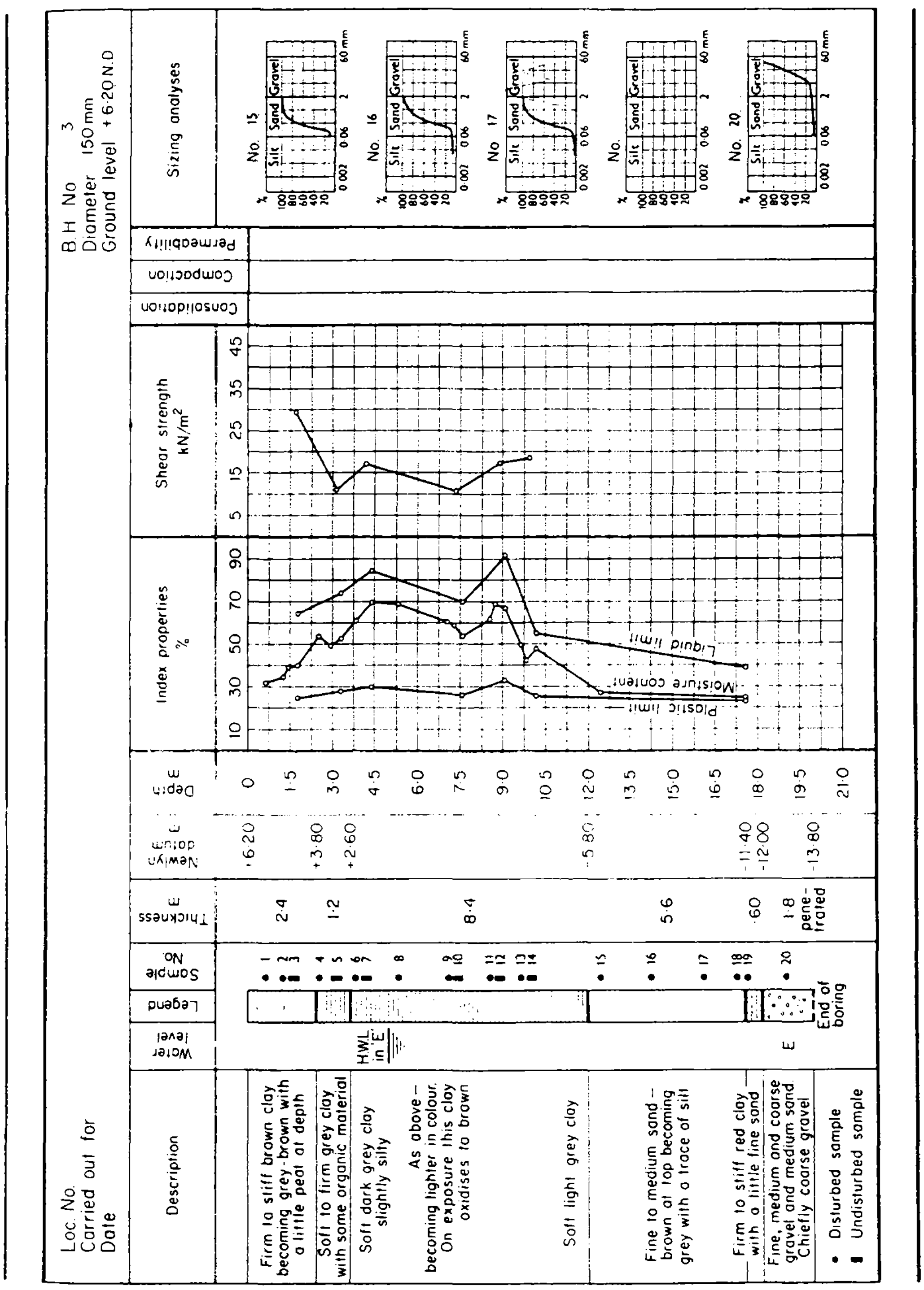
Such a sample can also be obtained from an exposed clay stratum by using a tool called
 - 'sampler' or 'spoon'
There are several types of samplers (e.g. a metal tube Ø 100 - 150 mm, 1 m - 1,5 m long; having an open



end with a cutting edge and at the opposite closed end there ist an air valve; as the sampler is driven down it gradually fills with clay (air excaping through the valve) it is withdrawn when full and the sample is removed.

Disturbed samples of soils are obtained during the actual boring operation. The sampler is attached to

BOREHOLE RECORD



the boring rod in the place of the bit, forced down into the loosened soil and withdrawn when full.

The soil cores are carefully removed from the sampler and placed in a box (about 1,5 m long, divided into compartments) in correct sequence and numbered in their proper order.

When laid end-to-end according to depth they reproduce a section showing the nature and thickness of each stratum.

Small specimens for laboratory tests are taken from the cores as required. These should be placed in an airtight container until needed.

TESTS

5.1.1.4 Tests

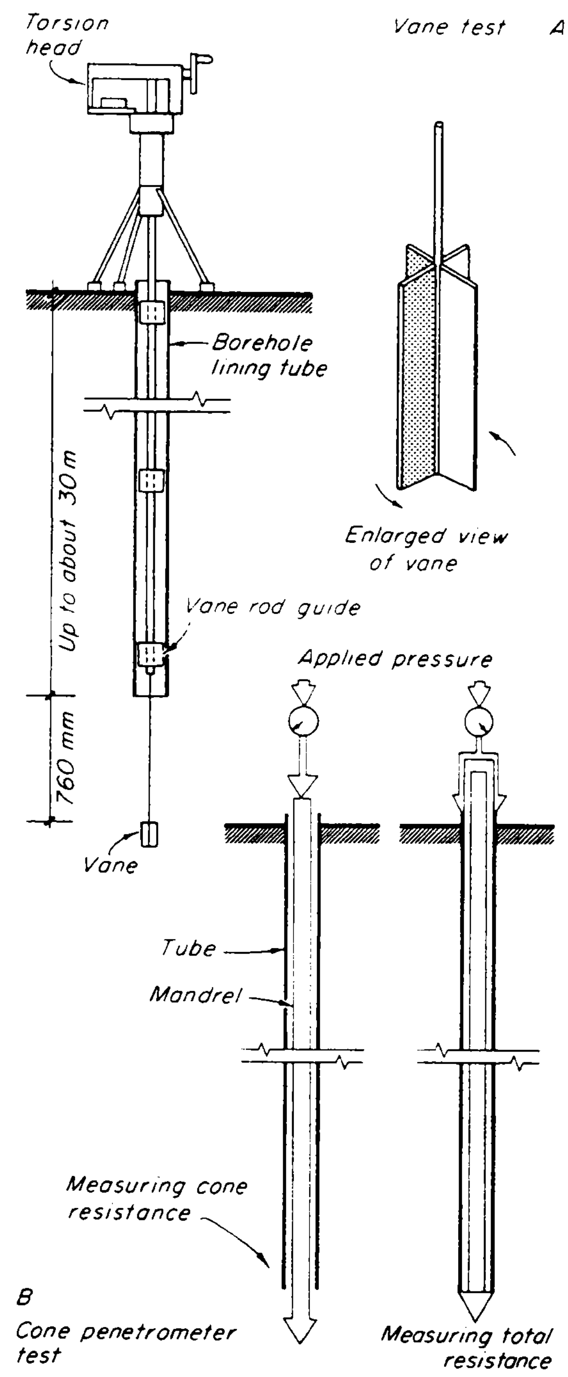
After having examined the samples carefully and the characteristics of the various soils noted and classified, a complete record is made, including a dimensionel sketch of the section showing the thickness and various strata.

Two tests are most important to the foundation designer:

1) consolidation test
2) shear test.

1) Consolidation test is usually applied to clay soils.
   The weight of the Building tends to consolidate the soil by squeezing out the water between the particles - and so producing settlement of the building.
   Test: The soil specimen is placed in a metal Cylinder between two porous stone discs. Pressure is applied and increased by stages, the amount and rate are noted at each stage, a time settlement curve is plotted.
   Result: Probable amount of settlement.

2) The load of a building sets up compression and shear stresses in the soil. The soil tends to squeeze out from under the load.
   The shear stresses are the forces tending to produce this sliding movement between adjacent portions of soil (clay., normally not gravel)
   The safe load which can be supported by a soil depends to a large extent upon its shear resistance.



In situ soil tests

TESTS

Test: A metal box is used(100 mm2 by about 75 mm deep). Two portions (upper and lower halves) are welded to one side of the top half as a projecting arm to which is fastened a length of wire fixed to a scale pan. The bottom half is clamped to the bench top and the wire is passed over the pulley, clamped at the edge of the bench, suspending the pan.
The box is filled completely with clay specimen and weights are placed on the pan until the upper half begins to slide over the lower - as the clay shears through at this level.
The total weight producing this, divided by the internal area of the box gives the shear strength of the soil.

5.1.1.5 Load or bearing test

This test is applied at the proposed level of the foundations (not at ground level!!).
There are several forms of equipment used for this test, two will be described below:

1) Consists of a level concrete raft (say 1,5m2; 30 cm thick) formed at foundation level. It serves as the loading table;

2) a hole is dug at foundation level to recive a square or circular steel sole plate of known area (say 1 m2) bedded level on a cushion of sand;
This supports centrally a steel tube or spindle (say 1,2 m high) having a cross-head forming the base of the loading platform (say 2 m2).
The whole is prevented from tilting by guys or other means, which must be arranged not to restrict the downward move - ment of the platform.
The weight of the apparatus must be known.

Loading: (same for (1) and (2)

- the table is loaded carefully and uniformly (bars of pig-iron- each of equal weight or bricks - the average weight of twelve being taken as the unit - may be used.)
- the load is applied in increase (say 204 bricks at a time) and at least two hours must elapse between the time one increment has been completed and the next started.
- Fine readings are taken with a dumpy level (with the staff at the centre and at each corner of the table top) immediately before and after each loading.
- The mean settlement is obtained. A record is kept of the readings and a load / mean - settlement curve is plotted.
- The amount of settlement after each increment - loading will depend upon the character of the soil, but if the bearing capacity is satisfactory it will only amount to a few mm.
- When the 'yield point'of the soil has been reached, as indicated when there is an appreciable increase in settlement after the last increment, this increment is removed from the table and the readings again taken after an interval of three or four days.
If no further settlement has taken place, half the total load on the table (together with the weight of the apparatus) divided by the area of the sole plate is taken as the safe bearing value of the soil.

$$\frac{\text{Total load table}}{2} : \text{area of sole plate}$$

= safe bearing capacity of the soil.

5.1.2 Soils and soil characteristics

The topmost layer of sil at ground level is an unsuitable material on which to found.
- It has been weathered,
- is relatively loose
- contains decayed vegetable matter
- is soft and exessively compressible

It is known as:
- Topsoil or vegetable soil (thickness varies from about 15 - 30 cm).

Below this lies the
- subsoil, from which the topsoil has developed and which consists of solid particles of varying shape and size devived from the weathering of solid rock. The spaces between are filled with water and - to some extent - air.

It is to this subsoil that the word 'soil' refers when used in relation to foundations.

5.1.2.1 Rocks and Soils

A broad classification, comprising five groups is:

1) rocks
2) cohesive soils
3) non-cohesive soils
4) peat
5) made ground.

The table below shows how these are classified and distinguished.

Group	Types of rocks and soils	max. safe - bearing capacity (MN / m2)
I Rocks	Ingeous rocks in sound condition	10
	Massively - bedded lime - stone and hard sandstones	4
	Slates	3
	Hard shales, soft sandstones	2
	Hard clay shales	1
	Hard solid rock	0,64
	Thinly-bedded limestones and sandstones	To be determind after inspection
	Heavily shattered rocks	
II Cohesive Soils	very stiff boulder clays and hard clays with a shaly structure	0.4 - 0.6
	stiff clays and sandy clays	0.2 - 0.4
	firm _"_	0.1 - 0.2
	soft _"_ and silts	0.05- 0.1
	very soft clays and silts	0.05- nil

III non-cohesive soils	sompact well-graded sands and gravel-sands	0.4-0.6
	loose well-graded sands and gravel sands	0.2-0.4
	compact uniform sands	0.2-0.4
	loose uniform sands	0.1-0.2
IV	Reat	To be determind after investigatie
V	Made ground	-"-

These embrace igneons rocks (which include granits) up to heavily shattered rocks

I Rocks

II Cohesive soils

These are soils, the particles of which stick together, such as clays. The degree of cohesion depends upon the size and shape of the particles and the water content. These clays are classified as: very stiff boulder clays up to very soft clays and silts (see fig.)

- Clay soils are subject to shrinkage and cracking in hot dry weather, followed by expansion in wet weather - The change in volume according to their water content.

- Adequate precontions have to be taken! Such movement may cause considerable damages to buildings errected on subsoils of very soft clay.

- As the movement decreases with the depth below ground level it is important that foundations should be relatively deep.
  - under external walls at least 90 cm
  - or of pile and beam type
  - or of raft construction

  In addition to having this undesirable property of expanding and contracting, clay soils have a relatively low shear strength and a small safe load bearing capacity.

III Non-cohesive soils include gravel and sands.
The strength or bearing capacity depends upon
- the grading,
- the packing and
- the average size of the particles.

In general : The better the grading (as distinct from uniformity) - the tighter the packing and : the larger the grains, the bigger the load bearing capacity.

These soils are divided into:
- compact well graded sands and gravel sands

up to
- loose unform sands (see table)

Non cohesive soils vary considerably in their value as building sites.
e.g. A deep bed of dry compact gravel provides an exellent support.
A subsoil of loose, uniform sand (if not confined by sheet piling) may develop considerable settlement when loaded.

The presence of groundwater affects the bearing capacity of soils. Thus, pumping operations may lossen a compact bed of gravel (and reduce the bearing capacity).

IV Peat
is decayed vegetable matter, black or darf brown in colour. It is highly compressible and quite unsuited to receive foundations (even those of light structurs).

If used for foundations - it must be supported on piles which ar driven down to an underlying firm stratum.

V Made ground or fill

This is excavated soil or house refuse, which has been depositied in a depression.

Such sides have to be avoided
- house refuse is in sanitary
- injurious conicals may be in industrial waste
- even excavated soil, such as quarry waste well compacted in thin layers beats a risk of unequal settlement. (foundations to be carried down to the original stratum or be supported by piles.)

SOIL CHARACTERISTICS and BEARING CAPACITIES

Subsoil types	*Condition of subsoil*	*Means of Field Identification*	*Particle size range*	*Bearing capacity kN/m²*	*Minimum width of strip foundations in mm for total load in kN/m of loadbearing wall of not more than*					
					20	30	40	50	60	70
Gravel	Compact	Require pick for excavation. 50 mm peg hard to drive more than about 100 mm. Clean sands break down completely when dry. Particles are visible to naked eye and gritty to fingers. Some dry strength indicates presence of clay	Larger than 2 mm	> 600	250	300	400	500	600	650
Sand			0·06 to 2 mm	> 300						
Clay	Stiff	Require a pick or pneumatic spade for removal. Cannot be moulded with the fingers. Clays are smooth and greasy to the touch. Hold together when dry, are sticky when moist. Wet lumps immersed in water soften without disintegration	Smaller than 0·002 mm	150–300	250	300	400	500	600	650
Sandy clay			See Sand and Clay	150–300						
Clay	Firm	Can be excavated with graft or spade. Can be moulded with strong finger pressure	See above	75–150	300	350	450	600	750	850
Sandy clay			See Sand and Clay	75–150						
Gravel	Loose	Can be excavated with a spade. A 50 mm peg can be easily driven	See above	< 200	400	600				
Sand			See above	< 100						
Silty sand			See Silt and Sand	May need to be assessed by test						
Clayey sand			See Clay and Sand	ditto						
Silt	Soft	Readily excavated. Easily moulded in the fingers. Silt particles are not normally visible to the naked eye. Slightly gritty. Moist lumps can be moulded with the fingers but not rolled into threads. Shaking a small moist pat brings water to surface which draws back on pressure between fingers. Dries rapidly. Fairly easily powdered	0·002 to 0·06 mm	75	450	650				
Clay			See above	75						
Sandy clay			See Sand and Clay	May need to be assessed by test						
Silty clay			See Silt and Clay	ditto						
Silt	Very soft	A natural sample of clay exudes between the fingers when squeezed in fist	See above	< 75	600	850				
Clay			See above	< 75						
Sandy clay			See Sand and Clay	May need to be assessed by test						
Silty clay			See Silt and Clay	ditto						
Chalk	Plastic	Shattered, damp and slightly compressible or crumbly	—	—	Assess as clay above					
Chalk	Solid	Requires a pick for removal	—	600	Equal to width of wall					

For loadings of more than 30·0 kN/m run on these types of soil: the necessary foundations do not fall within the provisions of Regulation D7 from which these figures are taken.

Pad foundations generally and surface rafts are designed using the bearing capacities for soils given in this Table. *Note.* See note on facing page regarding the use of values given in this table for bearing capacities of sands and gravels.

5.1.2.2 Stresses and pressures

Cohesive soils present serious problems when giving consideration to foundation choice and design.
The two major conditions to be considered are:

Shearing stress: the maximum stress under a typical foundation carrying a uniformly distributed load will occur on a semi - circle whose radius is equal to half the width of the foundation and the isoshear line value will be equal to about one-third the applied pressure - see Fig. The magnitude of this macimum pressure should not exceed the shearing resistance value of the soil.

Vertical pressure: this acts within the mass of the soil upon which the unacceptable settlement of the structure.
Vertical pressures can be represented on a drawing by connecting together points which have the same value forming what are termed pressure bulbs.
Most pressure bulbs are plotted up to a value of 0.2 of the pressure per unit area which is considered to be the limit of pressure which sould influence settlement of the structure.
Typical pressure bulbs are shown in the fig.
A comparison of these typical pressure bulbs will show that generally vertical pressure decreases with depth, the 0.2 value will occur at a lower level under strip foundations than under rafts, isolated bases and bases in close proximity to one another which form combined pressure bulbs. The pressure bulbs illustrated in the fig. are based on the soil being homogeneous throughout the depth under consideration. As in reality this is not always the case it is important that soil investigation is carried out at least to the depth of the theoretical pressure bulb.

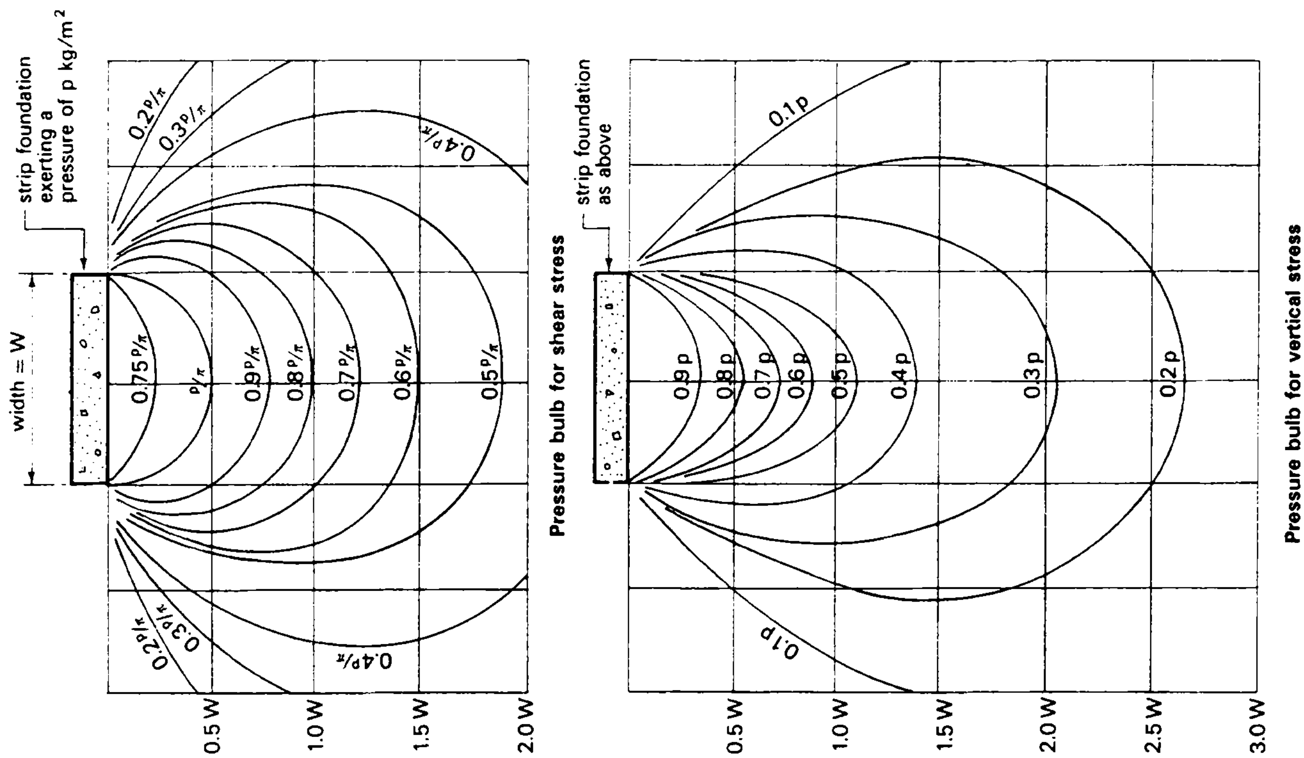
Great care must be taken where an underlying strata of highly compressible soil is encountered to ensure that these are not over stressed if cut by the anticipated pressure bulb.

Contact pressure
It is very often incorrectly assumed that a foundation which is uniformly loaded will result in a uniform contact pressure under the foundation. This would only be true if the foundation was completely flexible such as the bases to a pin jointed frame. The actual contact pressure under a foundation will be governed by the nature of the soil and the rigidity of the foundation, and since in practice most large structures have a rigid foundation the contact pressure distribution is not uniform. In cohesive soils there is a tendency for high stresses to occur at the edges which is usually reduced slightly by the yielding of the clay soil. Non-cohesive soils give rise to a parabolic contact pressure distribution with increasing edge pressures at the depth below ground level of the foundation increases. When selecting the basic foundation format consideration must be given to the concentration of the major loads over the position where the theoretical contact pressures are at a minimum to obtain a blanced distribution of contact pressure - see fig.

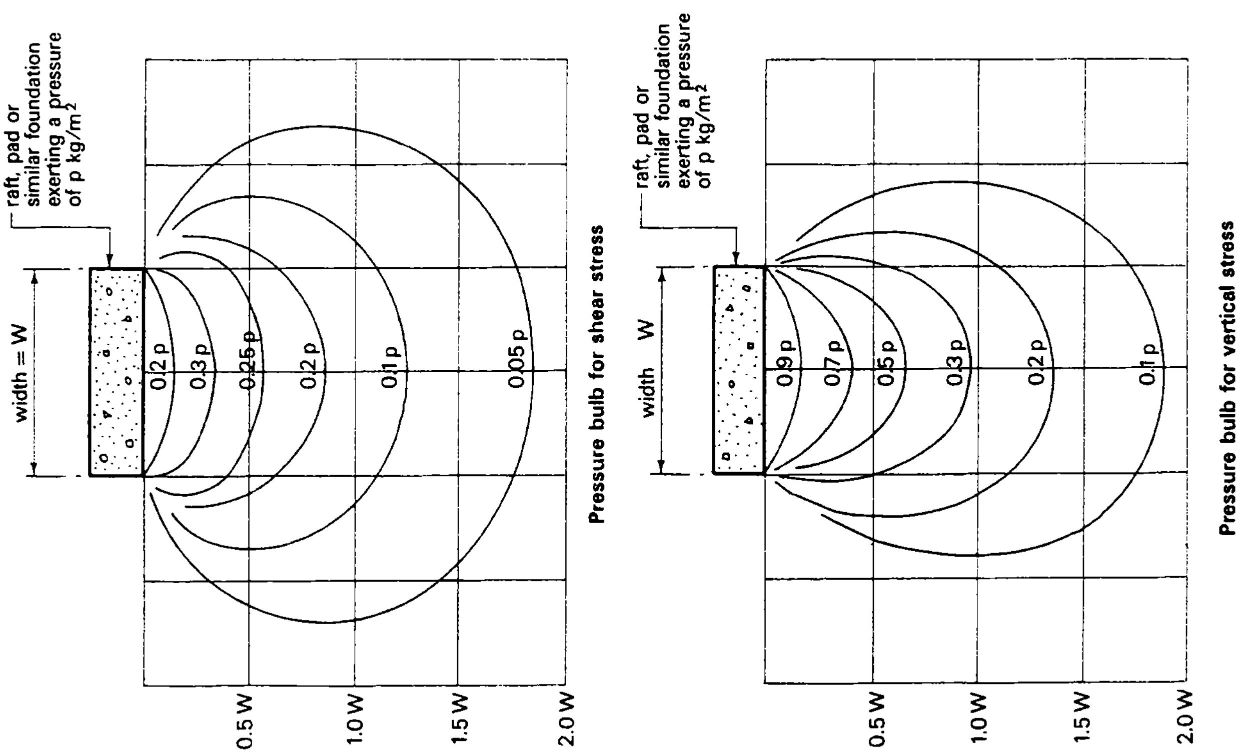
Plastic failure
This is a form of failure which can occur in cohesive soils if the ultimate bearing capacity of the soil is reached or exceeded. As the load on a foundation is increased the stresses within the soil also increases until all resistance to settlement has been overcome.
Plastic failure, which can be related to the shear strength of the soil, occurs when the lateral pressure being exerted by the wedge of relatively undisturbed soil immediately below the foundation causes a plastic shear failure to develop resulting in a heaving of the soil at the sides of the foundation moving along a slip circle or plane. In practice this movement tends to occur on one side of the building, causing it to tilt and settle - see fig. Plastic failure is likely to happen when the pressure applied by the foundation is approximately six times the shear strength of the soil.

TYPICAL PRESSURE BULBS

STRIP FOUNDATIONS



RAFT OR SIMILAR FOUNDATIONS



5.FOUNDATIONS	SOIL INVESTIGATIONS	BUILDING CONSTR.
compiled : D.VOLKE		LECTURE
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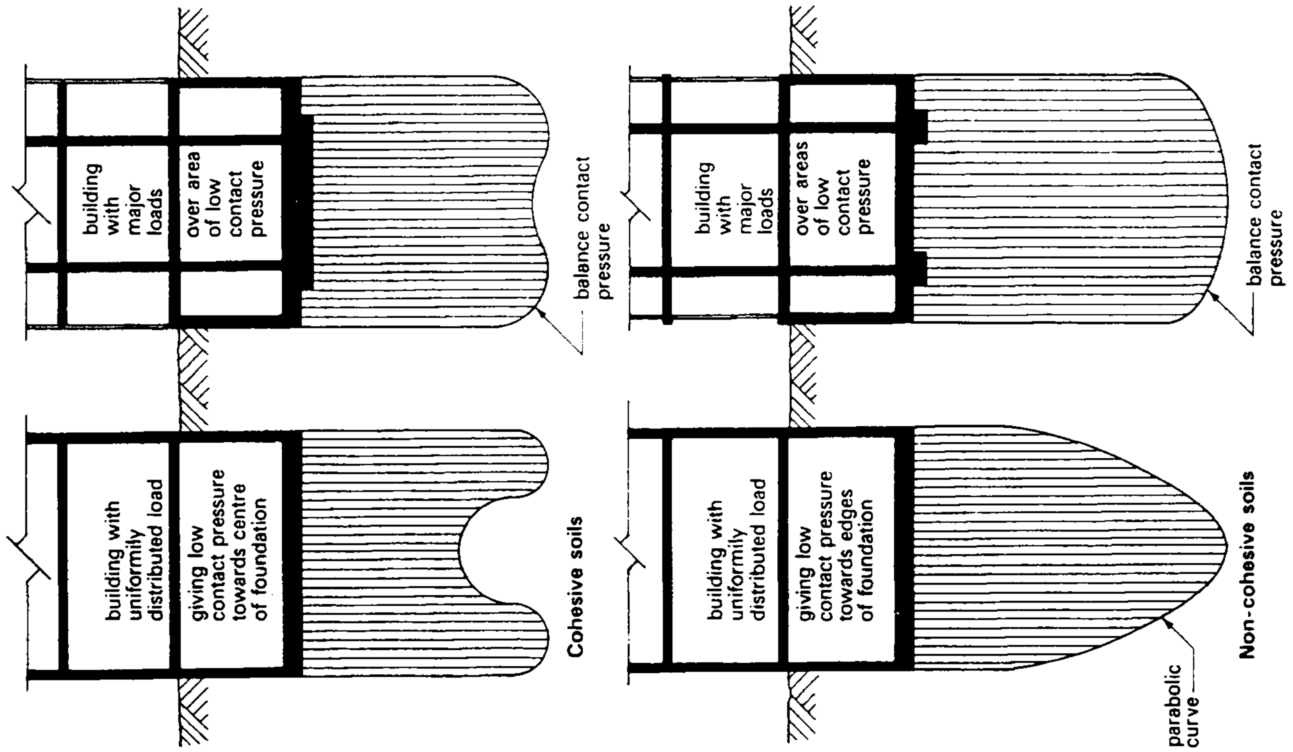
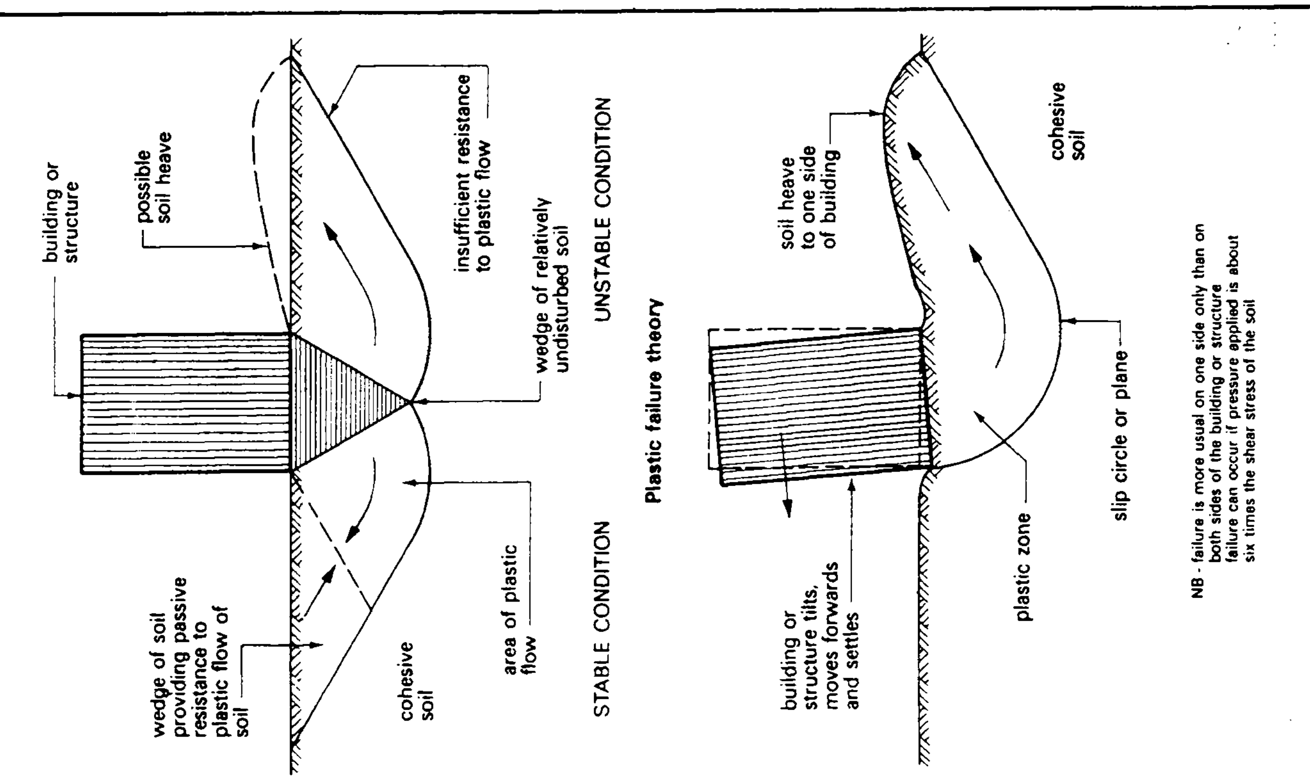
TYPICAL CONTACT PRESSURES



PLASTIC FAILURE of foundations



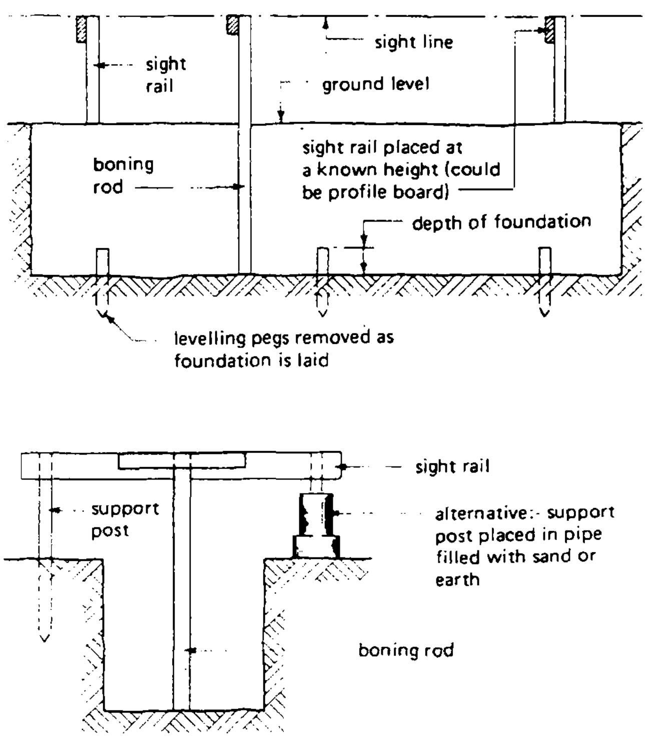
5.FOUNDATIONS	SOIL INVESTIGATIONS	BUILDING CONSTR.
compiled : D.VOLKE		LECTURE
MAY '83		CET 2031/15.113

5.2 EXCAVATIONS AND TIMBERING

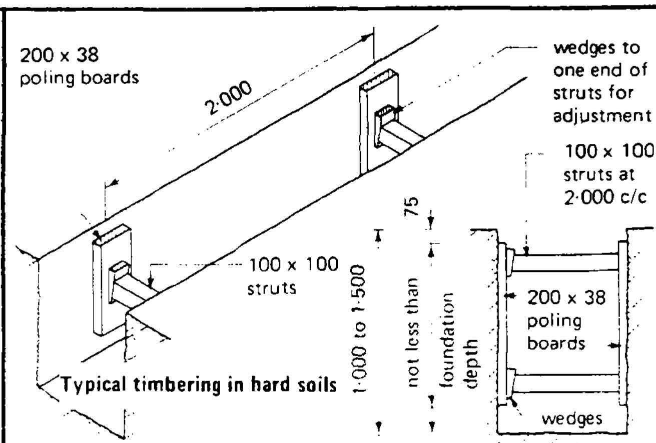
5.2 EXCAVATIONS AND TIMBERING

- Trenches which have to be dug for the foundations of walls are usually excavated by hand - in bigger building projects also mechanical trench diggers are used.
- If the trenches are of any depth it may be necessary to erect temporary timber supports to stop the sides of the trench from fallin in.
- The nature of the soils being excavated mainly determines at what depth of trench timber supports to the sides should be used.
- Soft granular soils readily crumble and the sides of trenches have to be supported for the full depth.
- Dry granular soils such as sand and made up ground may need closely spaced timbering to the sides. See fig.

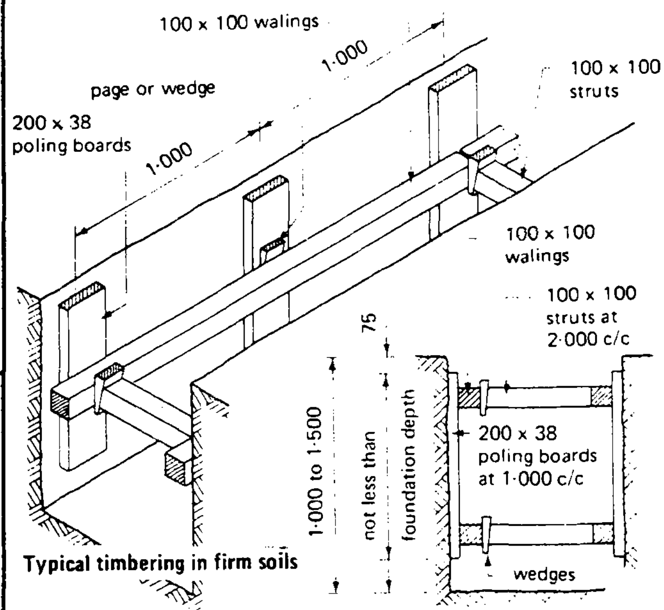
The sizes of timbers shown in the drawings are for guidance only.



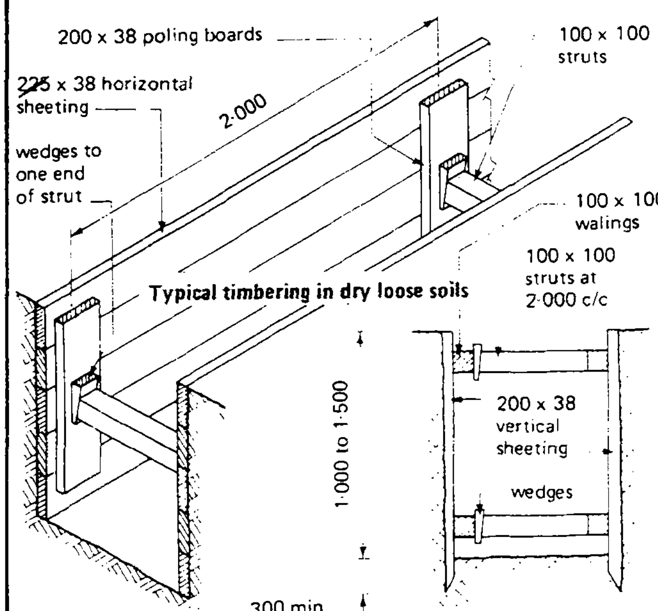
Trench excavations



Typical timbering in hard soils



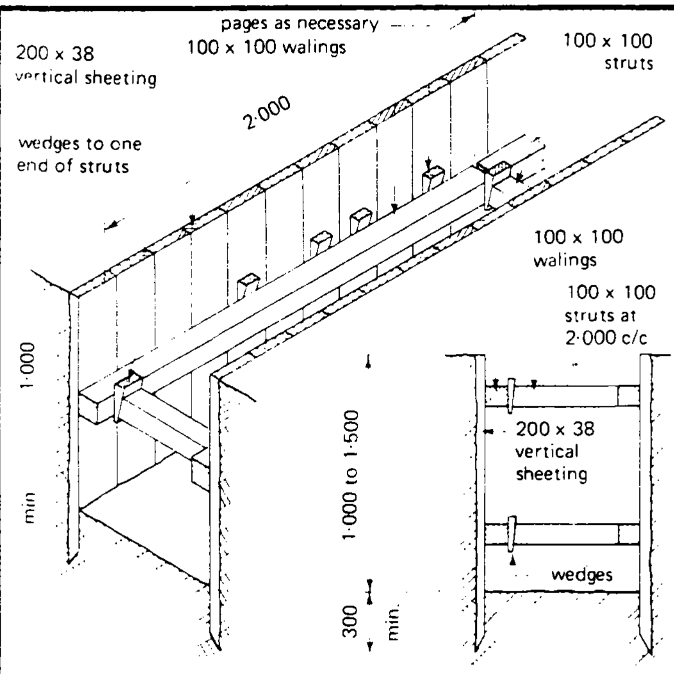
Typical timbering in firm soils



Typical timbering in dry loose soils

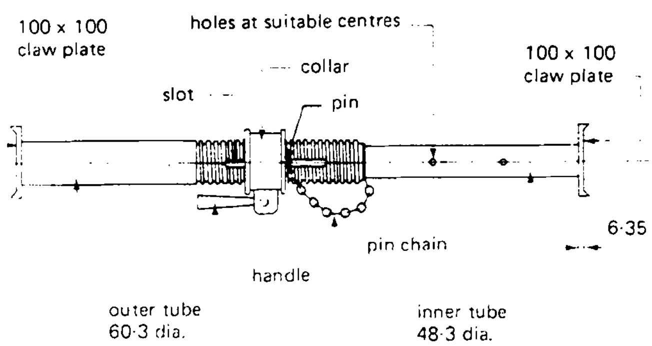
Once the excavations are finished, the foundations should be laid as soon as possible to prevent the ground from drying out and causing movement by shrinking. The ground immediately below the foundation is called the GROUND BEARING or the NATURAL FOUNDATION and should be levelled of and well rammed to receive the base. This is to ensure that there is no loose earth beneath the concrete base which could fail to hold the loading and thus cause a fracture.

- Clay soils do not usually require support for some depth (say 1.5 m) particularly in dry weather.
  In rainy weather, if the bottom of a trench in day soil gets filled with water, the water may wash out the clay from the sides at the bottom of the trench.
- The purpose of temporary timbering supports to trenches is to uphold the sides of the excavation as necessary, to avoid collapse of the sides.
- Whatever timbering is used there should be struts, that is horizontal members, fixed across the width of trenches. All struts must be firmly secured so that they are not easily knocked out of position.
- The sides of deep trenches in compact soils such as clay should - if necessary - be timbered as shown in the fig.
- If the soil is soft, such as loam, more closely spaced timbering will be needed as shown in the fig.

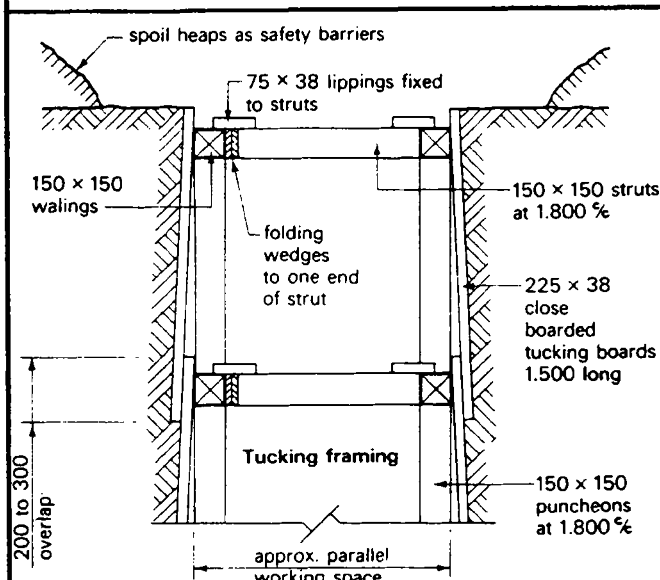


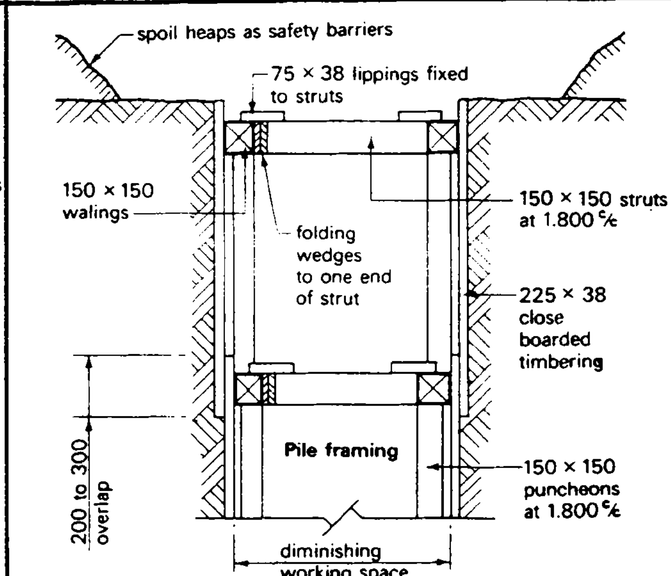
Typical timbering in loose wet soils

Adjustable metal struts—BS 4074



SIZE No.	MINIMUM LENGTH	MAXIMUM LENGTH
0	0·30 m	0·45 m
1	0·45 m	0·68 m
2	0·68 m	1·06 m
3	1·06 m	1·67 m





5.3 TYPES OF FOUNDATIONS

5.3.1 Classification
The many forms of foundations used in building work may be divided broadly into
I SHALLOW FOUNDATIONS and
II DEEP FOUNDATIONS

I Shallow foundations transfer the load to the soil at a level close to the lowest floor of the building and include SPREAD FOUNDATIONS in the form of
- strip foundations
- pad foundations and
- raft foundations

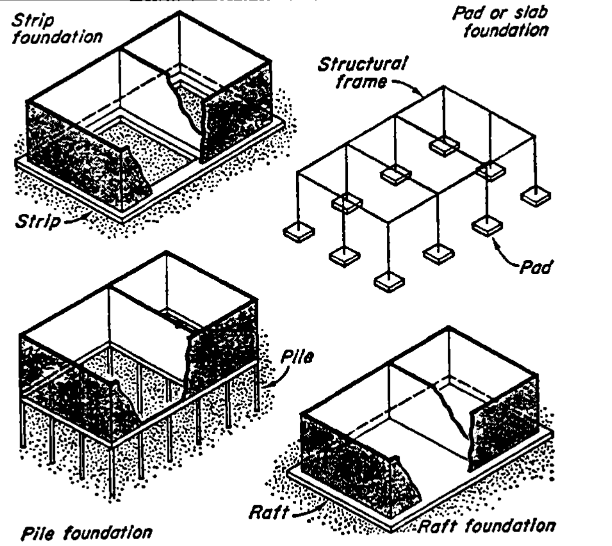
II Deep foundations include
- pile foundations and
- various types of piers which transfer their loads to the soil at a considerable distance below the underside of the building.

Shallow foundations are always the cheapest. An exeption may be the use of short bored piles instead of strip foundations in shrinkable clays.

STRIP foundations = under continous walls
PAD(or slab) -"- = under isolated piers or colums
are used on sites where a sufficient depth of reasonably strong subsoil exists near the surface of the ground.

RAFT foundation =
by which the whole of the building area is covered, are used e.g. where no firm bearing strata of soil exists at a reasonable depth below the surface and a maximum area of foundation is required to bring the imposed pressures within the low bearing capacity of the weaker soils and of some made-up ground.

PIERS and PILES =
may be viewed as columns passing through weak soil to transmit the building load to lower strata where the pressure can be safely resisted. They may also be used to transfer loads to the soil below the level likely to be affected by moisture movement.



5.3.2 Choice of foundation

The choice of a foundation must take account of both - soil and superstructure

For example: A stiff rigid building, one with plain monolithic concrete walls, will be affected by differential movement to a greater extent than one with brick or block walls. Within certain limits distortion can be accommodated in the latter by fine cracks distributed throughout the joints whereas in the former the distortion will rapidly cause large cracks to be formed.
In the case of small scale buildings the nature of the structure in respect of different movement is less important.

- Foundation design requires an appreciation of the ability of the structure to withstand relative movements without dangerous overstress and damage to the structure.

- Small scale buildings affect the soil at shallow depth only, so that account need to be taken only of soil movement due to causes other than loading.

- Where the soil is stable the possible causes of movement will be changes in moisture content of the soil. Movement can be avoided by placing the foundation at an adequate depth.

CHOICE OF FOUNDATIONS

- on unstable soils, special measures must be taken whatever the scale of the building.
- Overall or total settlement must be limited so that services and drains connected to the building are not damaged, alternatively, provision must be made for flexible connections.
- The table below indicates the sutibility of the foundation types described above to the various types of soil.

Soil type and site condition	Foundation	Details	Remarks
Rock, solid chalk, sands and gravels or sands and gravels with only small proportions of clay, dense silty sands	Shallow strip or pad footings as appropriate to the load-bearing members of the building	Breadth of strip footings to be related to soil density and loading (see Fig. 4.2). Pad footings should be designed for bearing pressures tabled in CP 101 : 1963. For higher pressures the depth should be increased and Civil Engineering Code of Practice No. 4. 'Foundations' consulted	Keep above water wherever possible. Slopes on sand liable to erosion. Foundations 0.5 m deep should be adequate on ground susceptible to frost heave although in cold areas or in unheated buildings the depth may have to be increased. Beware of swallow holes in chalk
Uniform, firm and stiff clays:			
(1) Where vegetation is insignificant	Bored piles and ground beams, or strip foundations at least 1 m deep	Deep strip footings of the narrow widths shown in Fig. 4.3 can conveniently be formed of concrete up to the ground surface	Downhill creep may occur on slopes greater than 1 in 10. Unreinforced piles have been broken by slowly moving slopes
(2) Where trees and shrubs are growing or to be planted close to the site	Bored piles and ground beams	Bored piles dimensions as in page 65.	
(3) Where trees are felled to clear the site and construction is due to start soon afterward	Reinforced bored piles of sufficient length with the top 3 m sleeved from the surrounding ground and with suspended floors, or thin reinforced rafts supporting flexible buildings, or basement rafts		
Soft clays, soft silty clays	Strip footings up to 1 m wide if bearing capacity is sufficient, or rafts	See page 63 and CP 101 : 1963	Settlement of strips or rafts must be expected. Services entering building must be sufficiently flexible. In soft soils of variable thickness it is better to pile to firmer strata (See Peat and Fill below)
Peat, fill	Bored piles with temporary steel lining or precast or *in situ* piles driven to firm strata below	Design with large safety factor on end resistance of piles only as peat or fill consolidating may cause a downward load on pile (*see Digest 63*) Field tests for bearing capacity of deep strata or pile loading tests will be required	If fill is sound, carefully placed and compacted in thin layers, strip footings are adequate. Fills containing combustible or chemical wastes should be avoided
Mining and other subsidence areas	Thin reinforced rafts for individual houses with load-bearing walls and for flexible buildings	Rafts must be designed to resist tensile forces as the ground surface stretches in front of a subsidence. A layer of granular material should be placed between the ground surface and the raft to permit relative horizontal movement	Building dimensions at right angles to the front of long-wall mining should be as small as possible

Soil type and site condition	*Foundation*	*Remarks*
Rock, solid chalk, sands and gravels or sands and gravels with only small proportions of clay, dense silty sands	Shallow strip foundations, pad foundations, (as appropriate to the load-bearing members of the building) Surface raft See Table 10	Keep above water wherever possible. Slopes on sand liable to erosion. Foundations to be 460 mm below ground level on ground susceptible to frost heave (see text)
Uniform, firm and stiff clays: 1 Where vegetation is insignificant	Strip or pad foundations at least 1·07 m below ground level Bored piles See Tables 10 & 12	With these soils downhill creep may occur on slopes greater than 1 in 10. Unreinforced piles have been broken by slowly moving slopes
2 Where trees and shrubs are growing or to be planted close to the site	Bored piles See Table 12	
3 Where trees are felled to clear the site and construction is due to start soon afterward	Reinforced bored piles of sufficient length with top 3 m sleeved from the surrounding ground and with suspended floor Thin reinforced rafts supporting flexible superstructure Basement rafts See Part 2	
Soft clays, soft silty clays	Strip foundations up to 850 mm wide if bearing capacity is sufficient See Table 10 Rafts See Part 2	Settlement of strips or rafts must be expected. Services entering building must be sufficiently flexible. In soft soils of variable thickness it is preferable to pile to firmer stratum
Fill (made up ground) Peat	Pier foundations Piles driven to firm stratum below Special raft foundations with or without flexible superstructure See Part 2	If fill is sound, carefully placed and compacted in thin layers, strip foundations are adequate
Mining and other subsidence areas	Special raft foundations with or without flexible superstructure See Part 2	

Table 11 Suitability of foundation types to various soils
Based on information in Building Research Digest 67

5.3.3 Spread foundations

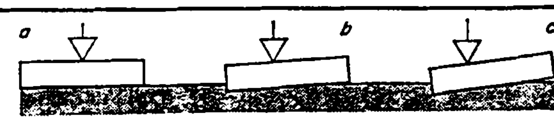
Must be designed so that
- the soil is not overstressed
- the pressure on the soil under them is equal at all points

in order to avoid unequal settlement under the actual foundation.

This is ensured by providing sufficient area of foundation and by arranging the centre of gravity of the applied loads to coincide with the centre of area of the foundation.

Strip foundations and pad foundations require the foundation to be placed symmetrically with the wall or column it supports

- If the load is applied eccentrically, the pressure on one side will be greater than the average pressure, causing greater consolidation of the soil on that side of the foundation.
- When the eccentricity is great, the increased stress could exceed the safe bearing capacity of the soil, even though the average stress might be well below it.
- When the eccentricity is greater than 1/6 of the foundation width, tensile stress occurs and causes the foundation to rise off the soil.

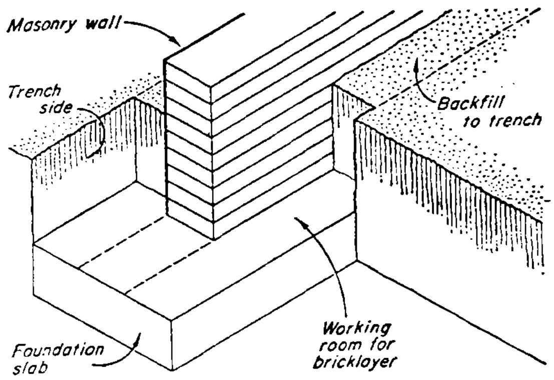


Effect of eccentric loading on foundations

STRIP FOUNDATIONS

5.3.3.1 Strip foundations

Consist of a strip of concrete under a continous wall carrying a uniform by distributed load.



Strip foundation

The stresses in the soil due to loading have to be well within the lowest limit of safe bearing capacity for any particular soil type, resulting in wider foundations than those which would fully stress the soil. This is the basis of the minimum widths laid down for stripe foundations in the Building Regulations and given in the table below.

Where the adges of a foundation project beyond the faces of the wall it supports bending due to contilever action will occur as a result of the resistance of the soil, causing bending and shear stresses in the foundation.

The tensile strength of unreinforced concrete is low, and in order to keep these stresses within the capacity of the concrete : the strip must be of adequate depth.

The required area (as in case of all spread foundations) is related to the imposed load and the bearing capacity of the soil.

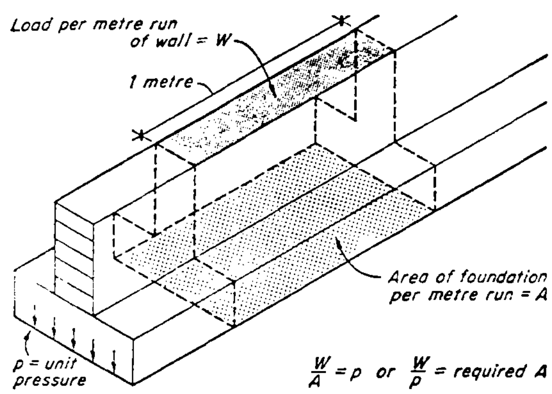
The imposed load is considered as load /m the width of the strip is made such as to give sufficient area/m run of foundation.

e.g. If the loading is 30 KN/m and the soil is stressed not more than 50 KN/m2 the min. width should be 0.60 m. (load : stress). That means : In every metre run of foundation the load of 30 KN will be distributed over 0.60 m2 of soil, resulting in a pressure of 50 KN/m2.

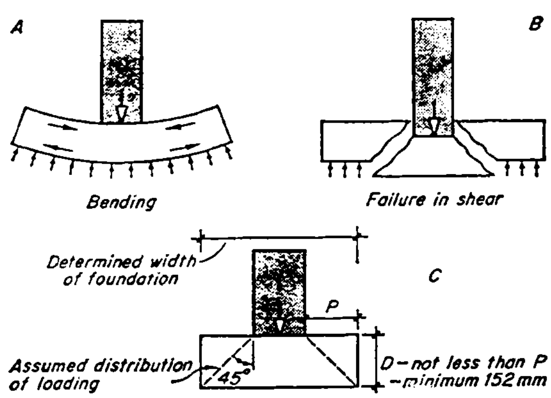
In cases of light loading on reasonably strong soils a strip no wider than the wall it carries may be sufficient.

In practice, with masonry walls some spread is usually provided (12,5-15,0 cm on each side) to allow working room. This also provides some stability to the wall before it is tied in by floors and roof.

For hand excavation : min. width 60 - 75 cm depending on the depth.



Foundation width



Foundation depth

DEEP STRIP FOUNDATIONS

Concrete fails under a compressive load usually by tensile shear failure along planes lying at an angle of about 45° to the horizontal.

Code of Practice 101: 1963 requires an angle of spread of load from the wall base to the outer edge of the foundation of not more than 45° which results in the thickness being not less than the projection of the base beyond the face of the wall it carries.

Vary wide strips are reinforced to keep their depth within economic limits.

Heavy loads concentrated at points in the run of a wall carrying otherwise uniformly distributed load will result in greater loads on the foundation at these points.
In order to ensure equal stresses at all points in the soil these extra loads must be distributed to the soil through larger foundation areas.

For mass concr., a 1:3:6 mix is commonly used, with fairly large aggregate - say 38-50 mm. Concrete should be poured as soon as possible after excavation of trences.
(Clays and chalk soils losing strength when become wet; clay drying -out causes shrinkage which is followed by expansion).
If concr. cannot be placed on completion of excavation, the bottom should be protected by 5 cm of weak concr. blinding, or 7,5 cm to 10 cm of soil should be left for excavation immediately prior to concreting.

Brick footings: Another way of speading the load of the walls to the soil is to make the base of the wall thicker by means of off-sets called footing courses.
The wall is built with 1/4 B off-sets each side for every course of bricks.
The effect is: a larger surface area in contact with the ground

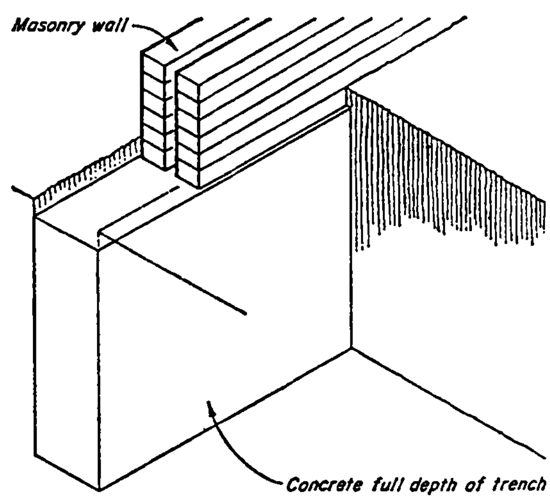
5.3.3.2 Deep strip foundations

Firm or stiff shrinkable clays are strong and when carrying light loads necessiate quite small foundations (possibly not wider than the wall carried). But these soils move considerably with changes in moisture content, therefore the bottom of the foundation should be at least 1 m below ground level.
Narrow excavation is required (perhaps 30 cm wide and more than 1 m deep)

- it has to be dug by mechanical means and filled with concrete to within a few cm of the ground surface.
- much less soil has to be excavated and backfilling is eliminated.
- where conditions are suitable it is cheaper to construct and quicker to complete than the wider strip foundations.

The conditions necessary to make it economic are

1) a self-supporting soil to avoid timbering (firm, shrinkable clays possess this characteristic)
2) adequate runs of straight trenching with a min. amount of corner trimming (to justify the cost of a mechanical excavator).



Deep strip foundation

5.3.3.3 Stepped foundations

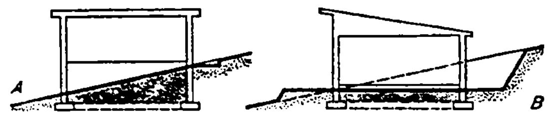
Exept in certain types of structures transferring inclined thrusts to the ground all foundations must bear horizontally on the soil.

If strip foundations to a building on a sloping site are at the same level throughout, those on the higher side will be greater distance below ground level than the remainer, necessiating deeper trenches and a greater amount of walling in the soil.

There are two ways in which this building into the soil may be reduced:
1) by cut or cut-and-fill to provide a horizontal plane off which to build

2) by stepping down the slope of the foundations to those walls parallel to the slope.

Overlap to be not less than T or 2 x H, which ever is the greater with a min. of 30 cm.



Foundations on sloping sites

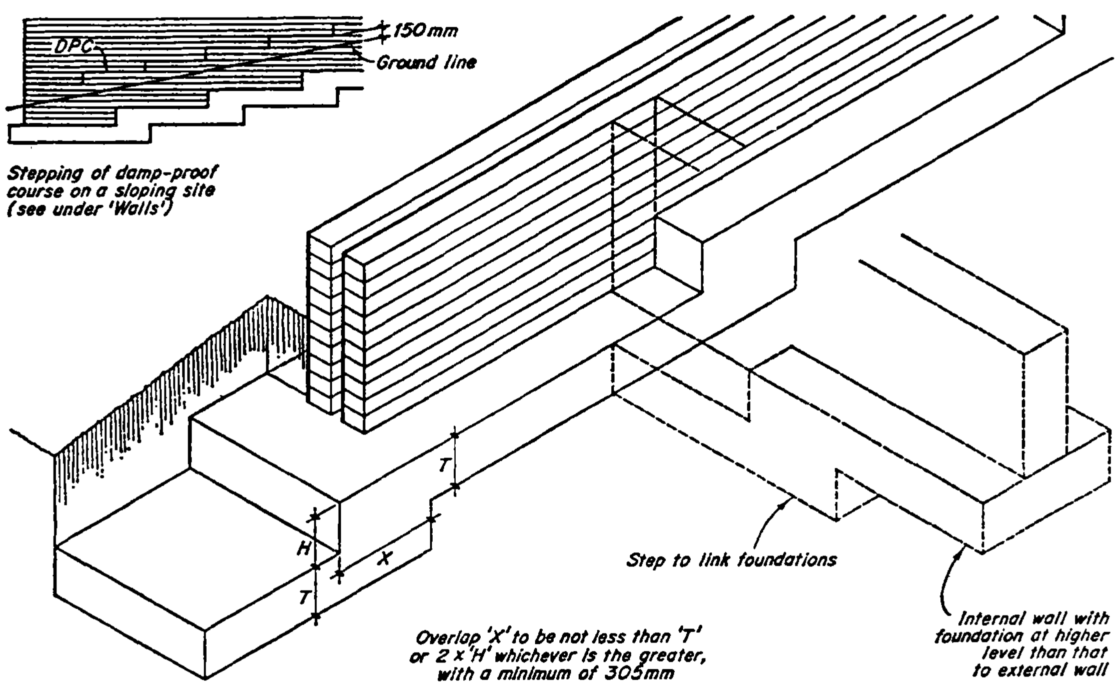
The steps should be relatively short and sufficient in number to keep their heights small and uniform. (Height of step should not exceed the thickness of the foundation).

The lengths need not be uniform, but should be varied (where necessary) to keep the heights as uniform as possible.

Ex each step the higher foundation must lap over the lower.

The foundations should be so arranged that a step accurs at any intersection with a cross wall, the step being on the side where the groundlevel is highest.

On sloping sites it is advisable to lay subsoil drainage, in the form of land drains, across the slope on the uphill side of the building.



Stepped foundation

PAD FOUNDATIONS

5.3.3.4 Pad foundations

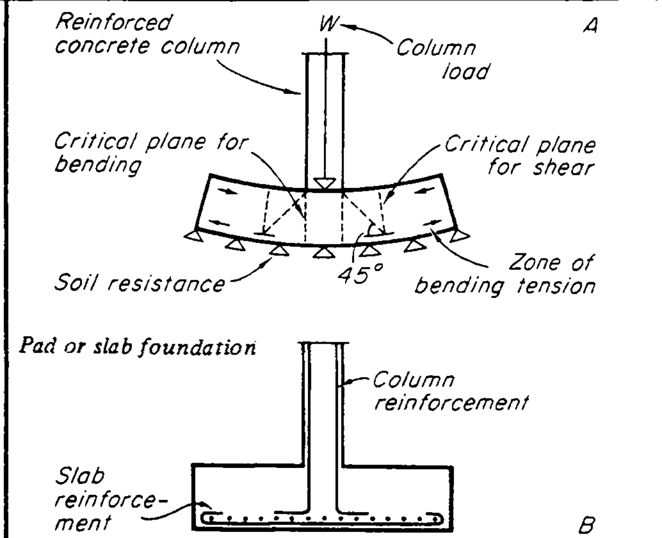
Isolated piers or columns are normally carried on an independet slab of concrete, commonly called a PAD FOUNDATION the pier or column bearing on the centre point of the slab.

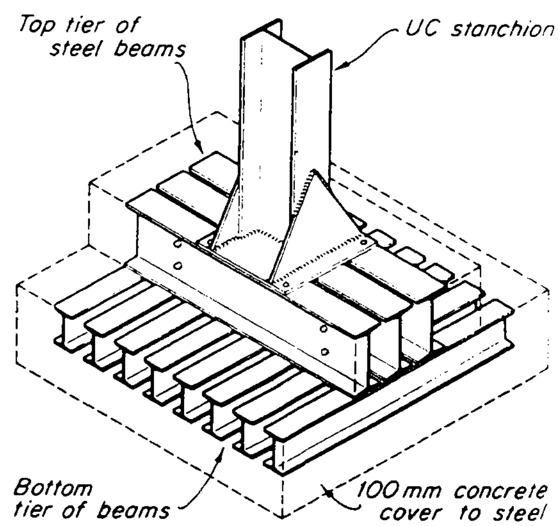
The area of foundation is determined by dividing the column load by the safe bearing capacity of the soil and its shape is usually a square.

Its thickness is governed by the same considerations as for strip foundations and is made not less than the projection of the slab beyond the face of the pier or column or the edge of the baseplate of a steel column.

It should in no case be less than 150 mm thick. As in the case of strip foundations when a column base is very wide a reduction in thickness may be effected by reinforcing the slab.

In a framed structure where loads on different columns vary, the sizes of the bases must vary in order to maintain equal soil pressure under each and thus eliminate differential or unequal settlement.





Steel grillage foundation

RAFT FOUNDATIONS

5.3.3.5 Raft foundations

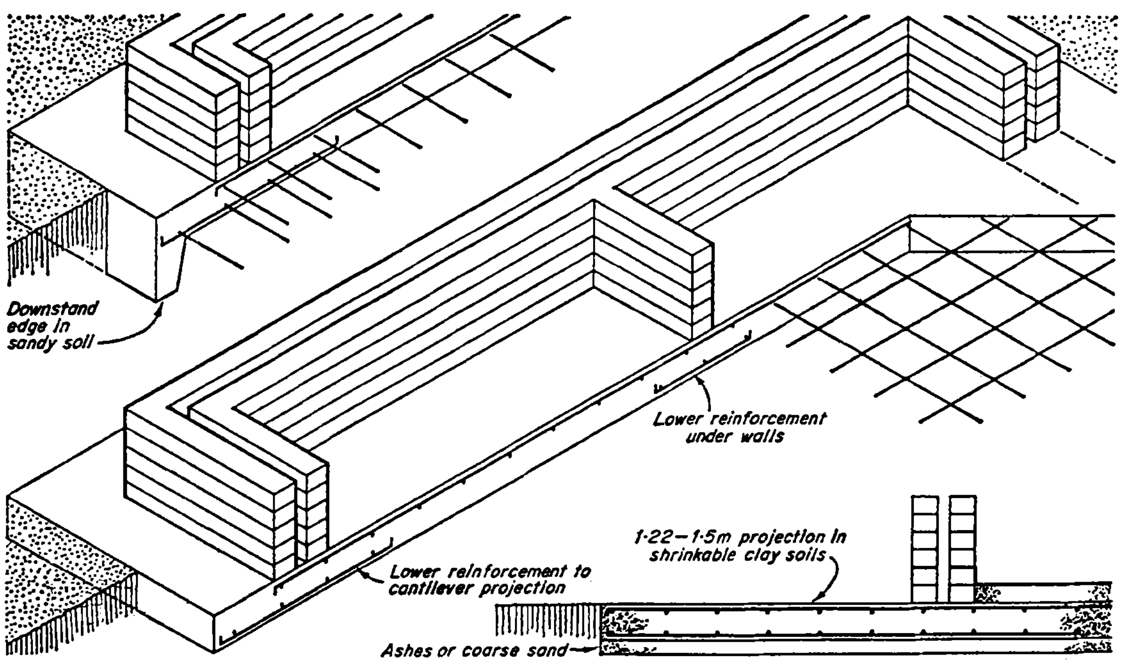
A RAFT FOUNDATION is a large slab foundation covering the whole building area, through which all the loads from the building are transmitted to the soil. When used for the purposes described here they are laid on, or just below the surface of the ground and are termed surface rafts.

Solid concrete ground floor slab construction is normal today. This slab, if about 150 mm thick and lightly reinforced, may be used as a light raft on all types of firm soils. Reinforcement is required at the top for crack control with some steel at the bottom under walls or columns to resist tensile stress in these zones, see fig. The raft should be extended about 300 mm beyond the perimeter walls. On sands it is preferable to form a 'downstand'edge all round to prevent erosion of the soil under the perimeter of the slab. If used on shrinkable clays the soil under the external walls should be protected from moisture changes and consequent movement by an extension of the slab 1.22 m to 1.5 m beyond the walls, see fig.

In this case reinforcement is generally as for rafts on other soils but top and bottom reinforcement must be provided under the external walls and in the extension to resist the tensile stresses at the top due to loads on the extension when the soil has shrunk under the slab edge and at the bottom due to the pressure of the clay when it swells.

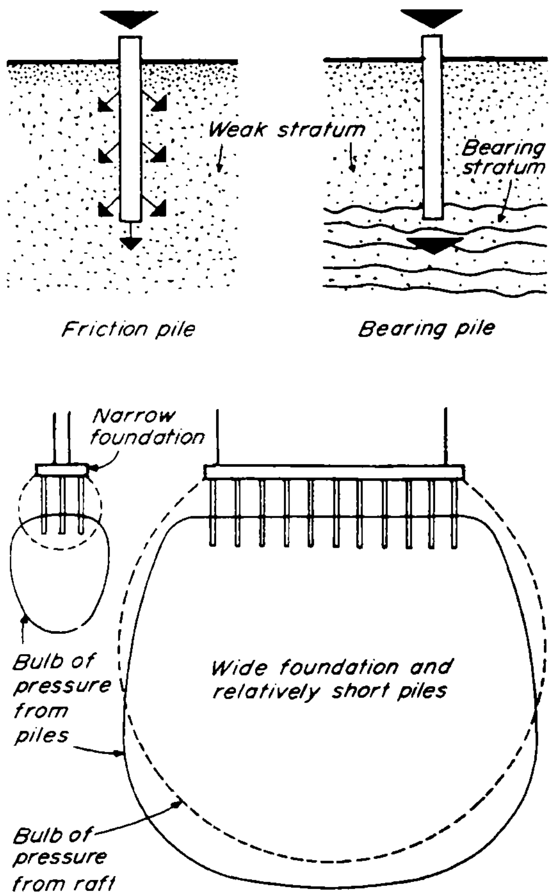
Light surface rafts can also be used to carry lightly loaded structures of certain types on soils subject to general earth movement.

As in all spread foundations the centre of gravity of the loads should coincide with the centre of area of the raft. This is facilitated when the building has a simple regular plan form with loadbearing elements such as walls, columns, stacks, disposed symmetrically about the axis of the building. Heavy elements such as stacks are best situated near the centre of the plan Excessive variation of loading results in problems which need careful consideration in the design of the foundation.



Surface raft foundation

PILE FOUNDATIONS



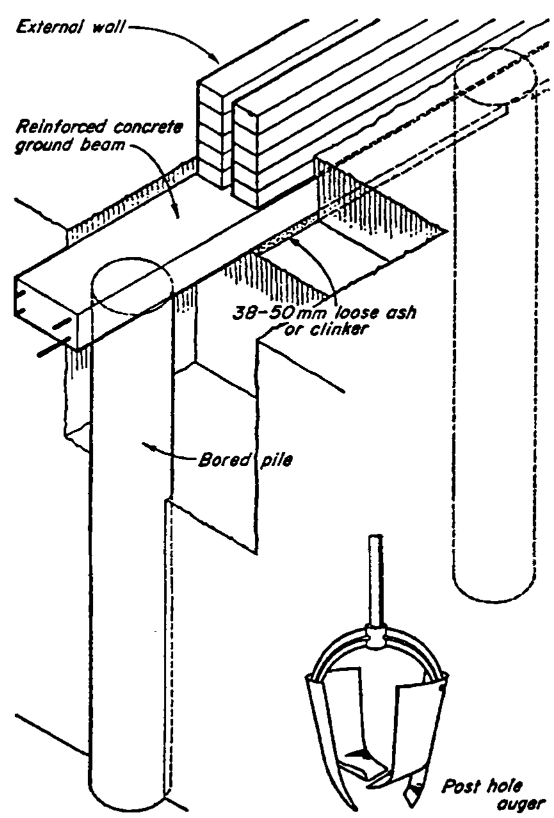
Pile foundations

5.3.4. Pile foundations

PILES are often used to transmit loads through soft soils or made-up ground. IN such circumstances, unless large in diameter, the piles will normally need to be reinforced. Piles of relatively short length can, however, be used economically in firm shrinkable clay as a means of founding below the zone of moisture movement. Such piles require no reinforcement because the diameter being large relative to length, the piles are stiff and they also receive considerable support from the firm soil through which they pass. In this type of soil the piles can be easily and quickly formed by boring. This particular form of pile is, therefore, called a short bored pile.

5.3.4.1 Short bored pile foundations

In shrinkable clays this foundation has a number of practical advantages over strip foundations: a reduction in the amount of excavated spoil, a cleaner site, faster construction and the fact that work can continue in weather which would make tranch digging impracticable. When mechanically bored in sufficient numbers this type of foundation is competitive in cost with a traditional strip foundation of appropriate depth. For a single building it may be slightly dearer than a deep strip foundation, although against this must be placed the advantages of the piles. Generally speaking, the stiffer the clay the cheaper will this type of foundation be relative to strip foundations.



Short bored pile foundation

In order to obtain the advantages of greater speed and economy relative to strip foundations the clay must be suitable for easy boring. If many tree roots are present and the soil contains a great number of stones, especially if large, trench digging is likely to be quicker and cheaper than boring for piles, although if mechanical boring can be used, auges larger than hand boring will permit can be adopted which cope more easily with stones.

Mechanical boring is much quicker than hand boring, especially when the holes must be large, but to be economic requires a sufficiently large contract of work on one site and, as for any mechanical plant, requires adequate preparation of the site and the programme of work to be carefully planned in advance to avoid idle time.

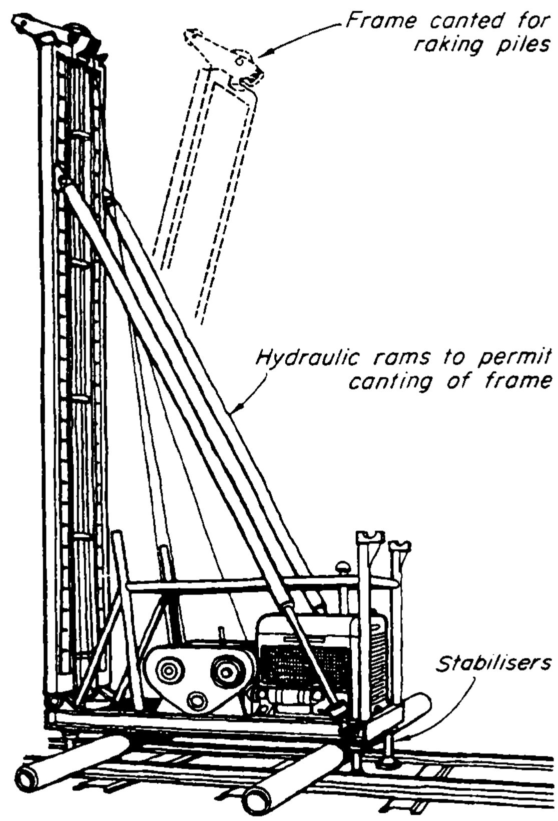
This type of foundation consists of a series of short concrete piles which, in the case of load-bearing wall structures, are spanned by a shallow reinforced concrete beam on which the wall is built (see fig.). Holes for the piles are bored manually or mechanically on the centre line of the beams to the required depth and diameter (see fig.). Small stones and layers of gravel present no problem but large stones must be broken up by a heavy chisel on extension rods. Larger augers cope with stones more easily than smaller ones but above 350 mm diameter the weight of the spil is too great for easy hand boring. A 250 mm diameter hole can be sunk 2.4 m in about 60 minutes, including rest periods, in soil free from stones.

In framed structures a pile or group of piles is placed under each column. In loadbearing wall structures piles are placed at the corners, at wall junctions and under stacks with further piles distributed between, sufficient to carry the imposed load, spaced as far as possible to produce uniform loading and to bring ground floor door and window openings centrally between piles.

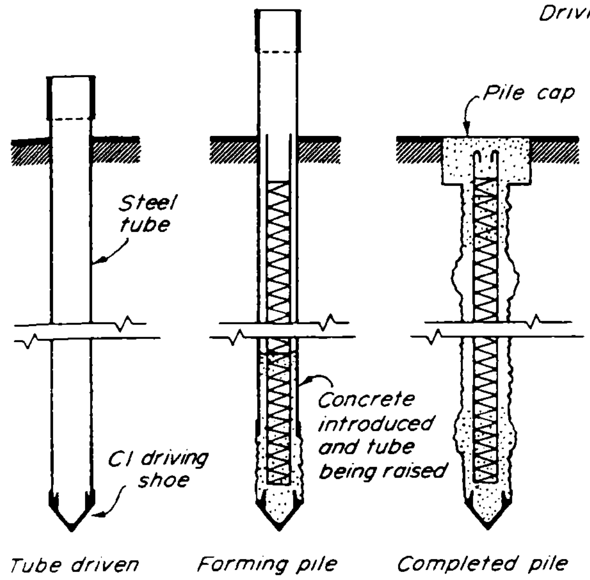
Soil strength classification	*Diameter of pile (mm)*	*Length of pile (m)*			
		2·4	3·05	3·66	4·27
		kN	kN	kN	kN
Stiff—cannot be moulded with fingers	254	40	50	60	70
(unconfined shear strength	305	50	60	75	90
more than 72 kN/m^2—see Part 2)	356	65	80	95	110
Hard—brittle or tough	254	55	65	80	90
(unconfined shear strength	305	70	85	100	115
more than 143 kN/m^2—see Part 2)	356	95	110	125	140

The figures are for clay which increases in strength with depth to the 'stiff' and 'hard' classifications near the bottom of the piles. The figures should not be applied to piles in other situations.

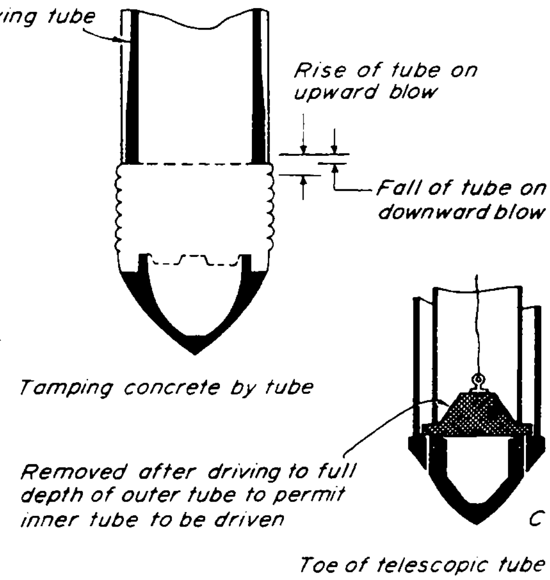
Table 12 Permissible loads on short bored piles
Based on information in BR Digest 67 (second series)



Piling frame



Top driven tube piles

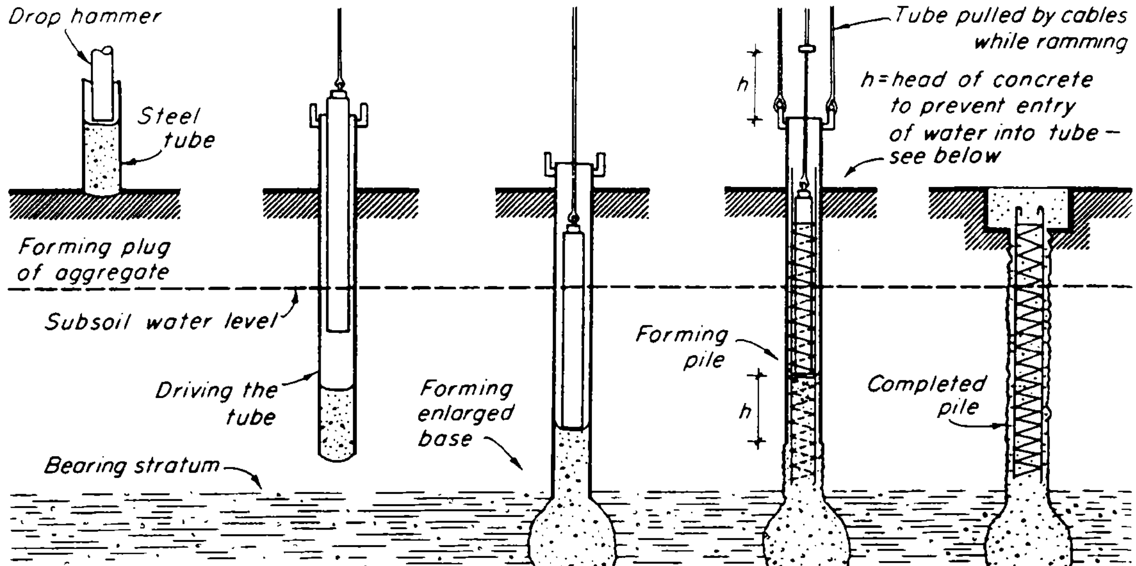


The shallow reinforced concrete ground beams should have a depth/span ratio of 1/15 to 1/20. Reduced 'equivalent bending moments' are used in their design taking account of the fact that the brickwork on the beam tends to act with the beam and as an arch tending to concentrate the load towards the supports. Top reinforcement is placed over the pile positions to take up the negative tensile stresses at these points.

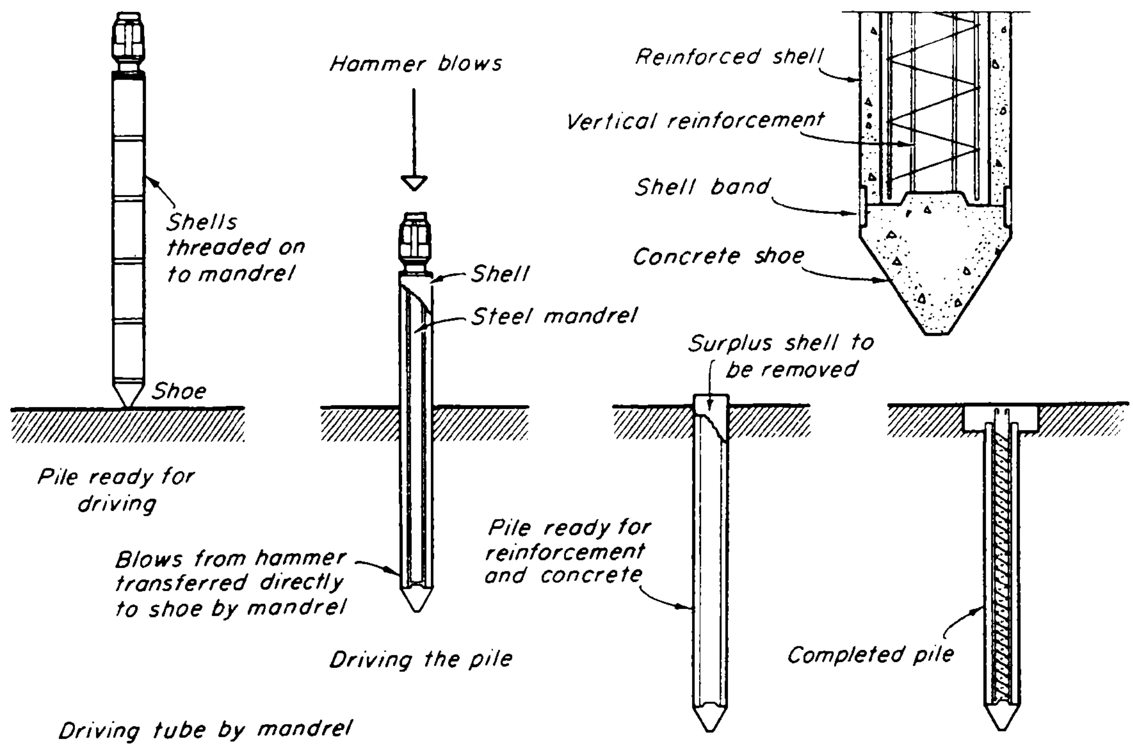
A 1:2:4 mix concrete is used for the work with a miminum water content to prevent excessive wetting and thus weakening of the clay. This is placed immediately each hole is bored, using a hopper to prevent soil entering the hole, each 305mm to 610 mm lift being thoroughly tamped. The beams are normally cast in a trench to avoid shuttering. If this is excavated before the holes are bored the concreting of piles and beams can be done simultaneously. If the beams are to be poured after the piles have set 9.5 mm diameter steel bars should be cast in the tops of the corner piles, set 610 mm in the pile and projecting 610 mm and bent over for casting in with the beams. A layer of 38 mm to 50 mm of loose ash or clinker must be placed under the beam to form a compressible layer to allow for ground movement below the beam.

Where trees exist on shrinkable clay soil closer to a building than their mature height or, in the case of groups or rows of trees, one and a half times their mature height, this type of foundation should always be used.

TOE DRIVEN TUBE PILES

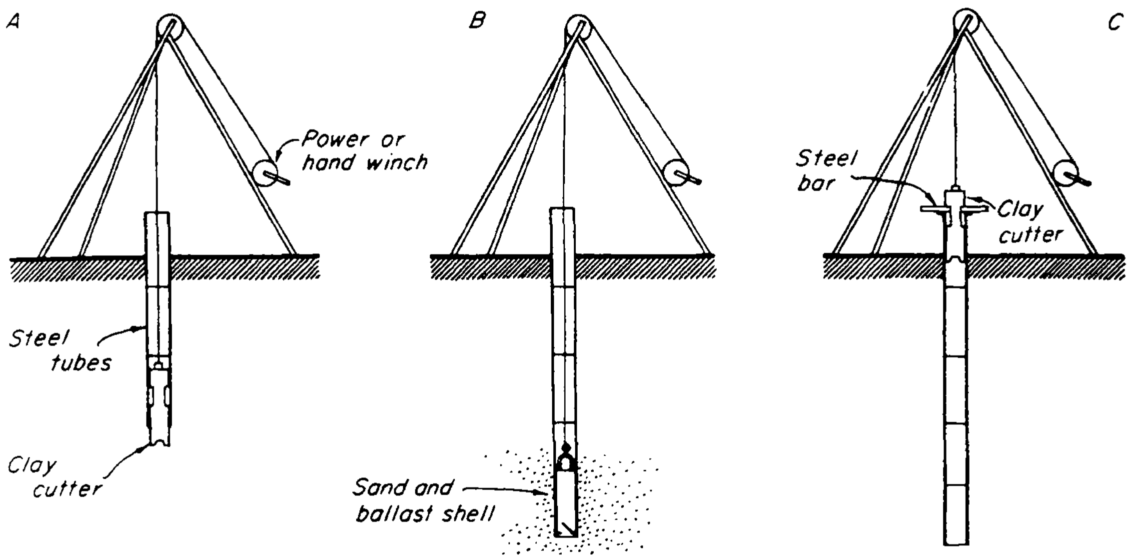


A Driving tube by drop hammer

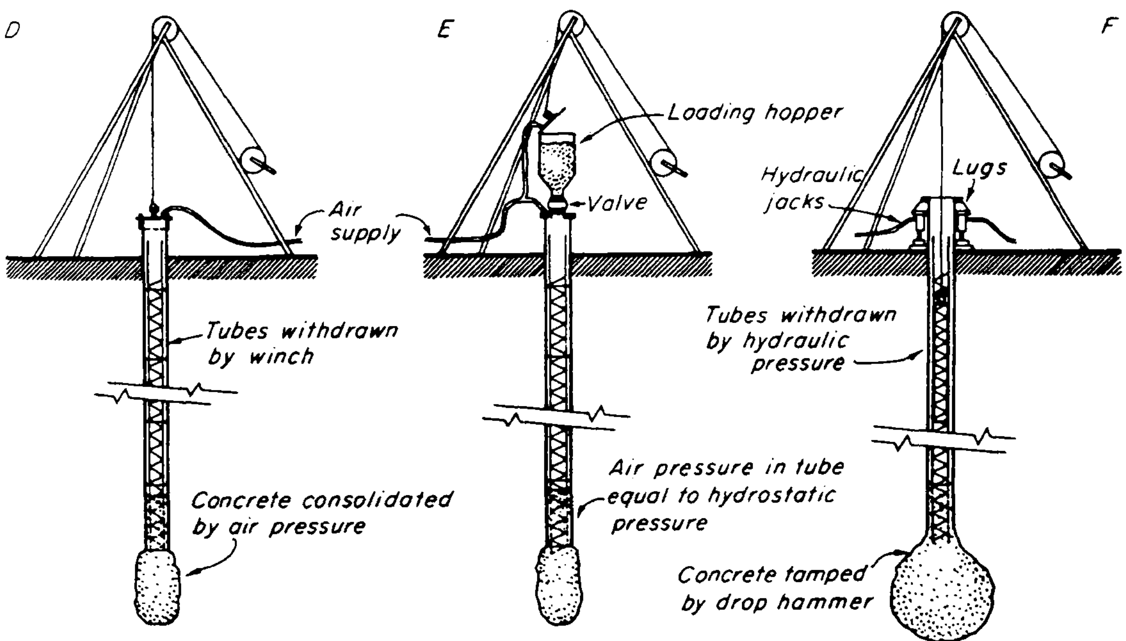


Driving tube by mandrel

BORED PILES



Sinking tubes through clay — *Sinking tubes through ballast* — *Tube driving (when necessary)*



Forming pile with compressed air — *Placing concrete through an air lock* — *Forming pile with a drop hammer*

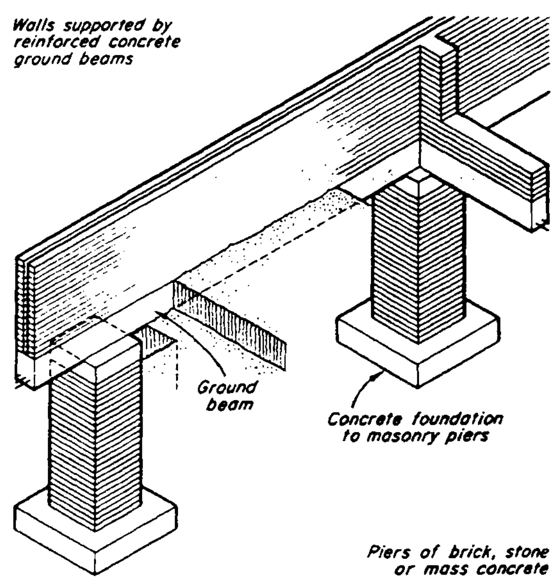
5.FOUNDATIONS compiled: D.VOLKE MAY '83	TYPES OF FOUNDATIONS	BUILDING CONSTR. LECTURE CET 2031/15.328
TCA TECHNICAL COLLEGE ARUSHA CHUO CHA UFUNDI ARUSHA	CIVIL ENGINEER DEPARTMENT	28

5.3.5 Pier foundations

These are frequently used on made-up ground where ordinary strip or pad foundations will often be inadequate to prevent excessive and unequal settlement, especially when the fill is poorly compacted. They can be economic up to depths of about 3.5 m to 4.5 m and consist of piers of brick, stone or mass concrete in excavated pits taken to the firm natural ground below. They are usually square and the size is dependent on the material used and the strength of the bearing soil below, but the smallest hole in which hand excavating can be carried out is about 1 m square. The foundation size is calculated as for a column base.

When this type of foundation is used the structure is carried on reinforced concrete ground beams spanning between the piers as shown in the fig.

Piles may be used in similar conditions but will need to be reinforced and as boring is not suitable through many types of fill on made-up ground piers provide a useful alternative within the economic limits of depth given above.



Pier foundations

Try to answer the following questions and use sketches for illustration

1. Foundations

   - Define the purpose of FOUNDATIONS!

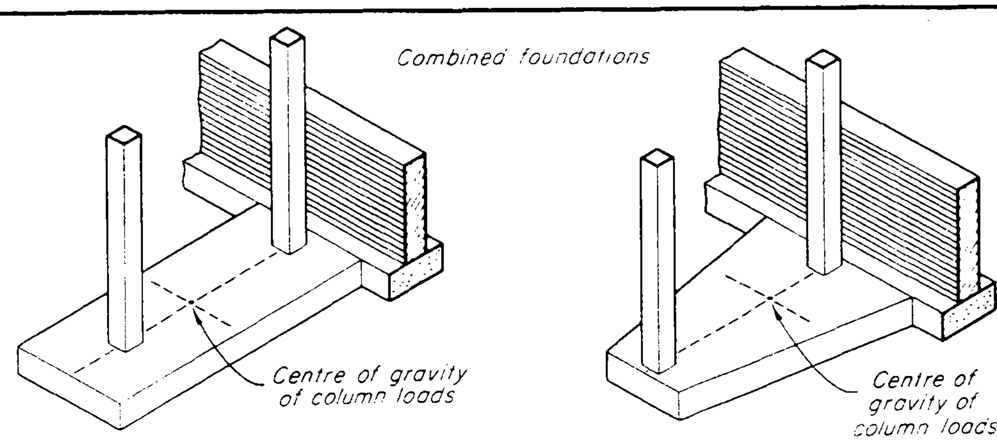
2. Soil Investigations

   - When becomes SITE EXPLORATION necessary?
   - What has to be considered digging TRIAL HOLES?
   - Where are BOREHOLES used for and how are they made?
   - Write notes on soil sampeling!
   - Which tests are most important to the foundation designer and how are they carried out?
   - Describe the LOAD or BEARING TEST!
   - Write notes on SOILS and SOIL CHARACTERISTICS!
   - Classify rocks and soils into 5 groups and describe briefly the type of soil of each group as well as their max. safe-bearing capacity.
   - Explain the following terms:
     . shearing stress
     . vertical pressure
     . contact pressure
     . plastic failure

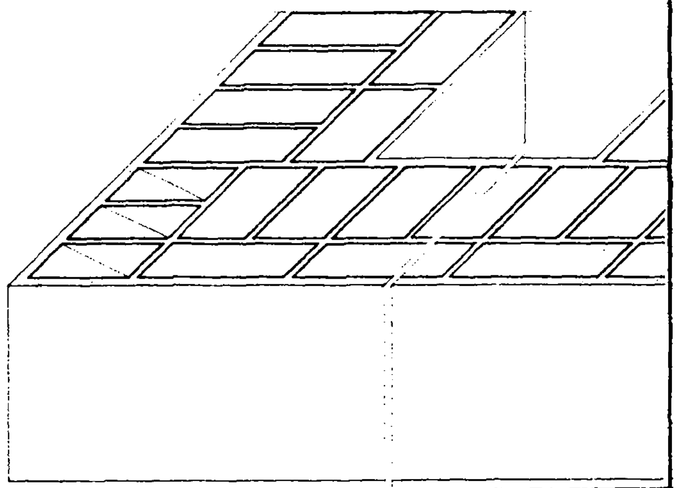
3. Excavations and Timbering
   - What do you have to consider in EXCAVATIONS and TIMBERING of trenches?

4. Types of Foundations
   - Classify the many forms of foundations
   - Which factors must be taken into account in the CHOICE OF FOUNDATIONS?
   - Write notes on
     . spread foundations
     . strip foundations
     . deep strip foundations
     . stepped foundations
     . pach foundations
     . raft foundations
     . pile foundations
     . short bored pile foundations
     . pier foundations

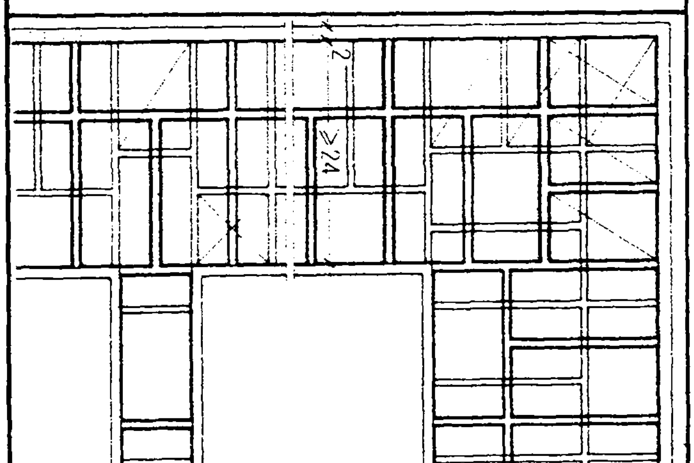
   and use neat sketches for illustration.



6. WALLS



CONTENTS:



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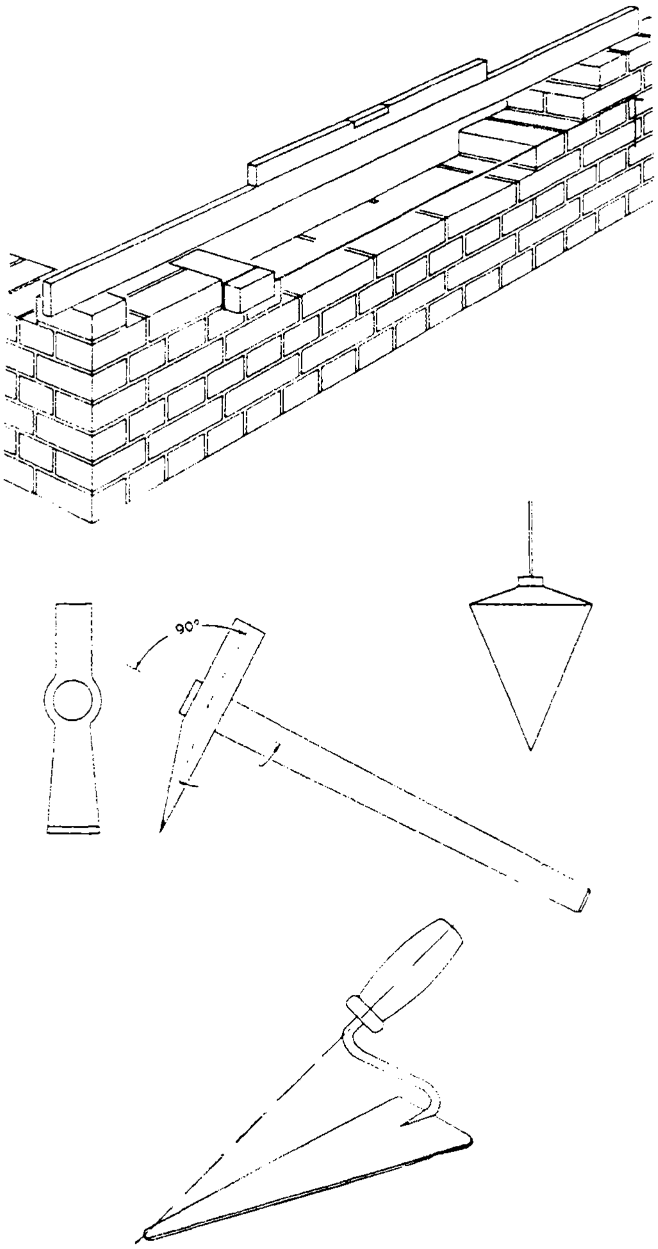

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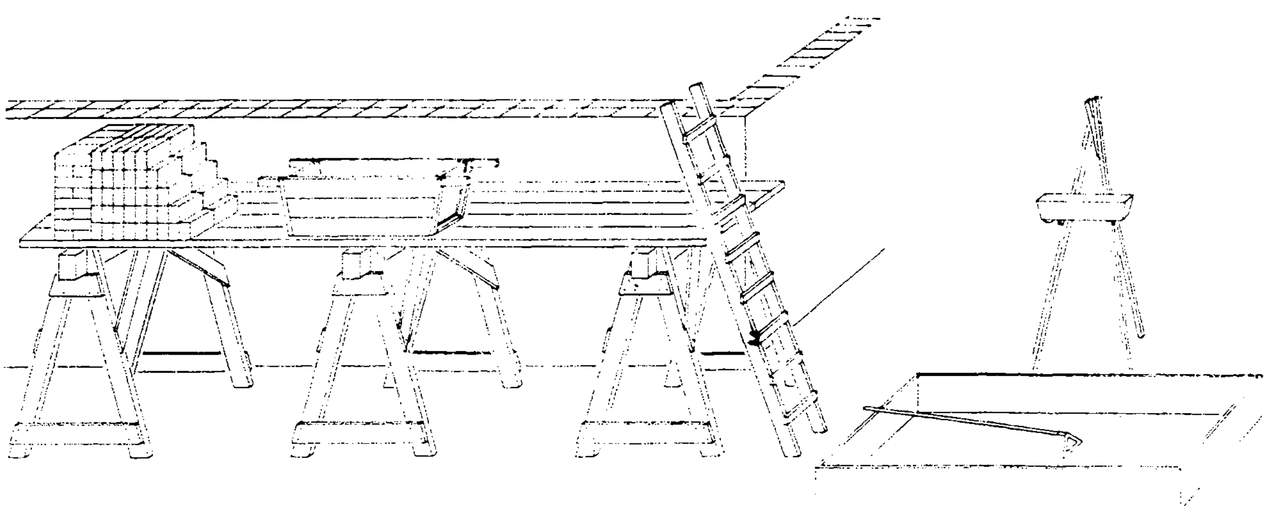
8. E. Neufert
   "Architect's Data."



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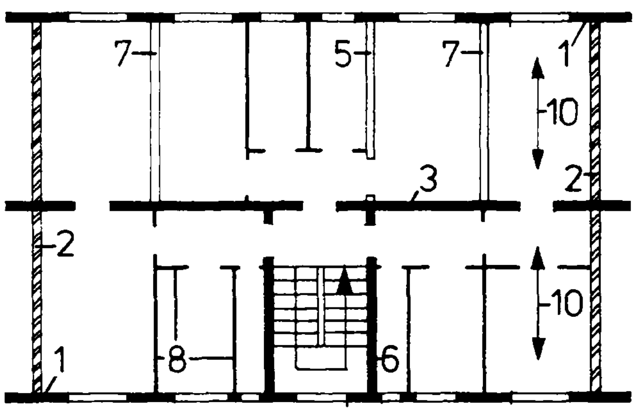
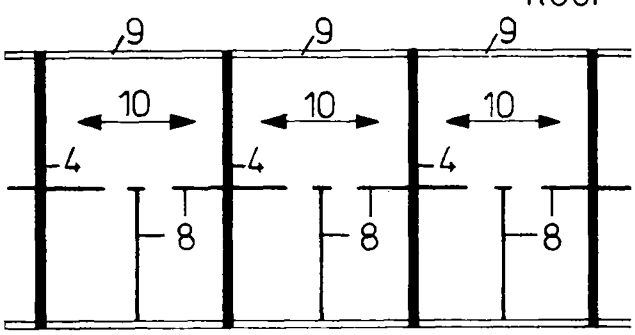
6. WALLS



1 EXTERNAL WALL ; load bearing
2 PARTY WALL ; fire proof
3 INTERNAL WALL ; load bearing
4 CROSS WALL ; load bearing
5 CROSS WALL ; stiffening
6 STAIRCASE WALL
7 PARTY WALL
8 PARTITION WALL
9 EXTERNAL WALL ; non load bearing
10 DIRECTION OF SPAN of the floor



6. Walls

6.1 Function and Properties of Walls

- Walls are the vertical ele - ments of a building
- They have to fulfill two func- tions:
  (1): loadbearing
  (2): space enclosing and di- viding
- There are certain requirements which a wall must satisfy:
  Adequate - strength and stabi- lity
  - weather resistance
  - thermal insulation
  - fire resistance

  (these functional requirements are not given in order of im - portance, since this will vary with the main function of the wall).

- STRENGTH and STABILITY:
  The strength of a wall is mea- sured in terms of its resistan- ce to the stresses set up in it
  o by its own weight
  o by superimposed loads and
  o by lateral forces (such as wind)
  Its stability in terms of its resistance to overturning
  o by lateral forces and
  o by buckling
  caused by excessive slender- ness.

The Building Regulations (which lay down requirements for the cal- culation of wall thicknesses) provide means for determining thicknesses other than by calcu- lating.

The Table below gives
RULES FOR DETERMINING THE THICK- NESS OF BRICK AND BLOCK WALLS (NON-CALCULATED)

TABLE 19 RULES FOR DETERMINING THE THICKNESS OF BRICK AND BLOCK WALLS (NON-CALCULATED WALLS)

Rule Number	Type of Wall	Building of which Wall Forms a Part	Height of Wall	Length of Wall	Minimum Thickness of Wall	Additional Requirements as to Thickness and Construction of Wall
1	Certain external walls and and separating walls not exceeding 12 m high	1. Single storey 2. Two storeys or more if the imposed load on each floor is less than 3 kN/m²	Not exceeding 3.6 m	Any length	200 mm for the whole height	(i) Subject to Rules 4 to 8 below the thickness of these walls shall be as in adjoining column. (ii) In addition the thickness of the wall, in any storey, for not less than one-quarter of its length, shall not be less than one-sixteenth of the height of that storey.
			Exceeding 3.6 m but not exceeding 9 m	Not exceeding 9 m	200 mm for the whole height	
				Exceeding 9 m	300 mm from the base for the height of one storey and 200 mm for the rest of its height	
			Exceeding 9 m but not exceeding 12 m	Not exceeding 9 m	Ditto	
				Exceeding 9 m	300 mm from the base for the height of two storeys and 200 mm for the rest of its height	
2	Certain other and external walls and separating walls not exceeding 12 m high	Other than those in Rule 1	Not exceeding 7.5 m	Unlimited	Subject to Rules 4, 5, 7 and 8, the thickness must be not less than 300 mm (200 mm for the top storey)	(i) In addition (*a*) the thickness of the wall between the base and 5 m below the top shall not be less than the thickness which would be obtained if the wall were to be built solidly throughout the space between straight lines drawn on each side joining the thickness at the base to the thickness at 5 m below the top. (*b*) The thickness of the wall in any storey for not less than one-quarter of its length to be not less than one-fourteenth of the storey height. (*c*) No offsets allowed in the wall except at the level of lateral supports.
			Exceeding 7.5 m but not exceeding 9 m	13.5 m		
			Exceeding 9 m but not exceeding 12.2 m	10.5 m		
3	Certain internal load-bearing walls (excluding a separating wall)	Any building other than a house of one or two storeys	Heights in Rule 1 or 2 (as the case may be) with lengths twice those in Rule 1 or 2 (as the case may be)		Half the thicknesses in Rule 1 or 2 (as the case may be)	
4	Certain external walls and separating walls of pier construction	Any	Heights and lengths in Rule 1 or 2 (as the case may be)		Subject to Rule 6, if the wall has piers distributed throughout its length and a pier at each end, the mean thickness of the wall (the plan area of the wall divided by its length) shall be not less than the thickness required by Rules 1 or 2 (as the case may be) and the thickness of the wall between the piers shall not be less than 200 mm.	
5	Cavity walls. *Ties placed 900 mm apart horizontally and 450 mm vertically, with an additional tie every 300 mm height at jambs to openings. Cavity not less than 50 mm or more than 75 mm wide.*	Any	Heights and lengths in Rule 1 or 2 (as the case may be)		Leaves to be not less than 100 mm thick. The overall wall thickness shall be not less than (i) 250 mm, or that required for a solid wall by Rules 1 or 2 (as the case may be) increased by the cavity width, *whichever is the greater.* Note that the *inner* leaf may be not less than 75 mm thick if: (*a*) the wall is of a single storey house or the upper storey of a two-storey house; and (*b*) the leaf is not more than 8 m long and 3 m high (5 m for a gable); and (*c*) the wall is built with mortar not weaker than 1 : 2 : 9; and (*d*) the number of ties given in column 2 is doubled; and (*e*) the roof load is supported by the outer leaf.	
6	External walls of certain small buildings and annexes	1. Single storey building other than a house if its width, measured in the direction of the roof span is not more than 9 m	Not exceeding 3 m	Any length	The walls may be not less than 100 mm thick provided: (i) it is bonded at each end and intermediately with piers or buttresses which are not less than 200 mm square on plan (including the wall thickness), or of such greater size as may be needed for stability, and so placed that the wall is divided into lengths not exceeding 3 m; and (ii) the wall is built with mortar not weaker than 1 : 1 : 6; and (iii) the wall is not subjected to any load other than the distributed load of the roof of the building or annexe of which it forms a part and is not subject to lateral thrust from such roof.	
		2. An annexe not more than 3 m high (*e.g.*, verandah, garage, tool shed, lavatory, etc.) attached to a house	Not exceeding 3 m	Any length		
7	Bays and gables over bay windows	Any	Rules 1 and 2 shall not apply to any part of an external wall which forms a bay for a bay window; and is above the level of the sill of the lowest window opening in such bay; and built with mortar not weaker than 1 : 2 : 9.			
8	Parapets	Any	Not to exceed six times the thickness	Any	Not less than 200 mm or that of the wall on which it is carried (whichever is the less)	

NOTES

Openings. The number and size of these shall not be such as to impair the stability of the wall. (It is considered that the maximum of window lengths in a wall is three-quarters of the wall length.)

Chases. Vertical chases to be not deeper than one-third of the wall thickness (one-third of the leaf thickness in cavity walls). Horizontal chases to be not deeper than one-sixth of the wall thickness (one-sixth of the leaf thickness in cavity walls).

RAIN

- WEATHER RESISTANCE:
  The external walls of a building are required to provide adequate resistance to rain and wind penetration.

The actual degree of resistance will depend
- upon the height of the wall and
- upon the locality and exposure.

- Wind penetration to walls rarely presents difficulties in solid wall construction only with some types of modern walling of dry construction (consisting of external cladding or sheathing and dry internal linings on some form of frame) problems may arise.

- Wind has considerable influence on rain penetration, forcing the water through pors and cracks which otherwise it might not penetrate (especially on high buildings).

WIND

- Rain penetration through walls can be resisted in three ways:

  (1) by ensuring a limited penetration only into the wall thickness
  (2) by preventing any penetration through the outer surface
  (3) by interupting the capillary paths through the wall.

  o In the first the water will be absorbed by a premeable walling material and held as in a sponge, near the outer surface until dry weather conditions, permit it to evaporate

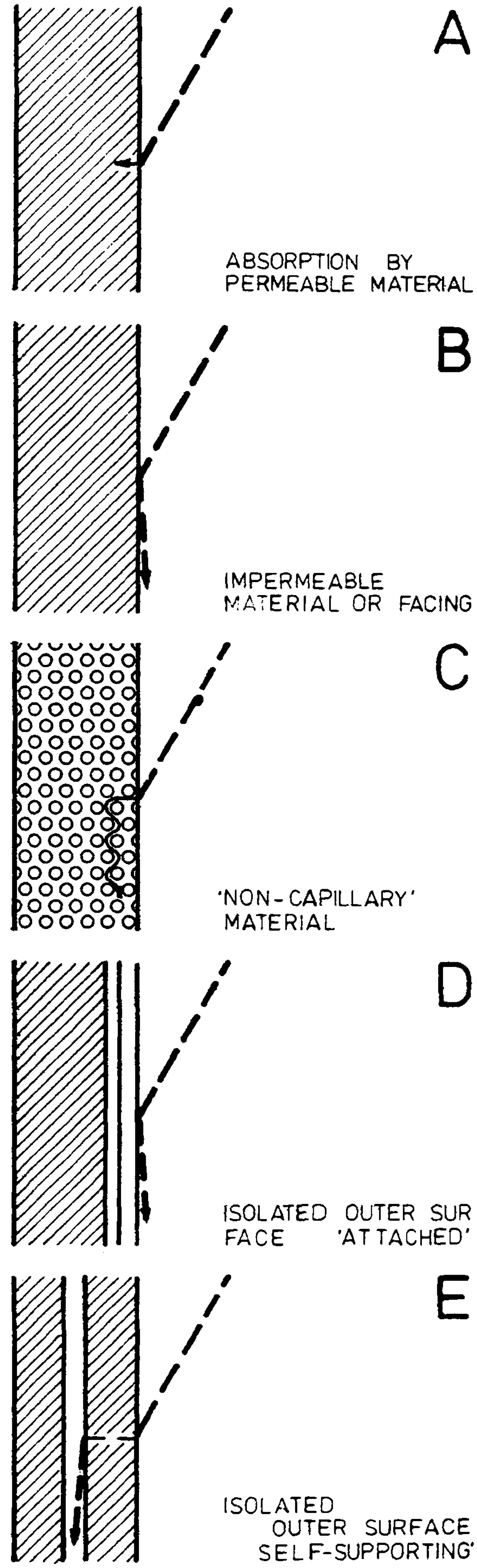
  o In the second the use of an impermeable walling material (or facing) will force the water to run down the wall face without entering the wall thickness
    - (Both methods present difficulties)-

  o The alternative to either the first or the second is the third method:
    The breaking of the capillary paths by the use of a solid wall structure in which no capillary path exist such as:

RAIN

- no-fines concrete (composed of cement and coarsed aggregate alone, the fine aggregate being omitted)
  or
- by the provision of an outer surface which is isolated from the inner surface by a continous gap or cavity. The outer surface or skin may be non - load bearing (i.e. tile hanging or large suspended cladding panels, or load bearing as in cavity wall construction)

- In addition to protection against lateral penetration of rain a wall must be protected at his base against ground moisture, in form of horizontal and vertical damp - proof. barries. Protection may be also necessary against the entry of subsoil water under pressure through basement walls.



FIRE

BS 476
PART 8 1972

- FIRE RESISTANCE:
  According to the Building Regulations chapter 5:
  'FIRE RESISTANCE of an element of structure, a door, or other part of a building means the period of time for which a specimen construction (of the same specification as the particular element, door, etc.) would satisfy the requirements of the test by fire to BS 476 : Part 8 1972 in respect of
  a) stability
  b) integrity and
  c) insulation'

  The term fire resistance is a relative term applied to elements of structure and not of material. It is not to be confused with non-combustibility.

THERMAL INSULATION

- THERMAL INSULATION:
  The external walls of a building, together with the roof must provide a barrier to the passage of heat in order to maintain satisfactory internal conditions without the wasteful use of an air conditioning system.
  Adequate thermal insulation depends mainly on the locality where the building will be erected. (At the coast region other provisions have to be introduced than in regions like Arusha, Iringa or Mbeya.)
  . Heat trnsmission values for various forms of construction are given in special handbooks (i.e. Mitchel Building Construction: Enviroment and Services) where the principles of thermal insulation are fully discussed.

WALL under LOAD

6.2 The Behavior of the WALL under load

- Under vertical loading, a wall may
  - o crush
  - o buckle or
  - o settle.

-crushing
-buckling
-settling

- CRUSHING:
Is caused by over-stressing the material of which the wall is constructed. This is avoided by adequate thickness at all points to keep the stresses in the wall within the safe compressive strength of the materials.

Eccentric loading (that is loading applied not through the centre of gravity of the wall) has the effect of increasing the compressive stress in the wall on the loaded side and of decreasing it on the unloaded side and tends to cause bending in the wall whatever its thickness.

The reason:
A moment is set up in the wall and to maintain equilibrium this must be resisted by an opposite moment within the wall (the forces for which must be provided by the walling material itself.)

This causes COMPRESSION on one side of the axis of the wall and TENSION on the other

The result of this can be twofold:

1 the increased compressive stress could become greater than the safe compressive strength of the walling material.

2 if the eccentricity is too great tensile stresses will be set up in the side opposite that on which the load is applied.

Fig. indicates the increasing compressive stress and the development of tensile stress with increasing eccentricity of load.

In practice the actual stresses in the wall are determined by the formula

$$\frac{W}{A} \pm \frac{We}{Z}$$

Where $\frac{W}{A}$ = stress due to the load applied axially

We = moment caused by eccentric loading

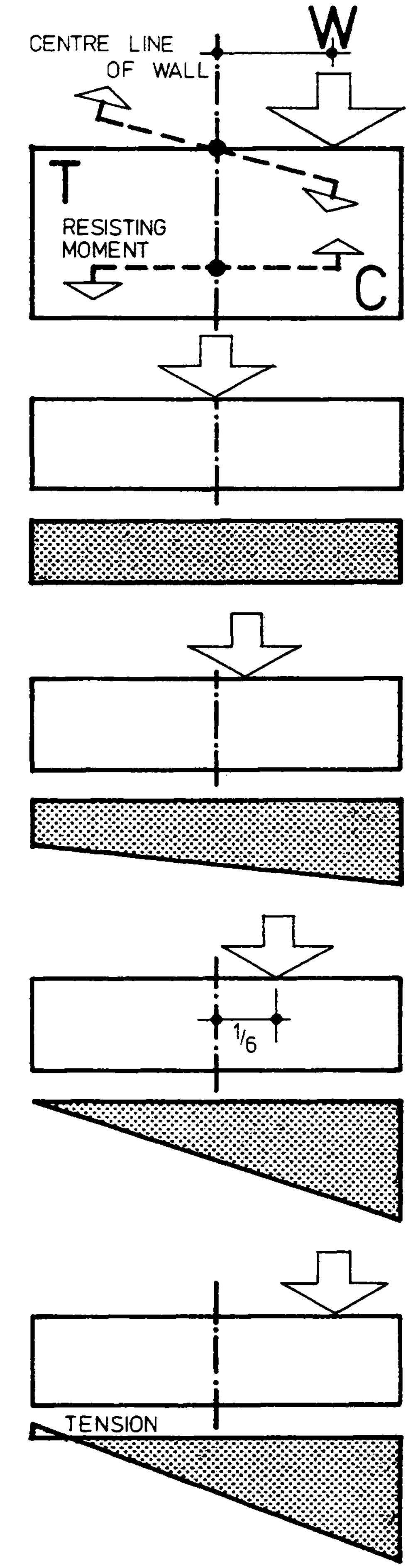
Z = a geometrical property relating to the shape and size of the crossection of the wall such that

$\frac{We}{Z}$ = stress at the faces of the wall due to eccentric loading.

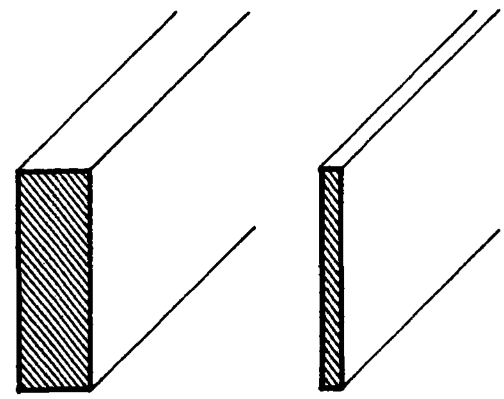
Z: Methods for computing this for any given section are given in standard textbooks on the theory of structures.

- tension will occur when the eccentricity is greater than 1/6 of the wall thickness.
- when the stress due to eccentric loading are too great they are reduced either by reducing the eccentricity or by increasing the thickness of the wall.

The last has the double effect of reducing the relative eccentricity and of increasing the value of Z.



- BUCKLING
  Will accur when the thickness of the wall is small relative to its height. Short walls or piers ultitately fail by crushing, but as the height increases they tend to fail under decreasing loads by buckling.



The terms "SHORT and TALL' in this context are relative to the thickness of the wall not to its actual height. They are defined in terms of the ratio of unsupported height to horizontal thickness known as

SLENDERNESS RATIO

The greater this is the tendency to buckle. Buckling is not related to the <u>strength of the walling material</u> but to the <u>stiffness of the wall</u>.

Buckling may be controlled either by
- o restricting height,
- o increasing thickness
- o stiffening by buttresses
- o intersecting walls or by
- o reducing the applied load.

- SETTLEMENT
  The downward force of a wall must be resisted by an equal, upward reaction from the soil on which it rests in order to maintain equilibrium.

  Soils vary in strength (some, verging on rock, are very strong, other are relatively weak).

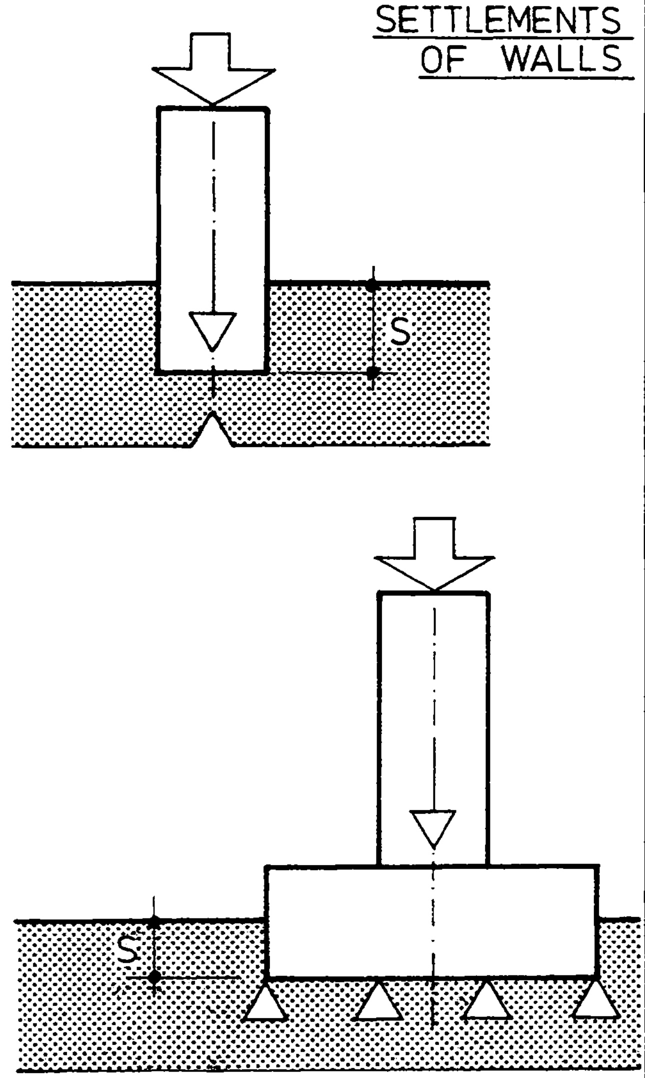
  All of these consolidate under-load but rock can resist very high stresses with little consolidation while the same stresses would cause excessive consolidations in others.

  This consolidation causes a vertical downward movement of the wall which is known as
  SETTLEMENT.

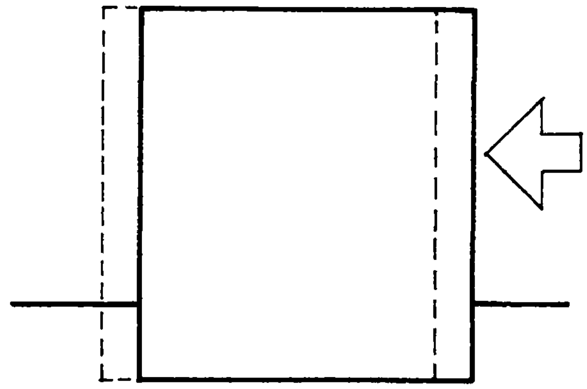
In order to keep the settlement within acceptable limits, the base of the wall has to be made of such a size that the load is distributed over a sufficiently large area of soil.

- Under horizontal loading a wall may
  - o slide or
  - o overturn

SETTLEMENTS OF WALLS

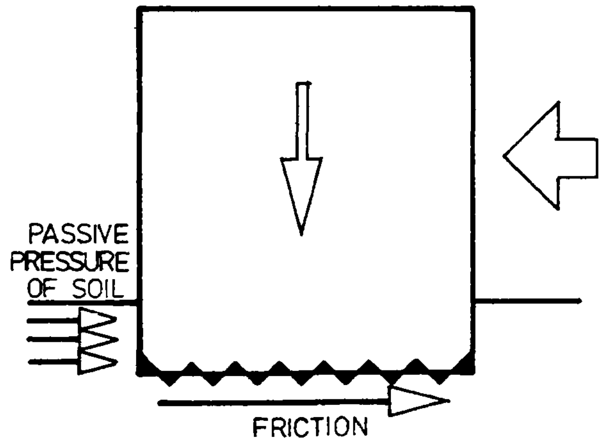


- SLIDING
  Occurs more likely in a free-standing wall than in a wall forming part of a building.



SLIDING

<u>Friction</u> and the <u>passive pressure of the soil</u> on which the wall rests are utilized to prevent sliding action.



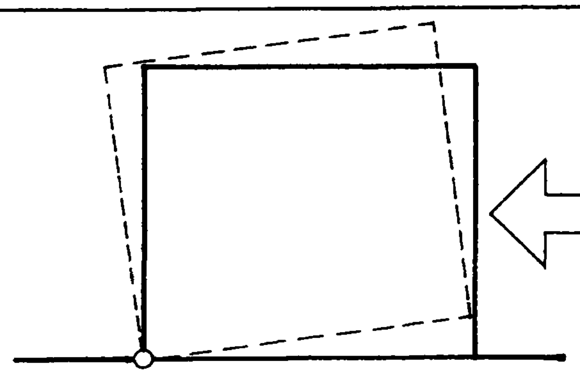
The amount of friction (or the frictional resistance) depends upon the weight exerted on the soil. That is the pressure between the two surfaces, and upon the degree of smoothness of the surfaces

The ratio of frictional resistance to weight is constant.

The ratio is termed COEFFICIENT OF FRICTION and varies according to the types of surface in contact.

Therefore:

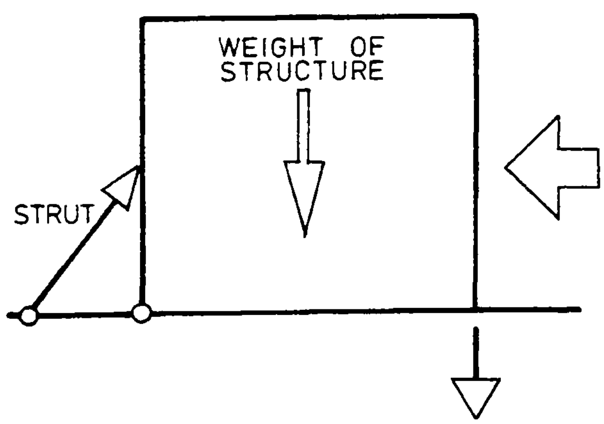
Frictional resistance = coefficient of friction x weight.



OVERTURNING

The other force which may resist the tendency of the wall to slide is the passive pressure of the soil.

The stresses in the soil caused by this pressure must be kept within the safe limits of the particular soil by taking the wall deeper into the soil (so that the pressure is distributed over a greater area.

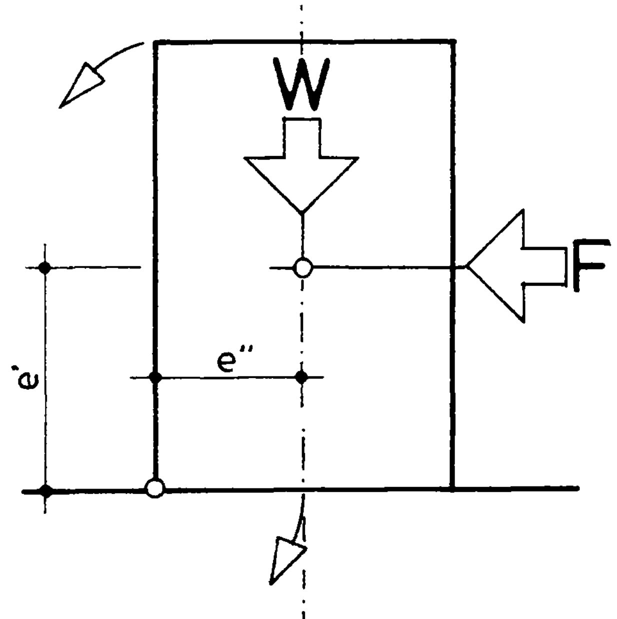


TENSION ELEMENT

- OVERTURNING
  may be caused by

  1 rotation or
  2 settlement.

Overturning by rotation occurs when the counter-moment We set up by the weight of the wall acting through its centre of gravity is too small to resist the moment Fe set up by the overturning force.

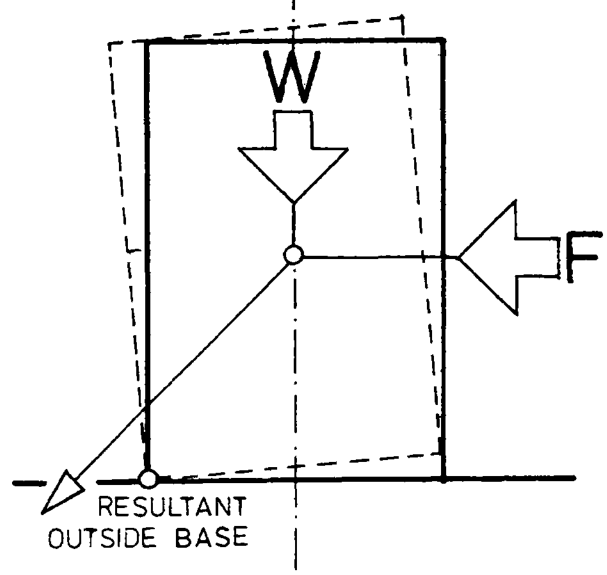


In these circumstances the resultant of the weight of the wall W and the overturning force F falls outside the base of the wall so that the base is wholly under tension and overturning occurs.

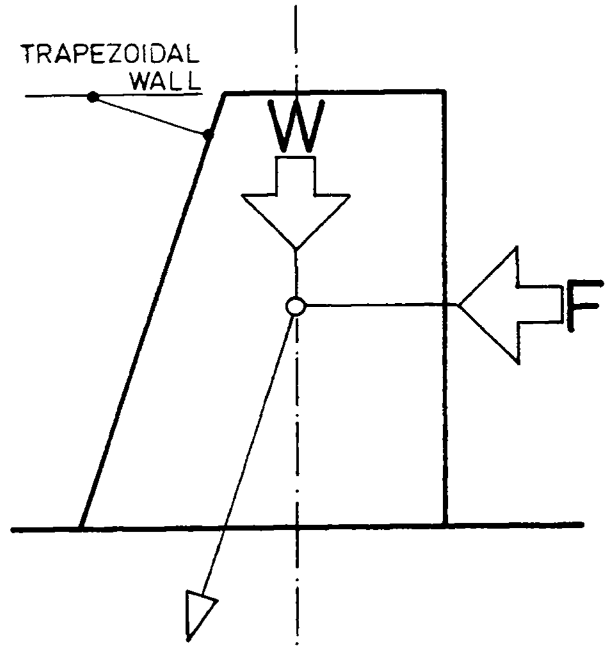
To prevent this:
The weight of the wall can be increased by increasing

its height
or thickness.

The latter is most beneficial because it also increases the width of the base within which the resultant must fall.



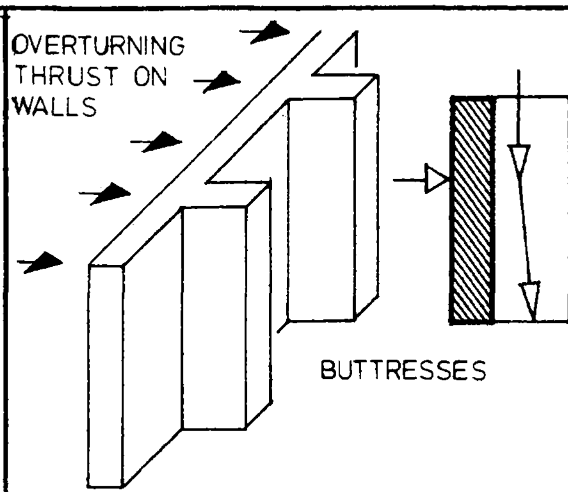
Alternatively (or in addition) the shape of the wall may be made trapezoidal to shift its centre of gravity relative to the base towards the overturning force thus reducing the eccentricity of the resultant at the base.



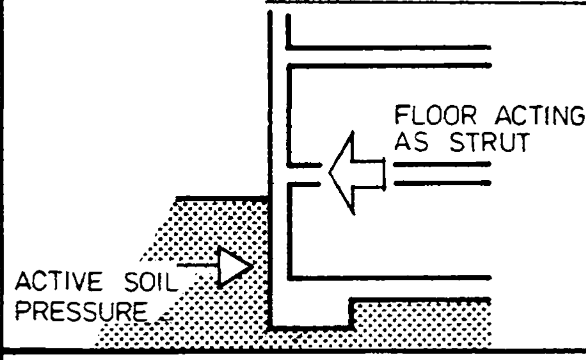
Another alternative is to use Buttresses

These methods are adopted for walls having little tensile strength. Alternative and (in case of tall walls) more ecconomic methods may be adopted when materials with adequate tensile strength are used, such as reinforced concrete.

The use of a strut to prevent rotation may be adopted and where a wall undergoing a lateral force forms part of a building a floor can often be made to function as a strut.



STABELISING of WALLS



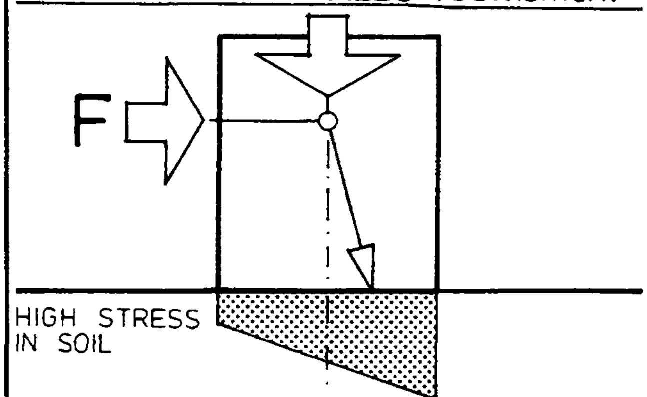
- OVERTURNING due to SETTLEMENT: may occur though overstressing of the soil causing excessive consolidation under the wall and the overturning force will always cause excentric pressure at the base of the wall leading to simular stress distributions to those in an eccentrically loaded wall.

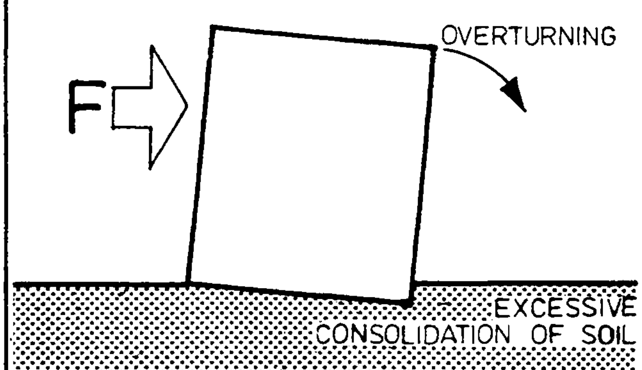
  This will result in a distribution of pressure in the soil with a pressure at the toe which might be considerably greater than the average pressure.

  If this overstresses the soil, excessive consolidation might occur at this point causing overturning through unequal settlement of the wall.

  This problem can be overcome by reducing the eccentricity of the resultant
  - o by increasing the thickness of the wall or
  - o by increasing the width of its foundation, or
  - o by making the wall trapezoidal in shape.

OVERTURNING of WALLS : settlement





CALCULATION of WALL THICKNESS

Calculation of wall thickness:

For determining the thickness of walls and piers certain terms have to be defined in relation to this.

SLENDERNESS RATIO

- SLENDERNESS RATIO = the ratio of effective height to effective thickness. (But in the case of walls it may be based alternatively on the effective length. if this is less than the effective height. This takes account of the stability which is provided by vertical as well as by horizontal lateral supports

EFFECTIVE HEIGHT

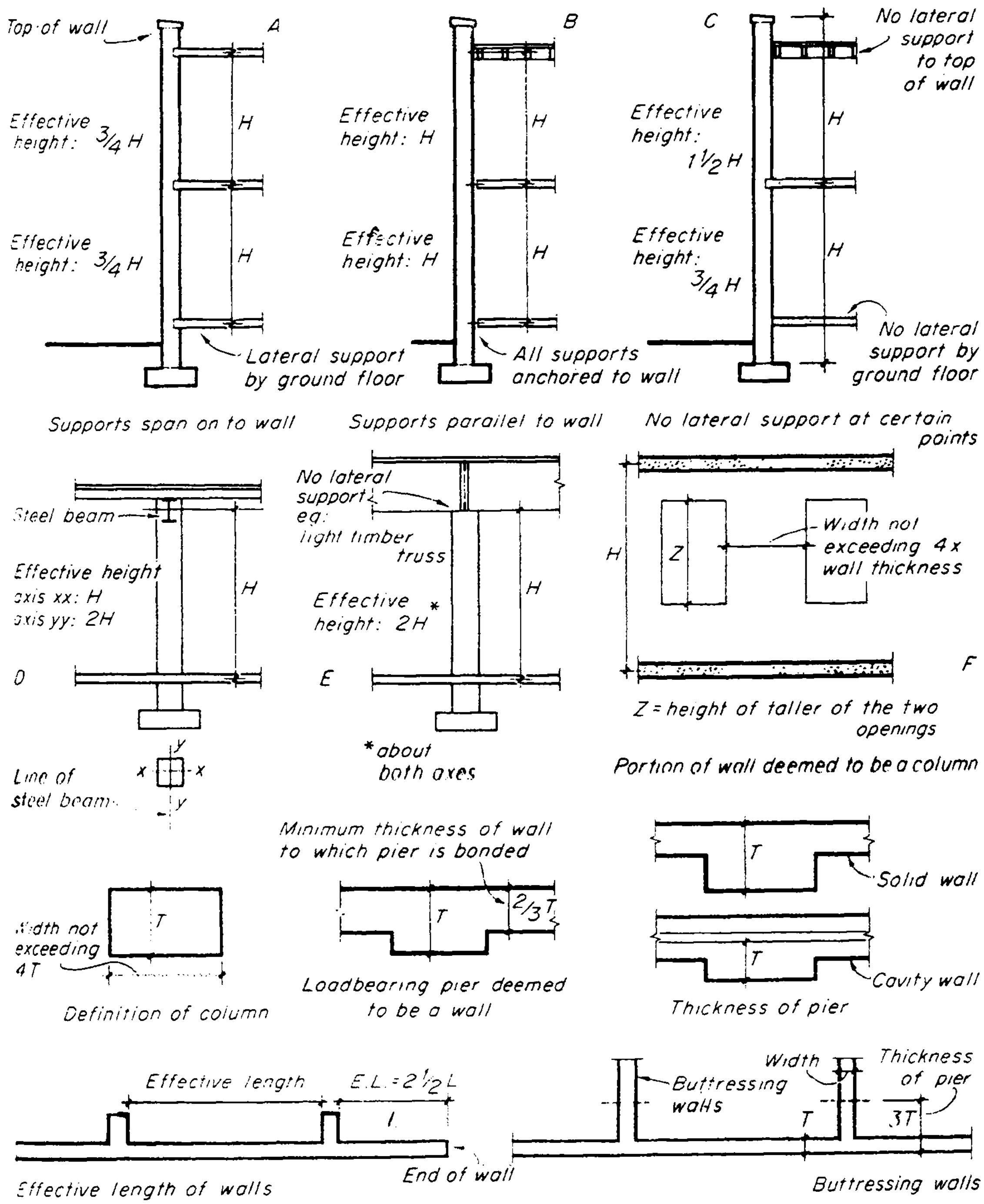
- EFFECTIVE HEIGHT = is based on the distance between adequate lateral supports provided by floors and roof and depends upon the degree of support they are assumed to provide. The greater the degree of support the smaller is the proportion of the distance between centres of support taken as the effective height. This is illustrated in the figures A to C in respect of walls and D, E in respect of columns.

  Columns must be considered about both axes. If lateral support is provided in one direction only, as indicated by the beam in (D), the effective height relative to that direction will be as shown, but in the other direction it must be twice its height above the lower support. In the absence of any top support (E) the latter value must be taken relative to both directions.

  Where the wall between two openings constitutes a column as in (F) its effective height is based upon the height of the taller of the openings, Z. Where Z does not exceed H/2 the effective height is 1 1/2Z. Where Z exceeds H/2 it must be taken as 1 1/2 Z or H, whichever is the less.

CALCULATED WALLS

- EFFECTIVE HEIGHT
- EFFECTIVE LENGTH



6.WALLS compiled: D.VOLKE JULY '80	CALCULATED WALLS	BUILDING CONSTR. — LECTURE — CET 3031/1 6.2 14

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EFFECTIVE LENGTH =

EFFECTIVE LENGTH = This is the distance between adjacent piers, buttresses or intersecting or return walls. The effective length of the end of a wall with no end stiffening is shown in the figure.

EFFECTIVE THICKNESS = This is the actual thickness of a solid wall excluding plaster, rendering, or any other applied finish or covering. Allowance is made for any stiffening piers which may be bonded to the wall by multiplying the actual thickness by a factor which varies with the size and spacing of the piers, resulting in an effective thickness greater than the actual thickness. Table 1 gives these factors. (Buttressing or intersecting walls may be considered as pier of width equal to the thickness of theintersecting wall and of a thickness equal to three times the thickness of the stiffened wall (figure).

If a column has no lateral support or has support in both directions the effective thickness will be based on the least dimensions, and the larger be adopted.

The maximum values for the slenderness ratio of masonary walls are shown in table 2

In many buildings where loading is light and the necessary wall thickness is small the slenderness ratio becomes the controlling factor, limiting as it does the height for any given thickness.

Thickness of pier / *Thickness of wall*	*Pier spacing* / *Width of pier* 6	8	10	15	20
1.0	1.0	1.0	1.0	1.0	1.0
1.5	1.2	1.15	1.1	1.05	1.0
2.0	1.4	1.3	1.2	1.1	1.0
2.5	1.7	1.5	1.3	1.15	1.0
3.0	2.0	1.7	1.4	1.2	1.0

Table 1. *Determination of effective thickness of wall stiffened by piers*

EFFECTIVE THICKNESS

SLENDERNESS RATIOS

Type of wall	*Maximum slenderness ratio*
Unreinforced brickwork or blockwork set in hydraulic lime mortar	13
ditto in buildings not exceeding two storeys	20
Brickwork or blockwork set in other than hydraulic lime mortar	27
ditto in walls less than 90 mm thick in buildings of more than two storeys	20

Table 2 *Maximum permitted slenderness ratios*

Table 3 *Basic stresses for masonry walls*

Description of mortar	*Mix (parts by volume)*			*Hardening time after completion of work†*
	Cement	*Lime*	*Sand*	
				days
Cement	1 1	0-¼* ½	3 4½	7 14
Cement-lime Cement with plasticizer § Masonry cement‖	1 1 –	1 – –	6 6 –	14
Cement-lime Cement with plasticizer § Masonry cement‖	1 1 –	2 – –	9 8 –	14
Cement-lime	1	3	12	14
Hydraulic lime	–	1	2	14
Non-hydraulic	–	1	3	28 ¶

PERMISSIBLE STRESS

PEMISSIBLE STRESS = The stesses permitted in a wall or column are regulated according to the strength of the bricks or blocks, the type of mortar to be used and the slenderness ratio of the wall or column. Basic stresses, arising from combined uniformly distributed dead and superimposed loads and reated to the strength of the units and the type of mortar used, are shown in table 3.

* The inclusion of lime in cement mortars is optional

† These periods should be increased by the full amount of any time during which the air temperature remains below 4.4°C plus half the amount of any time during which the temperature is between 4.4°C and 10°C

‡ Linear interpolation is permissible for units whose crushing strengths are intermediate between those given in the table

§ Plasticizers must be used according to manufacturers' instructions

‖ Masonry cement mortars must be used according to manufacturers' instructions, and mix proportions of masonry cement to sand should be such as to give comparable mortar crushing strengths with the cement: lime: sand mix of the grade

¶ A longer period should ensue where hardening conditions are not very favourable

Note: Where the cross-sectional plan area of a wall or column does not exceed 0.3 m^2, the basic stress should be multiplied by a reduction factor equal to

$$0.75 \times \frac{A}{1.2}$$

where A is the area (in m^2) of the horizontal cross-section of the wall or column

Basic stress in MN/m^2 corresponding to units whose crushing strength (in MN/m^2) ‡ is:

Brickwork members									*Blockwork members*								
2.8	7.0	10.5	20.5	27.5	34.5	52.0	69.0	96.5 or greater	2.8	3.5	7.0	10.5	14.0	21.0	28.0	35.0	52.0
0.28 0.28	0.70 0.70	1.05 0.95	1.65 1.45	2.05 1.70	2.50 2.05	3.50 2.80	4.55 3.60	5.85 4.50	0.28 0.28	0.35 0.35	0.70 0.70	1.05 0.95	1.25 1.15	1.70 1.45	2.10 1.75	2.50 2.10	3.50 2.80
0.28	0.70	0.95	1.30	1.60	1.85	2.50	3.10	3.80	0.28	0.35	0.70	0.95	1.10	1.35	1.60	1.90	2.50
0.28	0.55	0.85	1.15	1.45	1.65	2.05	2.50	3.10	0.28	0.35	0.55	0.85	1.00	1.20	1.45	1.70	2.05
0.21	0.49	0.70	0.95	1.15	1.40	1.70	2.05	2.40	0.21	0.23	0.49	0.70	0.80	1.00	1.20	1.40	1.70
0.21	0.49	0.70	0.95	1.15	1.40	1.70	2.05	2.40	0.21	0.23	0.49	0.70	0.80	1.00	1.20	1.40	1.70
0.21	0.42	0.55	0.70	0.75	0.85	1.05	1.15	1.40	0.21	0.23	0.42	0.55	0.60	0.70	0.75	0.85	1.05

REDUCTION FACTORS FOR

Slenderness ratio	Stress reduction factor*			
	Axially loaded	Eccentricity of vertical loading as a proportion of the thickness of the member		
		1/6	1/4	1/3†
6	1.00	1.00	1.00	1.00
8	0.95	0.93	0.92	0.91
10	0.89	0.85	0.83	0.81
12	0.84	0.78	0.75	0.72
14	0.78	0.70	0.66	0.62
16	0.73	0.63	0.58	0.53
18	0.67	0.55	0.49	0.43
20	0.62	0.48	0.41	0.34
22	0.56	0.40	0.32	0.24
24	0.51	0.33	0.24	–
26	0.45	0.25	–	–
27	0:43	0.22	–	–

* Linear interpolation between values is permitted

† Where in special cases the eccentricity of loading lies between $1/3$ and $1/2$ of the thickness of the member, the stress reduction should vary linearly between unity and 0.20 for slenderness ratios of 6 and 20 respectively

Table 4 *Reduction factors for slenderness ratios*

SLENDERNESS RATIO

For members with slenderness ratios up to six the basic stresses in the wall or column must be established by the application of a reduction factor to the basic stress. Values for this factor for varying slenderness ratios and eccentricities of loading are given in table 4.

In order to keep the thickness of walls within reasonable limits and, preferably, of the same thickness for the full height of the building, particularly in the case of cross wall construction, variations in the types of bricks and in the mortar mixes are made according to the stresses at different heights. Excessive variation is uneconomic and leads to difficulties in supervision on the site. Sufficient flexibility in strength can, however, be obtained in most buildings by the use of three to four grades of bricks with one or two mixes of mortar.

A non-calculated brick or block wall shall have a thickness at any level not less than onesixtieth of the height measured from that level to thetop of the wall.

A minimum thickness of 190 mm at any point is required in the case of an external wall, whether calculated or not.

Walls built of materials of differing strengths bonded together are less important now as load-bearing structures since the general practice is to use a thin 'veneer' of non-structural facing material attached to a stuctural backing, but provision is made for dealing with such a combination in two ways. The weaker material may be considered to be used throughout the full thickness and the permissible stress established on that basis. Alternatively, the area of that portion of the wall built of the strongest material only may be considered as carrying the load, in which case the permissible stress is established using a slenderness ratio calculated on the thickness of that material alone.

Random rubble walling should be based on permissible stresses of 75 per cent of the corresponding stresses for coursed walling of similar materials.

PROCESS of DESIGN

The design process may be summarized briefly as follows:

1. Calculate total load (W) per metre run of wall or on column at level under consider ation

2. Assume wall or column thick ness and establish slenderness ration.

3. Establish any eccentricity of loading.

4. Ascertain appropriate stress reduction factor (RF) (table 4)

5. Establish bearing area per metre run of wall or of column (A)

6. Establish 'euqivalent basic stress' = $\frac{W}{A \times RF}$

7. Select grade of brick and mortar with strengths appropriate to the equivalent basic stress (table 3)

TYPES OF WALLS

6.3 Types of Walls

- Walls may be divided into two types:

  1 LOAD - BEARING WALLS which support loads from floors and roof in addition to their own weight and resist side pressure (wind, stored material or objects)

  2 NON-LOAD-BEARING WALLS which carry no floor or roof loads.

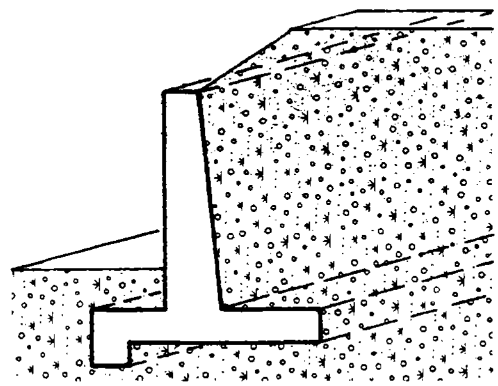
- Each type may be further divided into EXTERNAL (or enclosing)WALLS and INTERNAL (or dividing) WALLS

- The external -non-load-bearing wall (related to framed structures) is termed
  PANEL WALL (if of masonry construction)
  INFILLING PANEL (if of tighter construction)
  CLADDING (when applied to the face of the structure)

- The term PARTITION is applied to walls (generally non-load-bearing and only one storey high) dividing the space within a building into rooms.

  Internal walls which seperate different excupancies within the same building ore divide the building into compartments for the purpose of fire protection are termed
  PARTY (or PARTING) WALLS
  SEPERATING WALLS or
  DIVISION WALLS.

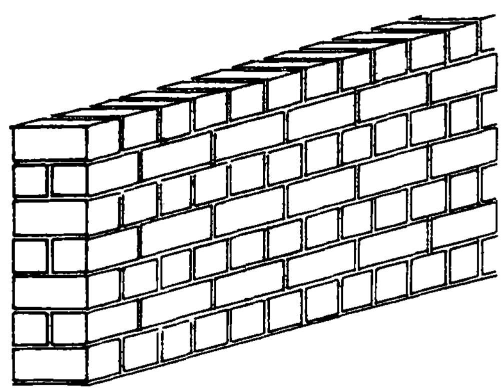
- RETAINING WALLS:
  There primary function is to resist the thrust of soil (or subsoil water) on one side. The most important functional requirement therefore is strength and stability.



RETAINIG WALL

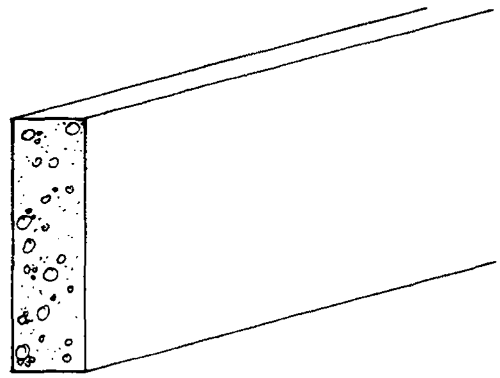
Regarding to the FORM OF CONSTRUCTION Walls may be described by the following terms:

- MASONRY WALL = The wall is built of individual blocks of materials, such as bricks clay or concrete blocks, stone etc., usually in horizontal courses cemented together with some form of mortar.



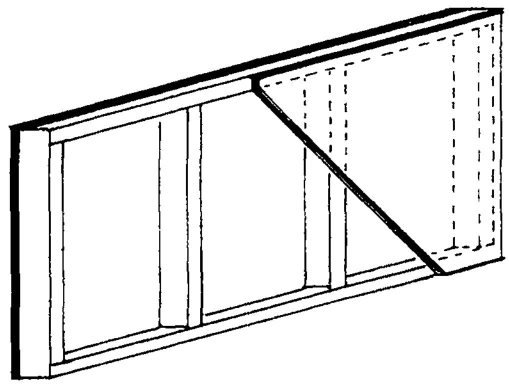
MASONRY WALL

- MONOLITHIC WALL = The wall is built of material requiring some form of support or shuttering in the initial stages. The traditional earth wall and the modern concrete wall are examples of this.



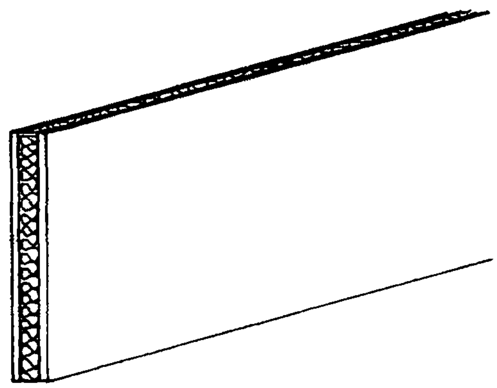
MONOLITHIC WALL

- FRAME WALL = The wall is constructed as a frame of relatively small members (usually of timber) at close intervals which together with facing on each side form a load bearing system.
  N.B. This is a wall construction not a struct. fram of a building.



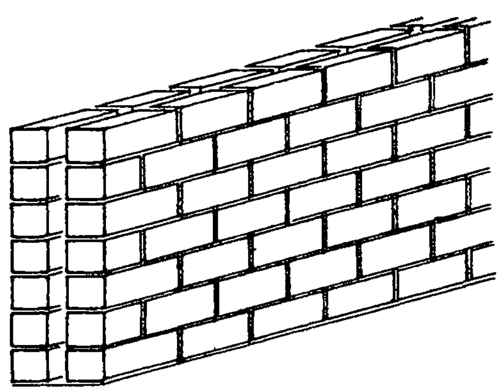
FRAME WALL

- MEMBRANE WALL = The wall is constructed as a sandwich: two thin skins or sheets of reinforced plastic, metal, asbestos-cement or other suitable material bonded to a core of framed plastic to produce a thin wall element of high strength and low weight.



MEMBRANE WALL

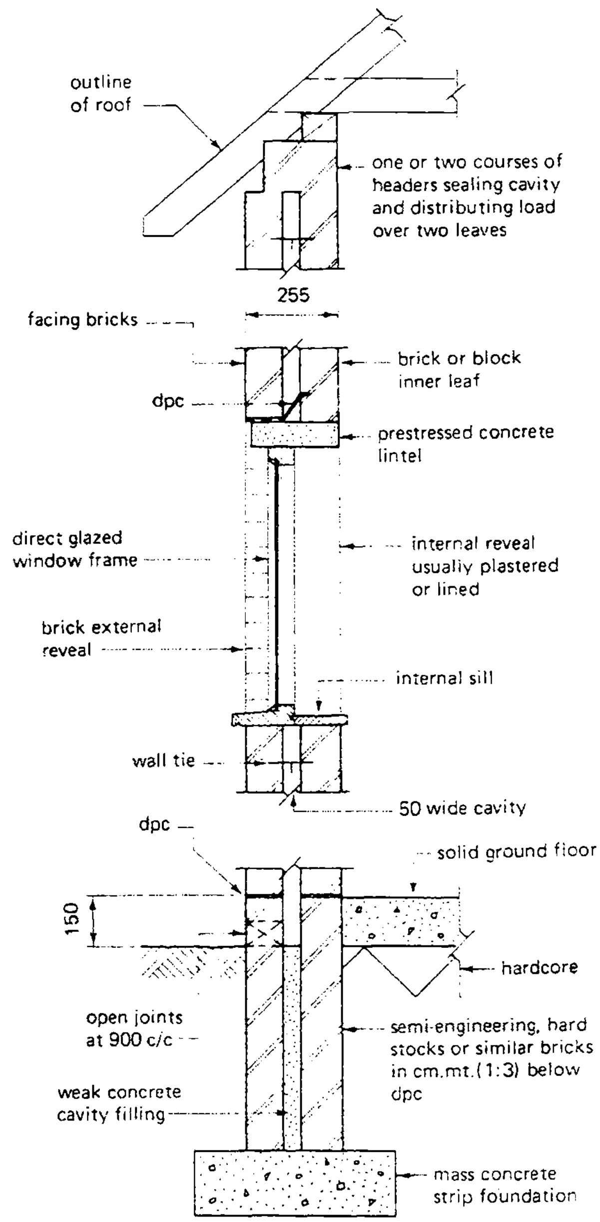
- CAVITY WALL = The wall is constructed in two leaves or skins with a space between, so that the outer surface of the wall is isolated from the inner surface by a continous gap.

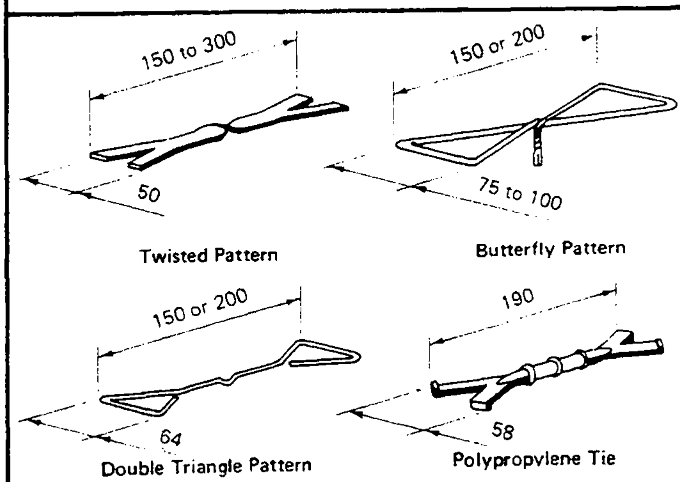


CAVITY WALL

CAVITY-WALLS

- Main purpose: to prevent the penetration of rain to the internal surface of the wall.
- It is essential that the cavity is not bidged in any way as this would provide a passage for the moisture.
- Air bricks are <u>sometimes</u> used to ventilate the cavity (- at the head and the base of the wall).
- There is a tendency for the 2 leaves to move towards each other (below ground level). To overcome this problem it is common practice to fill the cavity below g.l. with a work mix, of concrete thus creating a solid wall in the ground
- It is advisable to leave out every 4th vertical joint in the external leaf at the base of the cavity and above the cavity fill, to allow any moisture to escape.





<u>Building Regulations 1972</u>
<u>Schedule 7</u>

<u>Rule 4</u>: This gives the requirements of the strength of brick or blocks to be used in the construction of walls.

It sets out in detail the various crushing strengths and aggregate volumes of solid material required for various situations and classifications.

<u>Rule 11:</u> This sets out the constructional requirements for cavity walls and is of the utmost importance.

1. Bricks and blocks to comply with Rule 4 and be properly bonded and solidly put together with mortar.

2. The leaves to be securely tied together with ties complying with B.S. 1243:1964 or other not less suitable ties, details of horizontal and vertical spacing are given (Fig. II.21)

3. The cavity shall be not less than 50 mm nor more than 75mm in width at any level.

4. The leaves shall be each not less than 100mm in thickness at any level (unless covered by paragr. 6 of Rule 11).

5. The overall thickness to comply with paragraphs 3 and 4 or thickness required by Rules 7 or 8 for solid walls + the width of the cavity (for a nominal 255mm wide cavity wall of any length the maximum height is 3.60 m.

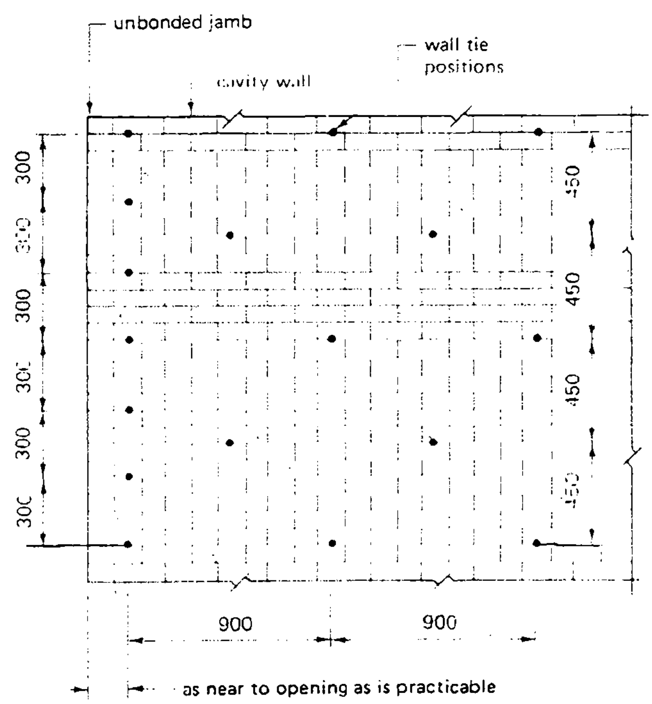
6.a) Inner leaf can be not less than 75mm thick if the wall forms part of a private dwelling house of one story or is the upper story of such a dwelling having only two storeys.

6.b) Inner leaf size not more than 8m in length and not more than 3m in height or 5 m in height if it is a gable wall.

6.c) A gauge mortar not weaker than 1:2:9 to be used.

6.d) Not less than twice the number of wall ties required by paragraph 2 of Rule 11.

6.e) The roof load is supported partly by the outer leaf.



<u>Advantages of cavity wall constructions.</u>

a) Able to withstand a driving rain in all situations from penetrating to the inner wall surface.

b) Gives good thermal insulation.

c) No need for external rendering.

d) Enables the use of cheaper and alternative materials for the inner construction.

e) A nominal 255mm cavity wall has a higher sound insulation value than a standard one brick thick wall.

- <u>Disadvantages of cavity wall constructions.</u>

a) Requires high standard of design and workmanship.

b) The need to include a vertical D.P.C. to all openings.

c) More expensive than a standard one brick thick wall.

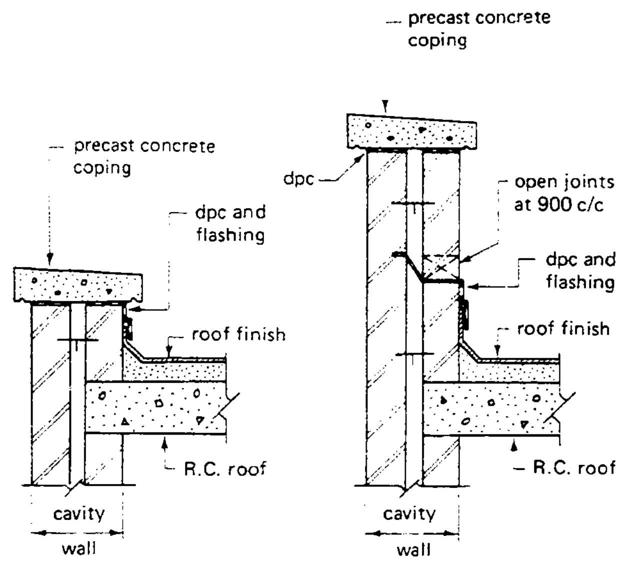
- Parapets, whether solid or cavity constructions are exposed to the elements on three sides.

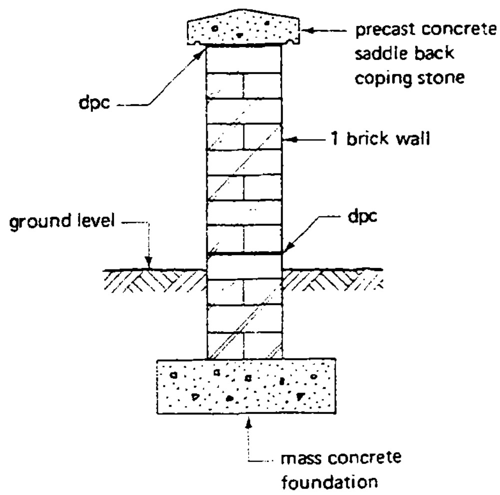
- Therefore an adequate barrier to moisture in form of d.p.c. must be provided.

- A parapet must not be less than 20 cm thick or not less than the thickness of the wall on which it is carried and its height must not exceed 6 x its thickness.
  (Schedule 7, Rule 14, Build. Reg.)
- The presence of water in brickwork can lead to
  - frost damage
  - mortar failure
  - efflorescence

- The incorporation of adequate D.P.C. and overhanging throated copings is of importance in this form of structure.

PARAPETS





- BOUNDARY WALLS
- are subjected to severe weather conditions and therefore should be designed and constructed correctly.

- as retaining walls = condition even more extrem, but the main design principle remains the same:Exclution of water.

- CROSS-WALLS

The term "cross-wall construction" is applied to buildings in which the walls at right angles to the principal axis are designed to carry the loads from the floors and roof, the lateral front and rear external walls being non-load-bearing.

Cross-wall construction being adopted for certain types of building is illustrated in its simplest form in the figure below.

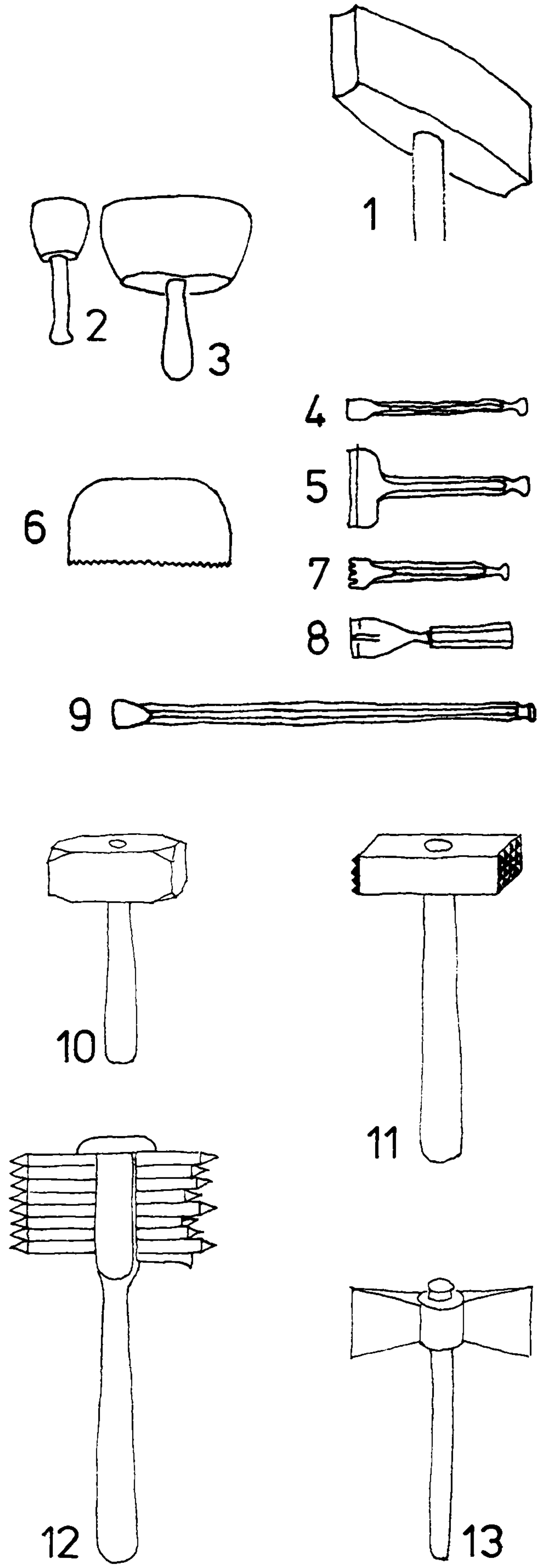
CROSS-WALL

STONEWORK

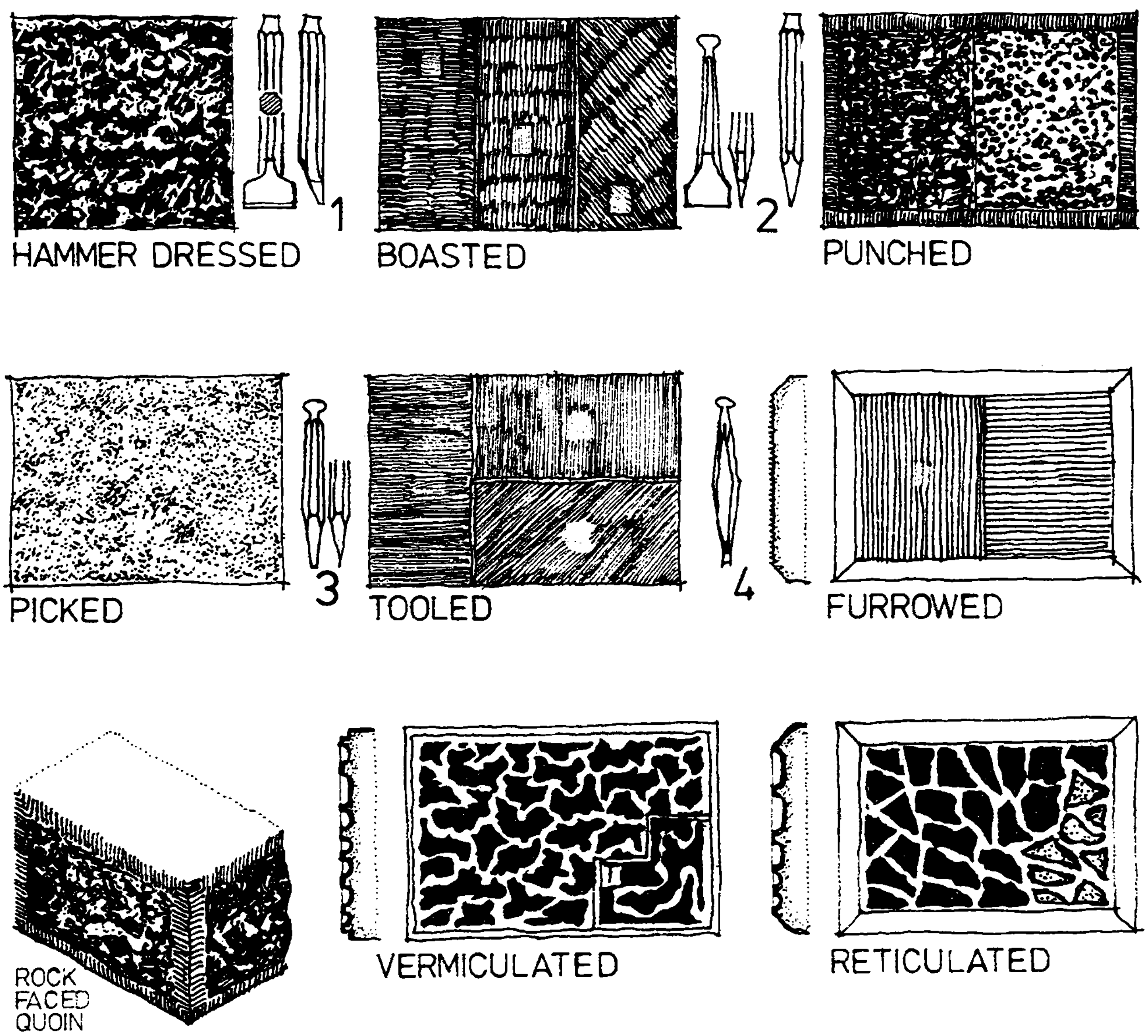
6.4. Stonework

TOOLS

1 SPALL HAMMER
2 DUMMY
3 MALLET
4 DRAFTING CHISEL
5 BROAD TOOL
6 DRAG
7 CLAW CHISEL
8 SOFT STONE CHISEL
9 JUMPER (0.50–1.80 m)
10 MASH HAMMER
11 SCRABBLING HAM.
12 BUSH HAMMER
13 FLAT LUMP HAM.



SURFACE FINISHES & TOOLS



1	PITCHING TOOL
2	BOASTER
3	POINT
4	GOUGE

BUILDING STONES

6.4.1 Building stones

- Stones used in building can be divided into 3 classes as follows:
  (1): Igneous
  (2): Sedimentary
  (3): Metamorphic

- Igneous stones: Originate from volcanic action being formed by the crystallisation of malten rockmatter derived from deep in the earth's crust.

- granites are typical of this class of stone: hard/durable and capable of a fine polished finish.
- granites are mainly composed of quartz, felspar and mica.

- Sedimentary stones: composed of material derived from the breakdown and erosion of existing rocks deposited in layers under the waters, which at that time covered much of the earth's surface.

- Sandstones and limestones are typical examples of sedimentary stones.
  - o Sandstones are stratified sedimentary rocks, produced by the eroded and disintegrated rocks, like granite, being carried away and deposited by water in layers. The brown and yellow tints in sandstones are due to the presence of oxids of iron.
  - o Limestones may be organically formed by the deposit of tiny shells and calcareous skeletons in the seas and rivers, or may be formed chemically by deposits of lime in ringed layers. Limestones vary considerably from heavy crystalline form to a triable material such as chalk.

- Metamorphic stones: have altered and may have been originally igneous or sedimentary rocks have been changed by geological processes such as
  - pressure
  - movement
  - heat

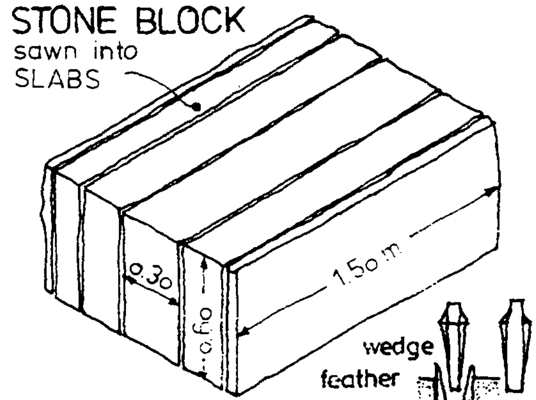
  and chemical reaction due to infiltration of fluids.

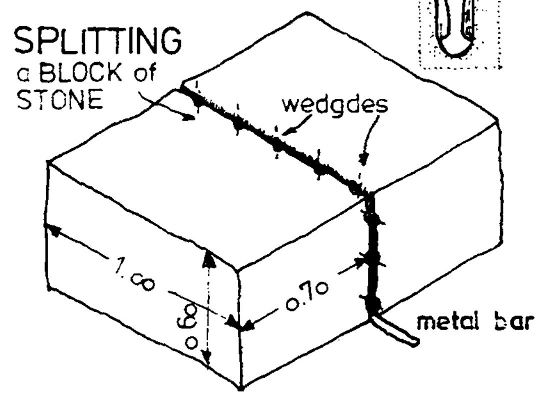
- Marbles and slates are typical examples.
  - o Marbles are metamorphic limestones, being changed by pressure. Being capable of taking a high polish/are used mainly for decorative work.
  - o Slate is a metamorphic clay, having been subjected to great pressure and heat; being derived from a sedimentary layer it can be easily split into thin members.

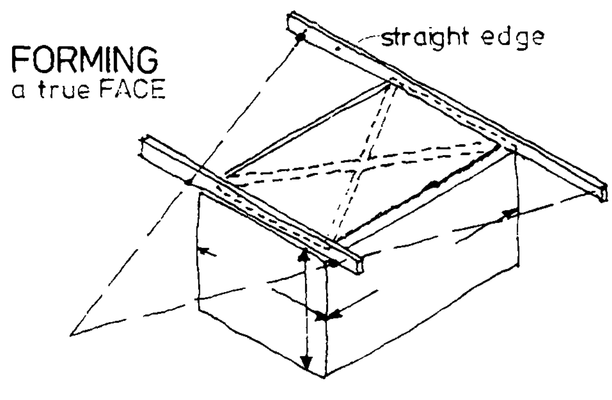
STONES

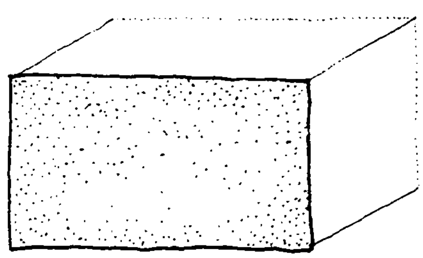
- Stones are obtained from quarries by blasting and wedging the block away from the solid mass. They are partly worked in the quarry and then sent to store yards where they can be
  - saw
  - cut
  - moulded
  - dressed or/and
  - polished.

Today, natural stones are sometimes used for:-facing prestige buildings;-constructing boundary or similar walls.





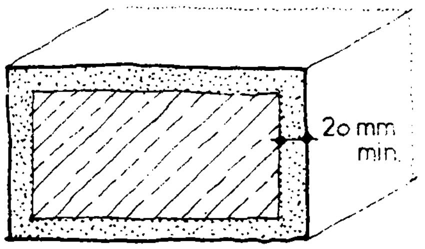




RECONSTRUCTED

- Reconstructed stones: are substitutes for natural stones. They are homogeneous throughout and therefore has the same texture and colour as the natural stones they are intended to substitute.

  - They can be worked in the same manner as natural stone or alternatively
  - they can be cast into shaped moulds.



- Artificial stones: consist partly of a facing material and partly of a structural concrete.
  - The facing is a mixture of fine aggregate of natural stone and cement.
  - The facing should be cast as an integral part of the stone and have a minimum thickness of 20 mm.
  - They are cheaper than reconstructed stones but have the disadvantage that if damaged the concrete core may be exposed.

DEFECTS IN STONE

- DEFECTS IN STONE

o Vents: are small fissures or hollows in the stone which may cause it to deteriorate rapidly, especially if exposed. Stone with vents should not be used for building purposes.

o Shakes or snailcreep: are minute cracks in the stone containing calcite (a carbonite of lime) and forming hard veins which - in course of time - project beyond the general face on account of their greater durability.
It is not advisable to use stone containing them on account of the difference in texture which results.

o Sand-holes: are cracks which appear in the stone and which are filled with sandy matter. Clay-holes are vents which contain matter of a clayey nature. Both are readily decomposed when subjected to the action of weather, and the stone should be rejected.

o Mottle: is a defect which causes the stone to have a spotted appearance due to the presence of small chalky patches. Such stone is unfit for building purpose.

o The presence of clay and oxide of iron is apt to cause disfigurement of the stone, producing brown-coloured bands which interfere with the uniformity in colour of the stone and diminish its durability.

o An inherent defect is the presence of shells fossils, cavities and flints. These are often not detected until the large blocks from the quarry are being converted into smaller units, the saw-arts revealing their presence. The affected portions must be removed and therefore wast results.

STONEWORK TERMINOLOGY

6.4.2 Stonework Therminology

Arris: meeting edges of two worked surfaces.

Ashlar: a square hewn stone; stonework consisting of blocks of stone finely squared and dressed to given dimensions and laid to courses of not less than 300 mm in height.

Bed joint: horizontal joint between two courses.

Bonders: through stones or stones penetrating 2/3 of the thickness of a wall.

Cramp: non-ferrous metal or slate tie across a joint.

Dowel: non-ferrous or slate peg morticed into adjacent joints.

Yoggle: recessed key filled with a suitable material, used between adjacent votical joints.

Lacing: courses of different material to add strength.

Natural bed: plane of stratification in sedimentary stones.

Quarry seep: moisture contained in newly quarried stones.

Quoin: corner stone

Stool: flat seating on a weathered sill for jamb or mullion.

String course: distinctive course or band used mainly for decoration.

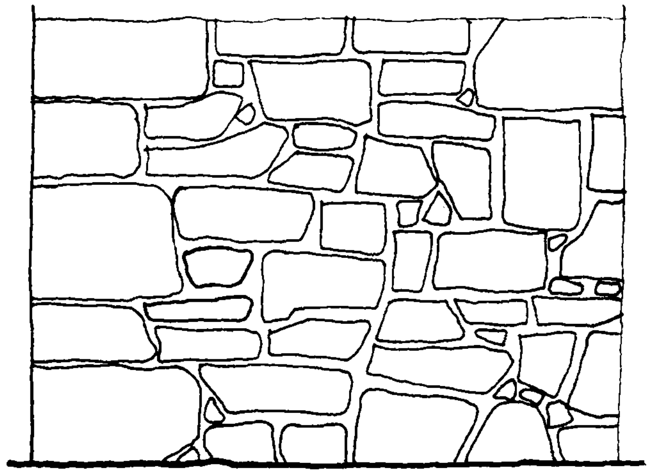
Weathering: sloping surface to part of the structure to help shed the rain.

STONEWORK CLASSIFICATION

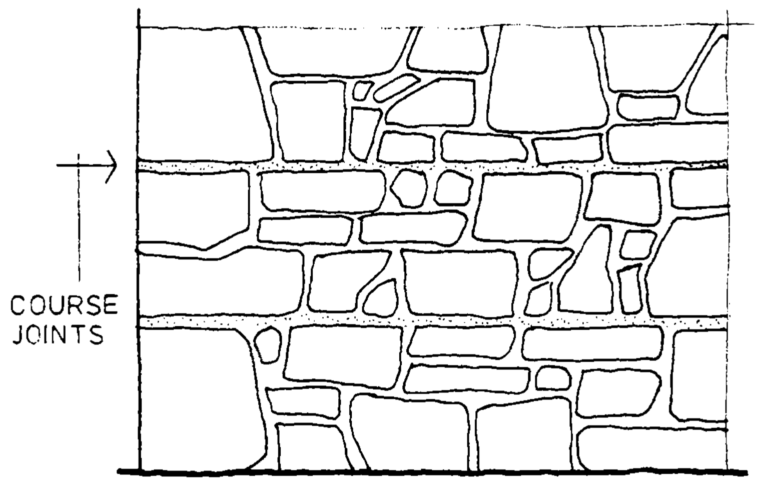
6.4.3 Stonework Classification
The various classes of stonework may be devided into:

(1) Rubble Work and
(2) Ashlar Work

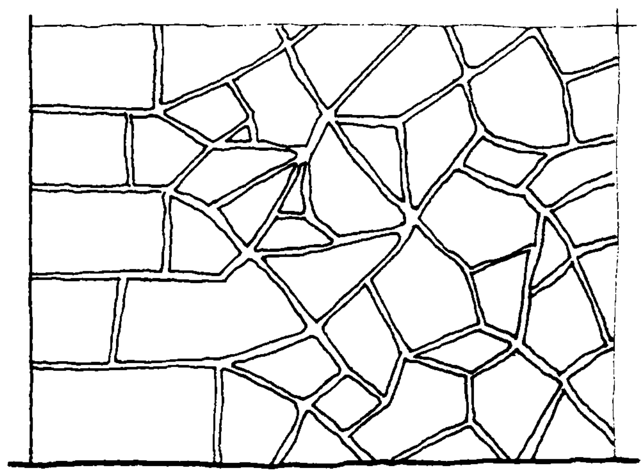
RANDOM RUBBLE
uncoursed



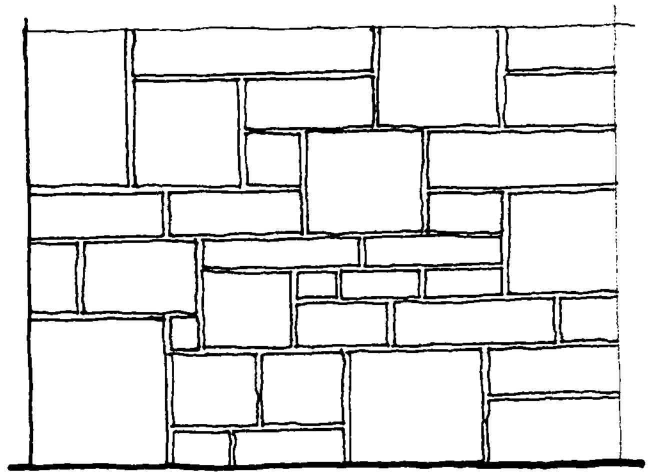
RANDOM RUBBLE
brought to courses



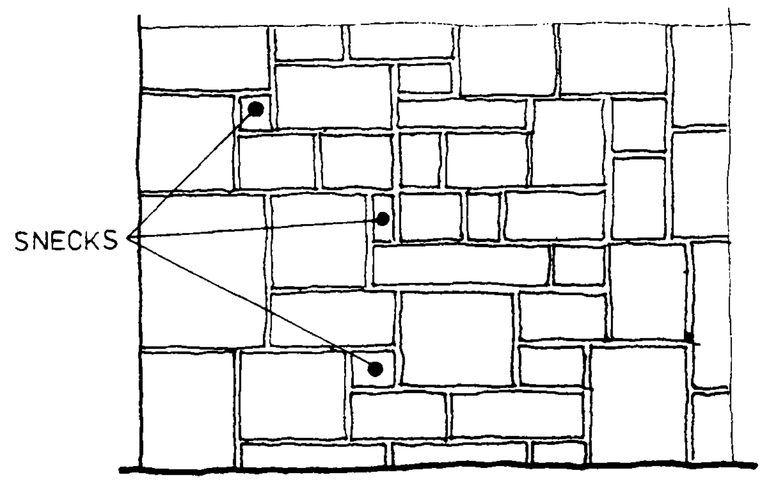
POLYGONAL RUBBLE



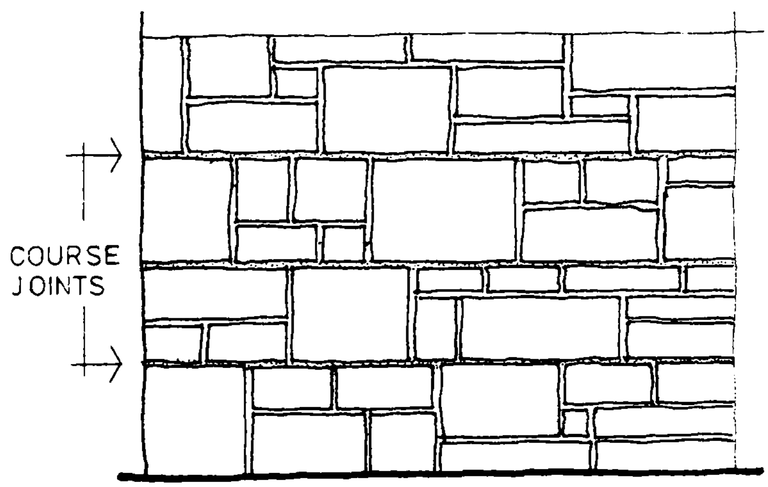
SQUARED RUBBLE
uncoursed



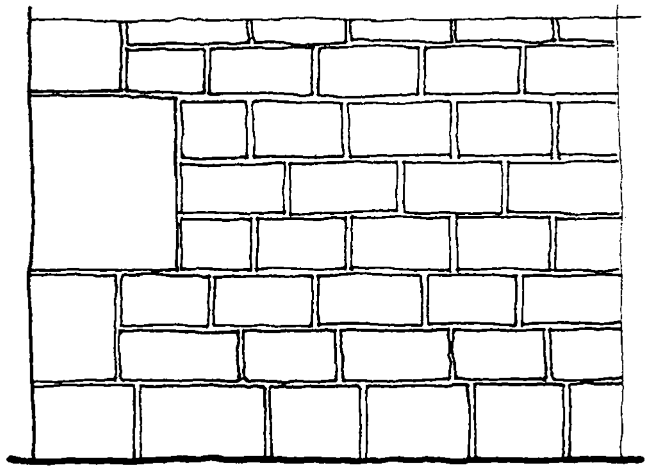
SNECKED RUBBLE



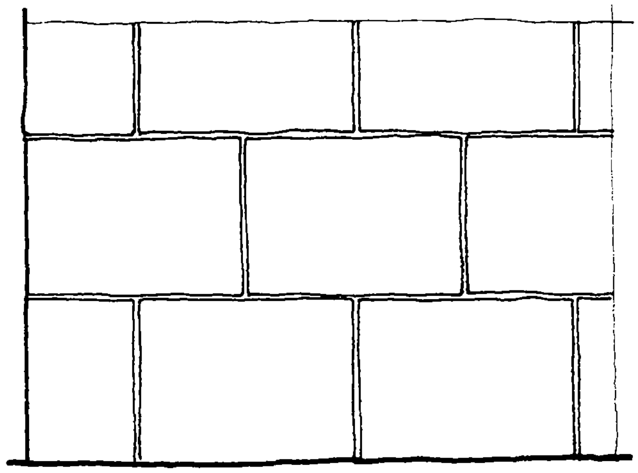
SQUARED RUBBLE
brought to courses



RUBBLE
regular coursed



ASHLAR



RUBBLE WALLING

6.4.4 Rubble Walling

- These walls are made of stones which are left rough or uneven thus presenting a natural appearance to the face of the wall.

- The stones are usually laid with a wide joint and are used in various forms.
  They can be laid:
  o dry
  o bedded in earth (in boundary walls)
  o bedded in Limemortar (i.e. outbuildings of farm houses)
  o bedded in cement or gauged mortar (in ashlar walls).

- Commonly the quins to corners, windows and door openings are dressed or ashlar stones.

- The face of any backing material to be treated with a suitable water-proofing coat (to prevent the passage of moisture).
- Precautions in form of d.p.c. are necessary to comply with Part C - Building Regulations.

- Rubble work includes:

  (a) Random Rubble
    (1) uncoursed
    (2) build to courses

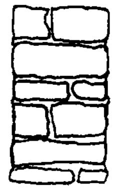
  (b) squared Rubble
    (1) uncoursed
    (2) build to courses
    (3) regular coursed

  (c) Miscellaneous
    (1) polygonal walling
    (2) flint walling

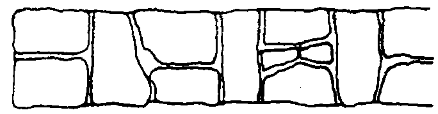
KNOW HOW

PROPPER BONDING

CORRECT

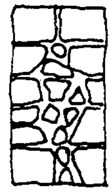


SECTION

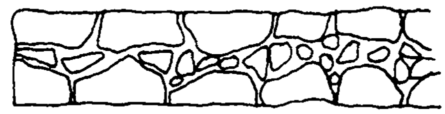


TOP VIEW

WRONG



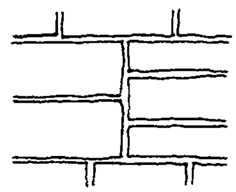
SECTION



TOP VIEW

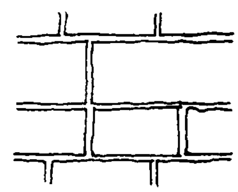
JOINTS

WRONG



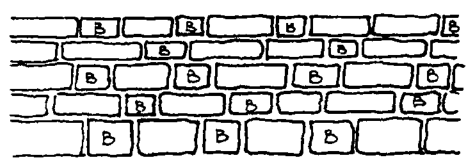
VERTICAL JOINTS (CROSS or HEAD-JOINTS) TROUGH DIFF. COURSES

OR

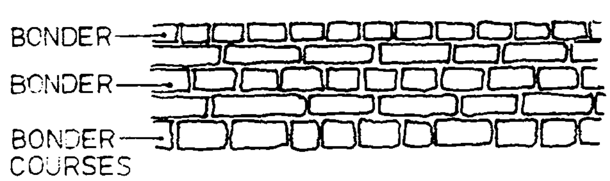


THE CROSSING OF JOINTS

TO BE AVOIDED



N.B. AFTER (at least) TWO STRETCHERS ONE BONDER has to follow!

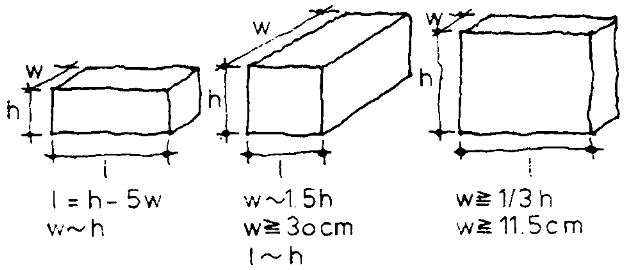


N.B. THE DEPTH of a BONDER to be approx. 1 1/2 the THICKNESS of the COURSE (min. 3o cm)

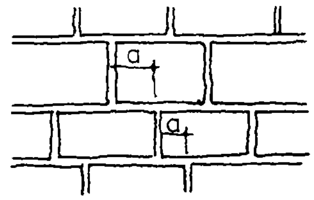
6.WALLS compiled: D.VOLKE JULY '80	STONEWORK	BUILDING CONSTR. — LECTURE — CET 3031/16.4 33

KNOW HOW

STRETCHER BONDER TILE

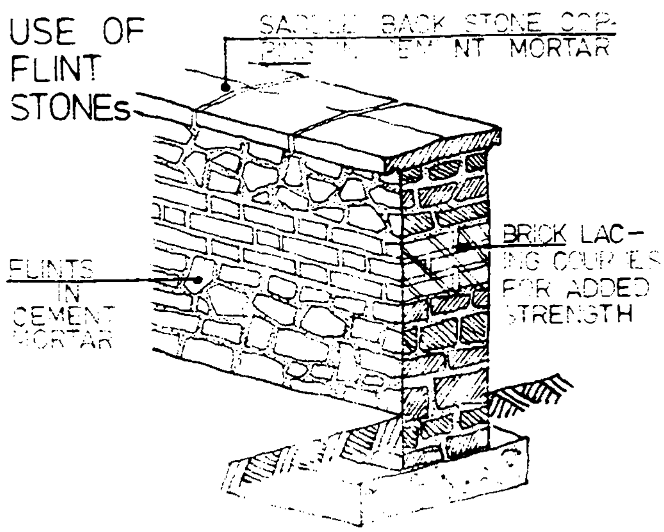


OVERLAPPING OF CROSS JOINTS



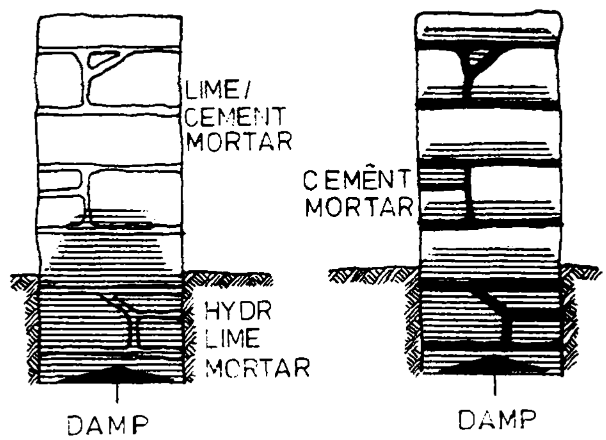
IN COURSED RUBBLE WALLS: a = 10 cm
IN ASHLAR WALLS a = 15 cm

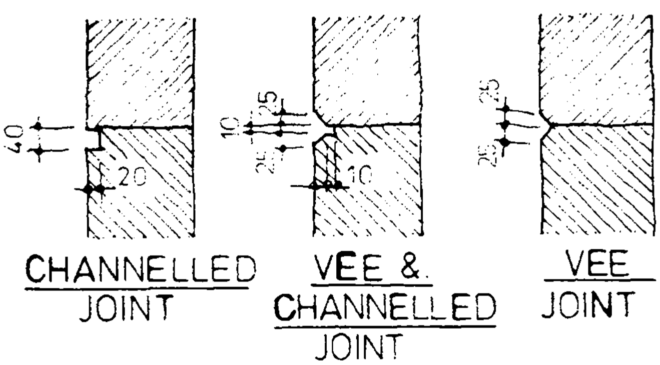
USE OF FLINT STONES



USE of MORTAR

CORRECT WRONG





6.WALLS	STONEWORK	BUILDING CONSTR.
compiled: D.VOLKE		LECTURE
JULY '80		CET 3031/16.4 34

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CIVIL ENGINEER DEPARTMENT

ASHLAR WALLING

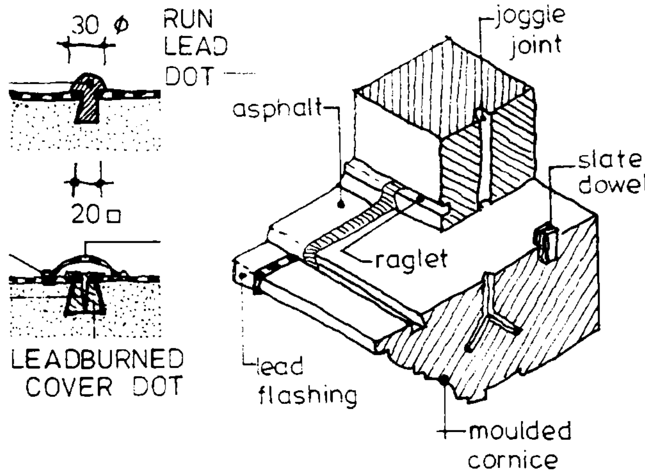
6.4.5 Ashlar Walling

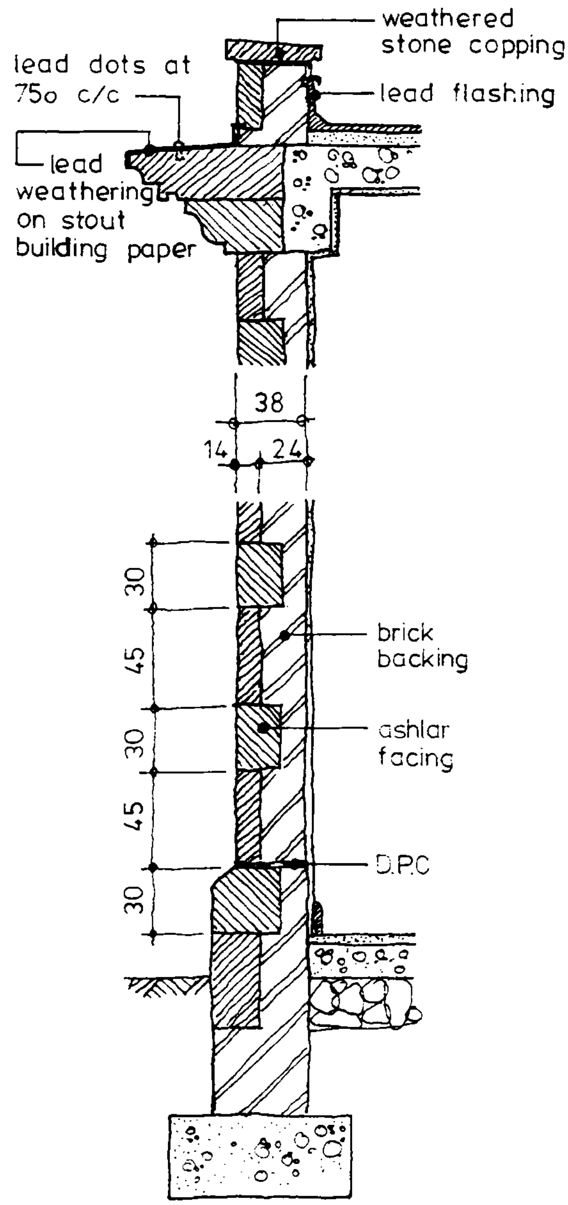
- This form of stone walling is composed of
  - o carefully worked stones
  - o regular coursed
  - o bonded
  - o set with thin rusticated joints

  and is used for the majority of high-class facingwork in stone.

- The quoins are sometimes given a surface treatment to emphasize the opening or corner of the building.

- Most of the ashlar work is carried out in Limestone (10-30 cm thick) and set in mason's putty which is a mixture of stonedust/lime putty/portland cement.
  Typical ratio: 7/5/2.





RULES

6.4.5.1 Rules for ashlar work

1. Back faces of ashlar stones should be painted with a bituminous or similar waterproofing paint.

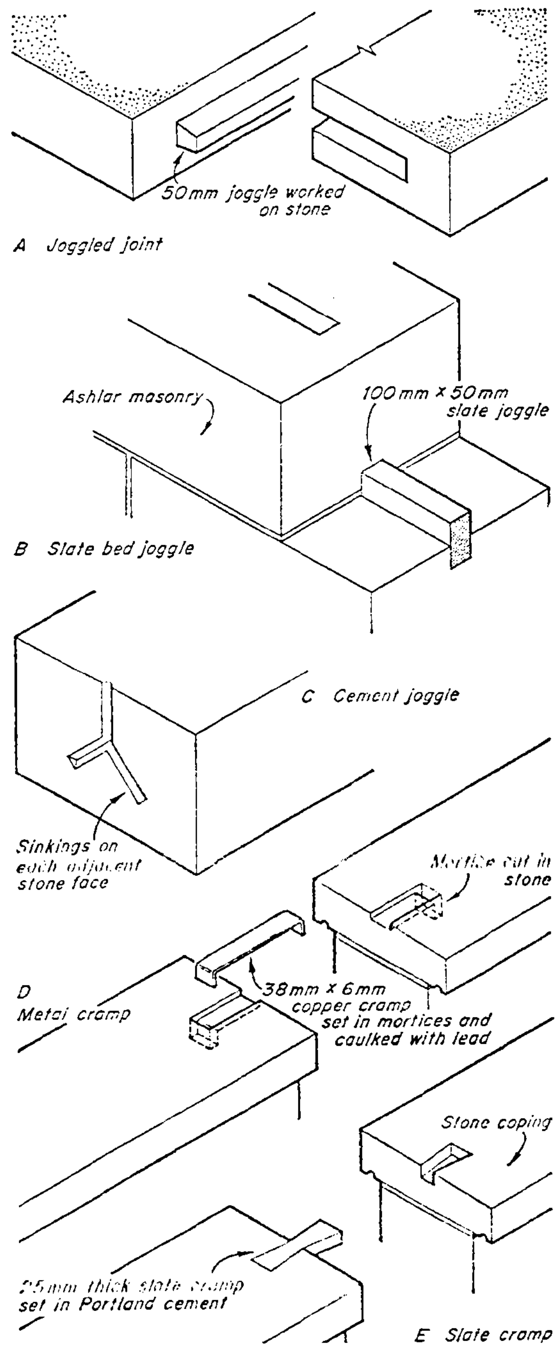
2. External stone work must not be taken through the thickness of the wall since this could create a passage for moisture.

3. Ledges of corcices and external projections should be covered with LEAD, COPPER, or ASPHALT to prevent damage by rain or birds.

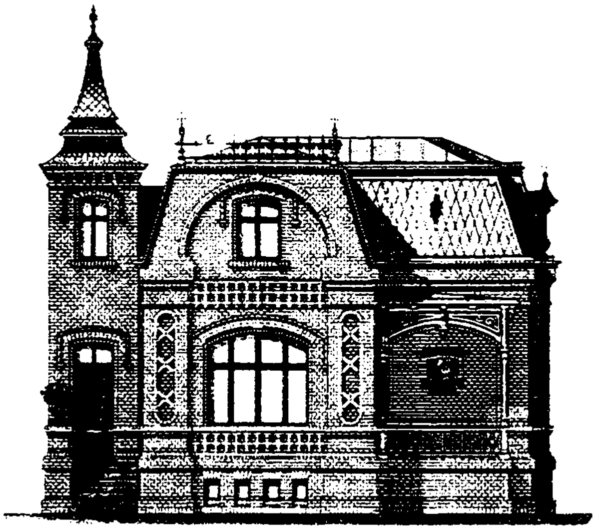
4. Moulded cornices should be raked back at 45° to counteract the cantilever action.

5. Face of stones should be given a protective coat of slurry during construction, the slurry being washed off immediately prior to completion.

JOINTS & CONNECTIONS



BRICKWORK



BRICKWORK : 19th CENTURY

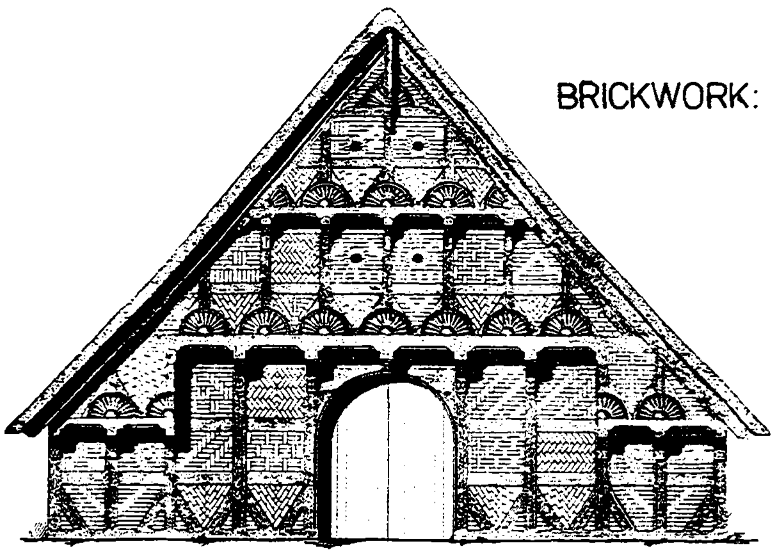
6.5 Brick work

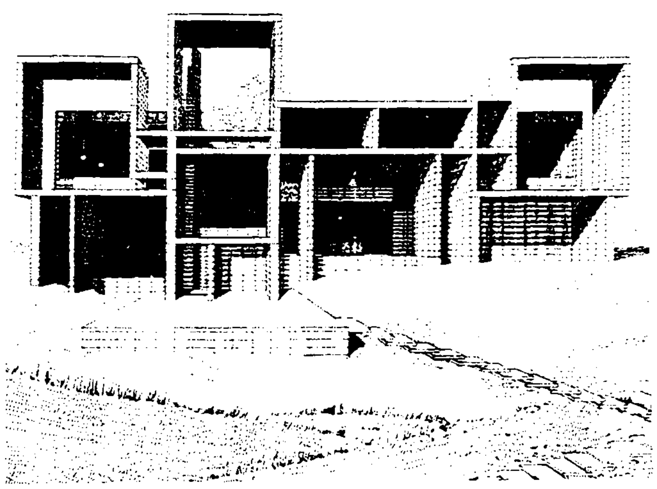
- In BS 3921, Part 2, a brick is defined as a walling unit not exceeding
  337,5 mm in length
  225,5 " " width
  112,5 " " height

This particular standard deals with bricks made of fired brick-earth, clay or shall; other standards deal with those made of calcium silicate or concrete.

Bricks are known by their format size (= actual size + 10 mm joint allowance to three faces).

BRICKWORK: 17th CENTURY





MODERN BRICKWORK: arch. RUDOLPH

- Brick work is used primarily in the construction of walls by bedding and jointing of bricks into established bounding arrangements.

  The term also covers the building in of - hollow blocks and other
  - light weight blocks.

BRICKWORK TERMINOLOGY

6.5.1 Brickwork terminology.

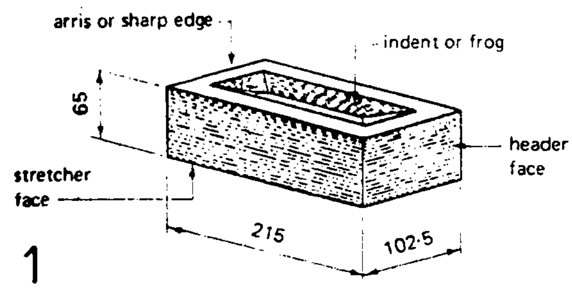
1 STANDARD BRICKS :

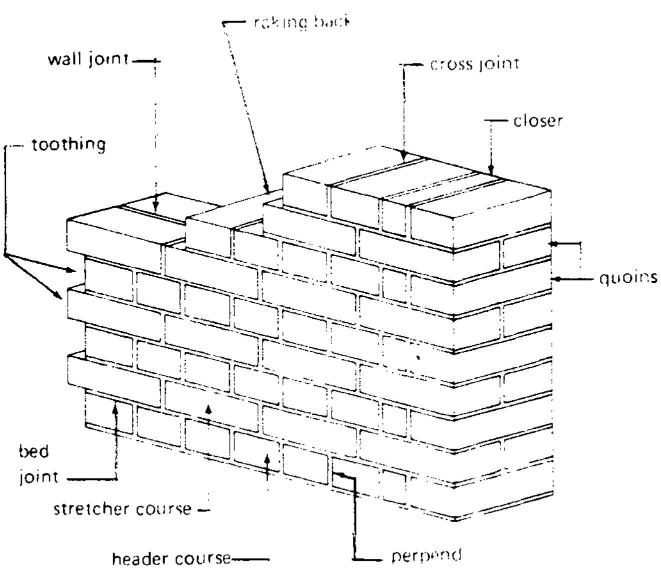
a) BRITISH STANDARD :

215 × 102.5 × 65 mm

b) GERMAN STANDARD :

240 × 115 × 71 mm





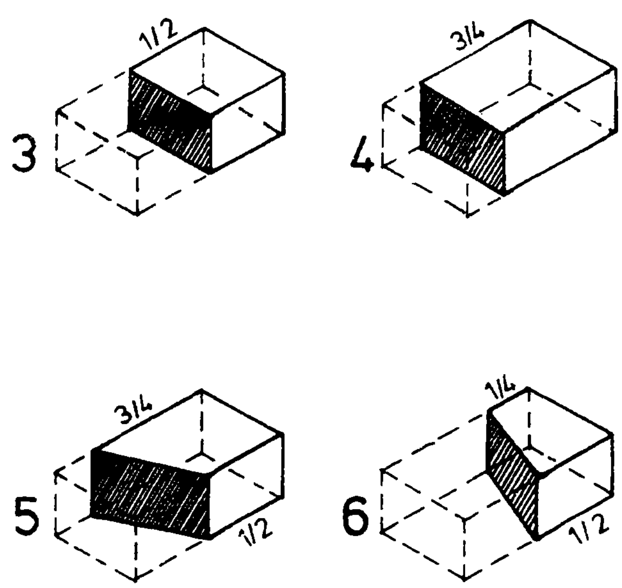
2 STOPPED END of a ONE BRICK WALL

3 HALF BAT

4 THREE QUARTER BAT

5 BEVELLED BAT-large

6 BEVELLED BAT-small



7 QUEEN CLOSER-HALF

8 QUEEN CLOSER-QUART.

9 KING CLOSER

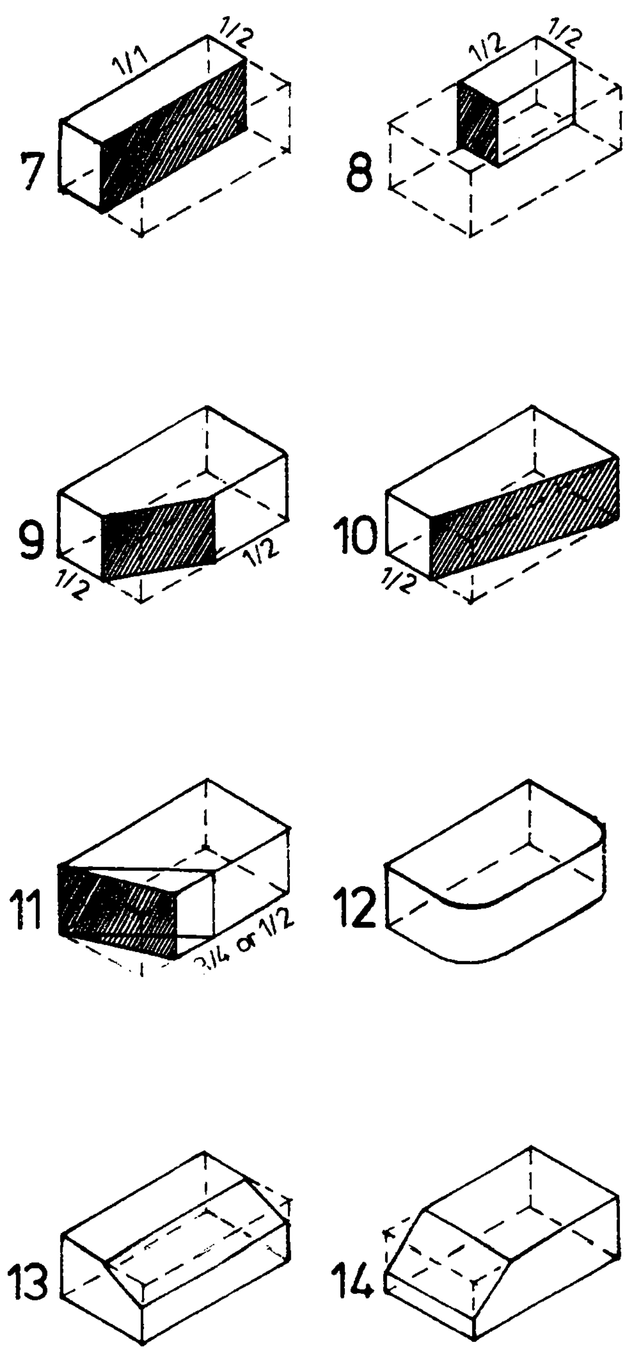
10 BEVELLED CLOSER

11 MITRED CLOSERS

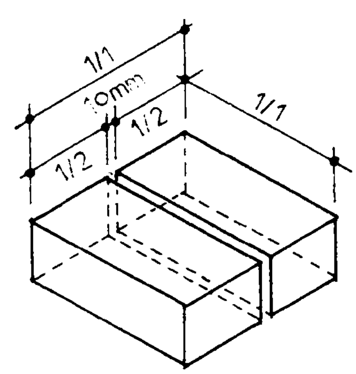
12 DOUBLE BULLNOSE

13 SPLAY-STRETCHER

14 SPLAY-HEADER



2 HEADERS + 1 JOINT (10mm)
= STRETCHER



6.WALLS compiled: D.VOLKE JULY '80	BRICKWORK	BUILDING CONSTR. — LECTURE — CET 3031/16.5 39
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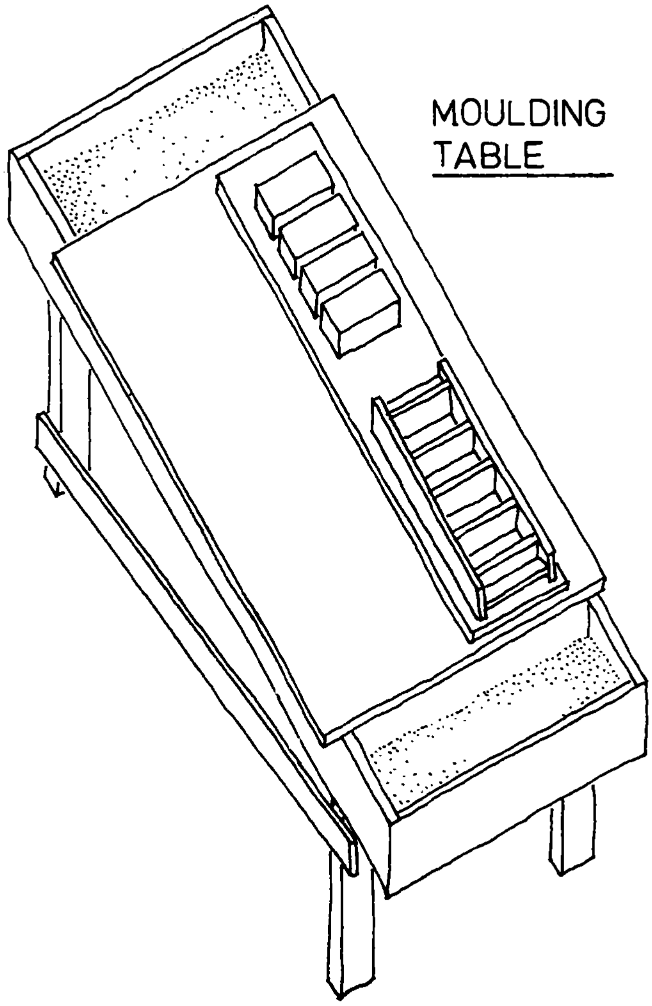
MANUFACTURE: clay BRICKS

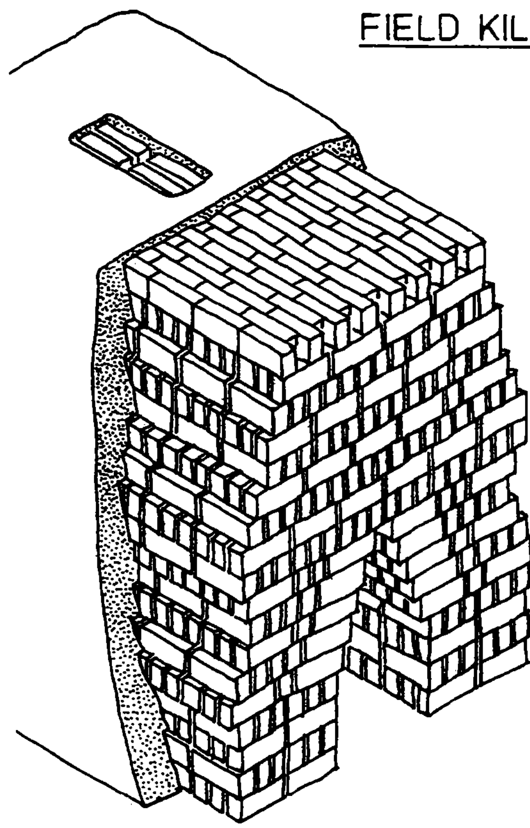


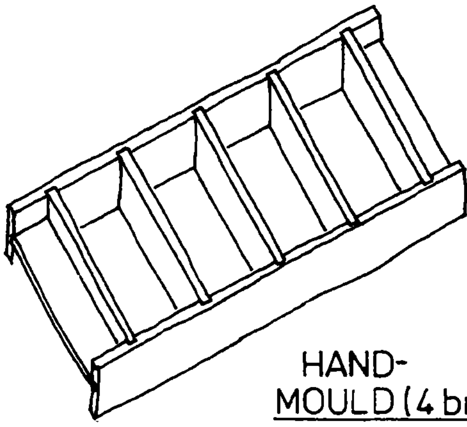
6.5.2 Manufacture of clay bricks

- The basic raw material is:
  - clay
  - shale or
  - brickearth

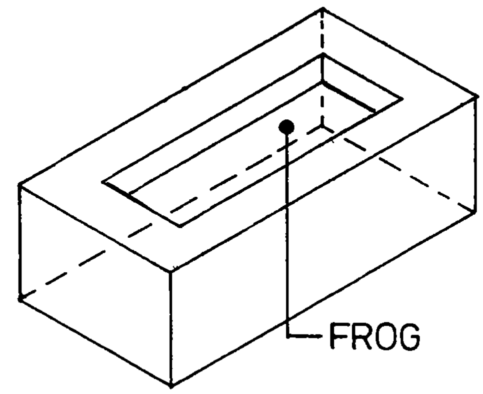
- The raw material to be
  - dug
  - prepared (by weathering or grinding)
  - mixed with water (to the right plastic condition)
  - formed (into the required brickshape)
  - dried (under a shed)
  - fired in a Kiln.

- Different clays have different characteristics (such as moisture content, chemical composition) therefore: distinct variations of the broad manufacturing processes have been developed.





PRESSED BRICKS



6.5.2.1 Pressed Bricks

- This type of brick is the most common used.
- There are 2 processes of pressed brick manufacture:

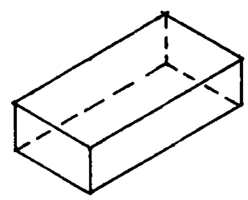
  (1) semi dry = clays which have a low natural plasticity. The clay is ground, screened and pressed directly into the moulds.

  (2) stiff plastic = The clays require more grinding and the clayclust needs tempering (mixing with water) before being pressed into the mould.

  Most pressed bricks contain frogs which are sometimes pressed on both bed faces. In general pressed bricks are more accurate in shape than other clay bricks with sharp arrises and plain faces.

6.5.2.2 Wire cut bricks

- The clay, which is usually fairly soft and of fine texture is extended as a continous ribbon and is cut into brick units by tightly streched wires spaced, at the height or depth for the required brick.
- Allowance is made during the extension and cutting for the shrinkage that will occur during firing.
- Wire cut bricks do not have frogs and on many the wire cutting marks can be clearly seen.



WIRE CUT BRICKS

EFFLORESCEN-CE

6.5.2.3 Efflorescence

= White stain appearing on the face of brickwork
  caused by deposits of soluble salts formed on or near the surface of the brickwork
  as a result of evaporation of the water in which they have been dissolved,

- it is usually harmless and disappears within a short period of time,
- dry brushing or with clean water may be used to remove the salt deposite but the use of acids should be left to the expert.

6.5.3 Brick classification

- No standard system for the classification of bricks has yet been devised.
  Bricks are generally known by the terms given in B.S. 3921 or by the description given by the brick manufacturer (or a combination of the two).

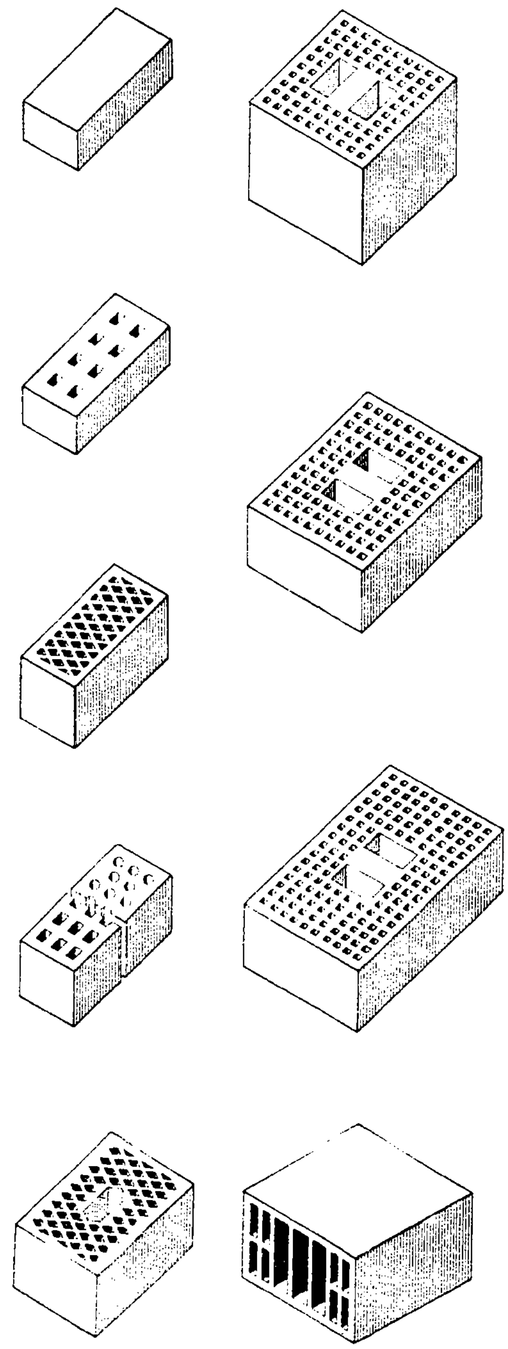
  BS 392, Part 2
  This standard gives 3 headings:

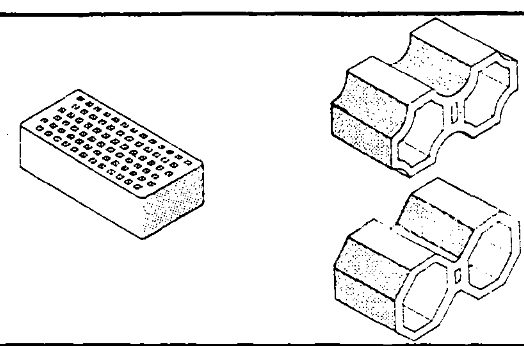
  (1) Varieties: - common
  - facing
  - engineering

  (2) Qualities: - internal
  - ordinary
  - special

  (3) Types: - solid/ holes do not exceed 25% of volume. Frogs do not exceed 20% of volume. (A small hole is difined as a hole less than 20 mm wide or less than $500mm^2$ in area).
  - perforated: holes exceed 25% of volume.
  - hollow: holes exceed 25% of volumes holes are larger.
  - cellular: holes are close at one end and exceed 20% of the volume.

CLASSIFICATION





Bricks may also be classified by one or more of the following:
- place of origin
- raw material (i.e. clay)
- manufacture (" wire cut)
- use (" foundation)
- colour
- surface texture (i.e.sand-faced)

CALCIUM SILICATE BRICKS

6.5.4 Calcium silicate bricks

- These bricks are also called sandlime and sometimes flint-lime bricks and are covered by B.S. 187, Part 2, which gives 8 classes of bricks - the higher the numbered class the stronger is the brick.

- The formate size = standard clay brick.

- These bricks are carefully selected clean sand and/or crushed flint mixed with controlled quantities of lime and water.
  (At this stage colouring pigments can be added if required). The relatively dry mix is then fed into presses to be formed into the required shape.

- The moulded bricks are then hardened in sealed and steam pressurised into claves.

- This process, which takes from seven to ten hours, causes a reaction between the sand and the lime resulting in a strong homogeneous brick which is ready for immediate delivery and laying the bricks are very accurate in size and shape but do not have the individual character of clay bricks.

CONCRETE BRICKS

6.5.5 Concrete Bricks

- These are made from a mixture of aggregate and cement in a similar fashion to calcium silicate bricks and are cured either by natural weathering or in an autoclave.

  Details of the types and properties available as standard concrete bricks are given in B.S. 1180.

MORTARS

mixes:

1:3

1:3

1:1:6
1:2:9
1:3:12

6.5.6 Mortars for brickwork

The mortar used in brickwork transfers the stresses, tensile, compressive and shear uniformly between adjacent brick. To do this it must satisfy certain requirements:

1. Adequate strength (not greater than the required for the designed strength).

2. Good workability

3. Plasticity long enough for the bricks to be laid.

4. Durable over lay period.

5. Bond well to the brick.

6. Able to be produced at an economical cost.

- If the mortar is weaker than the brick shrinkage cracks will tend to follow the joints of the brickcoat and these are reasonably easy to make good.

If the mortar is stronger shrinkage cracks will tend to be vertical through the joints and the brick thus weakening the fabric of the structure.

Typical mixes (by volume)

Cement mortar (1:3) suitable for brickwork in exposed conditions such as parapets and for brickwork in fondation.

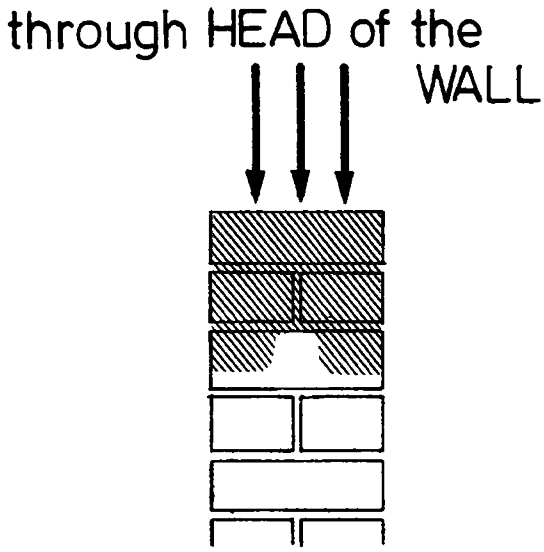
Lime mortar (1:3) for internal use.

Gauged mortar (cem./lime/sand)

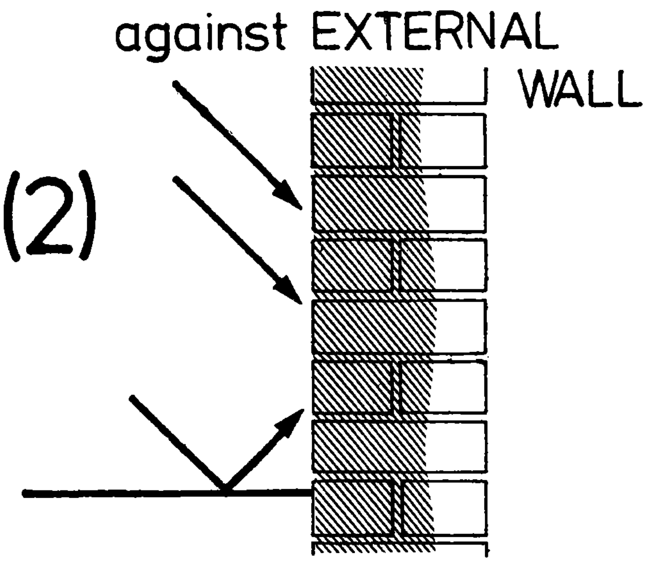
1:1:6 suitable for most conditions.
1:2:9 suitable for most conditions except those of severe expose.
1:3:12 internal use only.

DAMPNESS PENETRATION

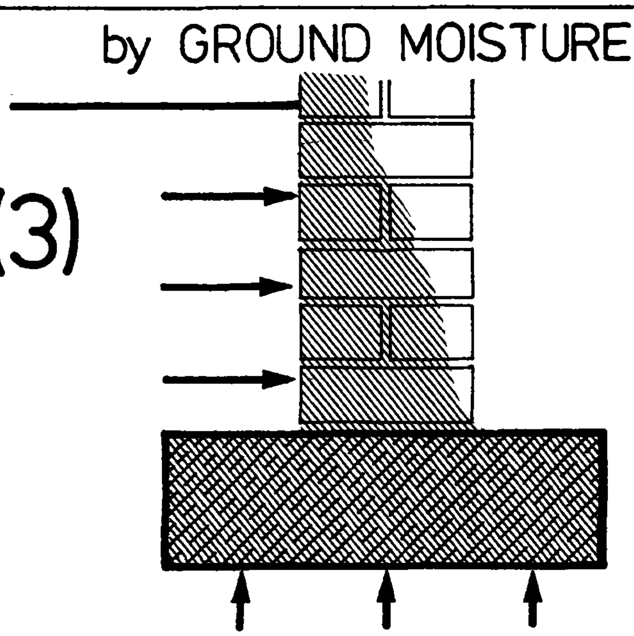
(1)



(2)



(3)



6.5.7 Dampness penetration

- It is possible for dampness to penetrate into a building through the walls by one or more of three ways:

  (1) By the rain penetrating the head of the wall and soaking down into the building below the roaf level.

  (2) By the rain beating against the external wall and soaking through the fabric into the building.

  (3) By ground moisture entering the wall at or near to the base and creeping up the wall by capillary action and entering the building above the ground floor level.

- Nos. 1 and 3 can be overcome by the insertion of a suitable D.P.C. in the thickness of the wall.

- No. 2 can be overcome by one of the two methods:

  (a) Applying to the exposed face of the wall a barrier such as cement rendering or some suitable cladding like vertical tile hanging.

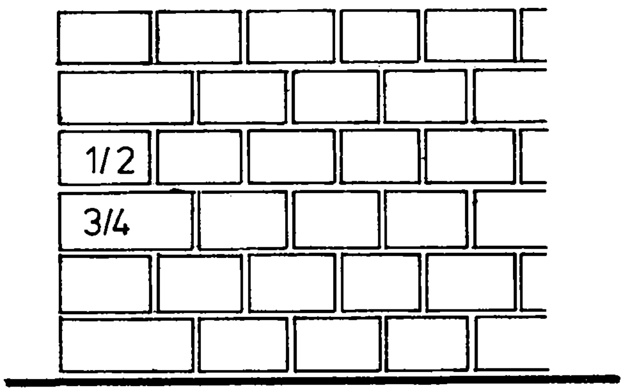
  (b) By constructing a cavity wall, whereby only the external skin becomes damp. The cavity, providing a suitable barrier to the passage of moisture through the wall.

BONDING

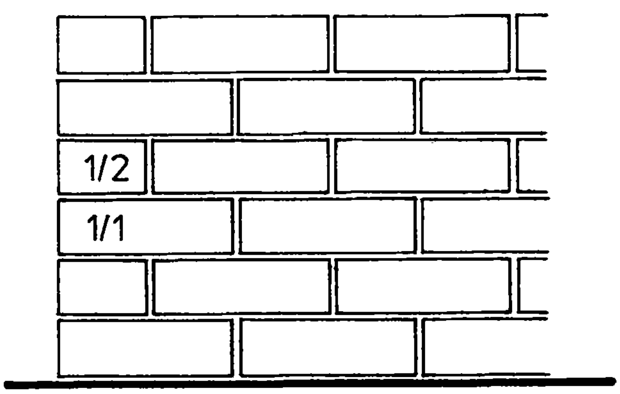
6.5.8 Brickwork bonding

- Bricks are layed to bonds, in order
  - to ensure stability of the structure and
  - to produce a pleasing appearance.
- No vertical joint in any one course to be directly above or below a vertical joint in the adjoining course.
- Special bricks are produced (or cut from whole bricks on site) to simplify this requirement (Fig. II 11)
- The various bonds are planned to give the greatest practical amount of <u>lap</u> to all bricks. (= not to be less than 1/4 of a brick length).
- Properly bonded brickwork distributes the load over as large an area as possible (angle at spread of the load = 60°)

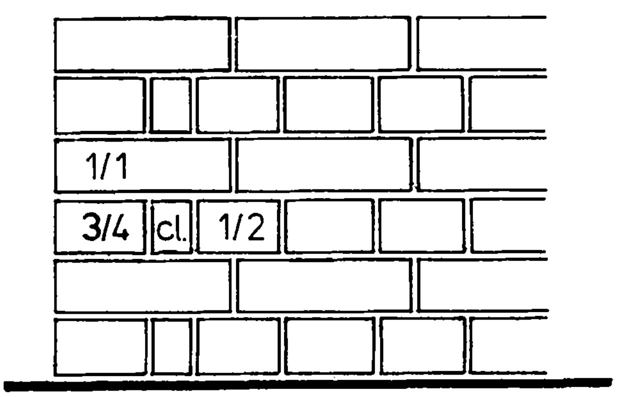
6.5.8.1 Common bonds



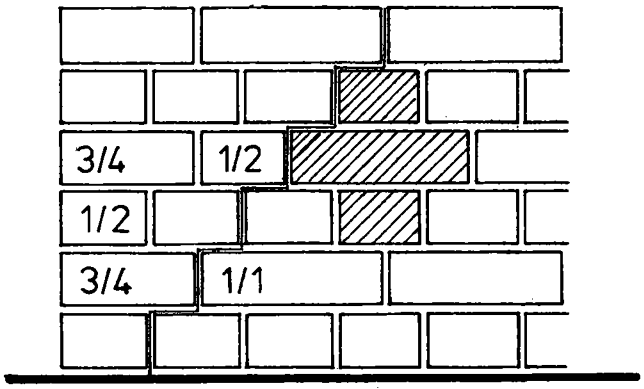
<u>Header bond</u>: Consists of all headers, with the bond being formed by 3/4 bats at the quoins. It is used for one-brick walls in footing courses or walling curved on plan.



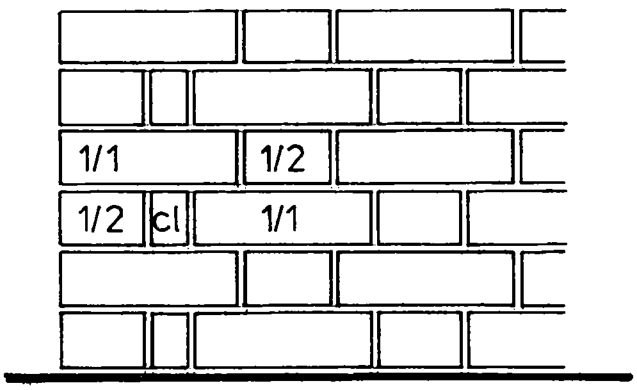
<u>Stretcher bond</u>: consists of all stretchers in every course and is used for half brick walls and the half brick skins of hollow or cavity walls.



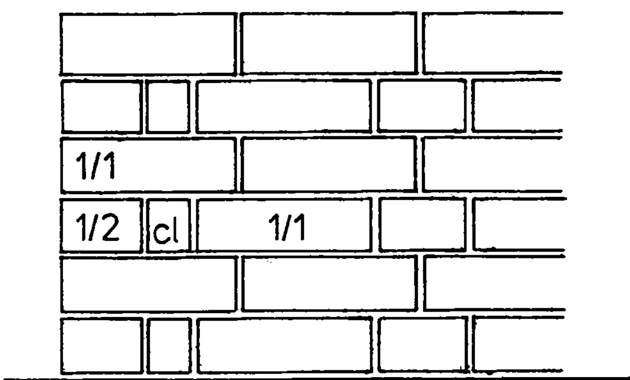
<u>English bond</u>: A very strong bond consisting of alternate headers and stretchers, with a queen closer placed next to the quion heder to form the lap.



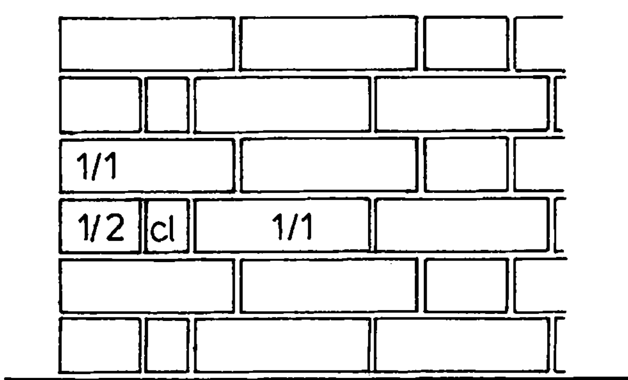
Cross bond: The strongest possible bond used for one-brick walls consisting of alternate courses of headers and stretchers, with the bond being formed by 3/4 bats at the quoins of the stretcher courses. In every second stretcher course the 3/4 bats are followed by a header.



Flemish bond: each course consists of alternate headers and stretchers, its appearance is considered to be better than English bond but it is not quite so strong. This bond requires fewer facing bricks (than Engl. bond) needing only 79 bricks/m^2 (Engl. bond: 89 bricks/m^2).

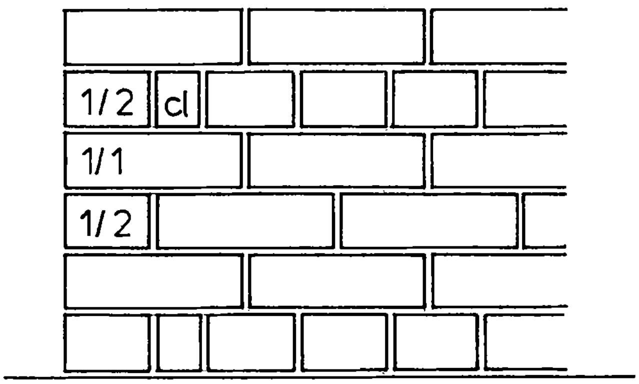


Monk bond: Consists of 2 stretchers to 1 header in each course. The header is laid centrally over the cross-joint between 2 stretchers in the course below.



Flemish garden wall bond: = 1 header/3 stretchers in every course.

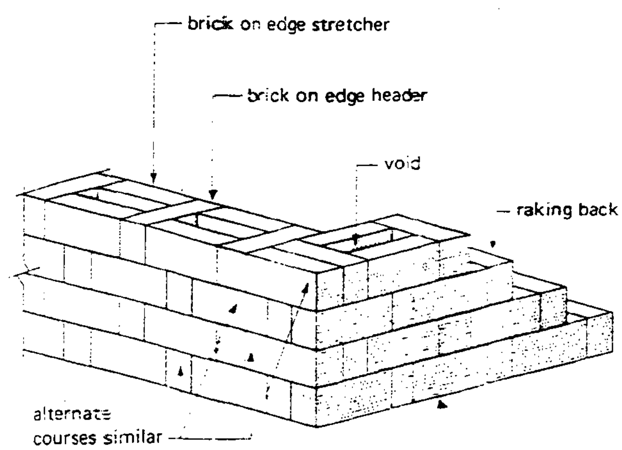
This bond is fairly economical in facing bricks and has a pleasing appearance.



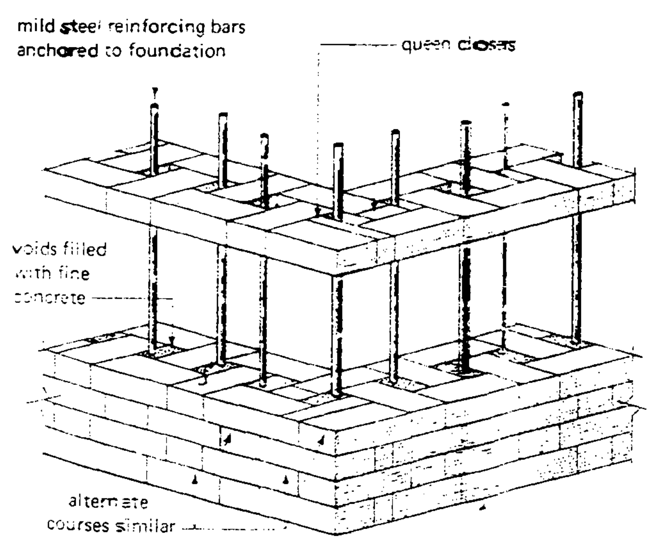
English garden wall bond: = 3 courses of stretchers/1 course of headers.

Special bonds:
Rat-trap bond (brick on edge b)
Quetta bond (1 1/2 brick walls)
(Fig. II.15)

RAT-TRAP BOND

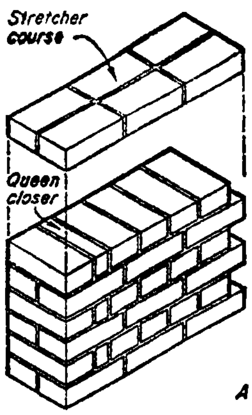


QUETTA BOND

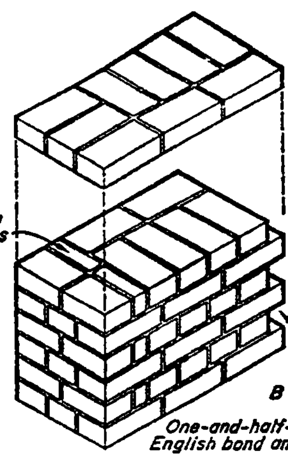


ISOMETRIC VIEW OF :

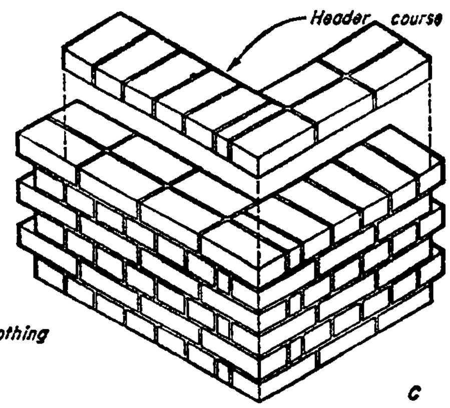
A	ENGLISH BOND
B	-II- -II-
C	-II- -II-
D	FLEMISH BOND
E	-II- -II-
F	-II- -II-
G	ENGLISH GARDEN WALL BOND
H	FLEMISH -II- -II- -II-
J	RAT TRAP BOND



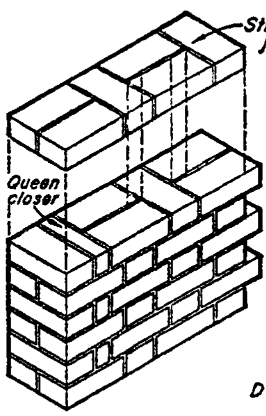
A
One-brick wall in English bond and stopped end



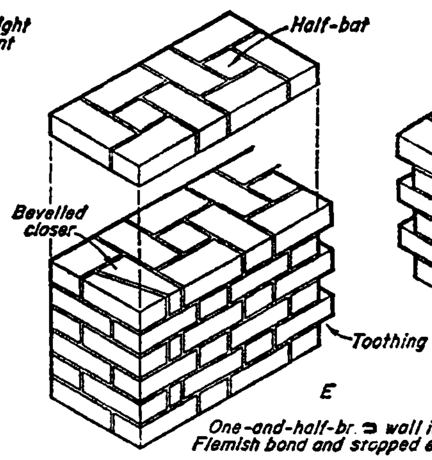
B
One-and-half-brick wall in English bond and stopped end



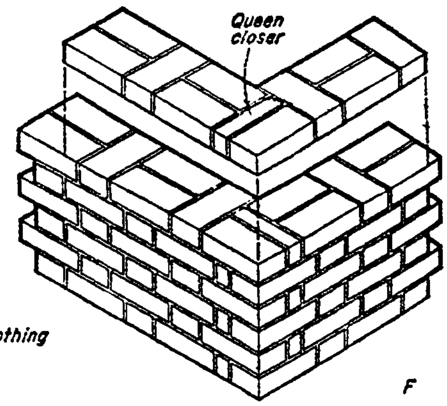
C
One-brick wall in English bond and quoin



D
One-brick wall in Flemish bond and stopped end

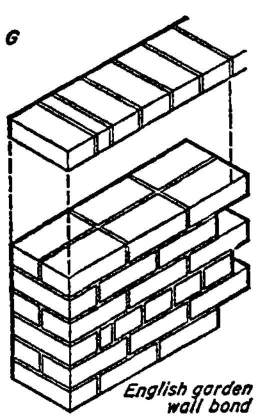


E
One-and-half-br. wall in Flemish bond and stopped end



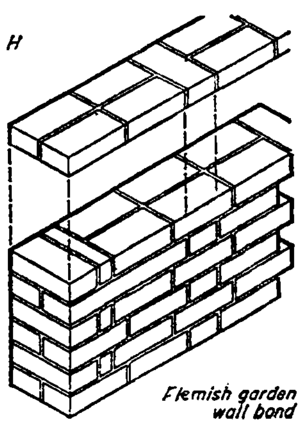
F
One-brick wall in Flemish bond and quoin

G

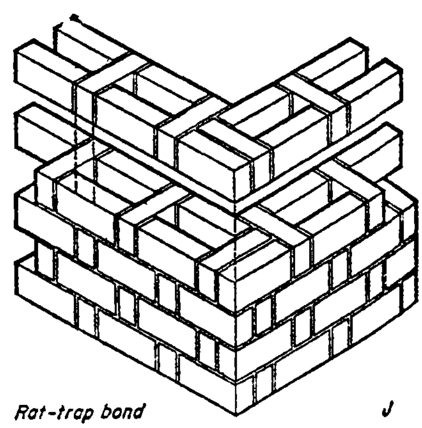


English garden wall bond

H



Flemish garden wall bond



Rat-trap bond

J

6.WALLS	BRICKWORK	BUILDING CONSTR.
compiled: D.VOLKE		LECTURE
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METRIC

BRITISH STANDARD

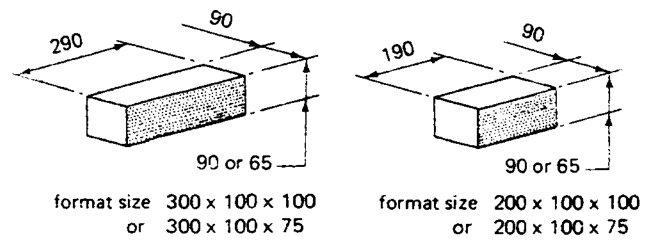
6.5.9 Metric Modular Brickwork

- The standard format brick does not fit reasonably well into the system of dimensional co-ordination with its preferred dimension of 300 mm, therefore METRIC MODULAR BRICKS have been designed (4 different formats).
  (Fig. II.16)

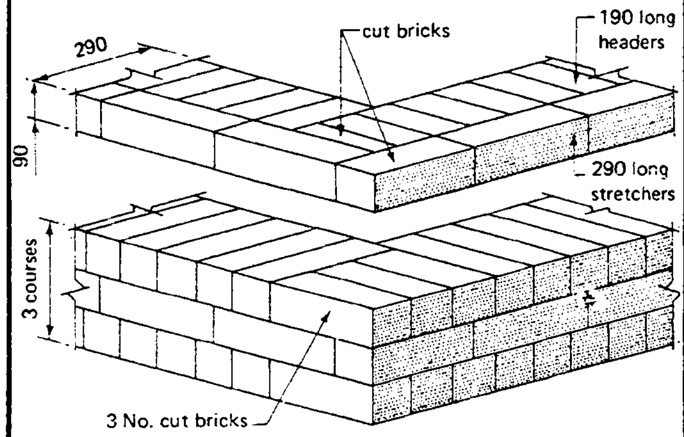
  - 300 x 100 x 100
  - 300 x 100 x 75

  - 200 x 100 x 100
  - 200 x 100 x 75

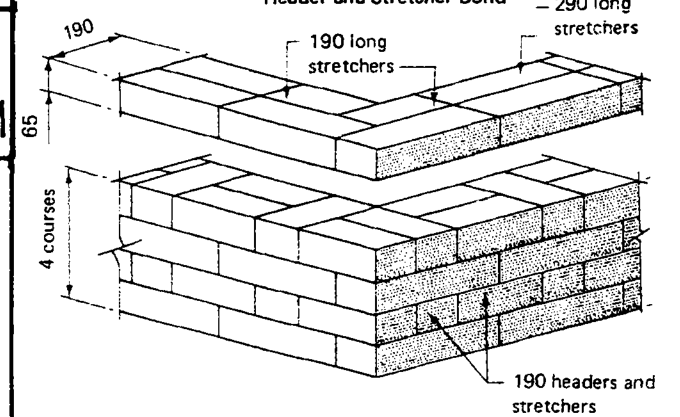
- The bond arrangements are similar to the well-known bonds but are based on THIRD BONDING: overlap = 1/3 of a brick (not 1/4 as with stand. form. bricks).



Metric Modular Bricks

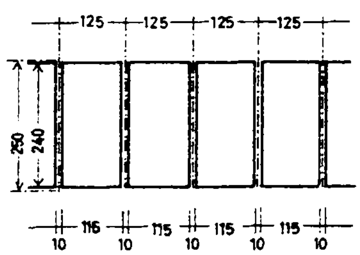


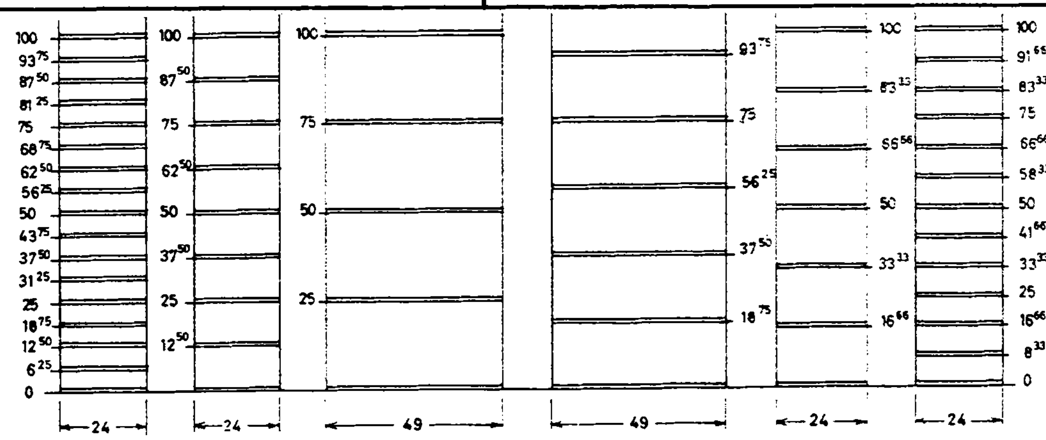
Header and Stretcher Bond



Header Stretcher Bond

GERMAN METRIC MODULAR SYSTEM



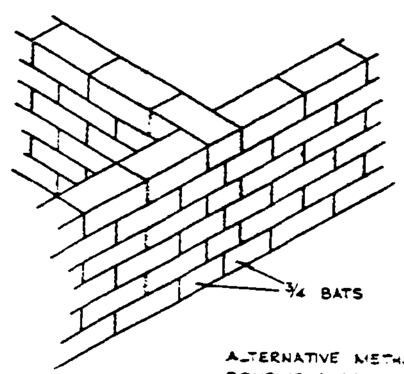


JUNCTIONS

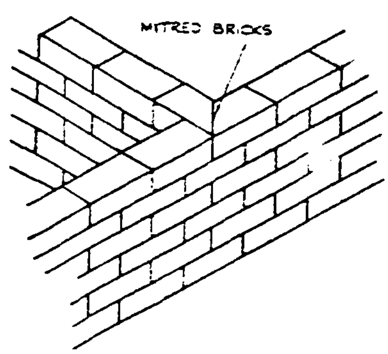
6.5.10 Junctions

- Junctions are classified into
  o right-angled junctions and
  o squint junctions.
- There are 2 forms of right-angled junctions:
  o tee-junctions and
  o cross junctions (or intersections)
- The examples shown in the figures are only few of several methods of bonding at junctions. The essential requirements are the avoidance of continous vertical joints with the employment of the minimum number of cut bricks.

tee junctions



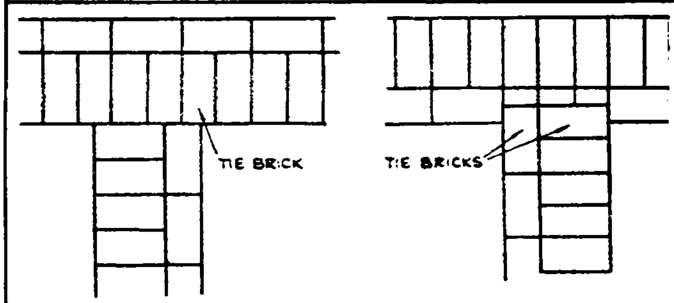
ALTERNATIVE METHODS OF BONDING A JUNCTION WALL IN STRETCHER BOND



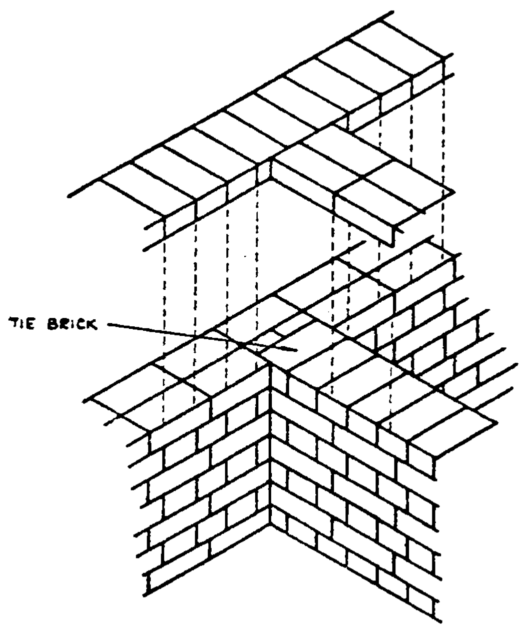
STRETCHER BOND

TEE-JUNCTION WALLS IN
ENGLISH BOND

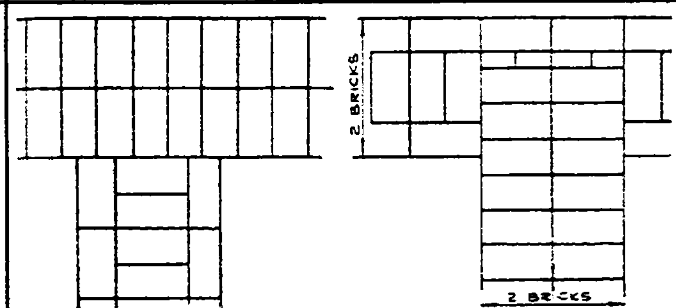
COURSE 1 COURSE 2



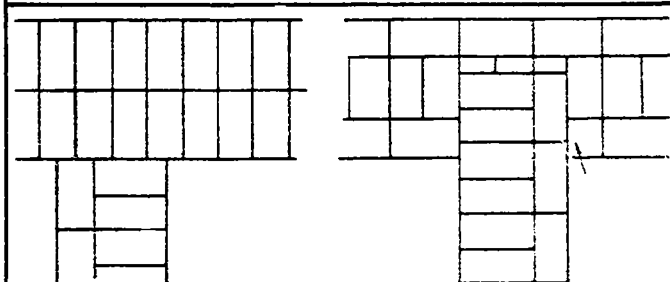
1 1/2- BRICK JUNCTION WALL



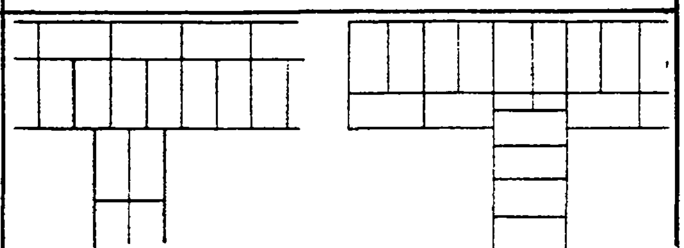
1-BRICK JUNCTION WALL ADJOINING A 1-BRICK MAIN WALL (ISOMETRIC VIEW)



2-BRICK JUNCTION WALL



1 1/2- BRICK JUNCTION WALL INTO A 2 BRICK MAIN WALL

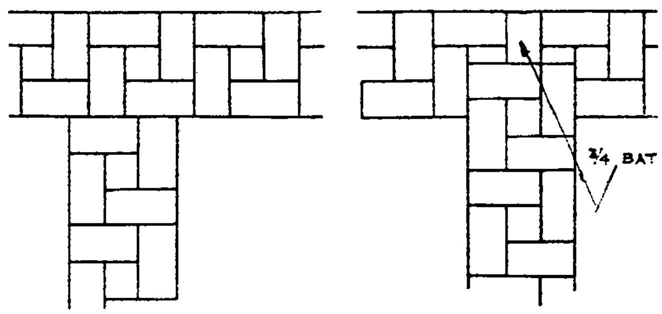


1 BRICK JUNCTION WALL INTO A 1 1/2 BRICK MAIN WALL

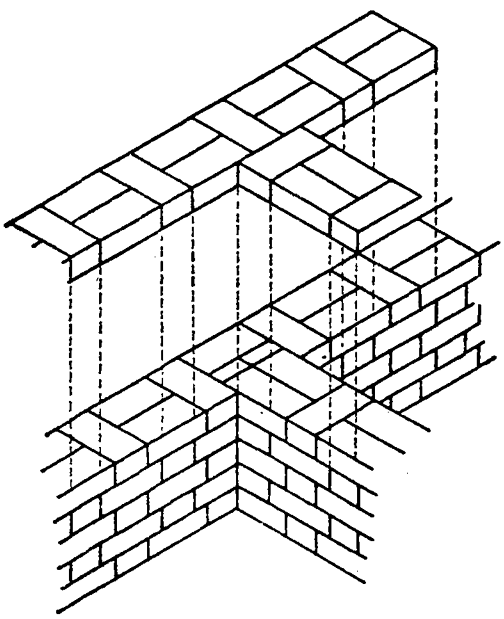
TEE-JUNCTION WALLS IN

FLEMISH BOND

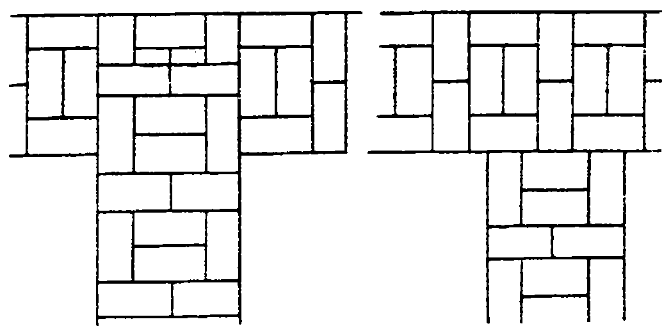
COURSE 1 COURSE 2



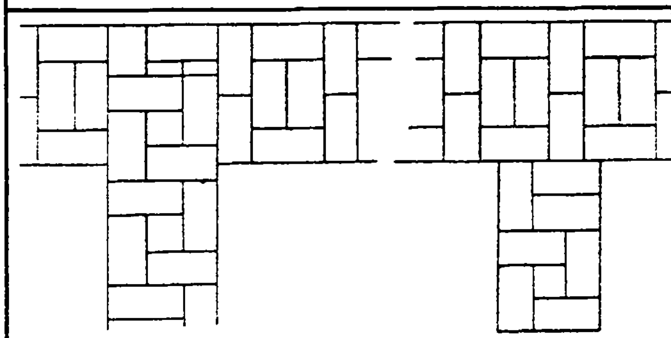
1 1/2-BRICK JUNCTION WALL



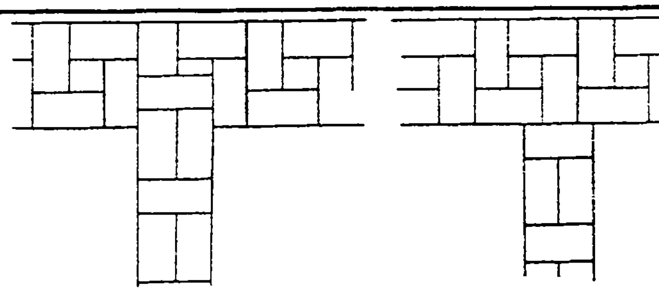
1-BRICK JUNCTION WALL ADJOINING A 1-BRICK MAIN WALL



2-BRICK JUNCTION WALL



1 1/2 BRICK JUNCTION WALL INTO A 2 BRICK MAIN WALL

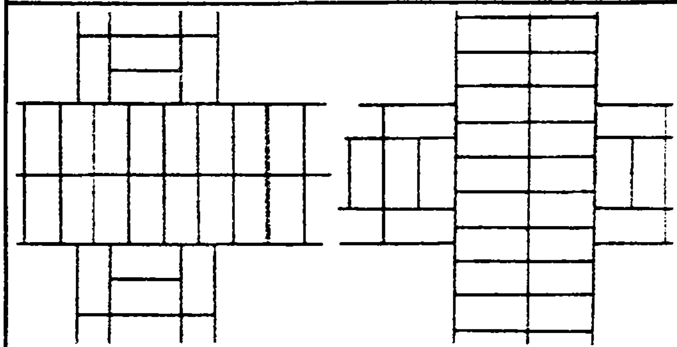


1 BRICK JUNCTION WALL INTO A 1 1/2 BRICK MAIN WALL

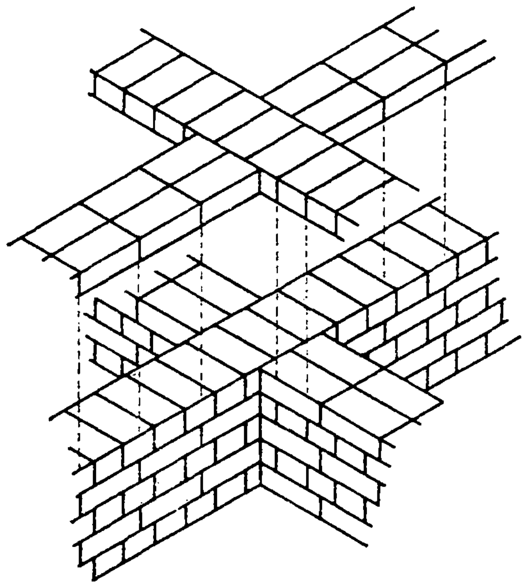
CROSS JUNCTION WALLS IN

ENGLISH BOND

COURSE 1 COURSE 2

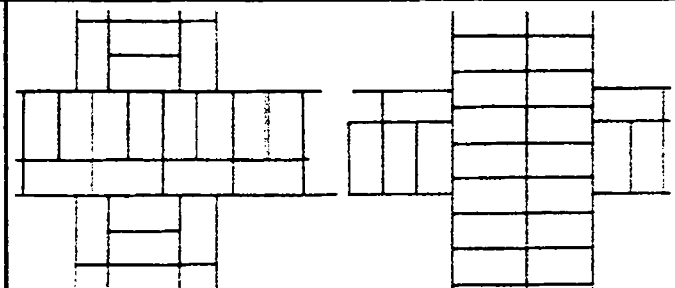


2-BRICK CROSS-WALL

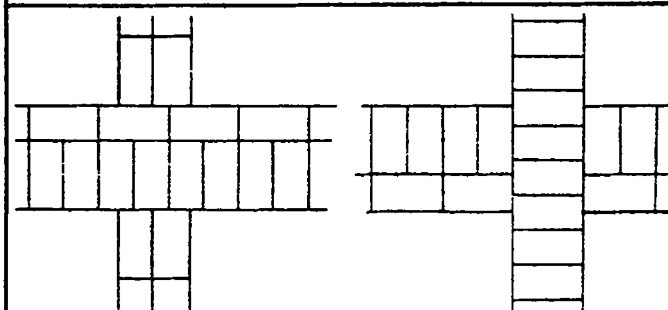


1-BRICK CROSS-WALL

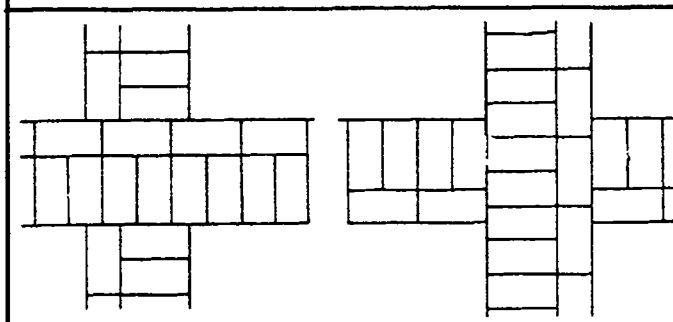
(ISOMETRIC VIEW)



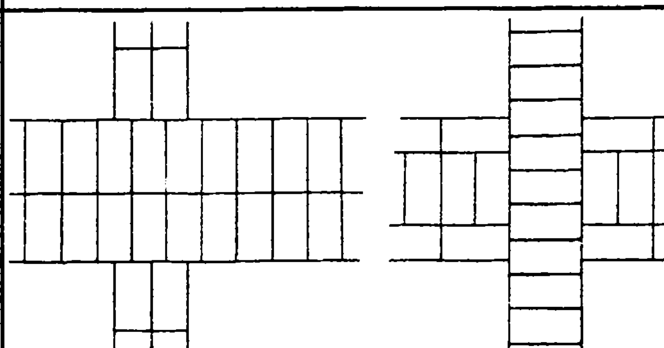
2-BRICK WALL CROSSING A 1 1/2-BRICK WALL



1-BRICK WALL CROSSING A 1 1/2 BRICK WALL



1 1/2-BRICK CROSS-WALL



1-BRICK WALL CROSSING A 2 BRICK WALL

6.WALLS	BRICKWORK	BUILDING CONSTR.
compiled: D.VOLKE		— LECTURE —
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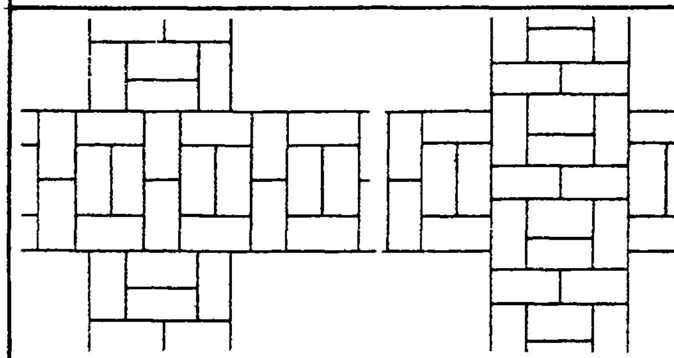
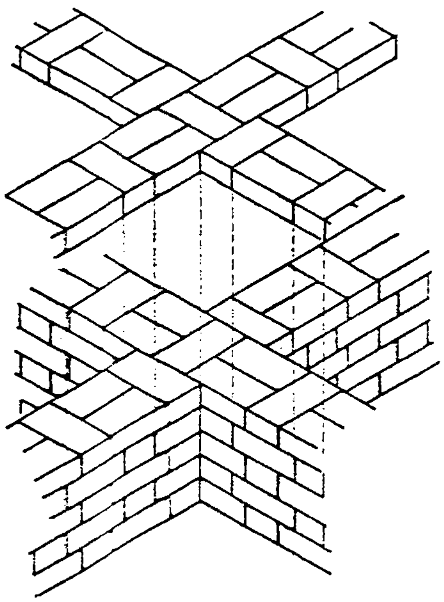
CROSS JUNCTION WALLS IN

FLEMISH BOND

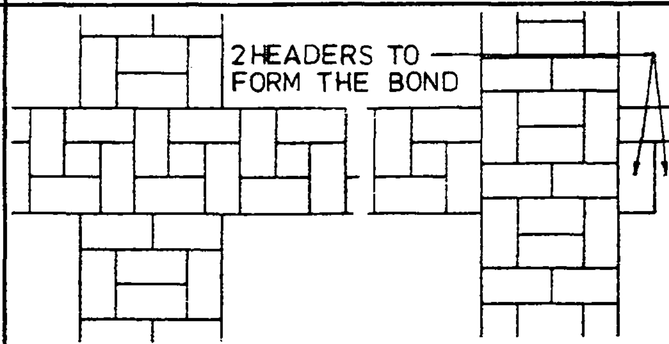
COURSE 1 COURSE 2



2-BRICK CROSS-WALL



1-BRICK CROSS WALL



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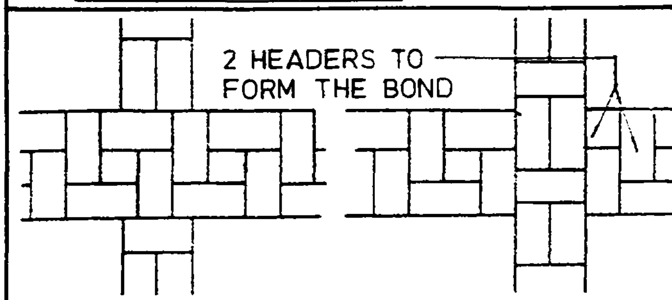
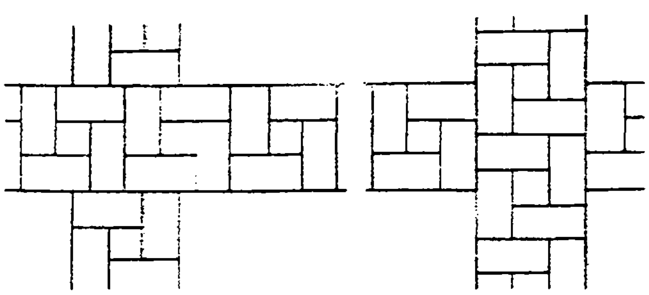
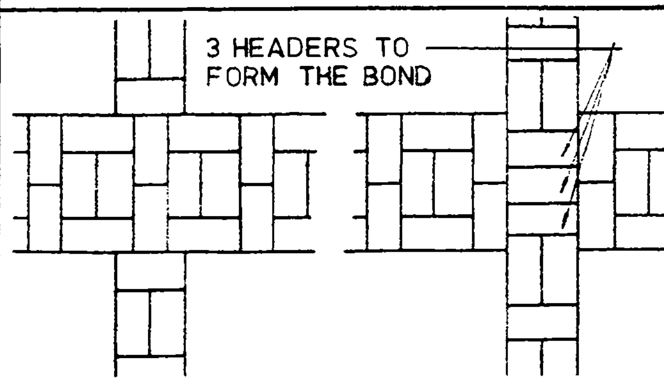


1-BRICK WALL CROSSING A 1 1/2-BRICK WALL



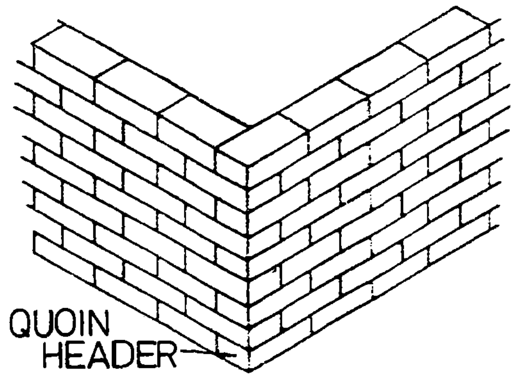
1 1/2-BRICK CROSS WALL



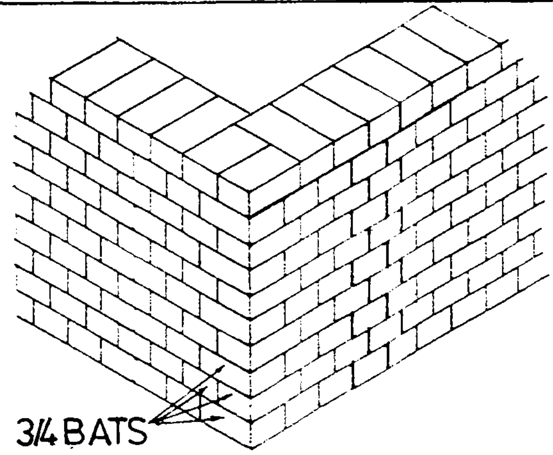
1-BRICK WALL CROSSING A 2-BRICK WALL

6.WALLS compiled : D.VOLKE JULY '80	BRICKWORK	BUILDING CONSTR. LECTURE CET 3031/16.5 55

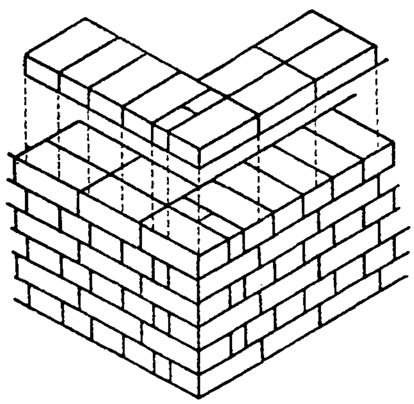
QUOIN: 1/2 BRICK STRETCHER BOND

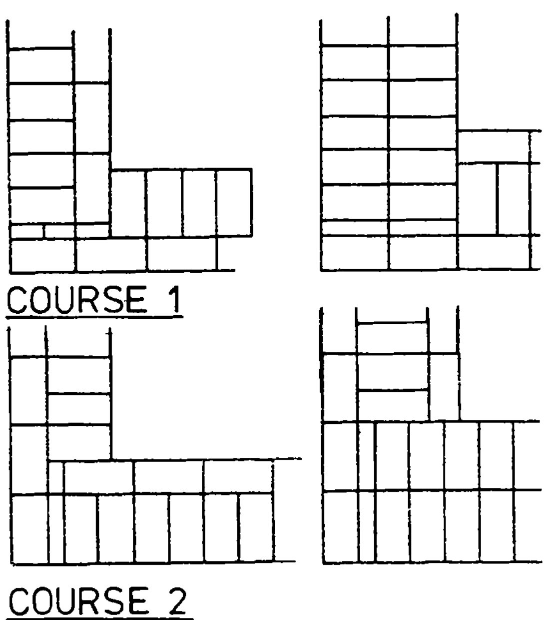


QUOIN: 1 BRICK HEADER BOND



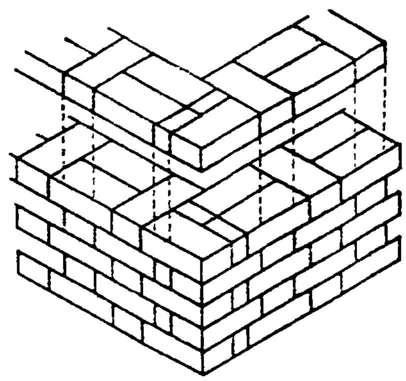
QUOIN: 1 BRICK ENGLISH BOND

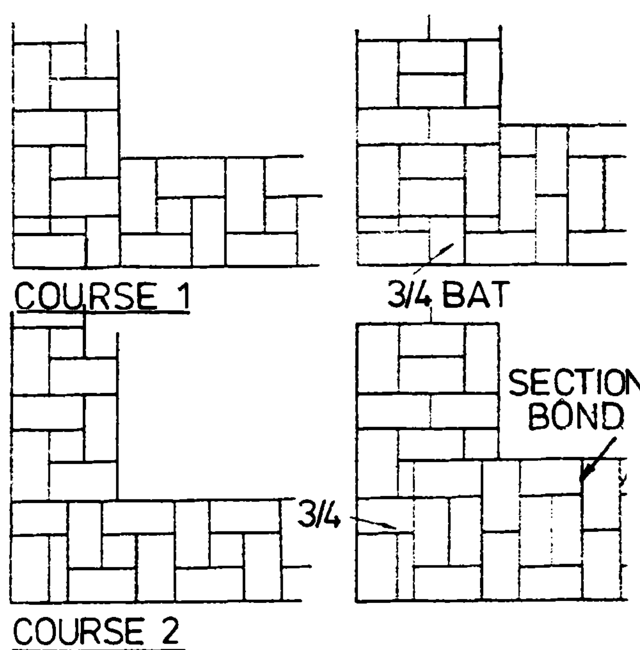




1 1/2 BRICK   2 BRICKS

QUOIN: 1 BRICK FLEMISH BOND

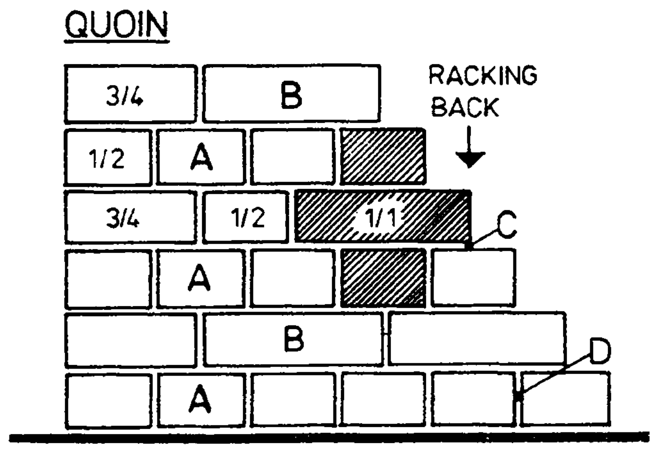




1 1/2 BRICK   2 BRICKS

6.WALLS compiled: D.VOLKE JULY '80	BRICKWORK	BUILDING CONSTR. — LECTURE — CET 3031/16.5 56

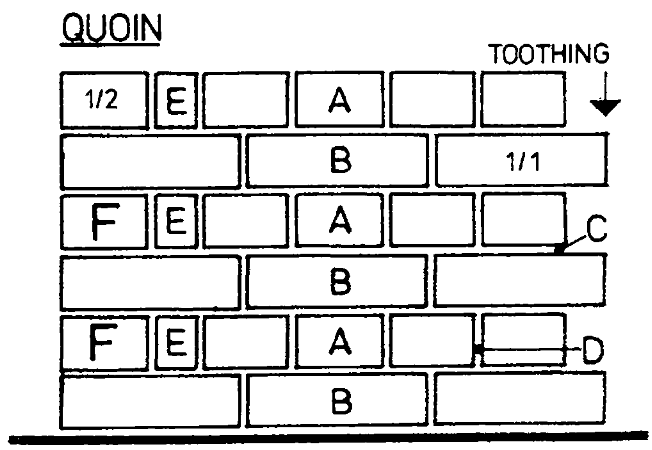
QUOINS



CROSS BOND

6.5.11 Quoins or External Angles

- There are two forms of quoins:
  - o right-angled (or square) quoins and
  - o squint guoins.
- A right-angled quoin is formed by two walls which meet at 90°, squint quoins are of two forms:
  - (a) obtuse quoins (internal angle greater than 90°)
  - (b) acute squint quoins (internal angle less than 90°).



ENGLISH BOND

A HEADING COURSE
B STRETCHING COURSE
C BED JOINT
D VERTICAL JOINT
E QUEEN CLOSER
F QUOIN HEADERS

PIERS

6.5.12 Piers (also known as pillars or columns) of brickwork are adopted either to support concentrated loads or to strengthen walls. Such piers may be isolated (detached) or attached to walls.

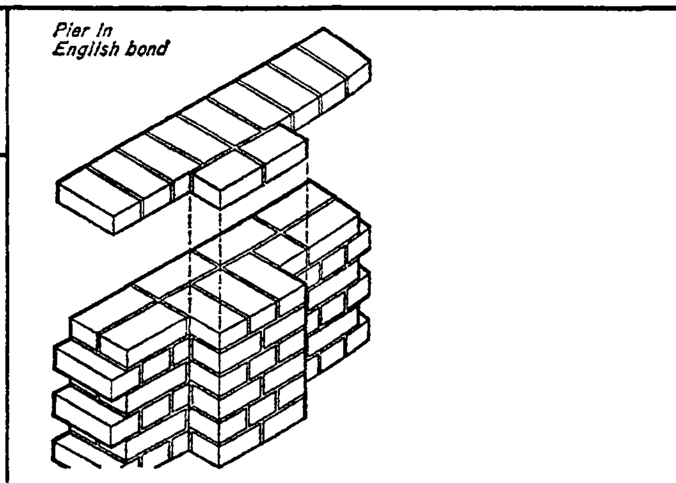
- The keyplan below shows a portion of a building in which piers are employed.
  (A) detached piers
  (B) attached piers.

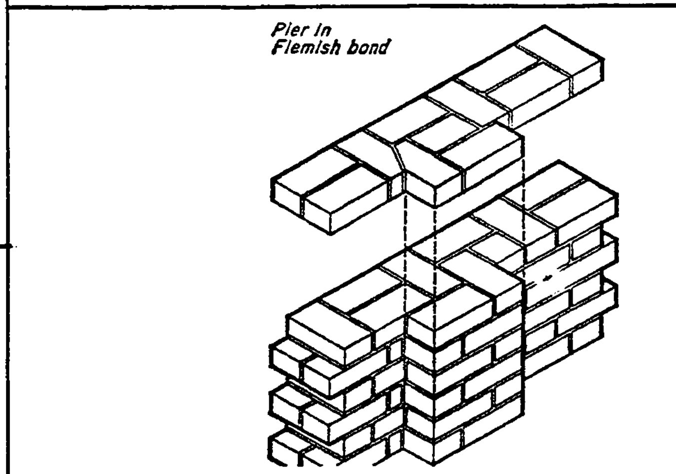
6.5.12.1 Detached piers: may be either square, rectangular, circular or polygonal on pla. The figures below show some alternate details of detached piers
(1) English bond
(2) Double flemish bond
Piers may be formed with rounded arrises by using bullnose bricks.

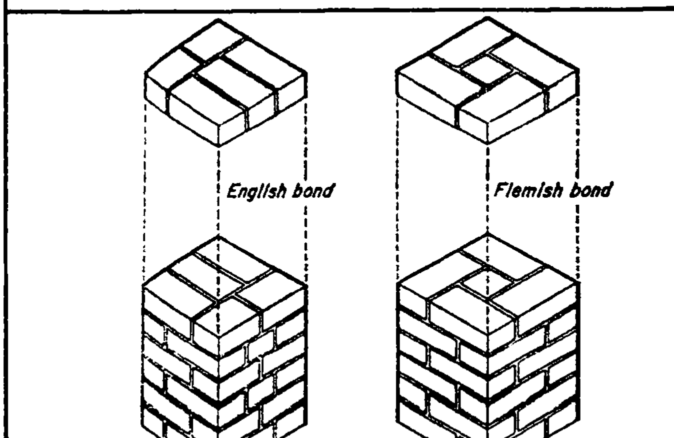
6.5.12.2 Attached Piers (or Pilasters).
The figures below show some alternate plans of attached piers.
(1) English bond
(2) Double flemish bond.
The width of a pier is usually a multiple of 112 mm and the projection may be either 112 mm, 225 mm or upwards.

6.5.12.3 BUTTRESSES are piers which are provided to resist thrusts from roof trusses or to strengthen boundary walls, etc.

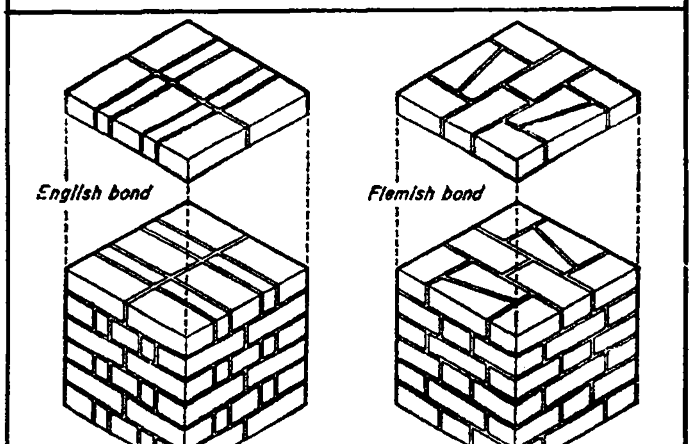
- Examples of buttress cappings are illustrated in the fig. below.







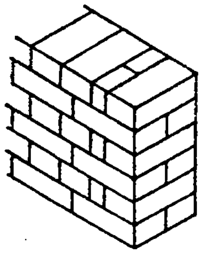
One-and-half brick column



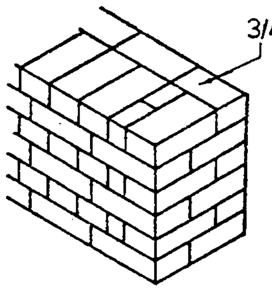
Two-brick column

STOPPED ENDS

ENGLISH BOND

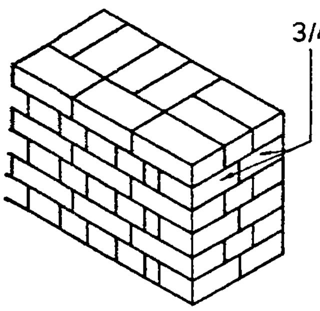


1-BRICK WALL



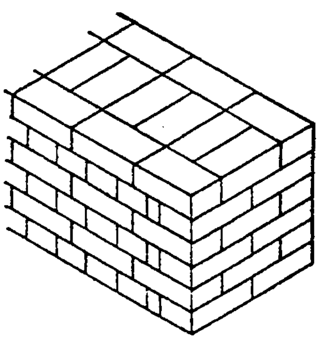
1 1/2-BRICK WALL

BOND ON THE END NOT VISIBLE



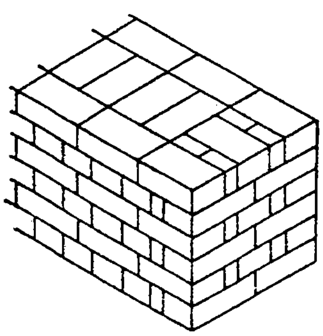
1 1/2-BRICK WALL

BOND ON THE END VISIBLE



2-BRICK WALL

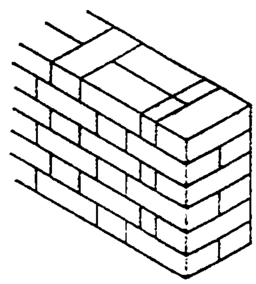
BOND ON THE END NOT VISIBLE



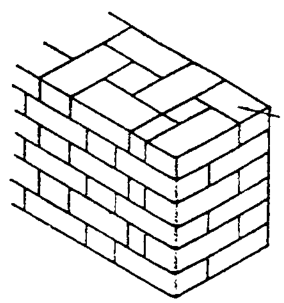
2-BRICK WALL

BOND ON THE END VISIBLE

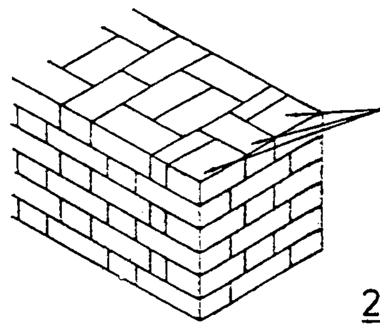
FLEMISH BOND



1-BRICK WALL



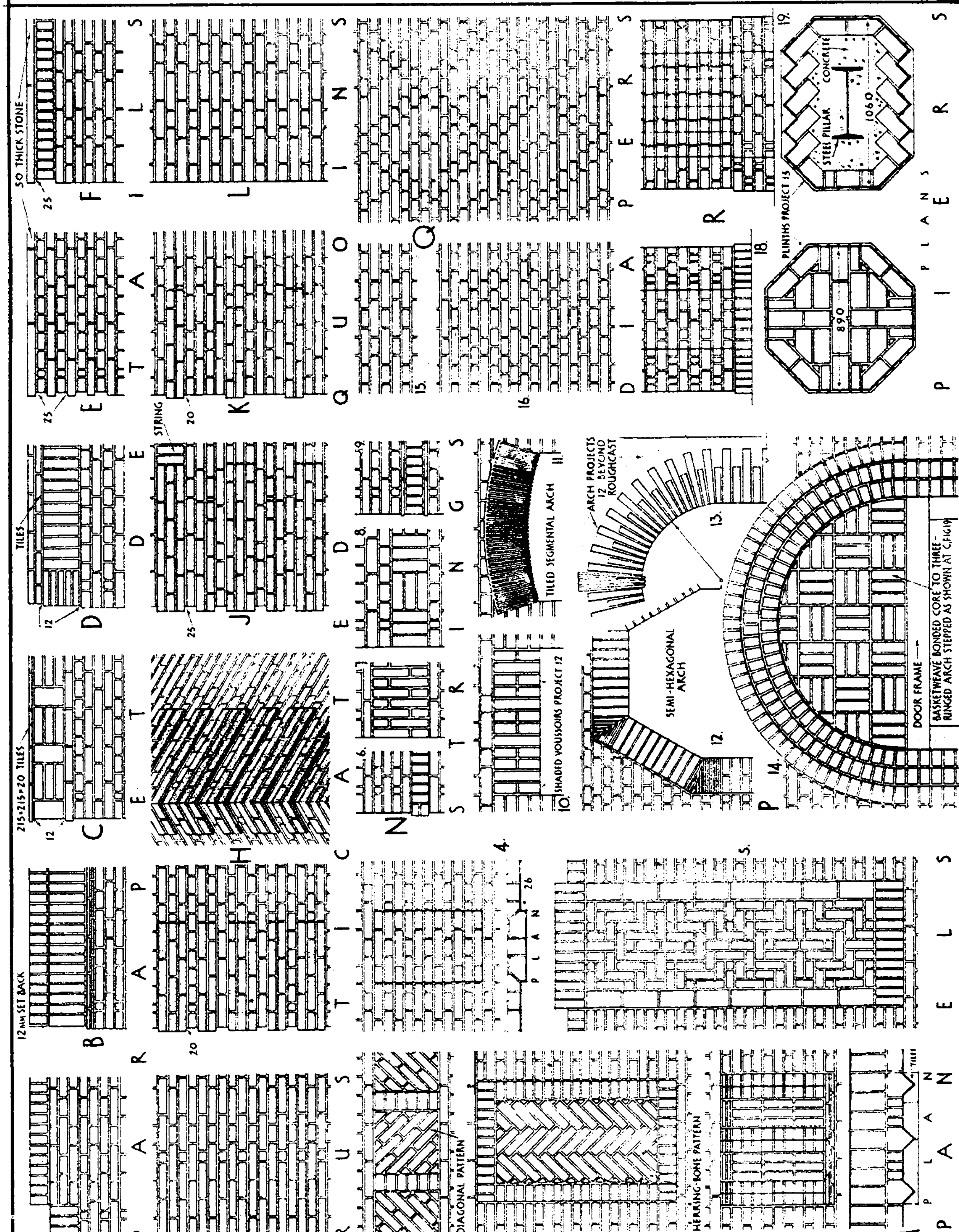
1 1/2-BRICK WALL



2-BRICK WALL

6.WALLS compiled: D.VOLKE JULY '80	BLOCKWORK	BUILDING CONSTR. — LECTURE — CET 3031/16.5 59

DECORATIVE BRICKWORK



6.WALLS	BRICKWORK	BUILDING CONSTR.
compiled : D.VOLKE		— LECTURE —
JULY '80		CET 3031 / 16.560

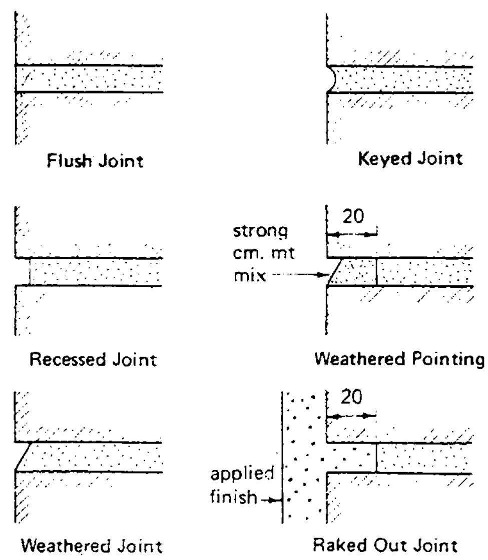
JOINTING & POINTING

Joint and pointing

- These termes are used for the finish given to both the
  - vertical and
  - horizontal joints in brick-work

  irrespective of whether the wall is of brick, block, solid or cavity construction.

FLUSH JOINT
KEYED JOINT
RECESSED JOINT
WEATHERED POINTING
(strong cem. mt. mix)
WEATHERED JOINT
RACKED OUT JOINT



- Jointing is the finish given to the joints when carried out as the work proceeds.

- Pointing is the finish given to the joints by raking out to depth of approx. 20mm and filling in on the face with a hard setting cement mortar which could have a colour additive.

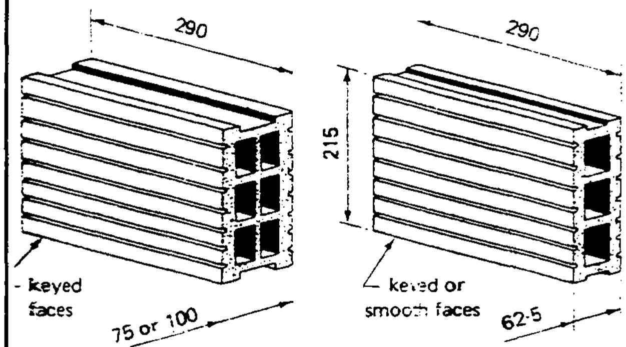
This process can be applied to both new and old buildings.

6.6 Blockwork

- A block is defined in BS 2028 as a walling unit exceeding the dimensions specified for bricks given in BS 3921 and that its height shall not exceed either its length or six times its thickness to avoid confusion with slabs or panels. Blocks are produced from clay, precast concrete and aerated concrete.

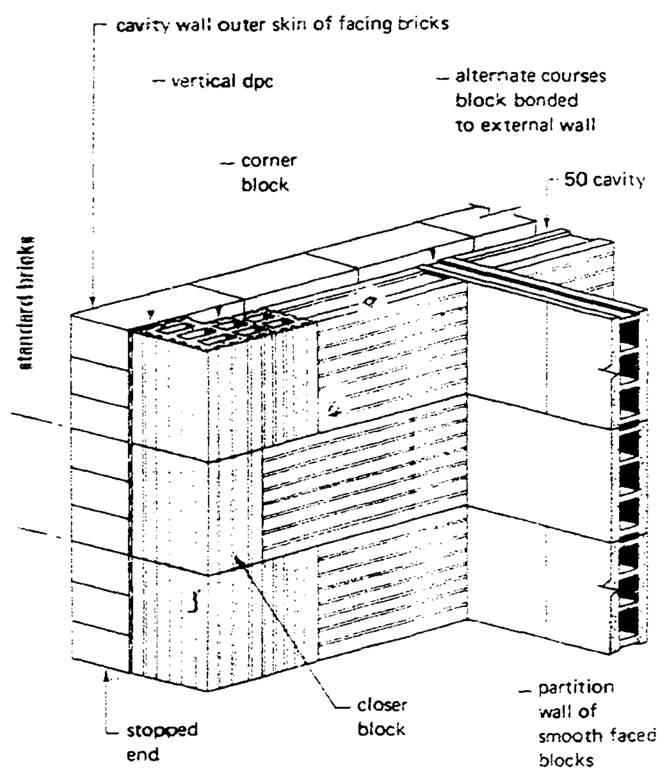
6.6.1 Clay Blocks

- These are covered by BS 3921 which gives a format size of 300 x 225 x 62·5; 75, 100 or 150 mm wide. These blocks, which are hollow, are made by an extrusion process and fired as for clay bricks. The standard six cavity block is used mainly for the inner skin of a cavity wall, whereas the three block is primarily intended for partition work. Special corner, closer, fixing and conduit blocks are produced to give the range good flexibility in design and layout. Typical details are shown in Fig. II.19.



Standard Block

Partition Block



PRECAST CONCR. BLOCKS

6.6.2 Precast concrete Blocks

- The manufacture of precast concrete and aerated concrete blocks is covered by B.S.2028: 1364 which gives three types:

Type A: for general use in buildings including the use below B.L. - D.P.C. Suitable aggregates are dense aggregates such as crushed gravel, crushed slag, broken brick.

Type B: for general use in buildings. Lightweight concrete blocks for load bearing walls.
Suitable aggregates include
- sintered pulverized fuel ash,
- foamed slag
- expanded clays and shalls
- furnace clinker
- expanded vermeculite and aerated concrete.

Type C: = similar to Type B but are intended for non load bearing walls.

6.6.3 Aerated Concrete Blocks

- Aerated concrete for blocks is produced by introducing air or gas into the mix so that when set a uniform cellular block is formed.

- The usual method: A controlled amount of aluminium powder to the mix reacts with the free lime in the cement to give off hydrogen which is quickly replaced by air and so provides an aeration.

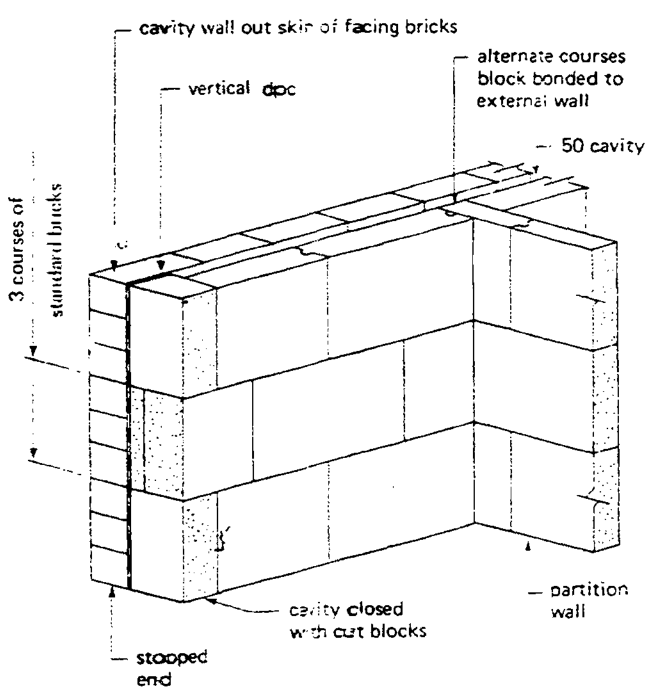
AERATED CONCR. BLOCKS

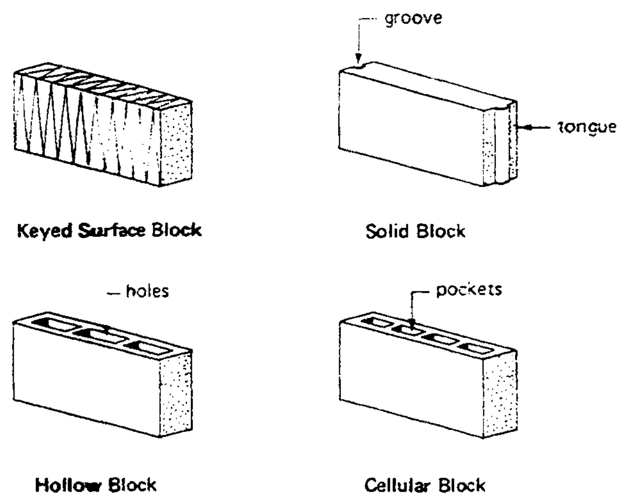
PRECAST CONCR. BLOCKS

- Precast concrete blocks are manufactured to a wide range of standard sizes. The most common face format sizes are:
  400 x 200 mm and
  450 x 225 "
  with a thickness of 75/100/140/215 mm. (Typical details: Fig. II.20)

- Concrete blocks are laid in stretcher bond, and are joined to other walls by block bonding or leaving metal ties or strips projecting from suitable bed courses. The mortar again should be weaker than the material of the walling unit. (1:2:9 gauged mix. for work above G.L.)

- Concrete blocks shrink on drying out. They should not be laid until the initial drying shrinkage has taken place. (About 14 days) and should be protected on site to prevent them becoming wet, expanding and causing subsequent shrinkage possibly resulting in cracking of the blocks and any applied finishes (such as plaster).





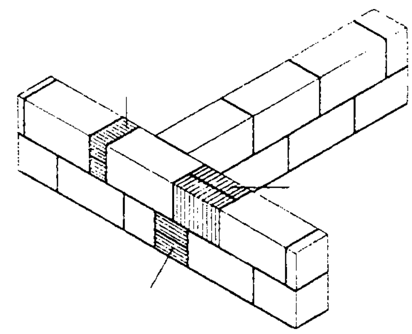
- The main advantages of blockwork over brickwork are:

  1. Labour saving - easy to cut, larger units.
  2. Easier fixings - most take direct fixing of screws and nails.
  3. Higher thermal insulation properties.
  4. Lower density.
  5. Provide a suitable key for plaster and cement rendering.

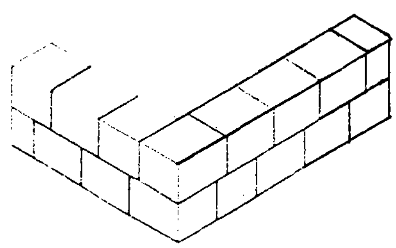
- The main disadvantages are:

  1. Lower strength.
  2. Less resistance to rain penetration.
  3. Load bearing properties less (one-or two-storey application.)
  4. Lower sound insulation properties.

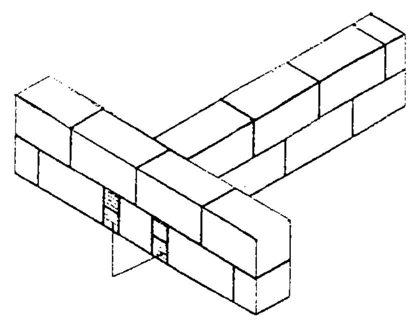
EXAMPLES : CORNERS & TEE-JUNCT's. in BLOCKWORK-BONDING



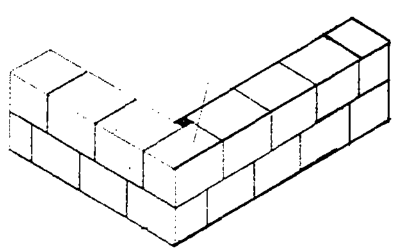
TEE-JUNCTION : 24 in 24 cm wall



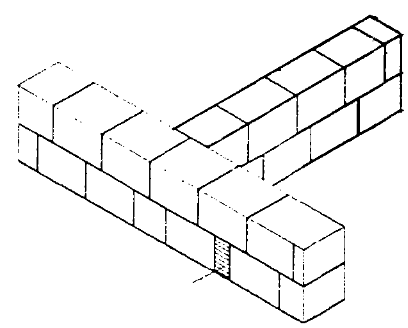
CORNER : 30 in 30 cm wall



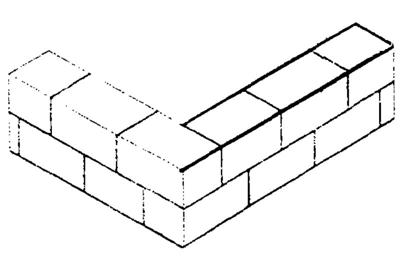
TEE-JUNCTION : 24 in 24 cm wall



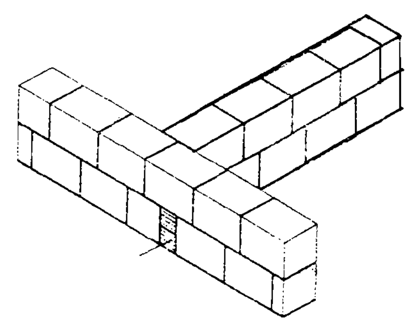
CORNER: 30 in 30 cm wall



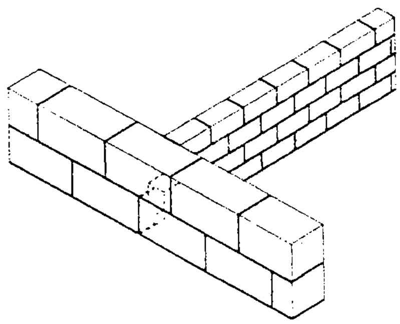
TEE-JUNCTION : 24 in 24 cm wall



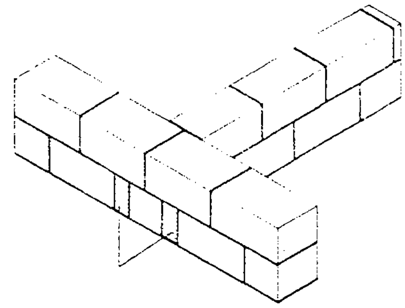
CORNER : 30 in 30 cm wall



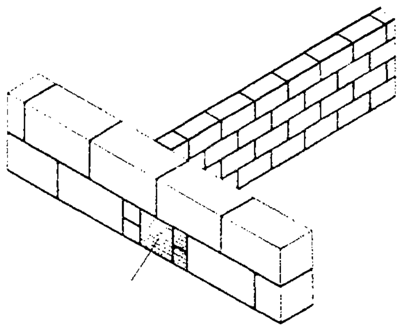
TEE-JUNCTION : 24 in 24 cm wall



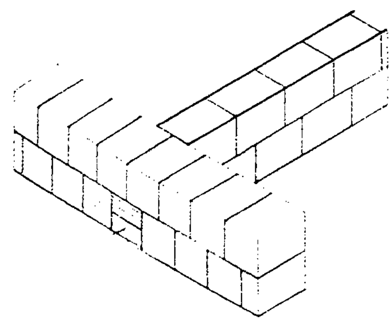
TEE–JUNCTION : 11^5 in 24 cm wall



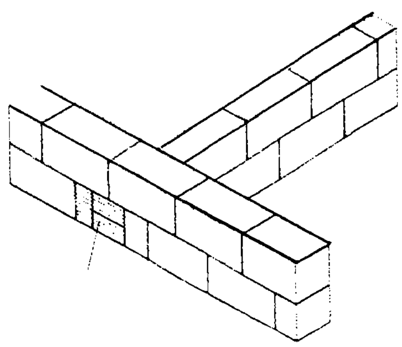
TEE–JUNCTION : 24 in 30 cm wall



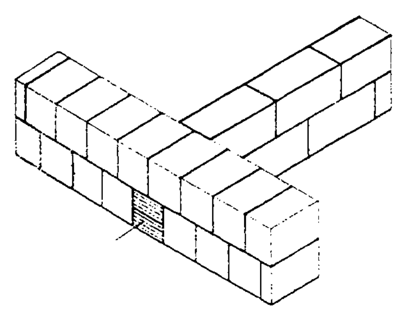
TEE–JUNCTION : 11^5 in 24 cm wall



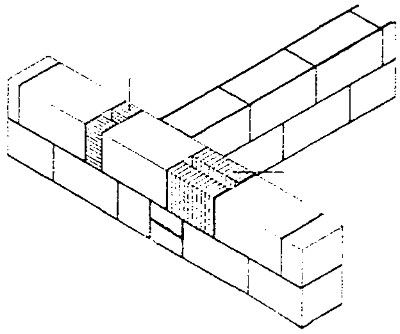
TEE –JUNCTION : 24 in 36^5 cm wall



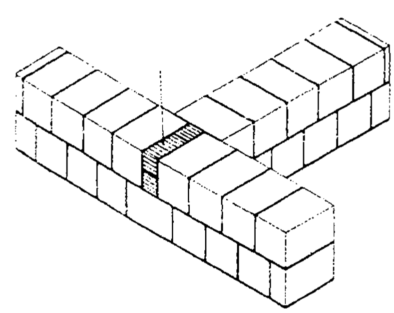
TEE–JUNCTION : 17^5 in 24 cm wall



TEE–JUNCTION : 24 in 36^5 cm wall



TEE–JUNCTION : 24 in 30 cm wall



TEE–JUNCTION : 36^5 in 36^5 cm wall

6.WALLS	BLOCKWORK	BUILDING CONSTR.
compiled : D.VOLKE		LECTURE
JULY '80		CET 3031/16.6 66

TCA TECHNICAL COLLEGE ARUSHA
CHUO CHA UFUNDI ARUSHA

CIVIL ENGINEER DEPARTMENT

CONCRETE WALLS

6.7. Concrete Walls

6.7.1 General

- Concrete Walls may be broadly classified as:
  - Plain monolithic concrete walls.
  - reinforced concrete walls

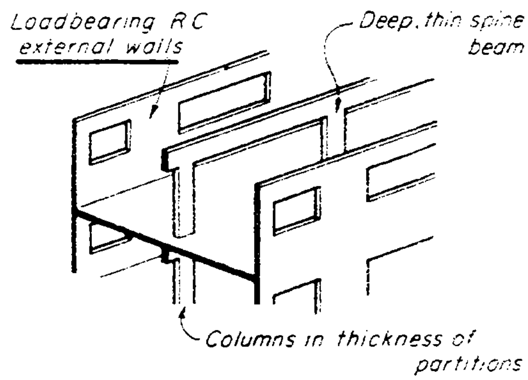
  The later can be subdivided into:

  - in-situ cast external walls
  - concrete box frame &
  - pre-cast panel structures.

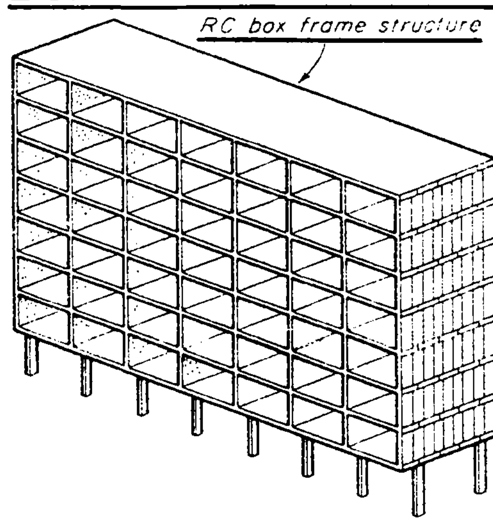
- A well graded and carefully mixed and placed Cement Concrete Wall can be impervious to water:
  - small areas can be quite water proof
  - with larger areas problems of cracking arise due to shrinkage and thermal movements and to possible settlement.

- Precautions against cracking are taken by controlling shrinkage and moisture movement by:
  - steel reinforcement
  - by allowing for thermal movement by means of expansion joints and
  - by careful detailing and execution of Construction Joints.

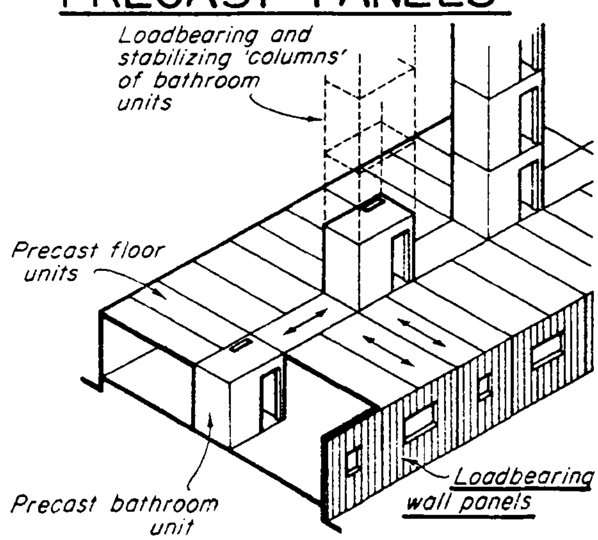
IN SITU CAST EXTERNAL WALLS



BOX FRAME STRUCT.



PRECAST PANELS

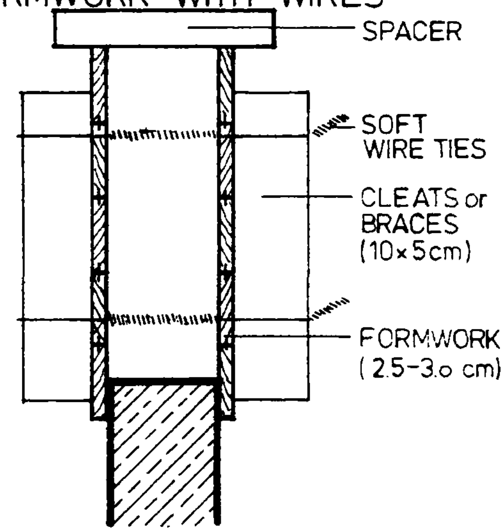


FORMWORK

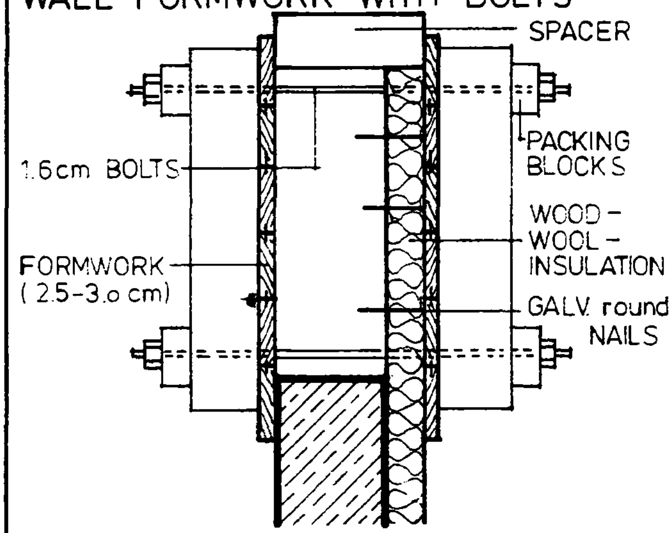
6.7.2 <u>Formwork</u>

- Formwork is required to support the concrete until it is firm.
- It has to be strong enough to bear (without sagging, the weight of the concrete as well as the concreting sand and plant used for placing.
- The joints of the boards must be tight enough to prevent loss of water and fine material
- Easy stripping through proper use of strutting, bolting, nailing and wedging should be possible.
  In order to resist vibration and movement when the concrete is being placed, extra props may be temporarily inserted under form work. (They can be removed immediately the concrete is in position, and re-erected elsewhere as the work proceeds).
- Adjustable steel props are excellent for this purpose.
- Formwork is usually of timber, but can be of <u>metal</u> as well.
- Potent methods also include
  - plastic
  - wood fibre
  - metal ceiling panels
  - precast concrete panels
- Permanent steel tubular scaffolding may also be used as a support for shuttering.
- Metal formwork must be cool when concrete is being placed.
- There are a number of systems of WALL-Formwork available (in wood, steel, concrete, etc.)
  Straight foreword methods are shown in the figure.

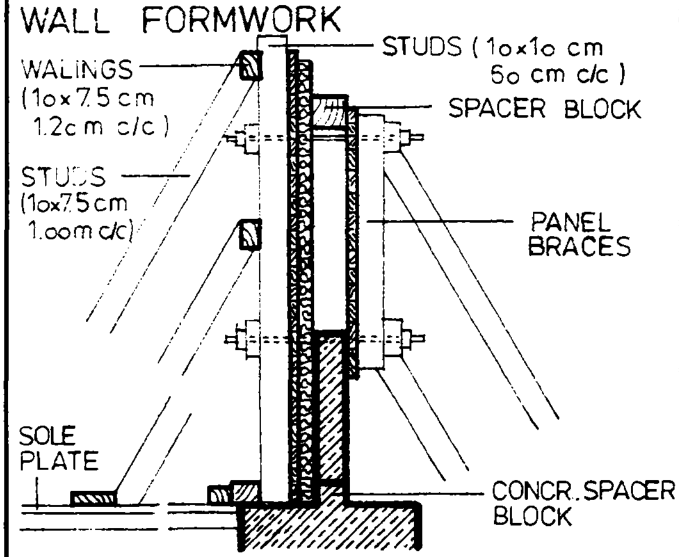
WALL FORMWORK WITH WIRES



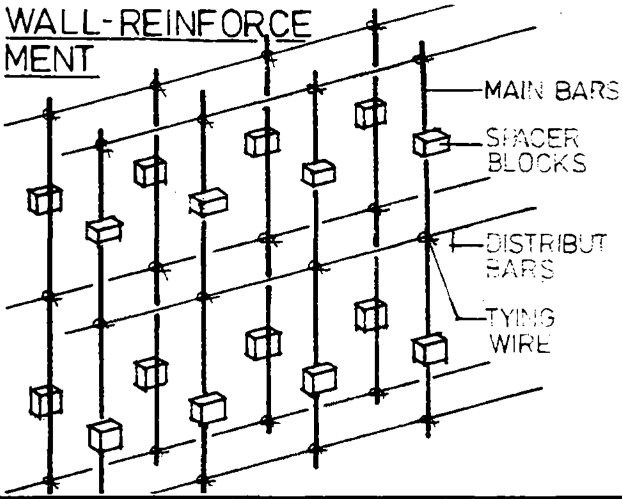
WALL FORMWORK WITH BOLTS



WALL FORMWORK

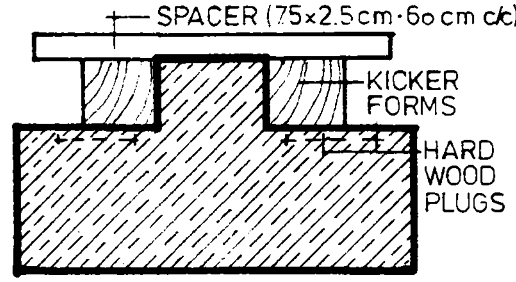


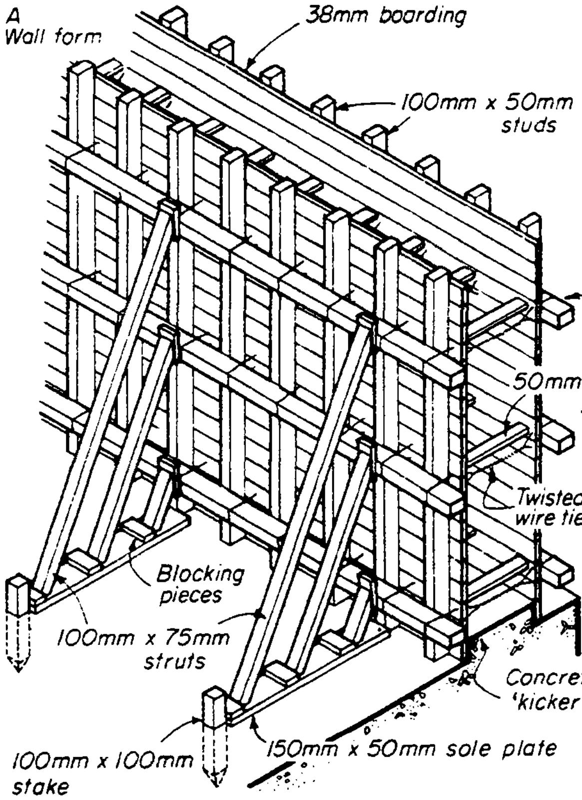
WALL-REINFORCEMENT

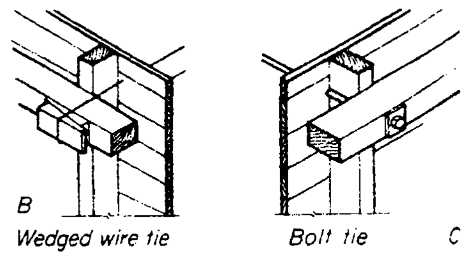


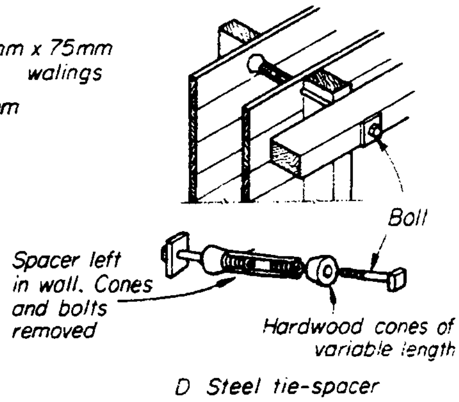
TIMBER

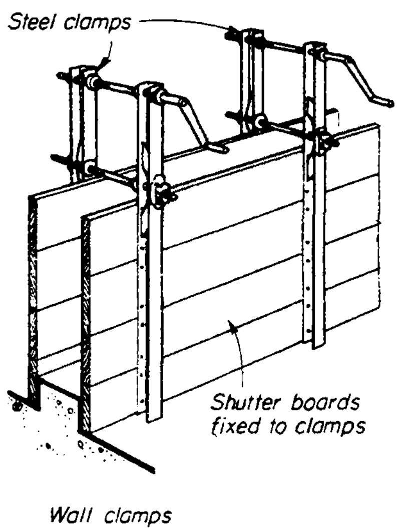
WALL FOUNDATION

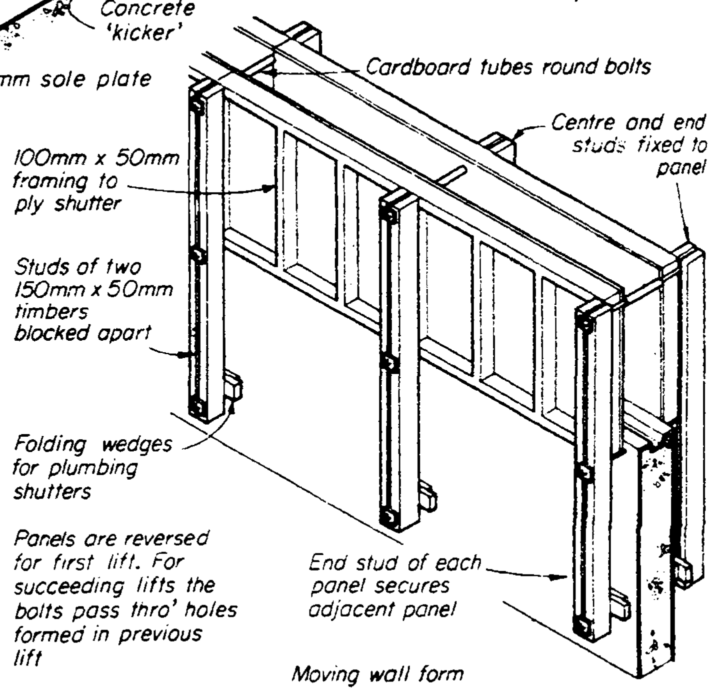






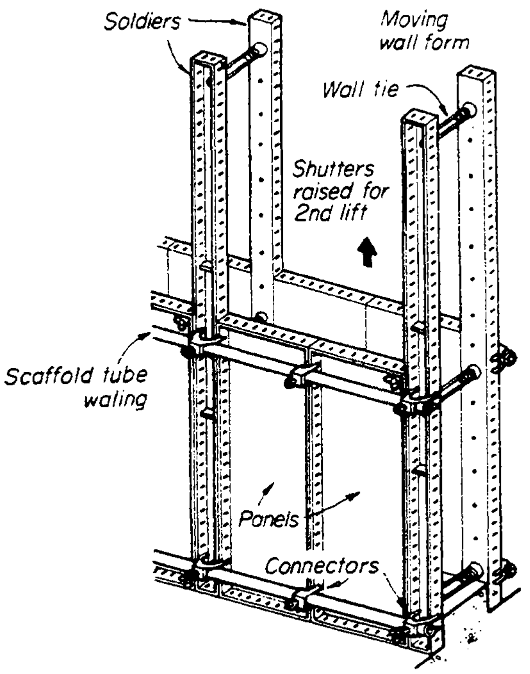


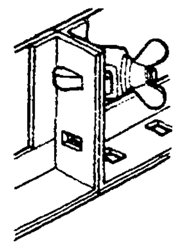




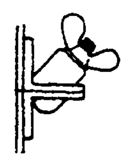
6.WALLS	CONCRETE WALLS	BUILDING CONSTR.
compiled: D.VOLKE		—LECTURE—
JULY '80		CET 3031/16.7 69

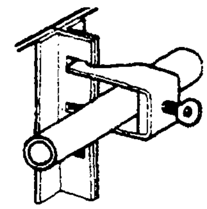
STEEL CONNECTORs



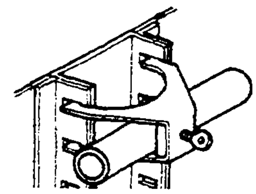


PANEL TO PANEL





PANEL TO WALING



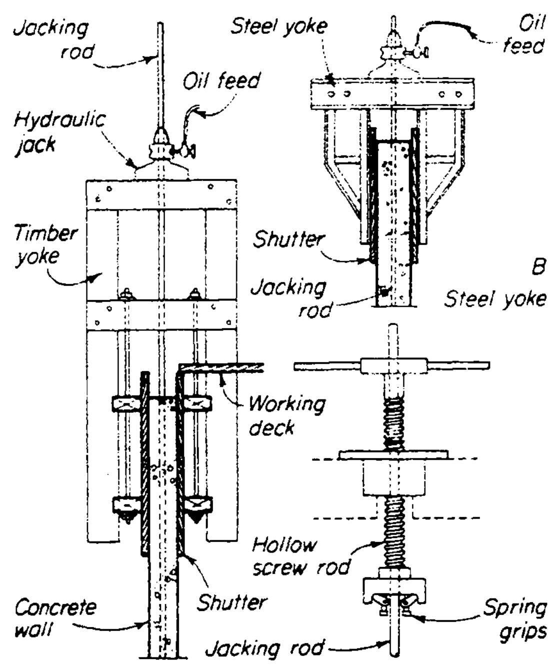
SOLDIER TO WALING

SLIP FORMs

Slip forms or sliding shutters

For the rapid construction of constant section walls it is possible to use a continuously rising form, usually known as a slip form or sliding shutter. By this means work may proceed continuously, the shutter rising from 150 to 300 mm per hour depending upon the rate of hardening of the concrete, since the cast concrete very rapidly becomes self-supporting. The form is about 900 mm or 1.20 m deep, fixed to and held apart by timber or steel frames or yokes, as shown in figure 260 *A*, *B*. On top of each yoke is fixed a hydraulic jack, through which passes a high tensile steel jacking rod, about 25 mm in diameter, which is cast into the wall as it rises. The jack contains a ram and a pair of upper and lower jaws which can grip the jacking rod and it works in cycles, each cycle giving a rise of about 25 mm. The jack works against the lower jaws to raise the yoke and the form with it. When the pressure is released, the upper jaws grip the rod and the lower jaws are released and raised under the action of a spring. An alternative to the hydraulic jack is the manually operated screw jack which is also illustrated (*C*).

A working deck is constructed level with the top of the form, from which is usually suspended a hanging scaffold from which the concrete may be inspected and rubbed down as it leaves the shutters.



A Timber yoke Screw jack C

PLAIN MONOLITHIC CONCR.

6.7.3 Plain Monolithic Concrete Wall

- The term 'monolithic' has been taken from the Greek language:
  mono = single (
  litho = stone
  Therefore a 'monolithic wall' is erected without any joints (like brick or blockwalls) having a structure like a rock or a 'single stone'

- The ideal material for such a 'monolithic' construction is concrete. (or reinforced concrete)

- The Plain monolithic concrete wall means a wall of cast in-situ concrete containing no reinforcement - either of normal, nonfines or lightweight concrete.

- As with reinforced concrete walls they are most economic when used both to support & to enclose or divide, provided they are at reasonably close spacing. That is to say, up to about 5.5 m apart. They are, therefore, used mainly for housing of all types, both as external and internal loadbearing walls, when low building costs can be attained.

- Dense concrete is generally used for high buildings although no-fines concrete has been used for heights up to ten storeys in this country. In Europe blocks as high as 20 storeys have been constructed with no-fines loadbearing walls more cheaply than with a frame.

- Plain monolithic concrete walls suffer certain defects which, in some respects, makes them less suitable as external walls than other types. With normal dense aggregates the thermal insulation is low and the appearance of the wall surface may be unsatisfactory, requiring some form of finishing or facing. In addition the unreinforced concrete wall, and particularly the no-fines wall, is unable to accommodate itself to unequal settlement as does a reinforced wall by virtue of the reinforcement or a brick or block wall to a certain extent by the setting up of fine cracks in the joints. Thus, as a result, large cracks tend to form in the wall. Nevertheless, where foundations are designed to reduce unequal settlement to a minimum such walls can successfully be used.

- Aggregates used for dense plain concrete are natural aggregates conforming to the requirements of BS 882, air-cooled blast furnace slag and crushed clay brick. Aggregates for light-weight concretes are foamed slag, clinker, pumice and any artificial aggregate suitable for the purpose. No-fines concrete may be composed of heavy or lightweight aggregate.

DENSE CONCr. WALLS

6.7.3.1.

Dense concrete walls are constructed from concrete made with a well-graded aggregate giving a concrete of high density. The London By-laws require, the thickness of any concrete external or party wall to be not less than 150 mm thick and CP 123, 101, 'Dense Concrete Walls', recommends a similar thickness for external walls.

In most buildings the thickness of any type of plain con crete wall must, by reason of other functional requirements, be thicker than the minimum dicteted by loadbearing requirements. An example of this is the dense concrete separating wall, which must be 175 mm thick in order to provide an adequate degree of sound insulation between houses and flats.

LIGHT WEIGHT AGGREGATES

6.7.3.2

Light-weight aggregate concrete walls will give better thermal insulation than dense concrete when used for external walls but care must be taken in the choice of aggregate for external use because of the danger of excessive shrinkage and moisture movement occuring with certain types. Clinker has a corrosive action on steel and should not be used if shrinkage reinforcement is to be incorporated.

All types of light-weight aggregate concrete are more permeable than dense concrete and where the wall is exposed to the weather a greater thickness of cover to the steel is required, with possibly the further protection of rendering. Concrete with a wide range of density and compressive strength can be obtained by the selection of appropriate aggregate and mix.

NON-FINES CONCr. WALLs

6.7.3.3 No-fines concrete walls are constructed with a concrete composed of cement and coarse aggregate alone, the omission of the fine aggregate giving rise to a large number of evenly distributed spaces throughout the concrete. These are of particular value in terms of rain exclusion. No-fines concrete is suitable for external and internal loadbearing walls or for panel wall infilling to structural frames.

The weight of no-fines concrete is about two-thirds that of dense concrete made with a similar aggregate. Aggregates graded from 19 mm down to 9.5 mm are used with mixes of 1 to 8 or 10 for gravel aggregate and 1 to 6 for light-weight aggregates. The aggregate should be round or cubical in shape and no more water should be used than that required to ensure that each particle of aggregate is thoroughly coated with cement grout without the voids being filled. The hydrostatic pressure on form work is only about one-third of that of normal concrete. This is an advantage since horizontal construction joint should be minimized and form work one or two storeys high can be employed without it being excessively heavy. Any normal type of shuttering can be used.

No-fines concrete walls should not be subjected to bending stresses nor to excessive eccentric or concentrated loads. Slender piers and wide openings are, therefore, unsuited to no-fines construction. Isolated piers should not be less than 450 mm in width or one-third the height of adjacent openings.

The bond strength of no-fines concrete is low but for openings up to about 1.5 m wide the walling itself may be reinforced to act as a lintel provided there is a depth of wall not less than 230 to 300 mm above the opening. As a precaution against corrosion the steel should be galvanized or coated with cement wash and bedded in cement mortar. For wider openings an in situ or precast reinforced lintel of dense concrete is generally necessary. Even when the wall above openings is not required to act as a lintel to carry floor or roof loads, horizontal reinforcement equivalent to a 13 mm steel bar should be placed above and below all openings. In buildings with timber floors the steel above the openings in external walls is usually made continuous.

Because of its weakness in tension, walls of no-fines concrete are sensitive to differential settlement. Particular attention must, therefore, be paid to the design of the foundations. For small buildings the lower part of the walls and the strip foundation should be of dense concrete, reinforced if necessary. For high buildings adequate stiffness is usually obtained by the use of rigid reinforced dense concrete cellular foundations.

BASIC STESSES FOR PLAIN CONCRETE WALLS

Cement	Aggregate	Nominal mix	Volume of aggregate per 50 kg of cement		Cube strength* within 28 days after mixing		Maximum permissible stresses
			Fine	coarse	Preliminary test	Works test	
			m^3	m^3	MN/m^2	MN/m^2	MN/m^2
Portland cement, Portland blast-furnace cement and other cements included in CP 110	Concrete with: (i) Natural aggregates to BS882 (ii) Air-cooled blast-furnace slag (coarse aggregate) to BS1047	1:1:2 1:1½:3 1:2:4 1:3:6 1:4:8	0.03 0.05 0.07 0.10 0.14	0.07 0.10 0.14 0.20 0.28	40 34 28 15 12	30 25.5 21 11.5 8.6	7.6 6.5 5.3 2.4 1.7
Portland cement, Portland blast-furnace cement and other cements included in CP 110	Concrete with: (i) Foamed blast-furnace slag to BS 877 (ii) Clinker aggregate to BS 1165 (iii) Such other artificial aggregates as may be suitable having regard to strength durability and freedom from harmful material	Proportions to be selected to give the required cube strength				14.0 11.0 8.3 5.5 2.8	2.6 2.1 1.6 1.1 0.5
	No-fines concrete with: (i) Natural aggregates to BS 882	Special mixes		0.28		7.0†‡ 3.5	1.3 0.6
	(ii) Air-cooled blast-furnace slag to BS 1047	1:8		0.28		2.8	0.5

NOTES on the table :

Intermediate values for other mixes may be found by interpolation.

* these requirements may be deemed to be satisfied if two-thirds of the value is obtained at 7 days.

† The average cube strength for mix design purposes should be 2.10 MN/m^2 in excess of the cube strength specified

‡ The attainment of this strength increases the density of the concrete to an extent where the thermal insulation properties may be impaired.

THICKNESS

6.7.3.4

Thickness of plain concrete walls

The procedure in calculating is the same as for masonry walls but using different permissible stresses based on varying types and grades of concrete (table A)[1] and a different set of reduction factors (table B) to apply to these stresses for slenderness ratios over fifteen, up to a maximum of twenty-four. An increase in the permissible stresses in a plain concrete wall may be made when the ratio of its storey height to length is less than 1 1/2. This varies linearly from zero at a ratio of 1 1/2 to 20% at a ratio of 1/2 or less. The length of the wall in this case is either the overall length or the length between adjacent openings.

The same increases may be made in the permissible stress in respect of eccentric and concentrated loads and lateral forces as for masonry walls.

It should be noted that notwithstanding the thickness established by calculation the London By-laws require the thickness of an external or party wall of concrete to be not less than 150 mm.

Slenderness ratio	15	18	21	24
Reduction factor	1.00	0.90	0.80	0.70

Linear interpolation between values for the reduction factors is permissible

Plain concrete walls: reduction factor for slenderness ratios

SHRINKAGE

6.7.3.5.

Shrinkage reinforcement may be required in in situ cast concrete walls, other than those of clinker aggregate or no-fines concrete, particularly in external walls, in order to distribute the cracking due to setting shrinkage and thermal movement, and thus minimise the width of the cracks. Where this reinforcement is considered to be necessary, the Code recommends that it sh should be not less in volume than 0.4 per cent of the volume of the concrete in an external wall. It also makes recommendations in respect of internal walls, the positioning and distribution of the reinforcement and the provision of extra reinforcement round openings where shrinkage effects are greatest

As the drying shrinkage of no-fines concrete is low, reinforcement for this purpose is not usually necessary except, perhaps, with some lightweight aggregates, because the stresses set up by the slight shrinkage are relieved by the formation of fine cracks round the individual particles of aggregate. Shrinkage reinforcement may also be omitted from dense concrete walls where the mix is lean and of low shrinkage and where end restraints on the walls are small and work can be carried out continuously.[2]

R.C. WALLS

6.7.4 REINFORCED CONCRETE WALLS

IN-SITU CAST

6.7.4.1 In-Situ Cast external walls

The reinforced concrete load-bearing wall used as the enclosing wall to a building is the alternative to its use as a dividing element in the concrete box frame described below. The wall areas over openings act as beams and those areas between openings as columns. These openings may be wide, since with normal sill heights there is ample depth of wall between window head and cill above to act as a deep, thin beam and the wide, narrow window is a characteristic of this form of construction. Alternatively the whole height of the wall may be regarded as a beam pierced by any necessary openings for windows.

Sufficient width of wall must, of course, be left between openings to act as columns taking all the vertical loads. The problems of appearance and thermal insulation are the same as with the plain concrete wall, but the danger of cracking due to possible unequal settlement is reduced because reinforcement is present to resist any tensile stresses set up.

BOX FRAMES

6.7.4.2 Concrete Box Frames

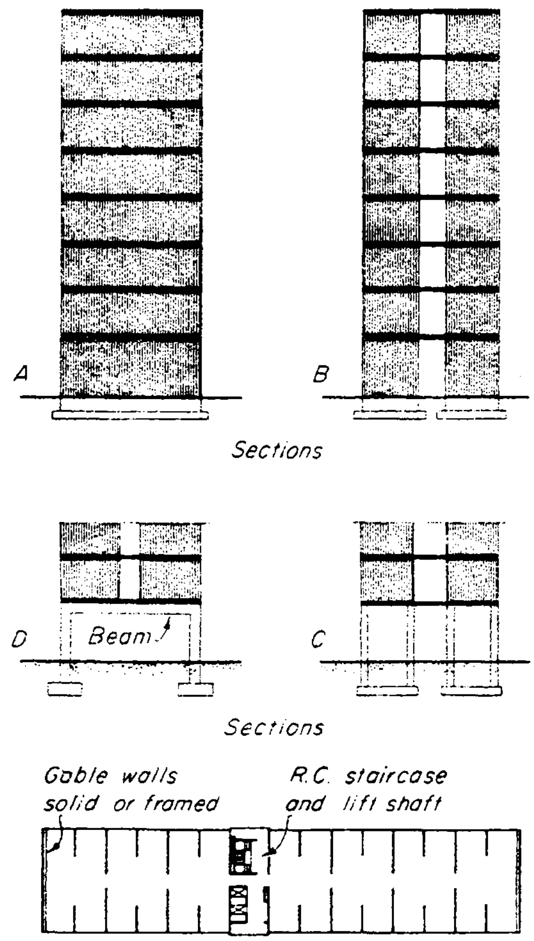
This is a form of cross-wall construction in which the walls are of normal dense concrete and, with the floors form box-like cells as shown in the fig. As in the case of brick or block cross-wall construction,

BOX FRAMES

it is suited to those building types in which separating walls occur at regular intervals and are required to have a high degree of fire resistance and sound insulation. The most common building type in this category for which it is suitable is the multi-storey flat or maisonette block.

In concrete walls of normal domestic scale, about 2.75m high and 100 mm thick, failure is almost wholly related to the strength of the concrete and very little to the slenderness of the wall. Reinforcement, therefore, may be nominal in amount or may be omitted altogether provided that the concrete is sufficiently strong to resist the stresses set up under load. For multi-storey blocks in the region of ten or eleven storeys high the mix would be designed to give a strength of around 15.5 N/mm^2 at 28 days, although for the two lowest storeys a stronger mix might be necessary as well as the inclusion of reinforcement.

Cracking due to the shrinkage is normally overcome by the inclusion of shrinkage reinforcement. Such cracking generally occurs only if the shrinkage is resisted by some restraint, such as that offered by changes in the plane of a wall or by a previously poured lift of concrete which has been permitted to take up its shrinkage before the next lift is poured on to it. Provided that concreting can proceed without undue delay and that the walls are in simple, straight lengths, shrinkage reinforcement in the walls may safely be omitted.



Typical plan

Although the junctions of walls and floors in a box frame are monolithic, if the walls are not reinforced the structure can only provide rigidity in the length of the building to the extent of the precompression set up in the walls by the floor loads and self-weight of the walls, as explained in the case of normal cross-wall construction (see page 132). Additional stability must normally be given by staircase and lift shafts of reinforced concrete, or by the inclusion of longitudinal walls at certain points in the plan. The box-walls themselves provide rigidity in the transverse direction.

BOX FRAMES

In its simplest and most economic form all the box walls run in a straight, unbroken line from back to front of the building and are supported directly by a strip foundation (fig.A). They may, however, be pierced by openings or be in completely separate sections on the same line, or staggered relative to each other provided that each section is in the same position throughout the height of the building (b). If the upper floors are to be supported on columns at ground level the necessity of beams and the disposition of the columns will depend upon the arrangement of the walls above. Straight, unbroken box walls can act as deep beams spanning between the supporting columns with any necessary reinforcement placed in the tension and shear zones. If the walls are broken extra columns must be introduced to enable each wall section to act as a beam (C) or, alternatively, a separate beam must be introduced to pick up the sections and transfer the loads to the columns (D).

P.C. PANELS

6.7.4.3. Large precast panel structure

In this form of construction the loadbearing elements are large panels not less than storey-height, used with precast floor and roof units (figure 6.7.4.2 D) Window openings may be cast in the external panels which are usually finished with an exposed aggregate or tooled or profiled surface and incorporate thermal insulation, either sandwiched between two leafs or applied to the internal face. Internal panels can be made smooth enough to make plastering unnecessay

Solid external panels are insulated internally. They are simpler to produce than sandwich panels but usually require a vapour barrier near the inner face. Certain types of these panels are in cavity or cored form.

Internal loadbearing wall panels are solid or cored and between 125 and 225 mm thick with nominal reinforcement. Adequate sound insulation can be achieved with a thickness of 175 mm if plastered on both sides and rather thicker if not.

Floor panels may be of solid or cored construction. The former may be reinforced as two-way spanning slabs and they also provide better air-borne sound insulation. The latter are lighter in weight, but can span in one direction only.

P.C. PANELS

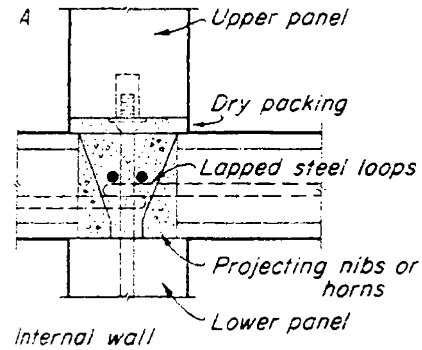
CASTING

- Casting panels

Horizontal casting is used for complicated panels which present some difficulty in casting, such as sandwich-panels for external walls, those with openings in them and those which are to have an integral or applied surface finish. When cast these are preferably removed from the moulds by means of pivoting mould beds or by vacuum pads, in order to avoid damage. The former method avoids the need for reinforcement to resist lifting stresses.

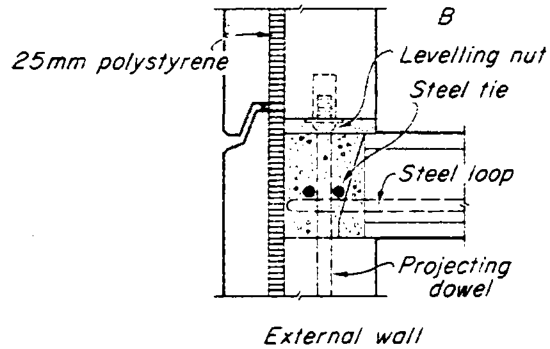
Vertical casting is preferable for wall and floor panels required to have a fair face both sides since this has the advantage of eliminating face trowelling. The moulds can be arranged in batteries with ten or more compartments, the division plates being of thick steel or concrete panels or of ply facing on both sides of a steel frame. The system of using two concrete panels, initially cast horizontally with a very smooth, true face, as the mould faces to reproduce a run of similar units was developed by the Building Research Station. The first panel is cast between the initial pair and has a true face on each side. After curing the three panels are spaced apart to provide the mould for two further panels, the five then being used to produce four more, and so on.

The method is most suitable for residential buildings since the dense concrete panels can provide, as well as the strength for load bearing, the degree of fire resistance and sound insulation required at the separating walls. Cellular, cross-wall and spine-wall plan forms may be used. The advantage of the cellular plan is its inherent stability and the fact that all walls may be loadbearing so that the floor panels may be two-way spanning.

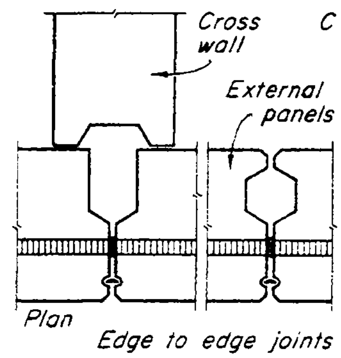


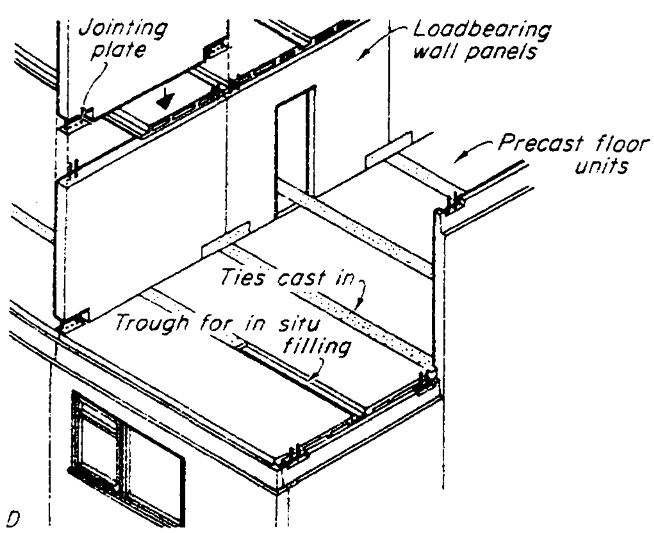
- Types of panels

External wall panels are commonly either of solid or of sandwich construction although waffle slabs are also used. The latter, however, have a number of disadvantages.



Sandwich panels have a layer of insulation incorporated either symmetrically or asymmetrically in the thickness of the slab (fig.6.7.4.2.). In the former both internal and external leaves are loadbearing with transverse ties strong enough to ensure that both act together. The restraint thus offered to thermal and moisture movement in the external leaf can cause it to warp. This is overcome by an asymmetrical positioning of the insulation since the thinner non-loadbearing leaf, usually external, required only to be attached to the loadbearing leaf by lighter forms of ties. These ties, either of hot-dipped galvanized mild steel, or of suitable non-ferrous metal, must have ends formed to ensure a mechanical anchorage between the leaves.





STRUCTURAL CONNECTIONS

- Structural connections

In situ concrete is commonly used to form the structural joints between panels. The method used to form the horizontal joint between the wall panels is shown in the fig. A, B.

It is preferable to limit the bearing of the floor slabs on the heads of the wall panels by the provision of projecting nibs or horns at about 150 to 225 mm centres along the edge of the floor panels, which provide the necessary support for the floor slabs. This permits the load from the upper wall panel to be transferred across the whole width of the wall directly to the panel below as shown. A threaded bar or dowel projecting from each end of the lower panel provides, by means of nut and washer, temporary support and a means of levelling the top panel. The joint is filled with in situ concrete and after this has set the gap above it is dry packed with cement mortar. When this in turn has set the nuts are run down to ensure contact between the upper slab and the packing thus off-setting the initial shrinkage of the mortar.

With cross and spine wall plans overall ridigity can be provided by in situ cast lift and stairwells, but this has the disadvantage of mixing precast and in situ work on the site. Fully precast construction uses bathrooms precast as reinforced concrete boxes complete with floor and ceiling and lift and stairwells precast in storey or half-storey heights which, when erected on each other, form structural 'columns' running the full height of the building. A number of these vertical units along the centre of the block form a structural spine to the remainder of the structure which is fabricated from large precast floor panels and storey height loadbearing wall panels (E).

OPENINGS IN WALLS

6.8. Openings in Walls

- An opening in an external wall of a
  - o head
  - o jamb (or reveal) and
  - o sill (or threshold)

6.8.1 HEAD: its function is to carry the triangular load of brickwork over the opening and transmit this load to the jambs at the sides. To fulfil this task it must have the capacity to support the load without unacceptable deflection.
A variety of materials and methods is available in the form of a LINTEL or BEAM such as:

- o timber: suitable for light loads and small spans, the timber should be treated with a preservative to prevent attack by beetles or fungus.

- o steel: for small openings a mild steel flat or angle section can be used to carry the outside leaf of a cavity wall, the inner leaf being supported by a concrete or steel Lintel,
  for medium spans - a chanel or joist section is usually suitable,
  for larger spans - a universal beam section to design calculations will be needed.

  Steel lintels which are exposed to the elements should be either galvanised or painted with several coats of bitumious paint to give them protection against corrosion.

- o Concrete: these can be designed as insitu or precast reinforced beams or lintels and can be used for all spans. Prestressed concrete lintels are available for the small and medium spans.

- o Stone: these can be natural, artificial or reconstructed stone but are generally used as a facing to a steel or concrete lintel.

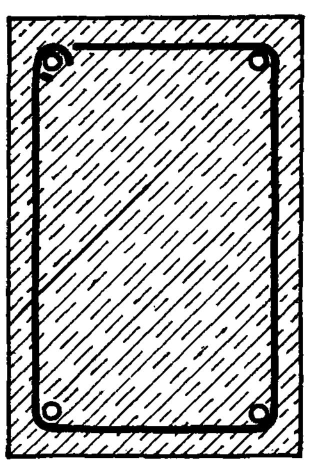
- o Brick: unless reinforced with mild steel bars or mesh, brick lintels are only suitable for small spans up to 1 m, but like stone, bricks are also employed as a facing to a steel or concrete lintel.

LINTELS

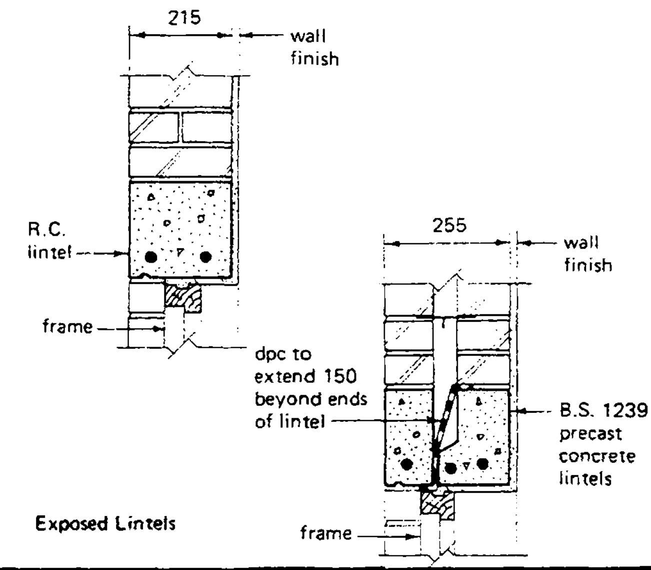
6.8.11 <u>LINTELS</u>:Require a bearing at each end of the opening, the amount will vary with the span but generally it will be:
100mm for the small spans and up to
225mm for the medium and large spans.

- In cavity walling a D.P.C. will be required where the cavity is bridged by the lintel and this should extend at least 150mm beyond each end of the lintel.

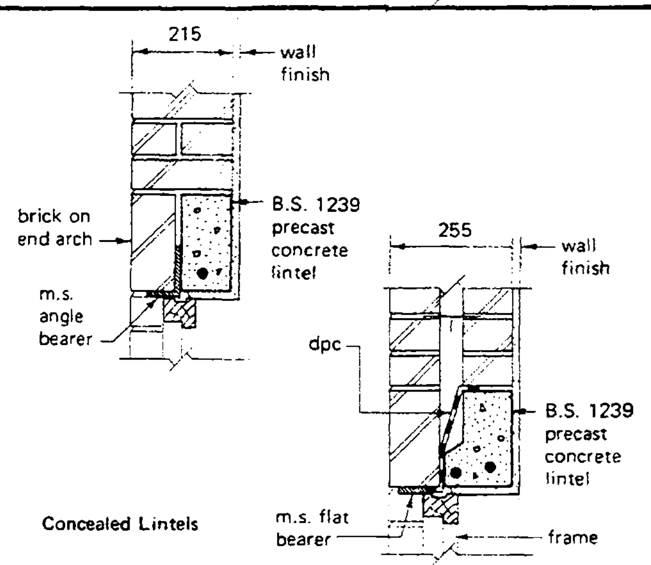
- Open joints are sometimes used to act as weep holes; these are placed at 900mm centres in the in the outer leaf immediately above the D.P.C.



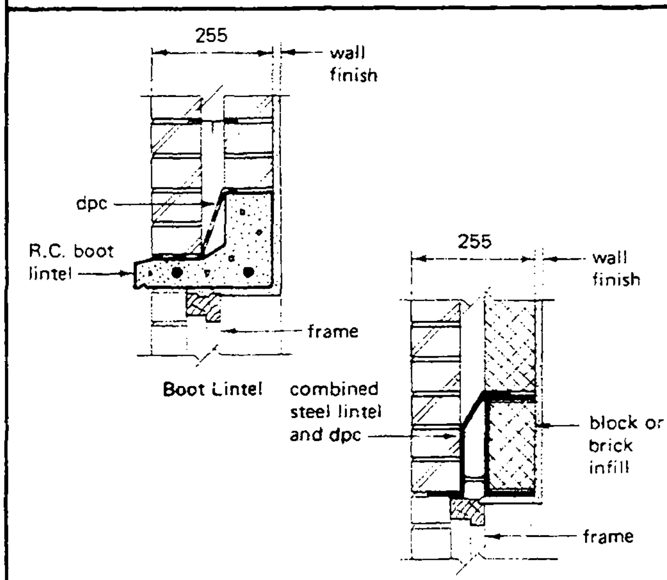
r.c. lintel



Exposed Lintels



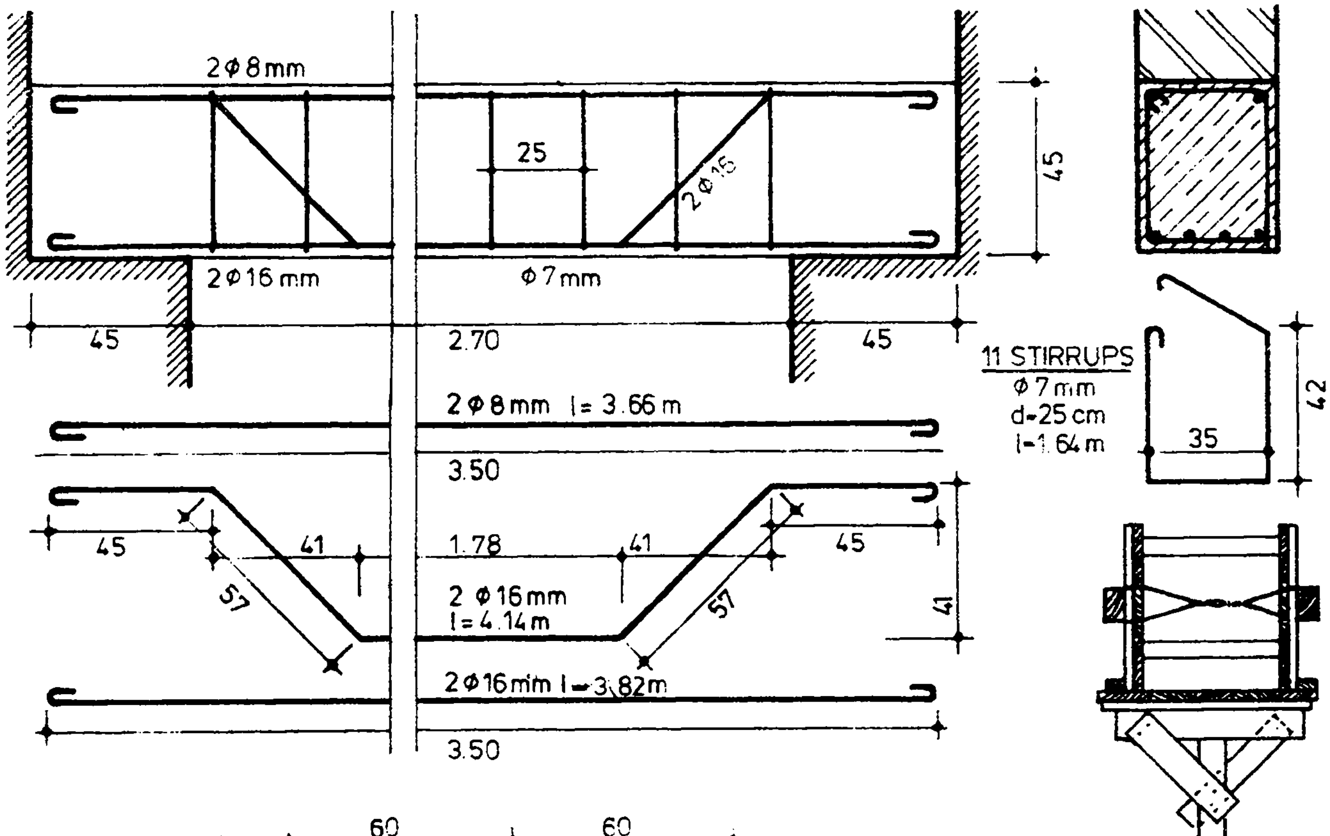
Concealed Lintels

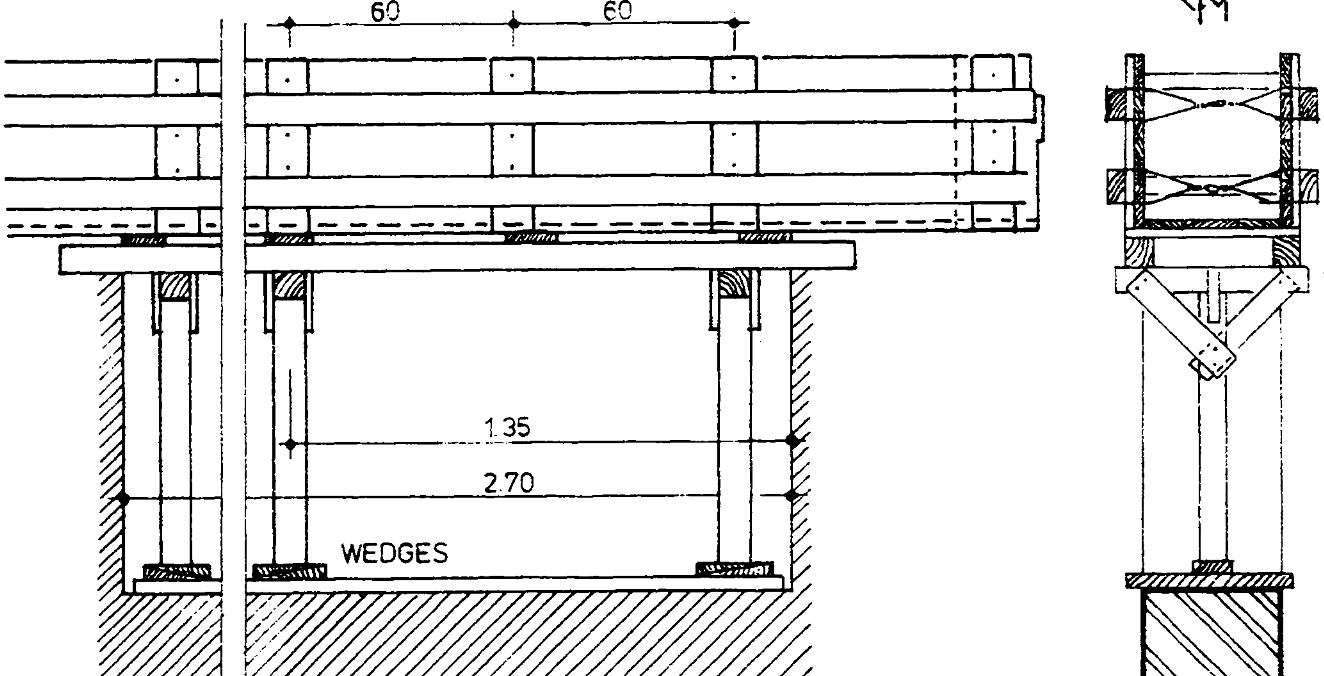


Boot Lintel

Pressed Steel Lintel

FORMWORK & STEELREINFORCEMENT BARS
for a simple R.C.LINTEL (span : 2.70 m)





CONSTRUCTION with :
1 PROJECTED and
2 HOUSED BOTTOM

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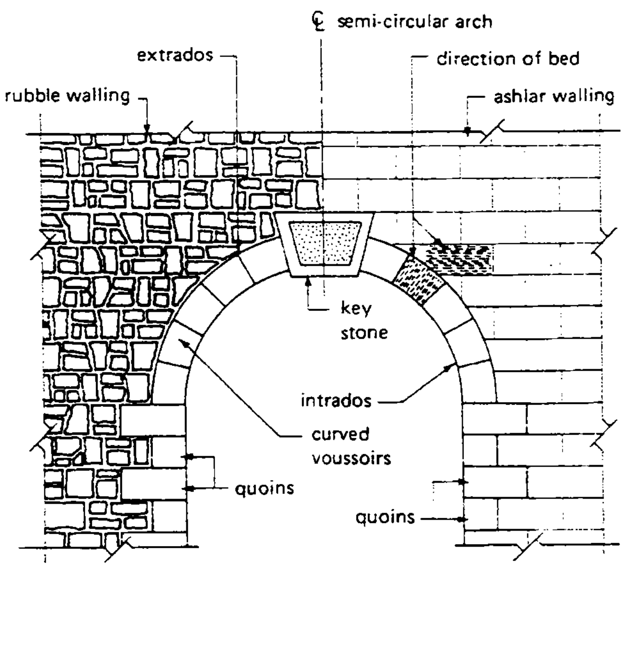
ARCHES

6.8.12 ARCHES: These are arrangements of wedged shaped bricks designed to support each other and carry the load over the opening round a curved profile, to abutments on either side.

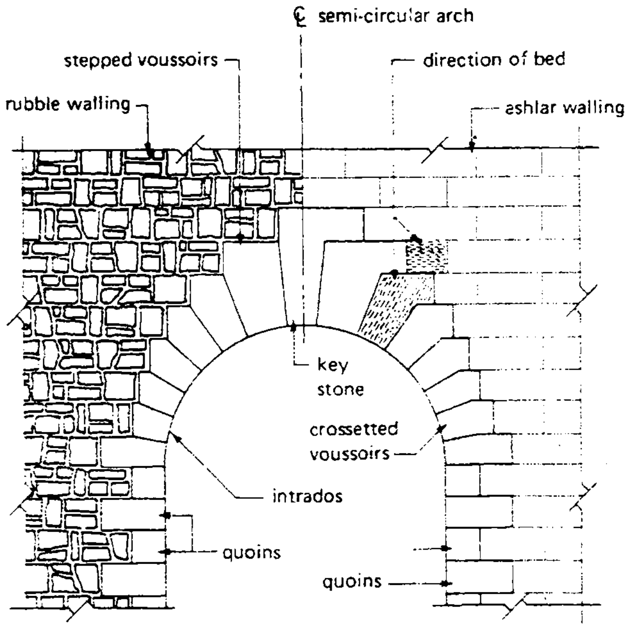
An exception to this form is the flat or "soldier" arch constructed of bricks laid on end or on edge.

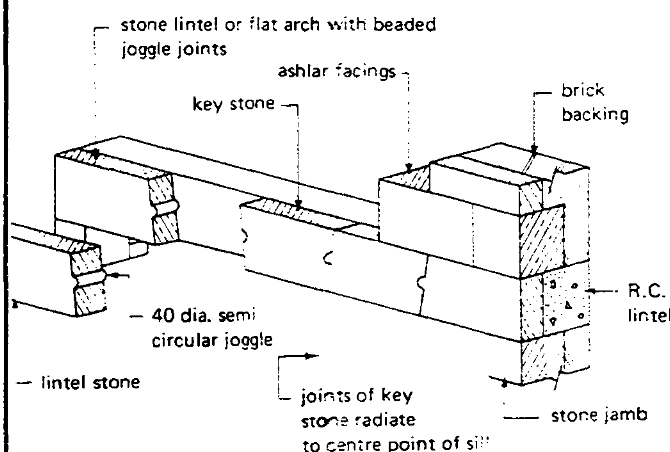
When constructing an arch it must be given temporary support until the brick joints have set and the arch has gained sufficient strength to support itself and carry the load over the opening. These temporary supports are called CENTRES and are usually made of timber; their design is governed by the span, load and thickness at the arch to be constructed.

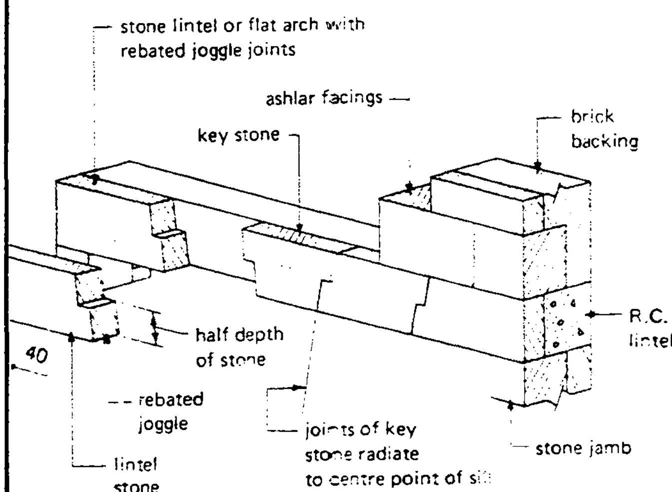


- ARCH Terminology:

- Voussoirs: The wedge-shaped bricks or blocks of stone which comprise an arch; the last voussoire to be placed in position is usually the central one and known as the KEY Brick or KEY Stone.
- Ring, Rim or Ring Course: The circular course or courses comprising the arch.
- Extrados or Back: The external curve of the arch.
- Intrados: The inner curve of the arch.
- Soffit: The inner or under surface of the arch.
- Abutments: the portions of the wall which supports the arch.
- Skewbacks: The inclined or splayed surface of the abutments prepared to receive the arch and from which the arch springs.







- Springing Points: The points at the intersection between the skewbacks and the intrados.
- Springing Line: The horizontal line joining the two springing points.
- Springes: The lowest voussoirs immediately adjacent to the skewbacks.
- Crown: The highest point of the extrados.
- Haunch: The lower half of the arch between the crown and a skewback.
- Span: The horizontal distance between the reveals of the supports.
- Rise: The vertical distance between the springing line and the highest point of the intrados.
- Centre (or striking point) and Radius: (See Fig.)
- Depth or Height: The distance between the extrados and intrados.
- Thickness: The horizontal distance between and at right angles to the front and back faces; it is sometimes referred to as the width or breadth at the soffit.
- Bed joints: The joints between the voussoirs which radiate from the centre.
- Spandril: The triangular walling enclosed by the extrados, a vertical line from the top of the skewback, and a horizontal line from the crown.
- Impost: The projecting course (or courses) at the upper part of a pier or other abutments to stress the springing line.

- CLASSIFICATION OF ARCHES:

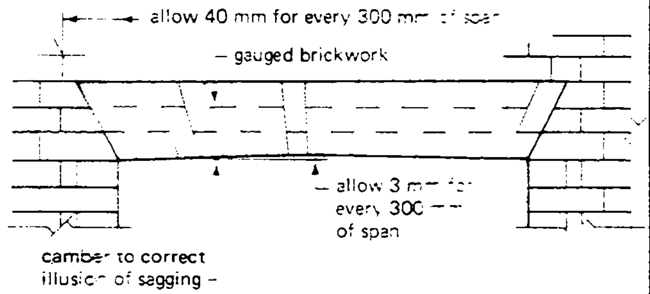
Arches are classified according to their
(a) shape and (b) materials and workmanship employed in their construction.

CLASSIFICATION

a

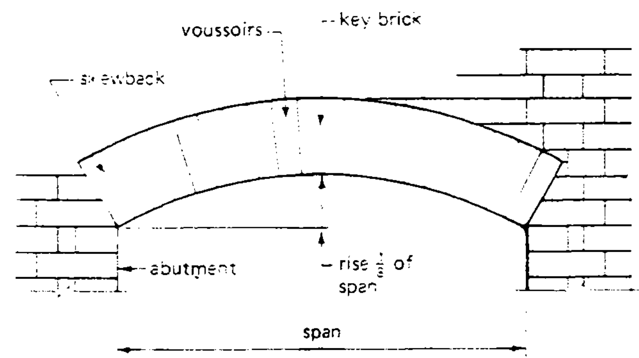
(a) The more familiar forms are:

flat (straight or camber) Archs.
- o gauged flat arch
- o purpose-made flat arch
- o axed brick flat arch.



Camber Arch

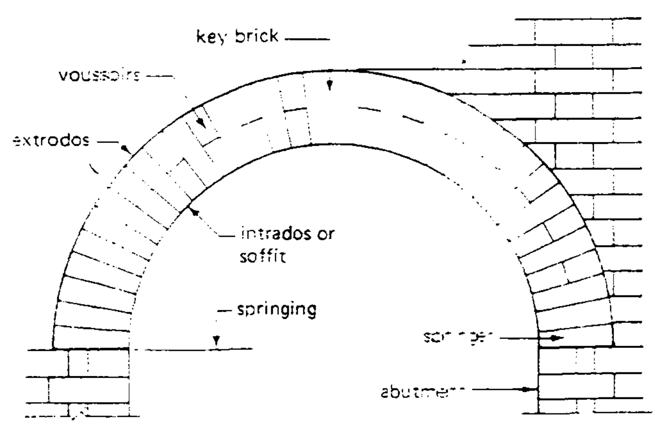
- Segemental Archs:
- o gauged segmental Arch
- o purpose-made brick segmental Arch
- o axed brick segmental Arch
- o rough brick segmental Arch.



Gauged Segmental Arch

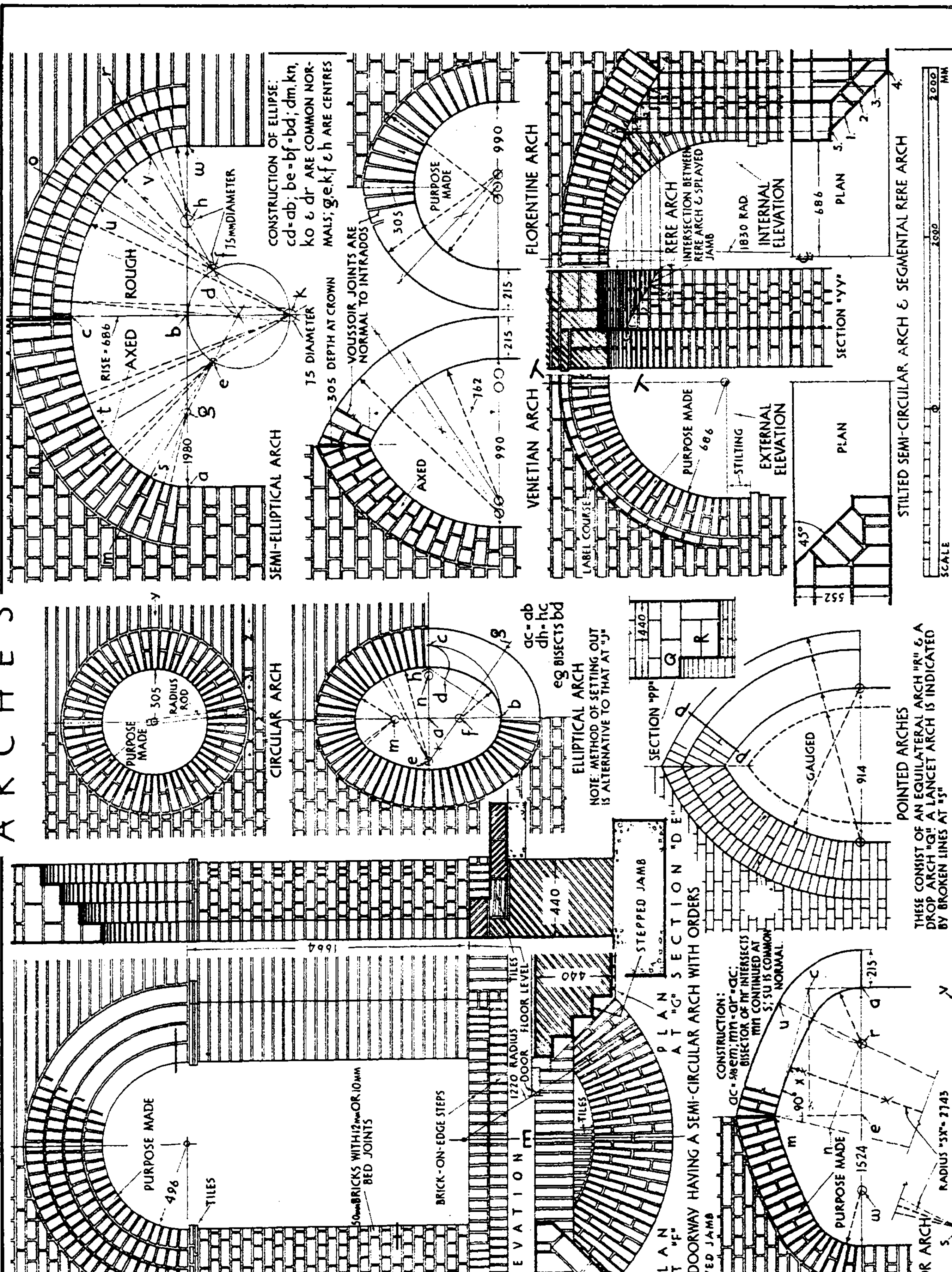
- Semicircular Archs:
- o gauged semicircular Arch
- o purpose-made brick semicircular Arch
- o axed brick semicircular arches
- o rough brick semicircular arch.

Others which are not so generally adopted are: Circular Archs, Semi elliptical Archs, Elliptical Archs, Pointed Archs.



Gauged Semi-circular Arch

b	(b) The voussoirs may consist of: o rubber bricks o purpose-made bricks o ordinary or standard bricks cut to wedge shape (known as axed bricks) o Standard uncut bricks.
RUBBER BRICKS (Rubbers, Cutters or Malms): soft bricks; various sizes; can be readily sawn and rubbed to the desired shape;are used in the construction of " gauged arch ".	GAUGED ARCHES
PURPOSE-MADE BRICKS: specially hand-moulded to the required shape; used for good class work of "Purpose-made brick Archs".	PURPOSE-MADE BRICK ARCHES
ORDINARY BRICKS CUT TO WEDGE SHAPE: are standard bricks, roughly cut to the required wedge shape by using a bolster and dressed off with a scutch, or axe. Used in the construction of "Axed brick Archs".	AXED BRICK ARCHES
ORDINARY STANDARD UNCUT BRICKS: When such bricks are used in the construction of arches, the bed joints are not of uniform thickness, but are wedge shaped. They are used for "Rough brick Archs".	ROUGH BRICK ARCHES



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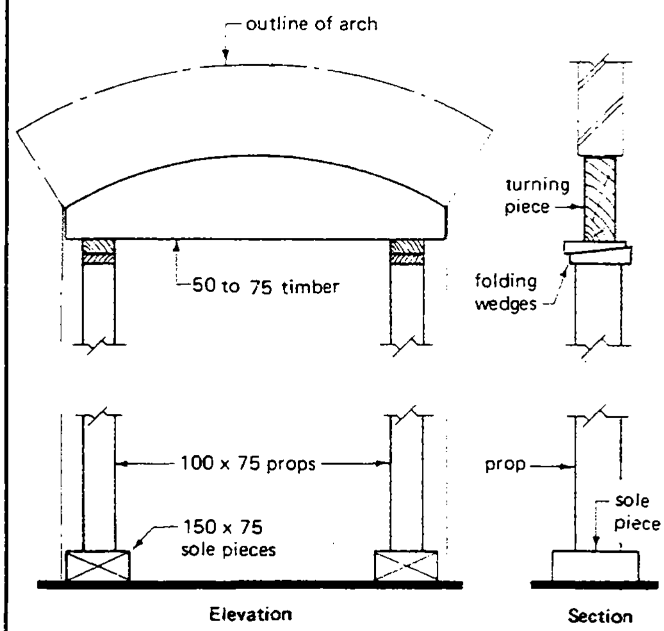
CENTRES

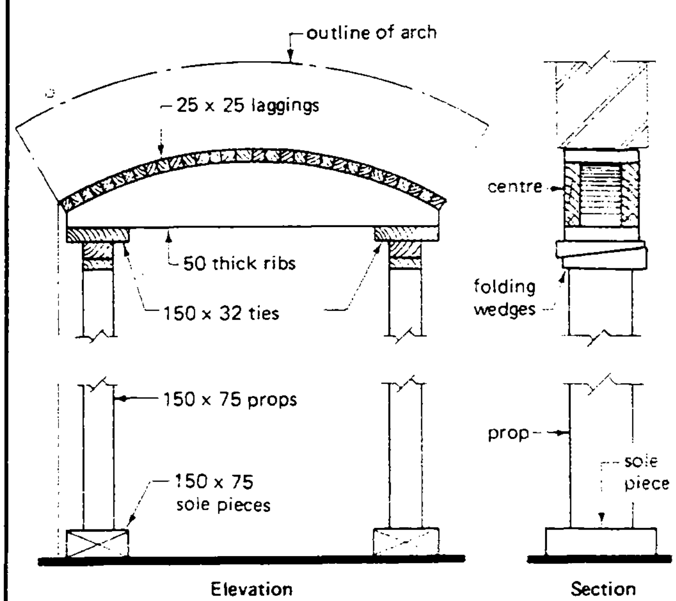
- CENTRES:
  Are temporary structures (usually of light timber construction) which are strong enough to support archs of bricks or stone while they are being built and until they are sufficiently set to support themselves and the load over the opening.

  A Centre is always less in width than the soffit of an arch to allow for plumbing (that is: alignment and verticality of the face with a level or rule.) The type of Centre to be used will depend upon:

  (1) The weight to be supported
  (2) The span
  (3) The width of the soffit.

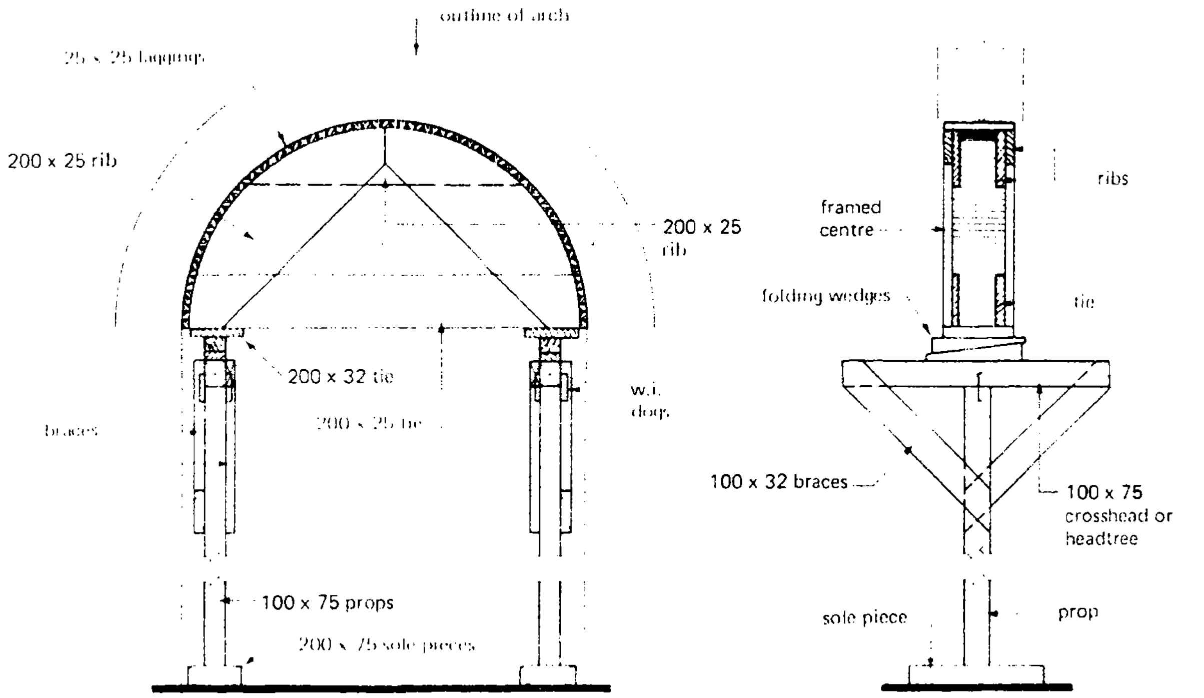


Generally soffits not wider than 150mm will require one rib at least 50 mm wide and are usually called turning pieces.
Soffits from 150-350mm require two ribs which are framed together using horizontal tie members called laggings.
Soffits over 350mm require three or more sets of ribs.
The laggings are used to tie the framed ribs together and to provide a base upon which the arch can be built.
Close laggings are those which are touching each other, forming a complete seating for a gauged arch.
Open laggings, spaced at twice the width of laggings, centre to centre, are used for rough arches.

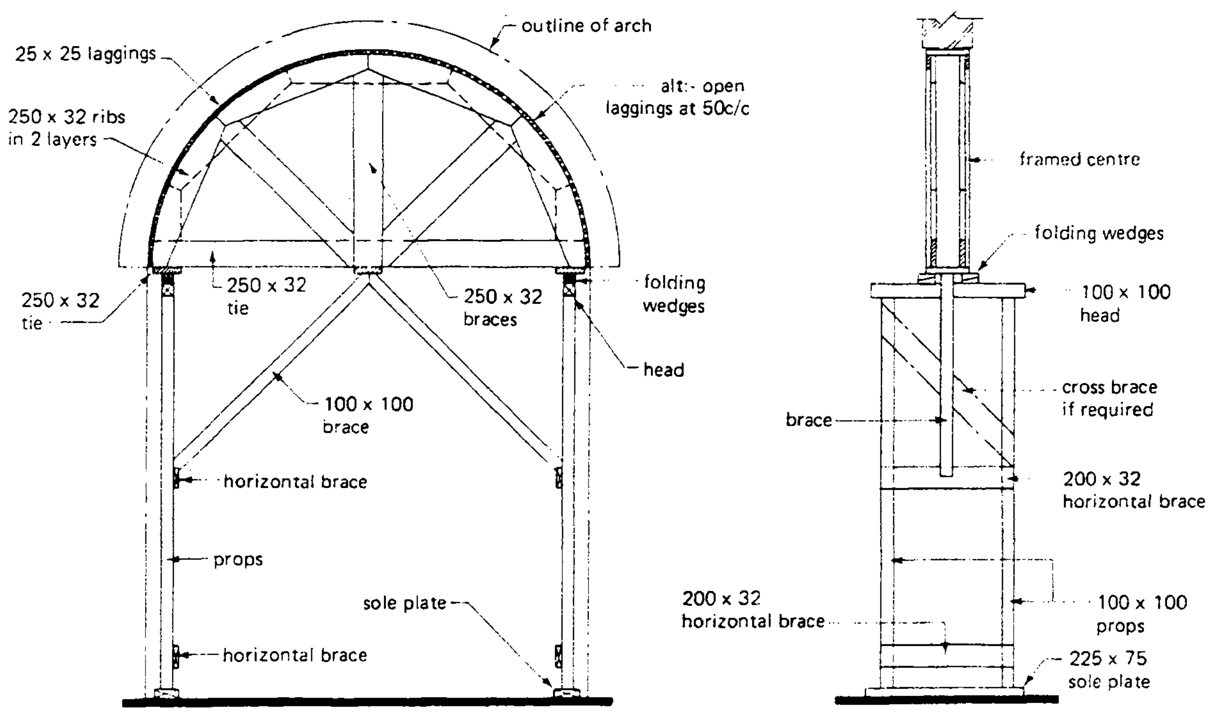


Centres for small span arches

If the arch is composed of different materials, i.e. a stone arch with a relieving arch of brickwork, a separate centre for each material should be used.



Typical framed centre for spans up to 1500 mm



Typical framed centre for spans up to 4 000

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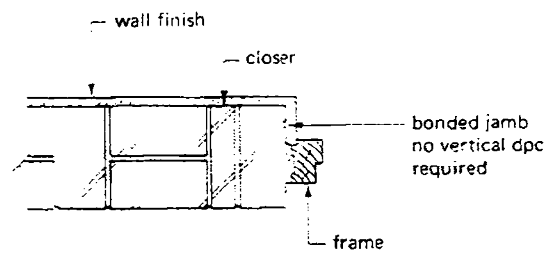
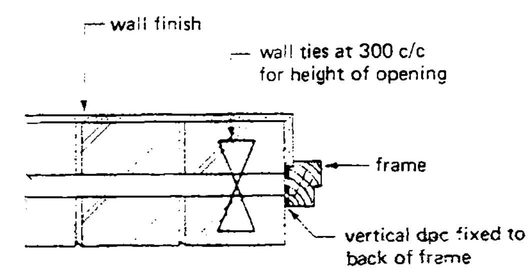
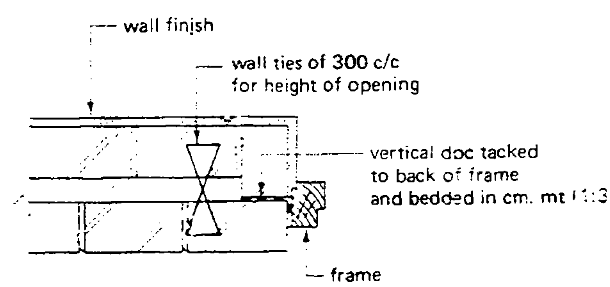
JAMBS

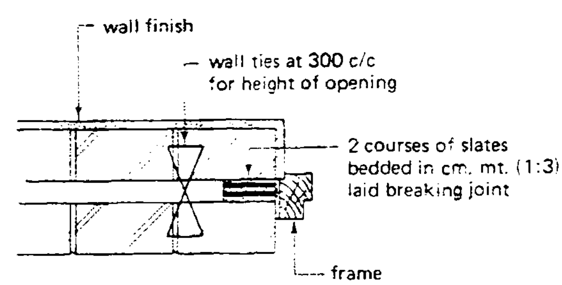
6.8.2 <u>JAMBS</u>: in solid walls these are bonded to give the required profile and strength.

In cavity walls the cavity can be closed at the opening by using a suitable frame or by turning one of the leaves towards the other forming a butt joint in which is incorporated a vertical D.P.C. (as required by the B.R.)









SILLS & THRESHOLDS

6. .3 SILLS and THRESHOLDS

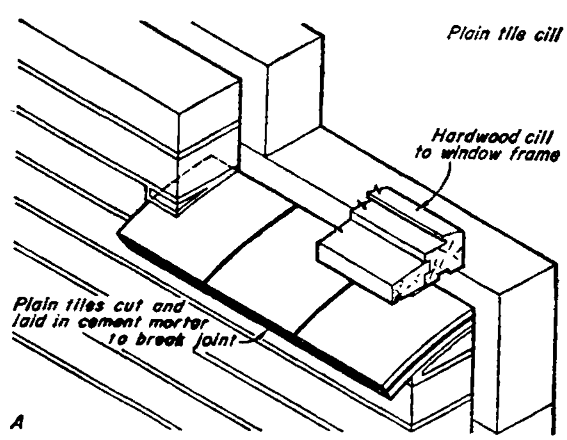
6. .3.1 SILLS: Are defined as the BOTTOM of a Window Opening.

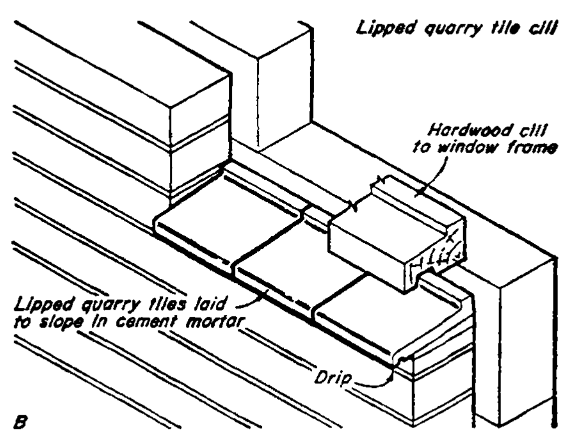
SILLS :

the function of a sill is to shed the rain-water, which has run down the face of the window or door and collected at the base, away from the opening and the face of the wall.

- o Many methods and materials are available.
- o Appearance and durability are the main requirements.
- o Sills (unlike lintels) do not require a bearing at each end.

- Usually a window frame is less thick than the wall in which it is built, so that there are horizontal surfaces of brickwork at the foot of the window.
- Most of the area of a window is glass which does not absorb water, and rain runs off it on to the external surface below.
- The FUNCTION of the SILL, therefore is to protect this part of the wall from the penetration of considerable quantities of water.
- Suitable materials for the construction of sills are:
  - stone
  - concrete
  - brick, slate, stone or quary tiles laid in cement mortar
  - roofing tiles laid to break joint in cement.
  - metal



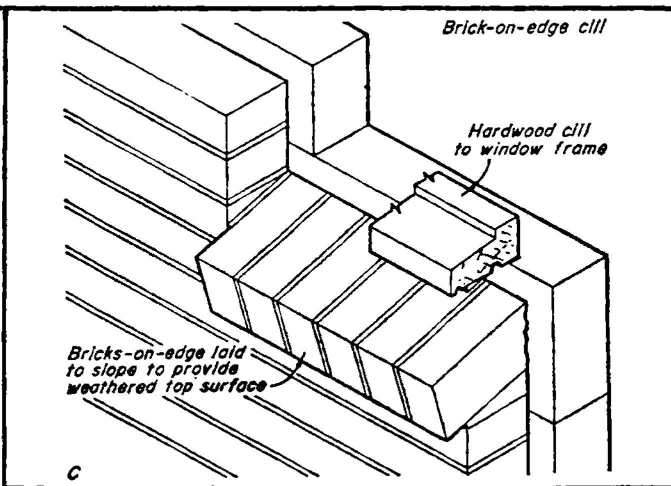


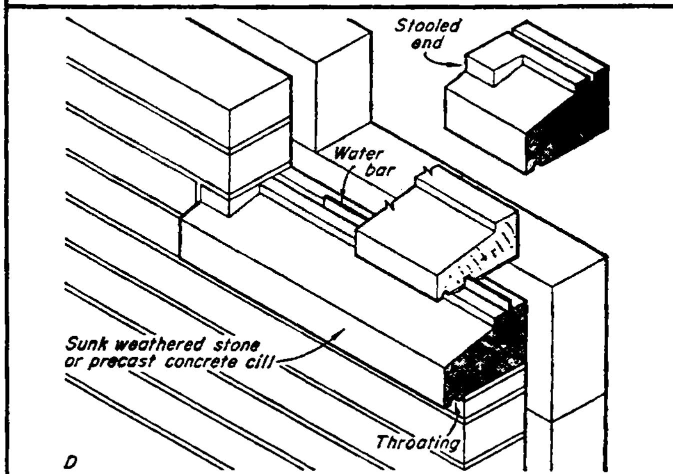
- The top surface of the sill is made to slope downwards and outwards: It is weathered in order to discharge rain water falling on it and the sill itself is made to project not less than 25mm to 40mm beyond the wall face in order to direct the discharge of water away from the face of the wall below.

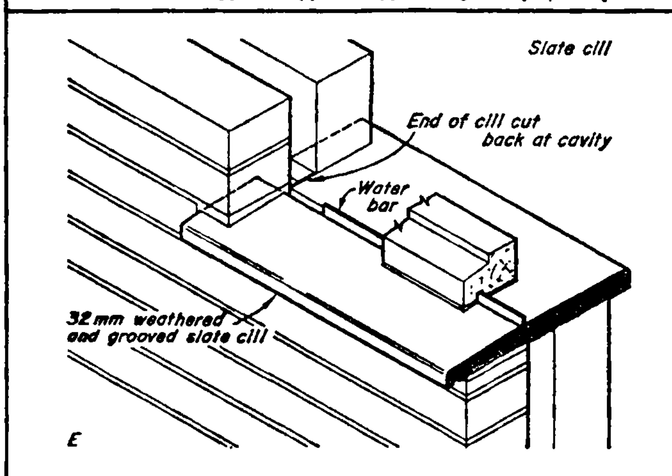
- To prevent backward flow across the undersite of this projection through wind or capillary attraction a drip is formed at the bottom front edge of the sill projection (a halfround groove 12mm in diameter is satisfactory)

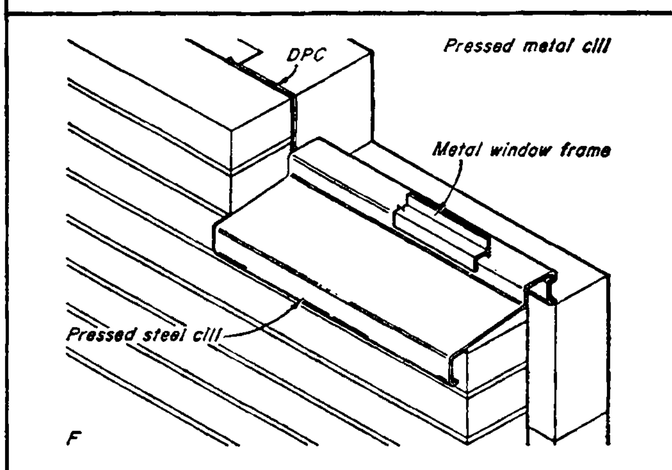
- The joint between sill and window frame is normally sealed with mastic. A feather barrier to water penetration may be incorporated in form of a strip of galvanised steel called a WATER BAR (20mm x 32mm to 32mm x 6.4mm) bedded half its depth in cement mortar in a groove formed in stone, concrete or moulded clay sills the upper projecting half engaging in a similar groove in the under side of the window frame, which is filled with white lead and oil or a mastic before the frame is bedded on the sill.

- As an additional means of protecting the joint, the weathered top surface of the sill, may be sunk slightly at the top. This has the effect of raising the joint above the water-retaining surface and serves to break the force of water blown back to the joint.









- Lipped quarry tiles may be used to achieve this and to fulfil the function of a water bar at the same time.

- The weathering to a stone or precast concrete sill may be stopped short of the ends to provide a flat seating for the brick jambs. This is called STOOL or STOOLING.

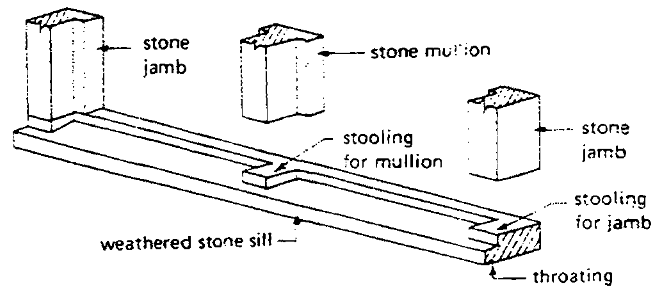
- Natural stone and precast concrete sills are similar in section and are normally not less than 75mm fluck with the depth varying according to the depth of the window reveal.

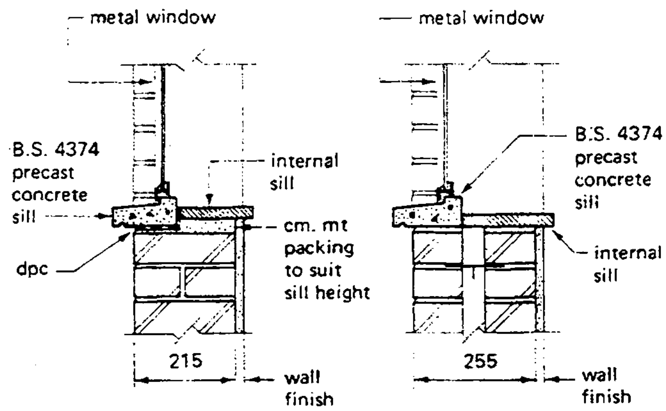
- Slate (by its nature) can be used in thin sections and slate sills may be safely carried across a vacity to form the internal sill.

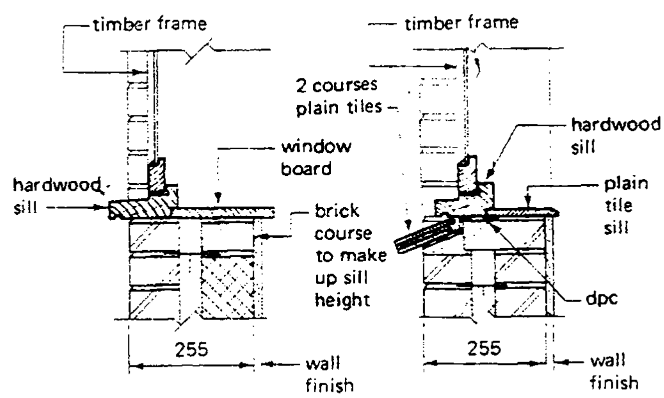
- Metal sills may be of
  - cast metal
  - hand-formed out of sheet copper or zinc.
  - pressed out of sheet steel
  - and secured to the wall by MS bracket.

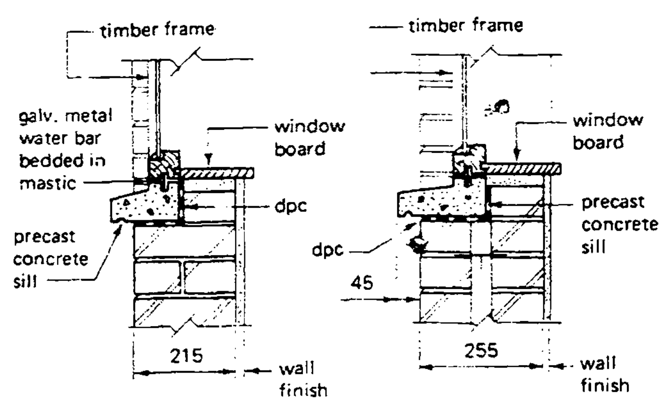
- When the windowframe is set close to the outer face of the wall the main sill (external sill) may be eliminated and its functions be fulfilled by a projecting timer sill to the windowframe.

- There are different ways of finishing the internal sill of windows. The figures show examples of typical internal sill constructions.







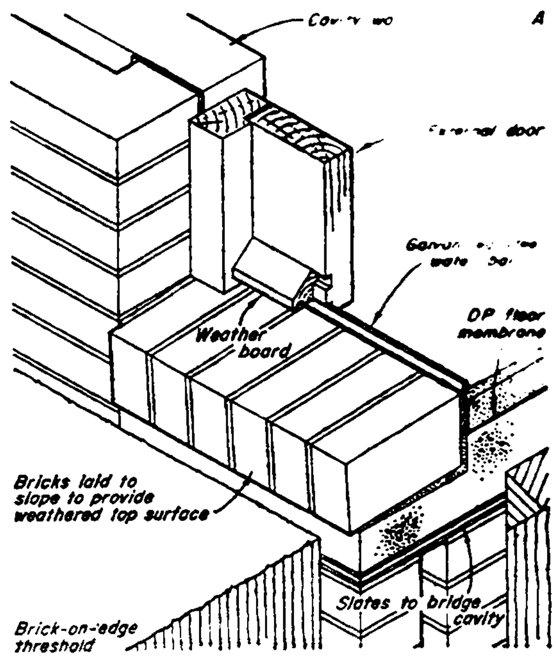


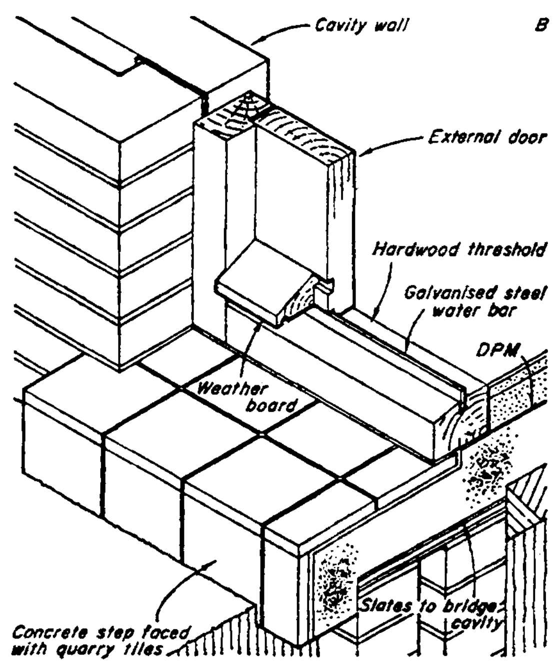
THRESHOLDS

6.8.3.2. THRESHOLDS

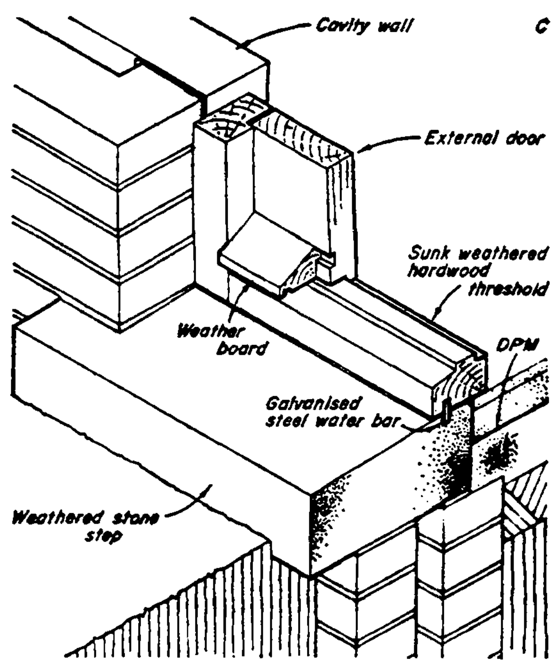
Are defined as the Bottom of a Door Opening.

- The width of a threshold should be wide enough to accommodate a human foot and be weathered on the top surface.
- Usually external doors open inwards and the incorporation of a water bar in the threshold and a weather - borad (or weather mould) on the door is advisable in order to prevent the entry of water under the door.
- A hardwood threshold is sometimes incorporated as a part of the door frame, especially where the door is set within a prefabricated wall unit including door, window and infilling panel. This is useful when the distance between ground and floor levels is somewhat greater than a reasonable rise for a single step. (See fig.)
- The provision of a timber threshold results in a drop in level immediately below the weatherboard and if the later is made to project slightly beyond this, water from the door does not fall on to the water retaining surface immediately in front of the water bar.
- People are less likely to trip over a water bar set in a relatively large and visible timber threshold than when it is set in a flush threshold as shown in the fig.





- In case of external doors it is applied to those members with the function of forming a firm and durable base to the doorway and to exclude water.
- Suitable materials are:
  - stone
  - concrete
  - brick
  - quarry tile
  - timber.
- As the floor level is normally above the ground level outside the door an external threshold usually incorporates a step. This may be formed in various ways, either:
  - as an extension of the concrete floor slab or
  - as a separate member of some other material shown in detail in the figure.



●REPETITION●exercises●●REPETITION●

Try to answer the following questions and use sketches where ever necessary and possible

1. Function and properties of walls:

1.1 Name the functions of a wall

1.2 List and give brief explanations (by means of sketches) on the functional requirements of walls

2. Behavior of walls under load:

2.1 Explain the following terms:
a) crushing; b) buckling; c) settling;
d) excentric loading e) slenderness ratio;
f) sliding ; g) frictional resistance
h) passive soil pressure i) overturning by
1. rotation, 2. settlement

2.2 Write notes on 'Calculation of wall thickness' and summarize briefly the design process.

3. Types of walls

3.1 Divide walls into different types

3.2 Explain the differences between:
a) partition walls ; b) party walls
c) seperating walls; d) division walls.

3.3 Describe briefly the characteristics of

a) Retaining walls	b) masonry walls
c) monolithic walls	d) frame walls
e) membrane walls	f) cavity walls
g) cross walls	g) parapets.

4. Stonework

4.1 Classify Building stones and explain briefly their characteristics.

4.2 Write notes on the use and treatment of Building stones.

4.3 What is the difference between 'Reconstructed' and 'Artificial' stones.

4.4 List and describe the main Defects in stone

4.5 Explain the following terms:
a) arris ; b) ashlar ; c) bed joint ; d) bonder
e) cramp; f) dowl ; g) yoggle ; h) lacing
i) natural bat; j) quarry seep ; k) quoin
l) stool m) string course n) weathering

4.6 Give the characteristics of RUBBLE WALLING
4.7 Give the characteristics of ASHLAR WALLING

5. Brickwork
5.1 Define a Brick (according to BS 3921, Part 2)
5.2 Give the size of Standard Bricks
a) British standard ; b) German standard

5.3 Explain by means of sketches:
a) $\frac{1}{2}$ bat b) $\frac{3}{4}$ bat ; c) bevelled bat (large)
d) bevelled bat (small); e) queen closer (half)
f) queen closer (quartes) g) bevelled closer;
h) mitred closer; i) king closer j) double bulluose
k) splay - stretcher e) splay header;

5.4 Describe briefly how bricks are manufactured.

5.5 What is meant with EFFLORESCENCE?

5.6 According to BS 392, Part 2 there are different types of bricks, such as: - solid / - perforated/ - hollow/ - cellular bricks. Explain the differences!

5.7 What are calcium silicate bricks?
What are concrete bricks?

5.8 Write brief notes on Mortars used in brickwork and give typical mixes.

5.9 Explain how to overcome the penetration of dampness in walls, which are affected
a) by rain, penetrating the HEAD of the wall,
b) by rain, beating against external walls;
c) by ground moisture of the base of the wall.

5.10 Sketch common bonds in brickwork such as
a) Header Bond; b) strecher Bond;
c) English Bond; d) cross bond
e) Flamish Bond; and list other kinds of brickwork bonding.

5.11 Explain the Metric Modular Brickwork and compare British standard and the German system.

6. Blockwork
6.1 What is the difference between Brickwork and Blockwork?
6.2 Characterize different types of blocks such as
a) clay blocks; b) precast concrete blocks;
c) aerated concrete blocks.

7. Concrete walls

7.1 How are concrete walls broadly classified?

7.2 What can be used as precaution against cracking in concrete walls?

7.3 Write notes on FORMWORK and sketch three different straight foreward methods used for concrete walls.

7.4 Explain the following terms.

a) Plain monolithic concrete walls;

b) Dense concrete walls;

c) Light - weight aggregate concrete walls
d) Non - fines concrete walls

e) in - situ cast reinf. concrete external walls?
f) concrete box frames
g) large precast panel structures.

8. Openings in walls.

8.1 What are the members of an opening in a wall?

8.2 Explain (by using sketches) the function and the way of construction of R.C. Lintels

8.3 List different forms of archs

8.4 What are JAMBS ?

8.5 Explain the function of a) a sill and b) a threshold.

8.6 List suitable materials for the construction of a) sills and b) thresholds

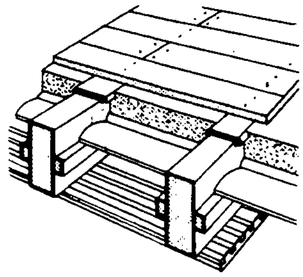
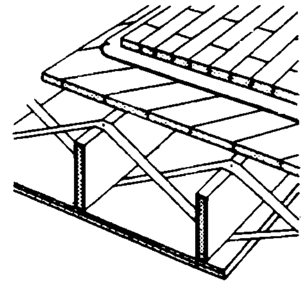
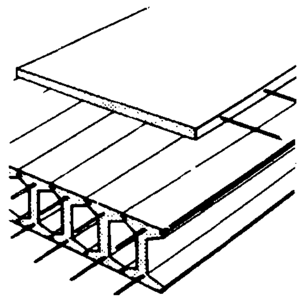
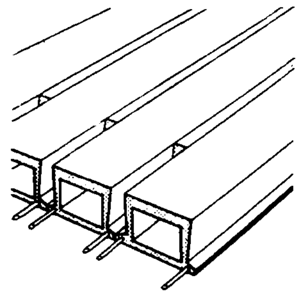
8.7 Sketch and explain different typical sill details, such as:
a) plain tile sill
b) lipped quarry tile sill
c) Brick - on edge sill
d) sunk weathered stone or precast concrete sill
e) weathered precast concrete sill
f) slate sill
g) pressed steel sill

8.8 Sketch and explain different typical threshold details, such as:
a) Brick - on edge threshold
b) concrete step, faced with quarry tiles
c) weathered stone step

8.9 Explain (if necessary by sketching) the terms:

a) internal sill ; b) stool or stooling, c) water - bar:
d) weather - board; e) hardwood threshold.

7. FLOORS

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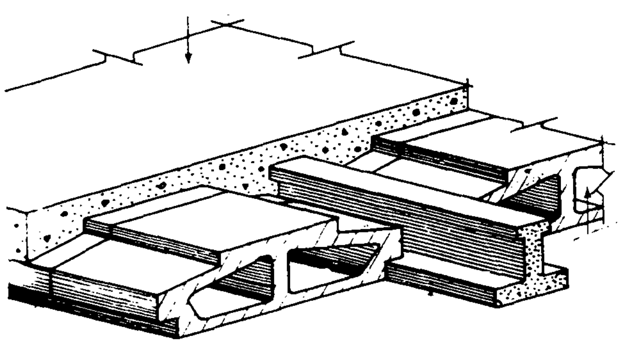

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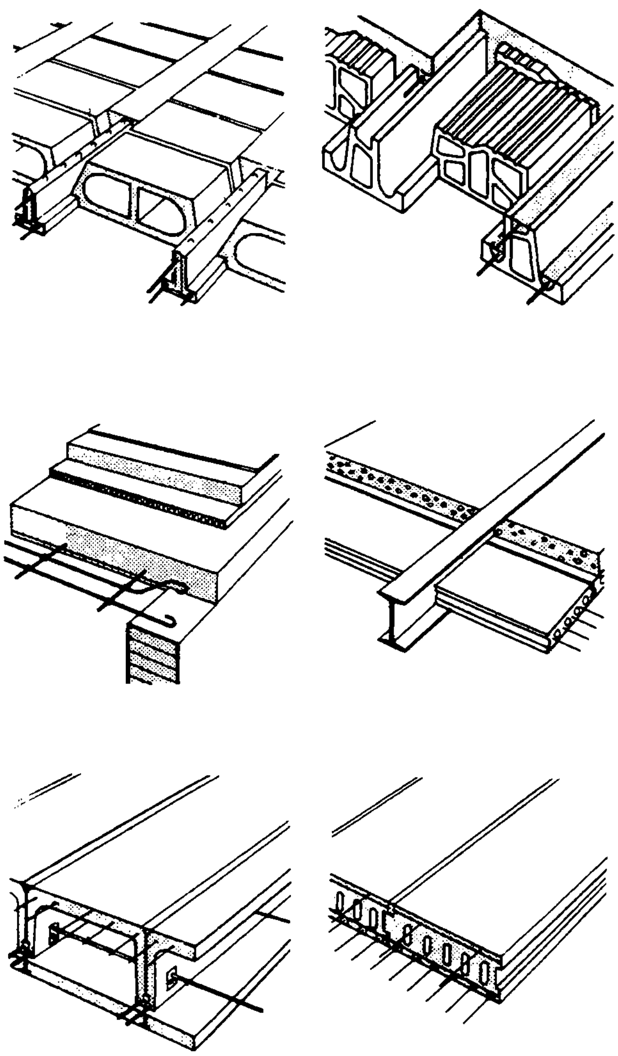
3. Jack Stroud Foster MITCHELL'S BUILDING CONSTRUCTION "Structure and Fabric" Part 1

4. N.S. Whyte and Vincent Powell-Smith "The Building Regulations" 5th Edition

5. BRE Digest "Building Construction"

6. E. Neufert "Architect's Data"

7. FLOORS



LOCAL BYLAWS

7. FLOORS

7.1 General

- Traditionally the GROUND-FLOOR of most small buildings were formed directly of the ground, the soil being rammed until it was firm and sometimes on it where laid flag-stones or bricks to form a hard surface.

  This was unsatisfactory, because the moisture which was continously withdrawn from the soil below the building made the floor DAMP, unconfortable and unhealthy.Therefore other types of floors have been developed in order to make buildings more comfortable and healthy.

- The CONSTRUCTION of a floor - especially in warm climates - will depend largely on its purpose and the material available. The chief factors affecting its design are
  - strength
  - comfort
  - coolness (or thermal insulation)
  - sound insulation
  - flexibility (especially in earthquake areas)

- LOCAL BYLAWS demand a certain capability of carrying load according to its destination; e.g.:
  - a domestic floor may be required to carry only 14,6 MN/m^2 (146 kg/m^2)
  - an industrial floor may be required to carry 48,8 MN/m^2 (488 kg/m^2)

SOLID GROUND FLOORS

7.2 Solid Ground Floors

- Concrete Ground Floors are most widely used today and are usually solid.
- On poor, or uneven ground, or where heavy loads are to be carried, they may be REINFORCED.
- The floor should be laid on HARDCORE of broken stones, concrete, rock, laterite, lumps or burned bricks - if obtainable.
- Where these items are in short supply, 25 cm of compact FOUNDATION SOIL will serve.
  Not TOP SOIL, because:
  1. to prevent plants, shrubs and trees from attempting to grow under the concrete.
  2. it readily contains moisture and would cause the concrete over it to be damp.

7.21Site Concrete:

- A continous layer of CONCRETE at least <u>10cm thick</u> to be spread over the site of all buildings within the external walls on a bed of HARDCORE at least 15cm thick.

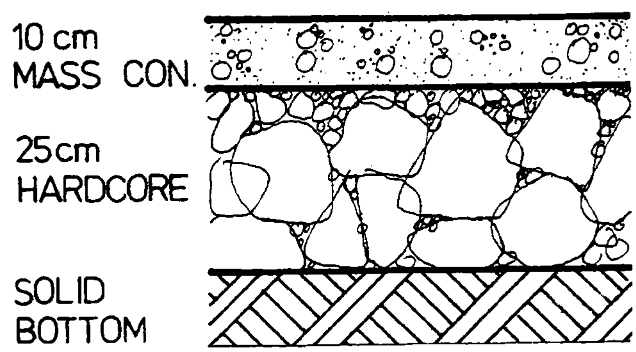
  <u>OR</u>

- A continous layer of CONCRETE at least <u>15 cm thick</u> can be used without HARDCORE underneath.
- The MIXTURE of concrete generally used is

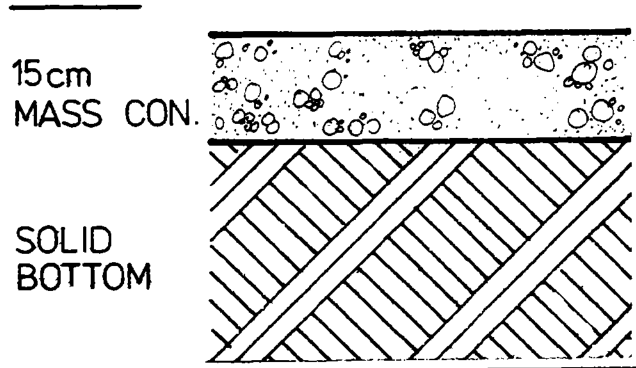
1	:	3	:	6
cement		sand		aggregate

SITE CONCR.

<u>7.21 a</u>



<u>7.21 b</u>



7. FLOORS compiled : D.VOLKE OCT. '80	SOLID GROUND FLOORS SITE CONCRETE	BUILDING COSTR. — LECTURE — CET 2031/1 7.2 02
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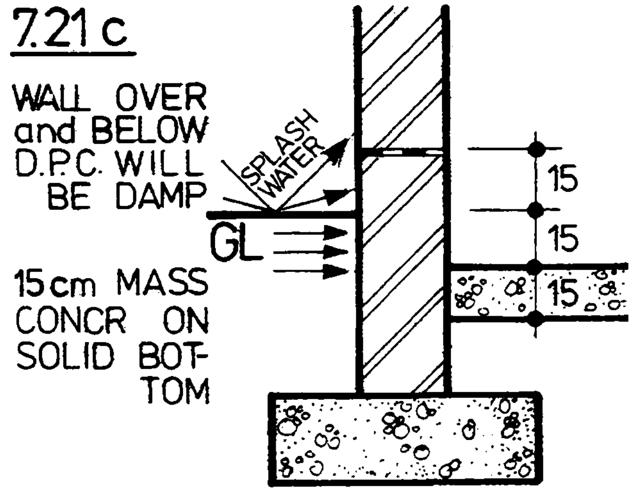
- The building regulations do not allow this site concrete to be laid directly on the turf or to soil of the site. All vegetable and top soil has to be removed first for reasons, which are already mentioned above.
- The depth of vegetable or top soil varies and on some sites it may be necessary to remove <u>30 cm or more</u>. If the 15 cm site concrete were <u>then</u> laid, the top surface of the concrete would be 15 cm <u>below</u> the site outside GROUND LEVEL. It will be remembered that DPC in all walls should be 30 cm above the ground, so that there would be 45 cm of the external walls below the DPC and 30 cm above the floor, making the building very liable to damp. One possibility would be to make the site concrete 45 cm thick to bring its top surface up to the correct level, but this would be an unnecessarily expensive method.

Instead - HARDCORE is spread to raise the level of the concrete. (The soil excavated from foundation trenches should <u>not</u> be taken for backfilling or raising the level of the concrete. The excavated soil will have been broken up in digging and would need quite thorough ramming to make certain it did not sink. Further, this soil would tend to retain moisture and make the site concrete damp.

7.21 c



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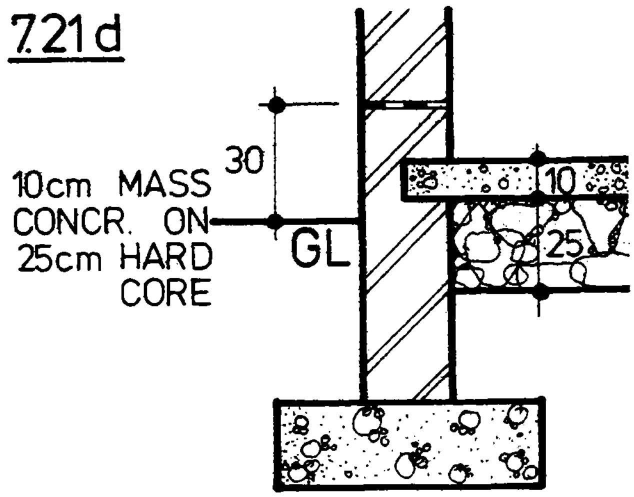
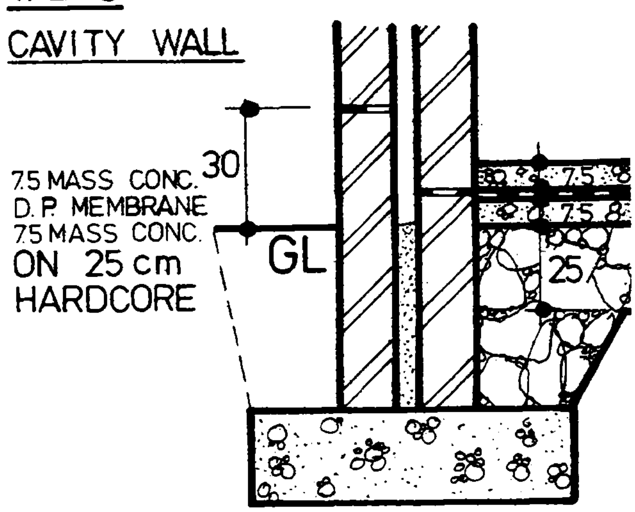


7.21 e

CAVITY WALL



HARDCORE

7.22 Hardcore:

- consists of irregular shaped lumps of
  - . broken bricks
  - . stone or concrete
  - . laterite lumps e.t.c.

  which are hard and do not readily absorb water.

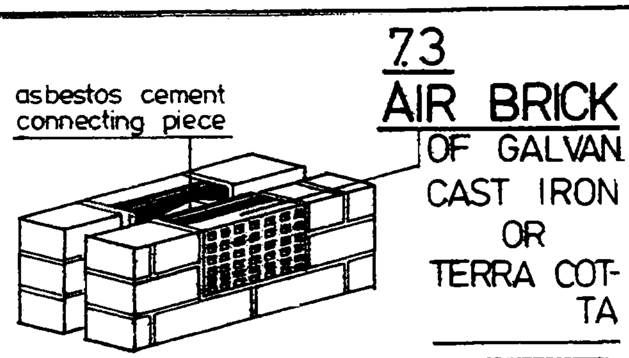
- HARDCORE is spread over the site within the external walls of buildings to such thickness as required to raise the finished surface of the site concrete.
- HARDCORE should be spread until it is roughly level and rammed until it forms a compact bed for the over-site concrete.
- The HARDCORE-BED is usually between 15 cm and 30 cm thick.
- The material used has to be reasonable clean to make it difficult for water to rise by capillary action.
- Before the concrete is laid one has to BLIND the top surface of the concrete - to prevent the wet concrete running down between the hardcore.
  For BLINDING (or sealing) the hardcore a thin layer of very dry coarse concrete can be spread over, or a thin layer of
  coarse clinker or ash
  or aggregate
  can be used.
  The BLINDING LAYER (or coat) will be about 5 cm thick.
  On it the site concrete is spread and finished with a true level top surface.

WATERPROOF MEMBRANE

7.23 Waterproof membrane:

- The waterproof membrane, sandwiched in the concrete prevents damp rising to the floor surface. Fig. 7.21e showes the arrangement.
- The membrane is formed by laying
  1. a 7,5 cm thickness of site concrete and allowing it to thoroughly dry out.
  2. a thin coat of tar or bitumen is poured and spread on the concrete.
  3. a second layer of concrete on to of the hardened tar or bitumen.

SUSPENDED TIMBER GROUND FLOOR



7.3 Suspended Timber Ground Floor

- Consists of:
  TIMBER BOARDS (or other suitable sheet material) fixed to JOISTS spanning over SLEEPER WALLS.
- A timber floor is used occasionally only because it has properties which a solid groundfloor lacks: Some flexibility and it will easily accept nail fixings.
- It is a more expensive form of construction than a solid ground floor and can only be justified on sloping sites which would need a great deal of filling to make up the ground to the required floor level.
- Suspended timber floors are susceptible to
  DRY ROT and
  DRAUGHTS
  the problem of DRY ROT, which is a fungus that attacks damp timber, can be overcome by adequate ventilation under the floor and the correct positioning of D.P.C. to keep the underfloor area and the timber dry.
  THROUGH VENTILATION is essential to keep the moisture content below 20 % of its oven-dry-weight (which would allow fungalgrowth to take place.
  - The usual method is to allow a free flow of air under the floor covering by providing in the external walls, AIR-BRICKS, sited near the corners and at approximately 2 m centres around the perimeter of the building.
- If a suspended timber floor is used in conjunction with a solid ground floor in an adjoining room, PIPES are used under the solid floor to convey air to and from the external walls.

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BUILDING REGULATIONS

7.31 Building Regulations

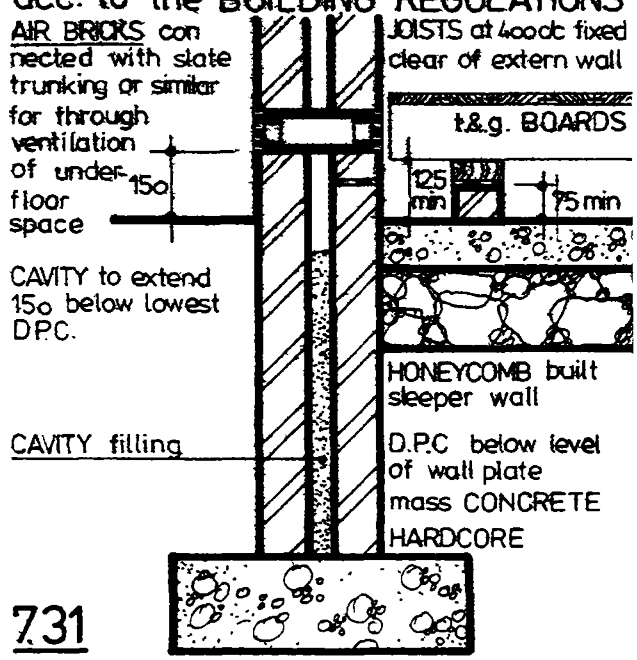
- Fig. 7.31 showes the minimum dimensions required under B.R.C 4 but in practice a greater space between the timber is usual.
- HONEYCOMB sleeper walls are usually built two or three courses high to allow good through ventilation.
- SLEEPER WALLS spaced a 2 m centres will give an economic joist size.
- The width of joists is usually taken as 50 mm (This will give sufficient width for the nails securing the covering.
- The depth can be obtained by reference to Table 1, Schedule 6, B.R. or by design calculations.
  The usual joist depth for domestic work is 125 mm.

TABLE 1, SCHEDULE 6, B.R.

SEE PAGE CET 2031/1-74 13

SUSPENDED TIMBER FLOOR

acc. to the BUILDING REGULATIONS



7.31

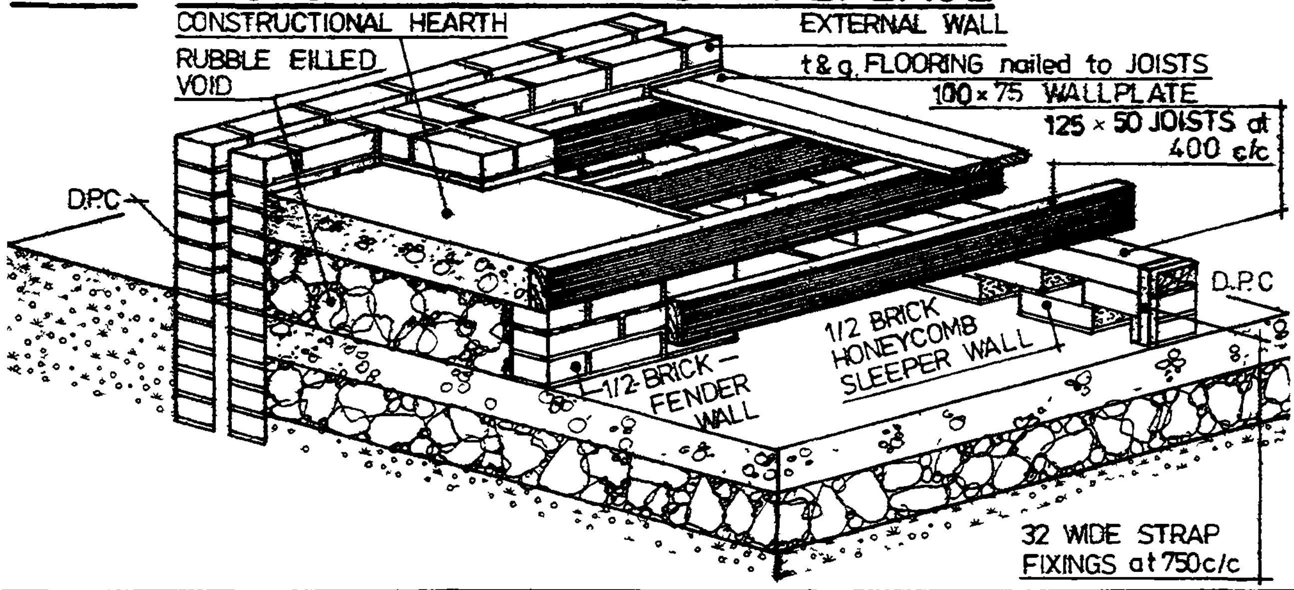
LAY OUT

7.32 Lay out:

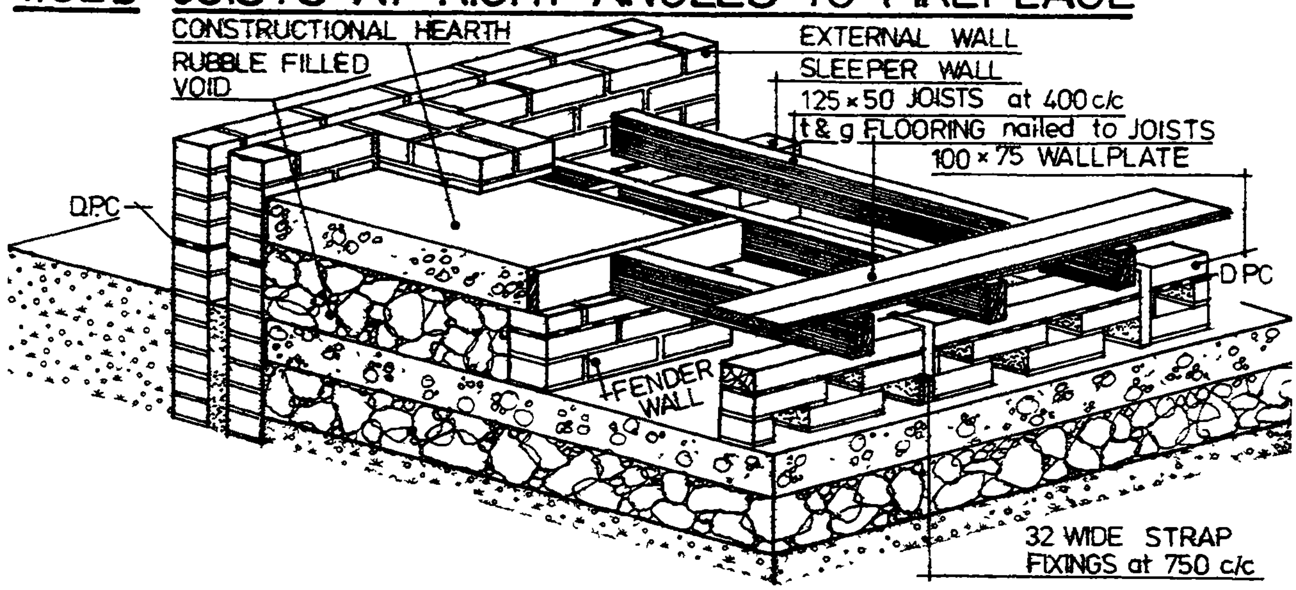
The most economic lay-out is to span the joists across the shortest distance of the room.

- This means the joists could be either parallel or at right - angles to a FIRE - PLACE.
  The fireplace must be constructed of NON-COMBUSTIBLE materials and comply with B.R. L3 and L 4.
- The figures 7.32 a+b show typical exemples.

7.32a JOISTS PARALLEL TO FIREPLACE



7.32b JOISTS AT RIGHT ANGLES TO FIREPLACE

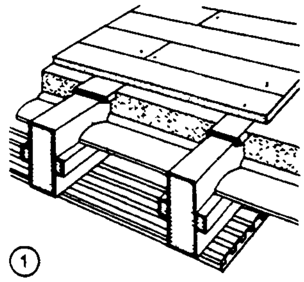


7 FLOORS compiled D.VOLKE OCT '80	JOISTS : LAY OUT	BUILDING CONSTR LECTURE CET 2031/1 7.3 07

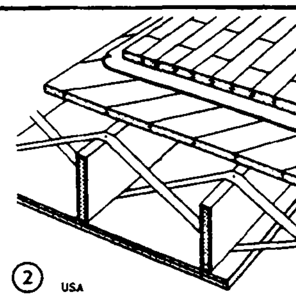
- Constructing ground floors and upper floors, problems of another kind have to be concidered.
  The main differences are:
  1 Ground floor
    - The floor rests directly on the ground
    - Good insulation against <u>moisture</u> is required.
  2 Upper floor
    - The floor is supported only at its edges
    - Good insulation against <u>noise</u> is required.

7.4 UPPER FLOORS

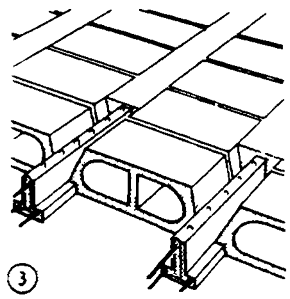
7.41 Types of UPPER FLOORS



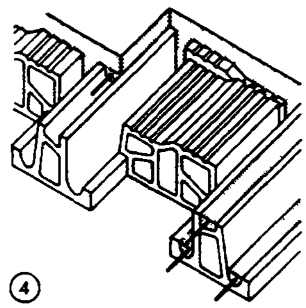
① Timber joist floor with tree segments and infill ~200-250 kg/m²



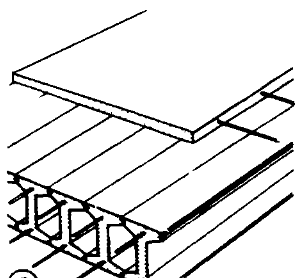
② USA plank floor with hoop iron bracing, weight without infill 65-90 kg/m²



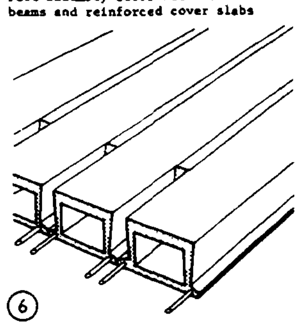
③ r.c. beam floor with non-structural infilling blocks



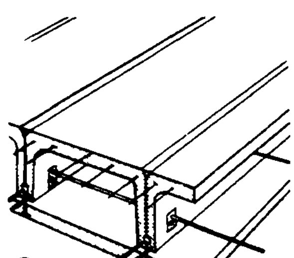
④ Part assembly floor with hollow beams and reinforced cover slabs



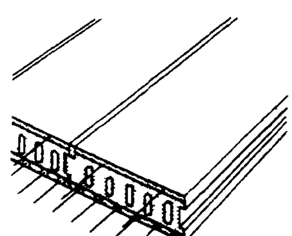
⑤ Complete assembly r.c. I-beam floor, precast



⑥ Complete assembly r.c. hollow beam floor, precast



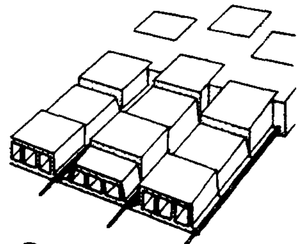
⑦ U-shaped r.c. beams close butting and bolted give lateral bracing



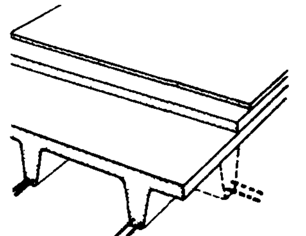
⑧ Pre-stressed hollow concrete plank floor: 20-30 mm concrete bottom layer with pre-stressed twist steel reinforcement, light weight concrete core and 10 mm concrete cover

7.41 types of UPP. FLOORs

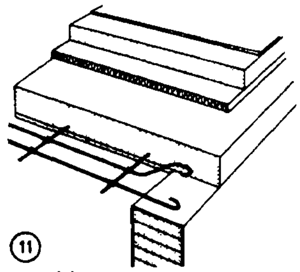
- One can divide types of upper floors into different categories
  - according to the <u>statical system</u>:
    - beam floors
    - slab - beam floors
    - slab - floors
  - according to the <u>kind of construction</u>:
    - constructed on site
    - partly prefabricated
    - prefabricated.
  - according to the <u>material used for construction</u>
    - timber floors
    - concrete or reinforced concrete floors
    - floors made out of masonry or brickwork (arches / domes)
    - floors made out of steel



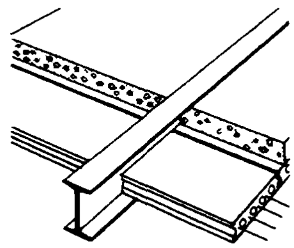
(9) Steel and hollow blocks with extended bottom flange. Ribs and cross jointing of in situ concrete



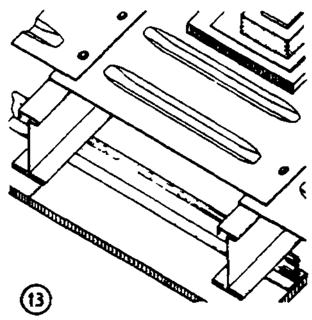
(10) r.c. ribbed floor cast in situ. Ribs c/c ≦ 700 mm, rib width ≧ 50 mm, thickness of slab = 1/10 beam spacing, bearing of beams ≳ 150 mm



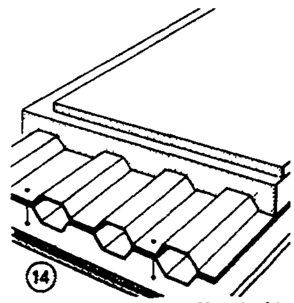
(11) r.c. slab cast in situ, 1 or 2-way reinforcement. ≧ 70 mm thick, economical ≦ 150 mm. With 2-way reinforcement proportion of width to length ≦ 1:1.5



(12) R.S.J. floors with infilling; lightweight or breeze concrete slabs reinforced (900-1 300 mm l, 350 mm w, 85 mm thick), topped with lightweight concrete



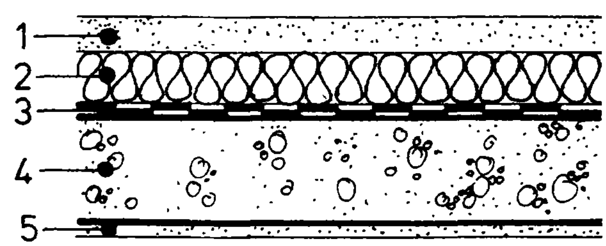
(13) Sheet metal floor for office and industrial buildings. Poor impact noise insulation



(14) Sheet metal floor in office buildings; good ducting for services; ceiling suspended on hangers and concrete topping give good sound insulation

7.42 Structure of upper floors:

<u>7.42</u> structure of an UPPER — FLOOR



1 FLOOR FINISH
2 INSULATION : thermal or sound
3 BARRIERE LAYER
4 LOAD BEARING MEMBER
5 CEILING

susp. timber UPPER FLOOR

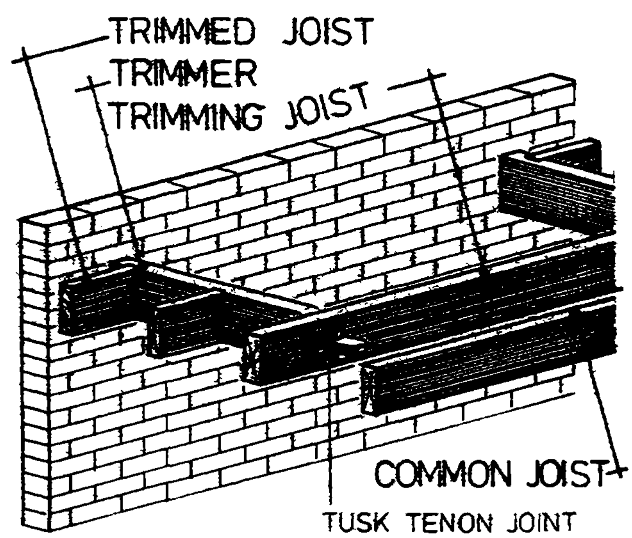
7.43 Suspended Timber upper Floors:

- Timber, being a combustable material, is restricted by Part E of the Building Regulations to SMALL DOMESTIC BUILDINGS as a structural flooring material.
- The construction of suspended timber upper floors is cheap in relation to other structural flooring methods and materials and does not involve WATER for construction.
- Structural soft wood is readily available, easily worked, has a good strength to weight ratio and is therefore suitable for domestic buildings.

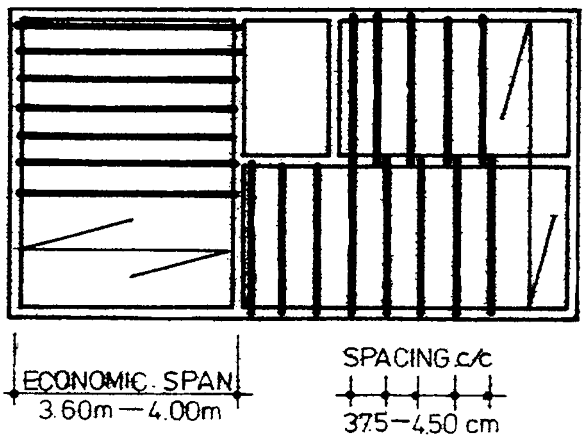
7.431 Floor joists

- The load bearing members of a timber floor are the FLOOR JOISTS.
- Terminology
  - Common Joist: a Joist spanning from support to support.
  - Trimming Joist: span as far as common joist, but it is usually 25 mm thicker and supports at TRIMMER JOIST.
  - Trimmer Joist: a joist at right-angles to the main span supporting the TRIMMED JOISTS and is usually 25 mm thicker than a comman joist.
  - Trimmed Joist: a joist cut short to form an opening and is supported by a trimmer joist, it spans in the same direction as common joists and is of the same section size.

7.431

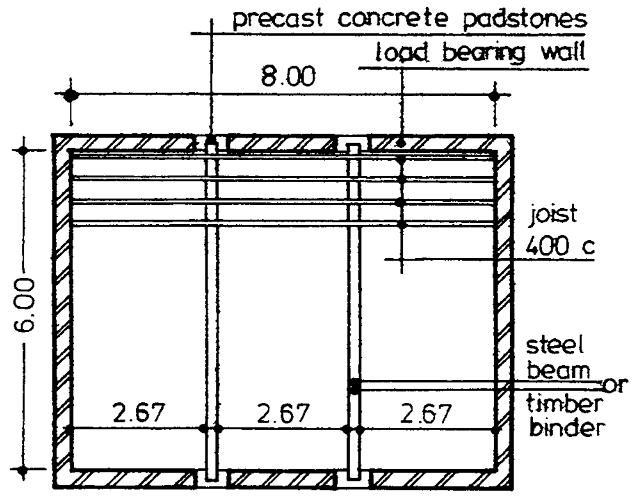


7.431 SPACING OF JOISTS

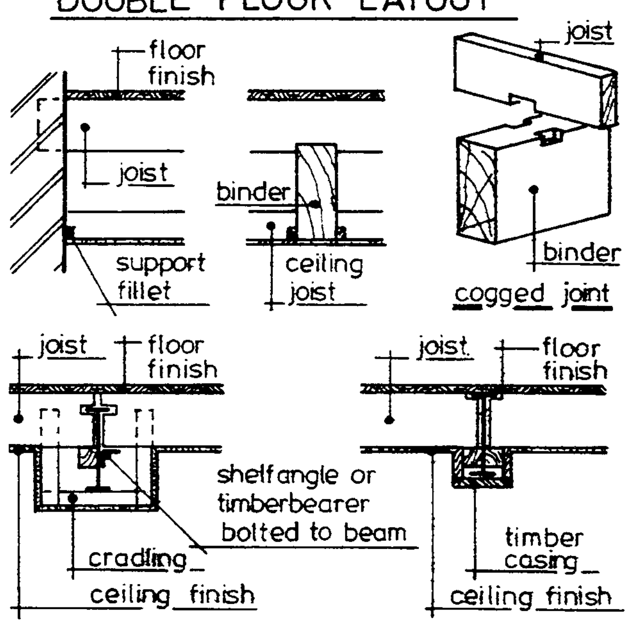


- Spacing of the Joists
  - The spacing of the joists is usually from 37,5 cm to 450 cm, measured from the centre of one joist to the next.
  - To economise in the use of timber the floor joist of upper floors usually span (are laid across) the least width of rooms from external wall to internal partitions.
  - The maximum economical span for timber joists is between 3.60 m and 4 m. For greater spans (than about 4,5 m) it is usually economic to reduce the span of the joist by the use of steel beam or timber binders, which is known as DOUBLE FLOOR CONSTRUCTION.

7.431 a DOUBLE FLOOR DETAILS



DOUBLE FLOOR LAYOUT



DETAILS USING TIMBER BINDER OR STEEL BEAM

7.FLOORS compiled: D.VOLKE OCT. '80	SPACING OF JOISTS DOUBLE FLOOR DETAILS	BUILDING CONSTR. — LECTURE — CET 2031/1 7.4 11
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- Strutting between joists: Timber shrinks when it is seasoned and timber - such as floor joists - which is not cut on the radius of the circle of log does not shrink uniformly. The shrinkage will tend to make the floor joists twist, or wind, and to prevent cracking of a plaster ceiling which this twisting would cause, timber strutting is used.

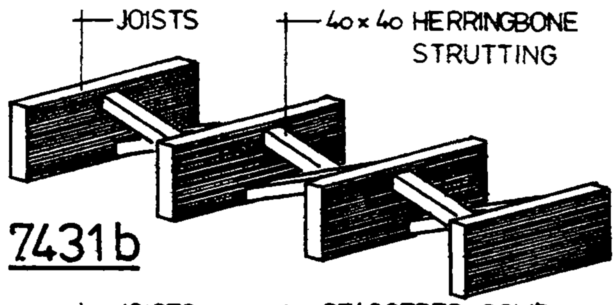
The commonly used type is

- HERRINGBONE STRUTTING
  This consists of short lengths of 4 x 4 cm soft-wood timber nailed between the joists.
- Alternatively a system of solid strutting is sometimes used. This consists of short lengths of timber of the same sections as the joists which are nailed between the joists - either in line or staggered

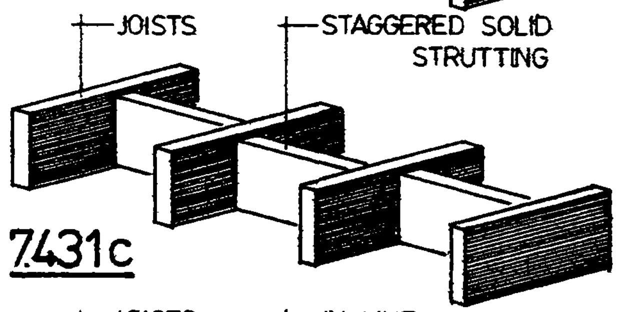
  It is not as effective as the herringbone system, because the solid lengths have to be cut very accurately to fit to the sides of the joists; they do not firmly strut between the joists.
- As with herringbone strutting the end joists are blocked and wedged up to the surrounding walls.
- Usually: one set of struts is used for joists spanning up to 3,60m and
  two sets of struts are used for joists spanning more then 3.60 m.

  A single set of struts is fixed across the floor at mid span.

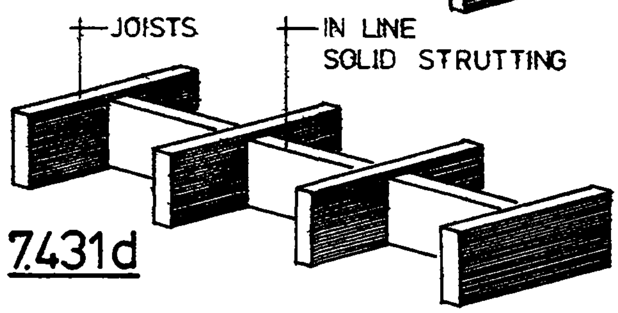
STRUTTING ARRANGEM.'S



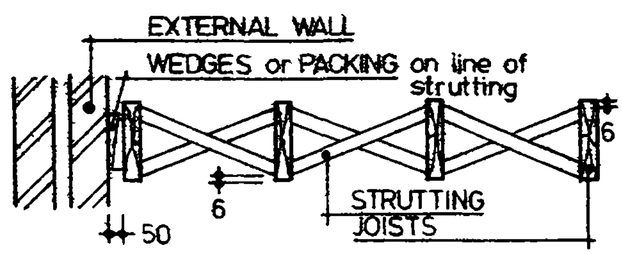
7431b



7431c



7431d



7431e

7 FLOORS	STRUTTING	BUILDING CONSTR
compiled D VOLKE		LECTURE
OCT '80		CET 2031/1 74 12

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JOIST SIZING

- **Joist Sizing:**

  There are three ways of selecting suitable joists for supporting a domestic type floor:

  1. Rule of Thumb:

     $$\frac{\text{span in mm}}{24} + 50\text{mm} = \text{depth in mm}$$

  2. Calculation:

     $$BM = \frac{fbd^2}{6}$$

     where
     BM = bending moment
     f = max fibre stress
     b = breadth (assumed to be 50 mm)
     d = depth in mm

  3. Building Regulations, Table 1, Schedule 6.

TABLE 1

FLOOR JOISTS

GS, MGS, M50, M75 or No. 2 Grade Timber

Size of joist (in mm)	Dead load (in kg/m²) supported by joist, excluding the mass of the joist								
	Not more than 25			More than 25 but not more than 50			More than 50 but not more than 125		
	Spacing of joists (in mm)								
	400	450	600	400	450	600	400	450	600
	Maximum span of joist (in m)								
38 x 75	1·05	0·95	0·72	0·99	0·90	0·69	0·87	0·79	0·62
38 x 100	1·77	1·60	1·23	1·63	1·48	1·16	1·36	1·24	1·00
38 x 125	2·53	2·35	1·84	2·33	2·12	1·69	1·88	1·73	1·40
38 x 150	3·02	2·85	2·48	2 83	2·67	2·26	2·41	2·23	1·83
38 x 175	3·51	3·32	2·89	3·29	3·11	2·71	2·82	2·66	2·27
38 x 200	4·00	3·78	3·30	3·75	3·55	3·09	3·21	3·03	2·64
38 x 225	4·49	4·24	3·70	4·21	3·98	3·47	3·61	3·41	2·96
44 x 75	1·20	1·08	0·83	1·13	1·02	0·79	0·98	0·89	0·70
44 x 100	2·01	1·82	1·41	1 83	1·67	1·31	1·51	1·39	1·12
44 x 125	2·71	2·56	2·09	2·54	2·38	1·90	2·08	1·92	1·56
44 x 150	3·24	3·06	2·67	3·04	2·87	2·50	2·60	2·45	2·03
44 x 175	3·77	3·56	3·10	3·53	3·34	2·91	3·02	2·86	2·48
44 x 200	4·29	4·06	3·54	4·02	3·80	3·31	3·45	3·26	2·83
44 x 225	4·81	4·55	3·97	4·51	4·27	3·72	3·87	3·66	3·18
50 x 75	1·35	1·22	0·93	1·26	1·14	0·89	1·08	0·99	0·78
50 x 100	2·22	2·03	1·58	2·03	1·85	1·46	1·66	1·53	1·23
50 x 125	2·84	2·72	2·33	2·70	2·55	2·10	2·27	2·09	1·71
50 x 150	3·40	3·26	2·84	3·23	3·05	2·66	2·76	2·61	2·21
50 x 175	3·95	3·78	3·30	3·75	3·55	3·09	3·22	3·04	2·64
50 x 200	4·51	4·31	3·76	4·27	4·04	3·52	3·67	3·46	3·01
50 x 225	5·06	4·83	4·22	4·79	4·53	3·95	4·11	3·89	3·39
63 x 150	3·66	3·52	3·17	3·50	3·38	2·97	3·09	2·92	2·54
63 x 175	4·25	4·10	3·68	4·07	3·93	3·45	3·59	3·40	2·96
63 x 200	4·84	4·67	4·20	4·64	4·48	3·93	4·09	3·87	3·37
63 x 225	5·43	5·24	4·70	5·21	5·02	4·41	4·59	4·34	3·78
75 x 200	5·10	4·93	4·51	4·90	4·72	4·27	4·43	4·20	3·67
75 x 225	5·72	5·52	5·06	5·49	5·30	4·79	4·97	4·71	4·11

END SUPPORT: FLOOR JOISTS

7,432 End Support of Floor Joists

The end of timber floor joists must in some way either be built
- into or
- supported against

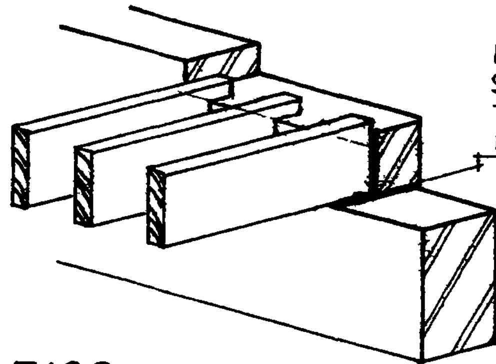
load bearing partitions and external walls.

- The most commonly used method of giving support to the ends of timber floor joists is to build them <u>into</u> walls and partitions.
  - There was a common practice to build the joistends some 10 cm into walls and partitions and to pack up under each joist with small peaces of slate or tile so that the top of the joists are level, if the underside of the joist does not comply with a brick course.
    - Distadvantage: displacing of tiles - out of level.

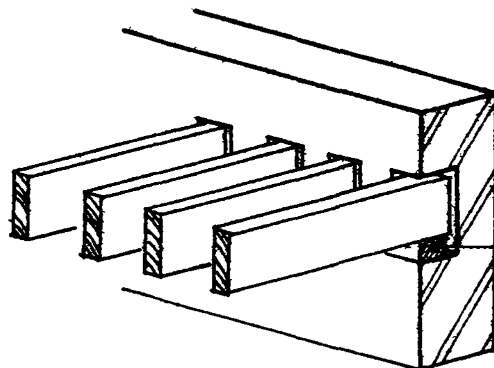
BUILT INTO

- A better solution is to build a wallplate (100 x 75 mm) into the wall as shown in Fig. 7.432 B
- Another possibility is the use of a mild steel wallplate(75 x 3 mm) as demonstrated in fig. 7.432 C.

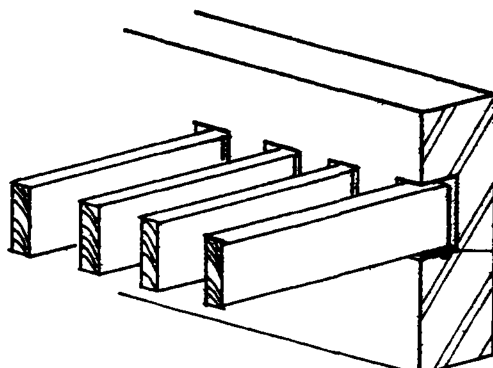
END SUPPORT OF FLOOR JOISTS



7.432 a BUILT INTO



7.432 b BUILT INTO



7.432 c BUILT INTO

7 FLOORS compiled : D.VOLKE OCT. '80	END SUPPORT of FLOOR JOISTS	BUILDING CONSTR. — LECTURE — CET 2031/1 7.4 14

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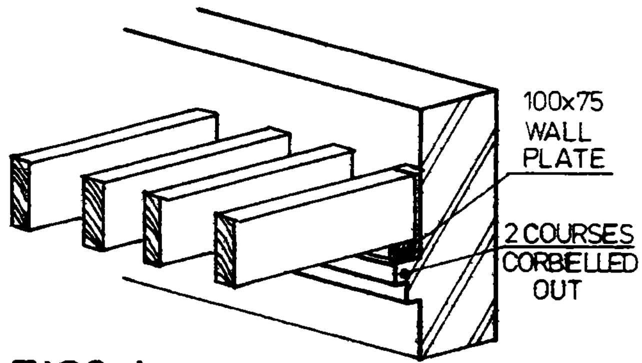
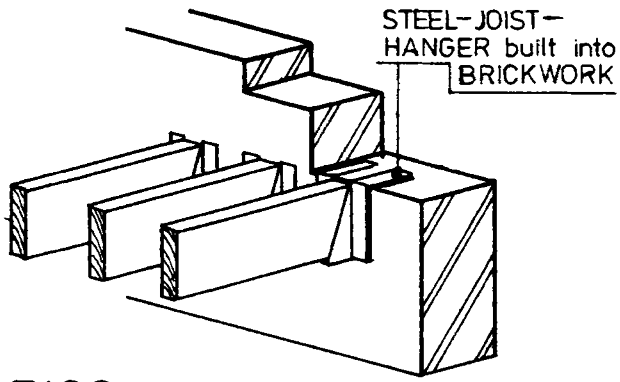
SUPPORTED AGAINST

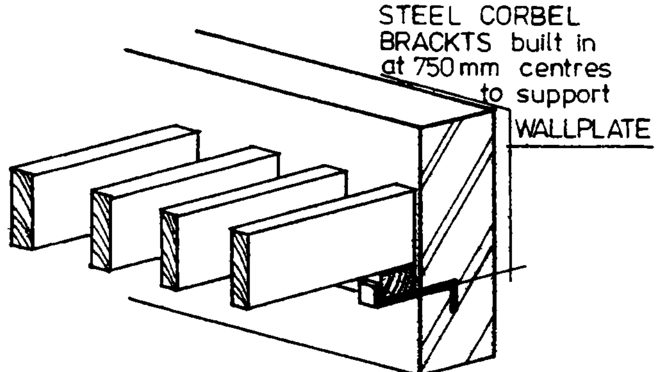
- If the ends of timber floor joists are built into a solid external wall, 1 brick thick, there is only 1/2 brick between the ends and the rain falling on the outside of the wall.
  Therfore: Joists will at time become saturated and then: the dry rot fungus may attac.
  This danger can be reduced by painting the ends of the joists with oily preservative.
  If the external wall is of cavaty construction, the joist-ends must not run into or across the cavaty (moisture!!).



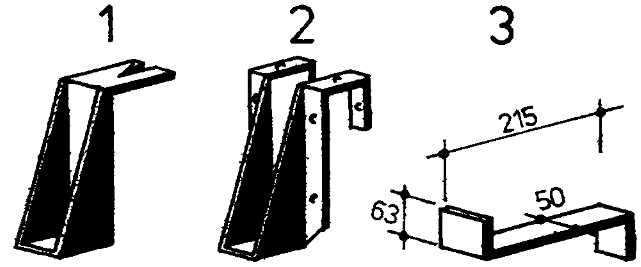
7.432 d SUPPORTED AGAINST



7.432 e SUPPORTED AGAINST



7.432 f SUPPORTED AGAINST



1+2 GALV. PRESSED STEEL JOIST HANGERS

3 CORBEL BRACKED

7.432 g

7. FLOORS compiled: D. VOLKE OCT. '80	END SUPPORT of FLOOR JOISTS	BUILDING CONSTR. — LECTURE — CET 2031/1 7.4 15
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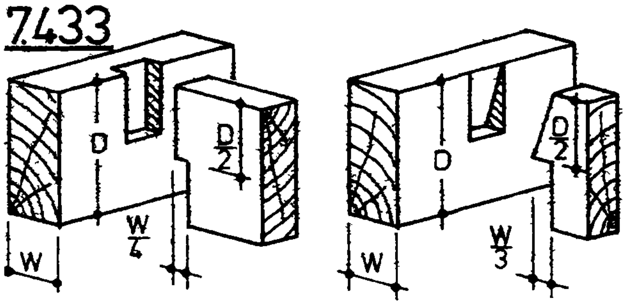
7.433 Trimming:

- This is a term used to describe the framing of joists around an opening of projection. Various joints can be used to connect the members together, all of which can be substituted by JOIST HANGERS.
- Typical trimming joints and arrangements are shown in Fig. 7433

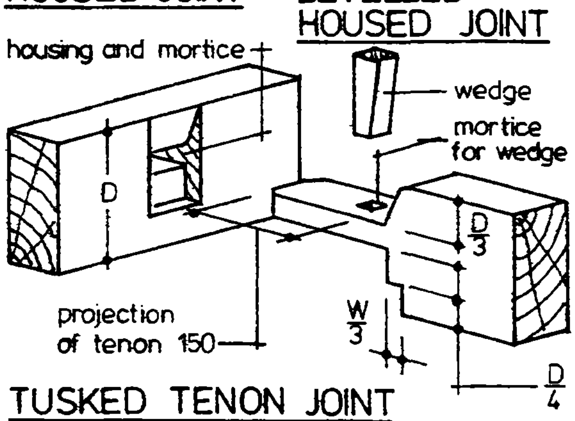
TRIMMING

FLOOR TRIMMING JOINTS 7433



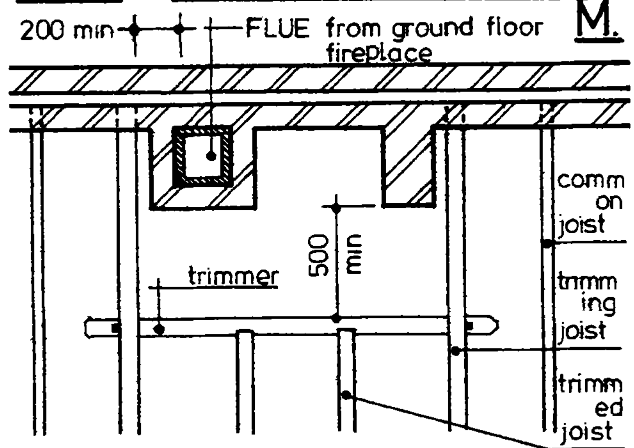
HOUSED JOINT

BEVELLED HOUSED JOINT

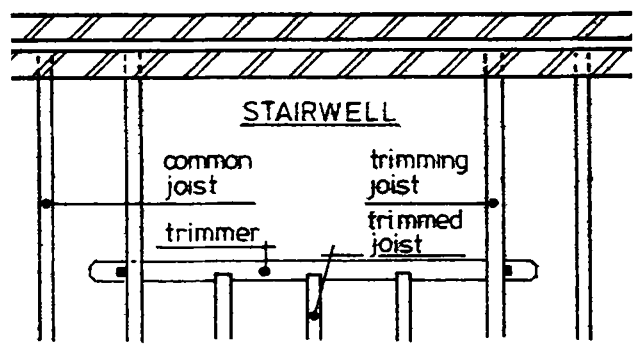


TUSKED TENON JOINT

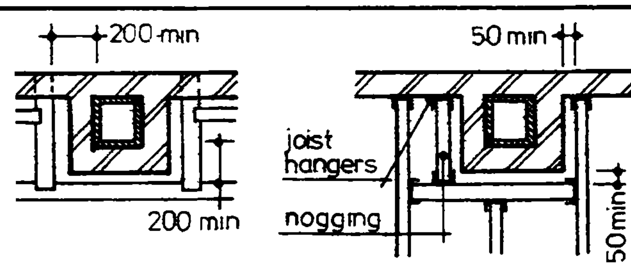
7433 TRIMMING ARRANGE-M.



TRIMMING TO UPPER FLOOR FIREPLACE



TRIMMING TO STAIRWELL



TRIMMING AROUND FLUES

REINFORCED CONCRETE upper floors

7.44 Reinforced concrete upper floors.

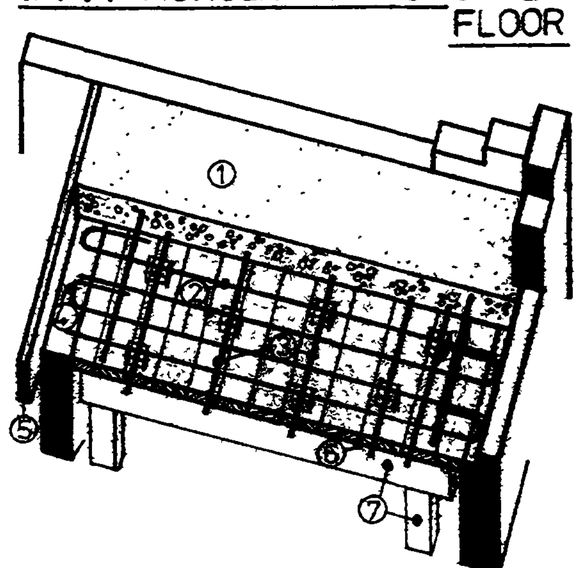
- Reinforced concrete floors have a better resistance to demage by fire and can safely support greater superimposed loads than timber floors.
  Therefore they are used for most offices, larger blocks of flats, factories and public buildings.
- There are many different types of reinforced concrete floors. Some of the most common r.c. upper floors are demonstrated in the following

7.441 Monolithic Reinforced Concrete Upper Floor

A monolithic r.c.floor is poured 'in situ' on formwork, consisting of concrete and reinforcement steel bares. After drying out it becomes a new "monolithic" building material: REINFORCED CONCRETE which is capable to resist both compression and tension forces.

- R.C. upper floors are in most cases between 10 cm und 30cm thick
- Usually mild steel is used for reinforcement (either bares or mats)
  Reinforcement and concrete mix have to be in accordance with the statical calculations.
- Disadvantages of Monolithic R.C. Upper Floors:
  - Need Forwork
  - Time taken for the concrete to cure before formwork can be released
  - very little is contributed by a large portion of concrete to the strength of the floor.
- Fig. 7.441 showes an typical example of a monolithic r.c. upper floor.

7441 MONOLITHIC R.C. UPPER FLOOR



1 CONCRETE CAST IN SITU
2 MAIN REINFORCEMENT BARS (150 c/c)
3 DISTRIBUTION BARS (450 c/c)
4 ENDS OF BARES BENT UP
5 TIMBER FORMWORK
6 TIMBER CENTERING
7 TIMBER SUPPORT FOR CENTERING

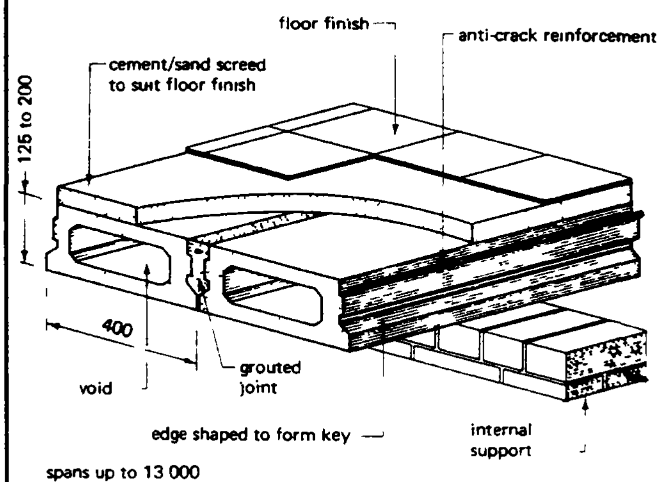
PRECAST CONCRETE upper floors

7.442 Precast Concrete Upper Floor

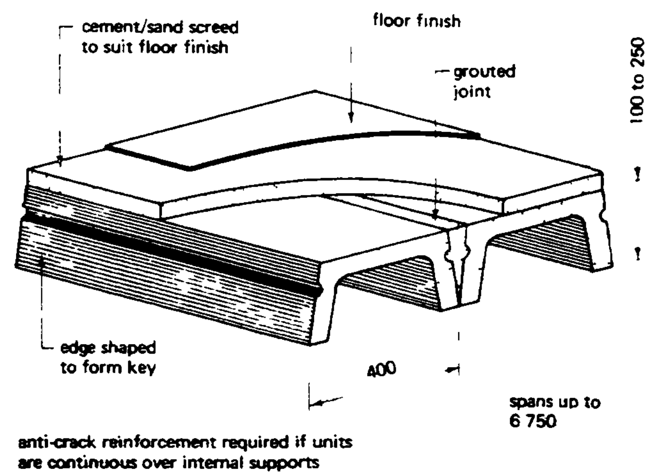
- Floors composed of reinforced precast concrete units have been developed over the years to overcome some (or all) the disadventages of monolithic reinforced concrete slab.
  To realise the full economy of any one particular precast flooring system the design of the floors should be within the SPAN, WIDTH, LOADING and LAYOUT LIMITATIONS of the units under cosideration.
- The systems available can be considered either PRECAST HOLLOW FLOORS or COMPOSITE FLOORS.

• Precast hollow floors
Units are available in a variety of sections such as boxplanks or beams, tee sections, I-beam sections and channel sections.

- The economies which can be reasonable expected over the 'in situ' floor are:
  1. 50 % reduction in the volume of concrete
  2. 25 % reduction in the weight of reinforcement
  3. 10 % reduction in the size of foundations.
- The units are cast in precision moulds, around inflatable formers or framed plastic cores.
- The units are laid side by side with the edge joints being grouted together.
- No structural topping is required, but the upper surface of the units are usually screeded to provide the correct surface for the applied finishes.
- Means of mechanical lifting is required to offload and position the units.
- Hollow units are normally the cheapest form of precast concrete suspended floors for simple straight spans with beam or wall supports to maximum a span of 20 m.
- They are not suitable for heavy point loads.



Typical hollow floor unit details



Typical channel section floor unit details

Precast concrete hollow floors

7 FLOORS compiled D VOLKE OCT '80	PRECAST CONCRETE HOLLOW FLOORS	BUILDING CONSTR LECTURE CET 2031/1 74 18

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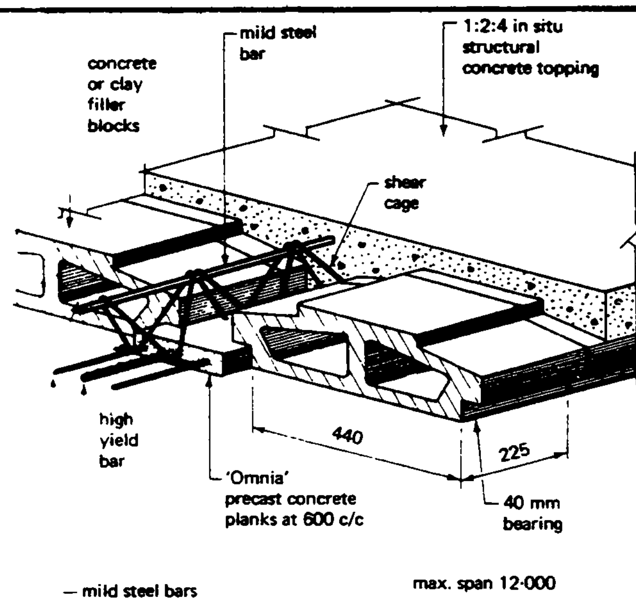
- Composite floors.

  Are a combination of PRECAST UNITS and IN SITU CONCRETE.

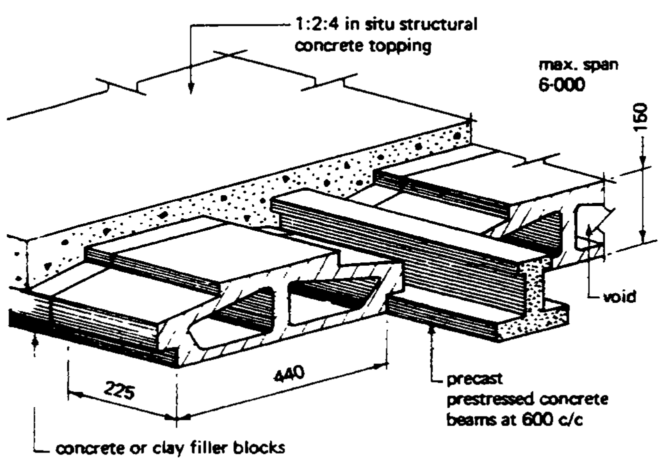
- The precast units (usually prestressed or reinforced with high yield steel bars) are used to provide the strength of the floor and at the same time act as a permanent formwork to the in situ topping which provides the compressive strength required.
  It is essential that an adequate bond is achieved between the two components (in most cases this is provided by the upper surface texture of the precast units).

COMPOSITE FLOORS

- Generally there are two forms of composite floors:
  1. Thin pressed planks with a side key and covered with an in situ topping
  2. Reinforced or prestressed narrow beams which are placed at 600 mm centres and are bridged by concrete filler blocks.
     The whole combination being covered with in situ topping.
     Most of the beams used in this method have shear reinforcing cage projecting from the precast beam section.
- In both forms temparary support should be given to the precast units by props at 1,80 m to 2,40 m centre until the in situ topping has cured.



Typical composite floor using P.C.C. planks



Typical composite floor using P.C.C. beams

Composite floors

7 FLOORS	COMPOSITE FLOORS	BUILDING CONSTR.
compiled: D.VOLKE		LECTURE
OCT. '80		CET 2031/1 7.4 19

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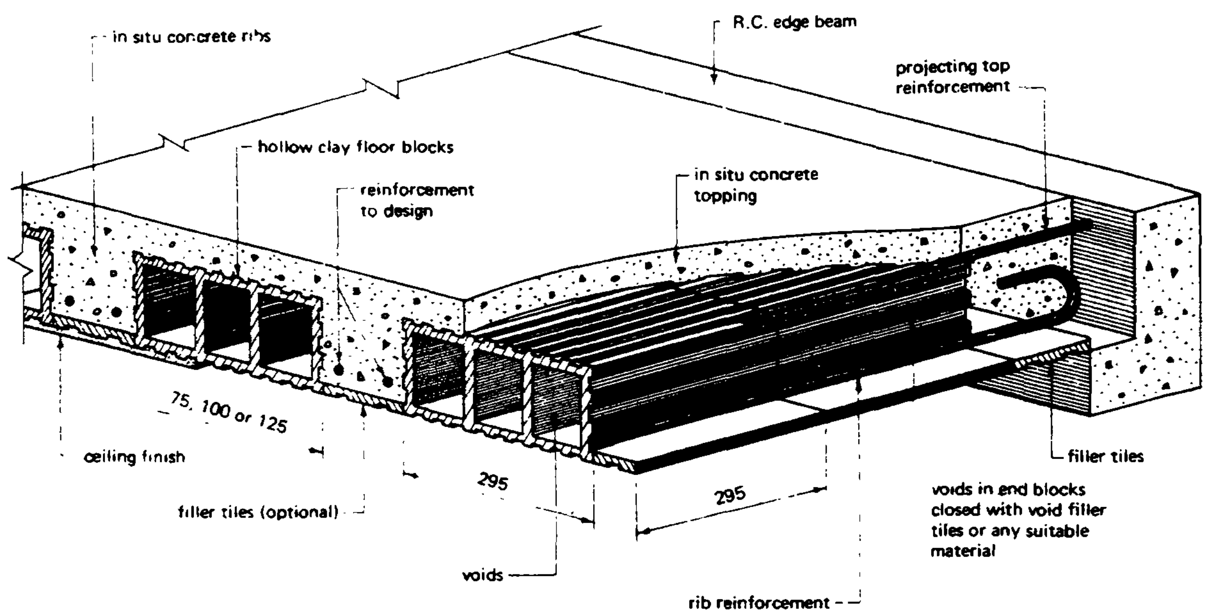
HOLLOW-BLOCK & WAFFLE FLOORS

7.443 Hollow Block and Waffle Floors.

- Precast concrete suspended floors are generally considered to be for light to medium loadings spanning in one direction.
  HOLLOW BLOCK (or hollow pot) and WAFFLE (or honeycomb) FLOORS can be used as an alternative to the single spanning precast floor since they can be designed to carry heavier loadings.
  They are in fact RIBBED FLOORS consisting of closely spaced narrow and shallow beams giving an overall reduction in depth of the conventional reinforced concrete monolithic beam and slab floor.

• HOLLOW BLOCK FLOORS

- These are formed by laying over conventional floor soffit formwork a series of hollow light weight clay blocks (or pots) in parallel rows with a space between these rows to form the ribs.
- The blocks act as permanent formwork giving a flat soffit suitable for plaster application and impact to the floor good thermal insulation and fire resistance.
- The ribs formed between the blocks can be reinforced to suit the loading concitions of the floor.
- The main advantages are:
  its light weight
  its relatively low cost.



7. FLOORS compiled : D.VOLKE OCT. '80	HOLLOW-BLOCK FLOORS	BUILDING CONSTR. LECTURE CET 2031/1 7.4 20
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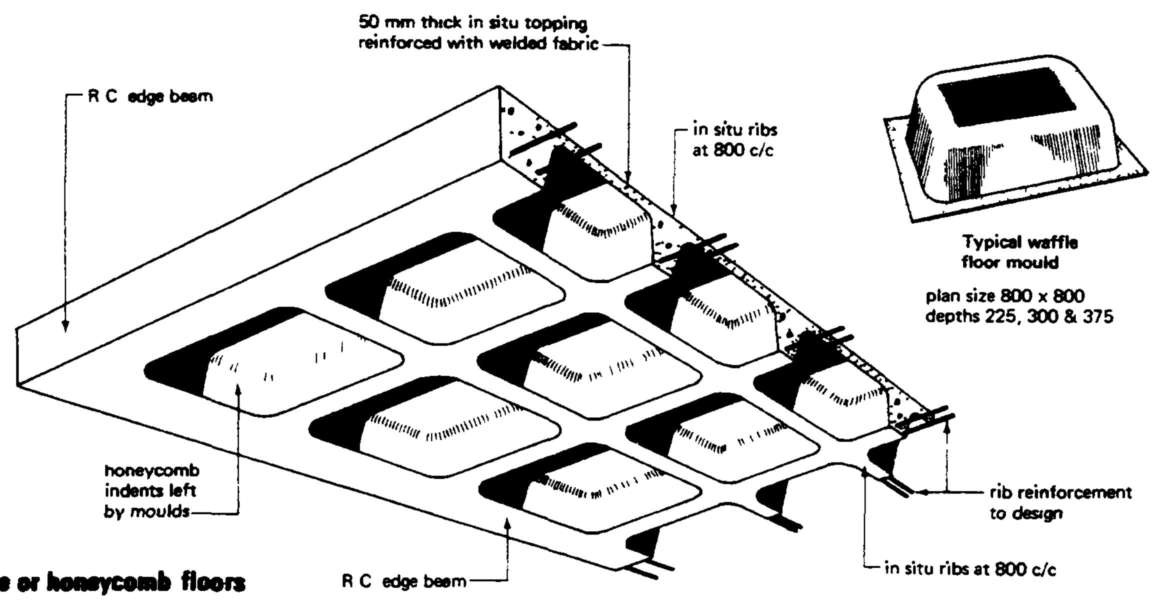
WAFFLE or HONEYCOMB floors

. WAFFLE FLOORS

- These are mainly used as an alternative to an in situ flat slab or a beam and slab suspended floor, since it requires less concrete, less reinforcement and can be used to reduce the number of beams and colums required.
- The honeycomb pattern on the underside can add to the visual aspect of the ceiling by casting attractive shadow pattern.
- The floor is cast over light weight moulds or pans made of glass fibre, poly-propylen or steel forming a TWO DIRECTIONAL FLOOR.
- The reinforcement in the ribs is laid in two directions to resist both consitudinal and transverse bending moments in the slab.
- It is advisable to allow for a floor screed to be applied to the in situ topping at a later stage in the contract prior to the fixing of the applied finish.



Waffle or honeycomb floors

7 FLOORS compiled D.VOLKE OCT. '80	WAFFLE FLOORS	BUILDING CONSTR LECTURE CET 2031/1 7.4 21
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FLOOR FINISHES

7.5 Floor finishes

- Floor finishes may be classified into four categories:
  1. Jointless floor finishes
  2. slab floor finishes
  3. sheet floor finishes
  4. wood floor finishes
- The choice will depend on many factors; e.g. cost, durability, colour, hardness, slipperness, resistance to oils, acids, heat, sunlight, abrasion, noise and ease of maintenance.

JOINTLESS FLOOR FINISHES

7.51 Jointless floor finishes

7.511 The most common of these is the CEMENT / SAND SCREED. It will give a suitable finish especially for bare feet and sandals.

- There are different ways of construction:

7.511 a Monolithic Construction

The screed is laid on the in situ concrete base within 3 hours (before it has set). In that case, a complete BONDING is obtained

- screed and base shrink together
- Thickness of the screed: only 12 mm necessary, on application thicker than 25mm has to be avoided, in order to restrict shrinkage forces from the SCREED.
- it will be the best solution to eliminate cracking and curling but...
- a proper planning (at the design stage) and complete PROTECTION of the area where screed has been applied is necessary.

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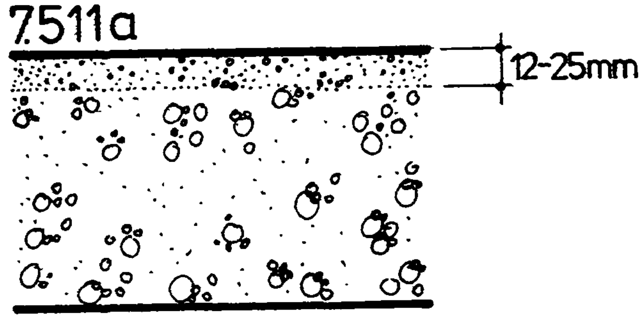


MONOLITHIC CONSTRUCTION

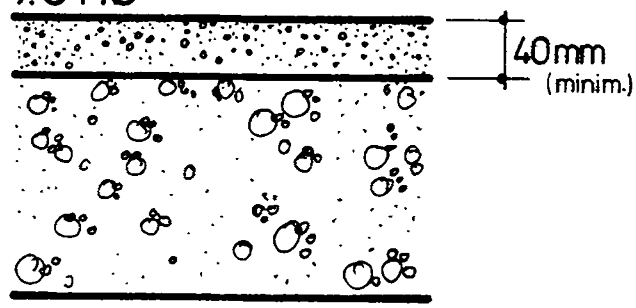
7.511b Seperate Construction

Once the concrete has set, monolithic construction can no longer be used.

- The strength of the bond between screed and base will depend on the way the base has been prepared.

  To achieve a maximum bonding, the base has to be
  - hacked (by mechanical means)
  - cleaned
  - damped (to reduce suction) and
  - grouted (or a bonding agent can be used)
- Minimum thickness : 40 mm.

7.511b



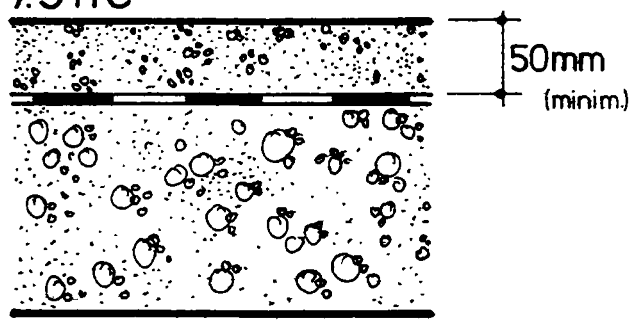
SEPERATE CONSTRUCTION

7.511c Unbonded Construction

If it is not possible to achieve a bond between base and screed (i.e. in case of an screed appli - cation on top of a damp-proof-membrane) the screed layer has to be applied thicker

- Mininum thickness 50 mm.

7.511c



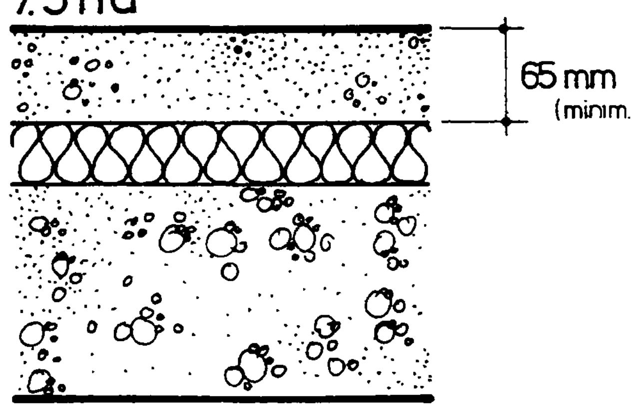
UNBONDED CONSTRUCTION

7.511 d Floating Construction

Is a screed to be laid on compressible layers of thermal or sound insulation, the material should be applied to a

- minimum thickness 65 mm.

7.511d



FLOATING CONSTRUCTION

7 FLOORS compiled : D.VOLKE OCT. '80	JOINTLESS FLOOR FINISH	BUILDING CONSTR. — LECTURE — CET 2031/1 7.5 23

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FLOOR SCREEDS

GRANOLITHIC CONCRETE FINISHES

7.511 e Division into bays

In order to avoid cracking and to reduce curling screed should be laid in alternate bays.

- The bay sizes should not be more then 15 m^2.
- The ratio between the sides of the bays may be approxemately 1:1 1/2. - long, narrow bays to be avvoided.
- Expansion joints are required only where similar joints are provided in the main structure.

7.511f Mix designs

- For screeds up to 4o mm, mixtures of 1 : 3 up to 4 1/2 cement / sand are used. (mixes less rich in cement will cause LOWER SHRINKAGE)
- For thicker screeds: FINE CONCRETE of 1 : 1 1/2 : 3 (cement fine aggregate: coarse aggregate) may be applied. The maximum size for coarse aggregate is 10 mm.

7.512 Granolithic concrete finishes

is used where a more durable surface is needed and suitable granite chippings are available.

- It is laid about 30 mm thick in the same way as cement sand (1 part cement : 3 parts granolithic) and trowelled smooth.
- It is used for paved areas, yards, factories, warehouses, and balconies.
- It should be kept damp and protected from hot sun for at least 24 hours after laying and cured for 3 days afterwards.
- Where a non-slip surface is needed, CARBORUNDUM may be spread into the granolithic finish while it is still green.
- Surface hardeners are often applied to granolithic and cement and sand floors. One type of hardener consists of 1 volume of sodium silicate to 4 volumes of water sprayed on after the concrete has set.
- Two applications are usual.
- For heavy industrial floors, especial steel or plastic grids may be inserted which divide up the floor into TILES.
- Synthetic plastics may also be used in place of granite chippings and give a pleasing finish.

TERRAZZO

7.513 TERAZZO
consists of 2 parts marble chippings of various colours and 1 part (white) Portland cement; laid about 12 mm thick on a screed of cement/sand (1:4).

- Strips of brass or plastic are bedded into the screed and left standing to divide the terrazzo into bays (1-2m²)
- The floor is ground smooth with a carborundum machine, or by hand, after it has hardened.
- Plastic pellets are also used in place of marble chippings. Synthetic resins and plastics are available in paste form and can be laid 6 mm thick on screeded floors. They have the advantage of being non-slippery when wet.
- It is important that both mixingbays and materials be kept clean and free from soil, otherwise the floor finish will show stains.

SLAB FINISHes

7.52 Slab Floors finisehes

- natural stone slabs and slates
- quarry and vitreous tiles

The vitreous types are of better quality than quarry and are produced in brighter colours and patterns. The surface can be smooth or ribbed.

Tiles should be soaked and bedded on to a damp screed and tamped into position with a short straight - edge. The joints are grouted and the floor cleaned off. It should NOT be used for several days.

- Concrete tiles make a durable floor and are produced in many colours. Even TERAZZO TILES are widely used.
- PVC and vinyl-asbestos tiles

  are light and obtainable in plenty of different colours. The screed is coated with a primer and tiles stuck with adhesive. Care must be taken not to lay on too thick a coating of abhesive, because this may ooze through the joints in hot climates and look unsightly. As they are grease- and oil - proof, thermoplastic tiles are used in factories, hotels, kitchens and garages.
- Marble mosaic floors can be laid in many patterns: Pieces of marble of varying colours, about 25 mm square, are pushed into a soft screed of mortar to create the pattern. This is very highly skilled work. The mosaics can be also sticked to sheets of stiff paper on which the pattern has been drawn. The sheets are cut up, numbered and pressed - TILES DOWNWARDS - into the soft screed. When set, the paper is soaked off and the joints are filled with grout.

SHEET FLOOR FINISHES

7.53 Sheet Floor finishes

- Linoleum
- Cork and
- Rubber are satisfactory coverings.
- Plastic floor coverings are now also widely used. PVC flooring takes several forms: it can be supplied in rolls of about 2o m length and a width between 9oo and 18oo mm wide. It is stuck down with a proprietary adhesive.

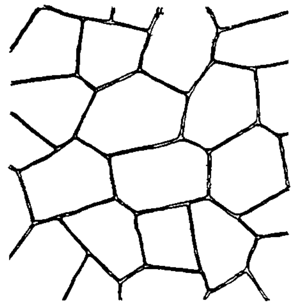
WOOD FLOOR FINISHES

7.54 <u>Wood floor finishes</u>

- Boarded floor finishes, tounged and grooved flooring boards, 2,5 mm thick and 5 cm to 15 cm wide are nailed on wood bearers.
- Wood-blocks (common measurements are 23x7,6x2,5cm) are laid in numerous patterns and are stuck on to a dry screeded floor with pitch mastic.
- Wood-mosaic consists of strips of hardwood (120 x 2,5 x 10.o cm) arranged in 12 cm squares to form a basket-weave pattern. They are laid similar to wood-blocks, and finished with a sanding maschine.
- Wood pavement is a very durable wood floor finish. The cross-cut end of small wood blocks (6x6x6 cm, 8x8x6, 8x25x6 cm) are exposed to the floor surface and laid in soft asphalt or stuck on to a dry, screeded floor with pitcemastic. For decoration even round sections of wood blocks (up to a diameter of a about 30 cm) are used, the joints are grounted and the surface sanded and polished.

1 NATURAL STONE SLABes -irregular

2 NATURAL STONE SLABes -roman bond



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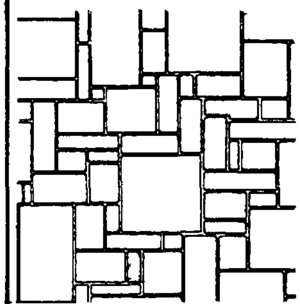
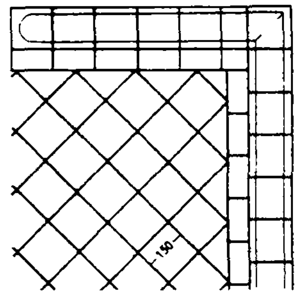


2

3 ARTIFICIAL STONE SLABes with gutter and frieze

4 QUARRY or VITREOUS TILEs hexagonal; with frieze



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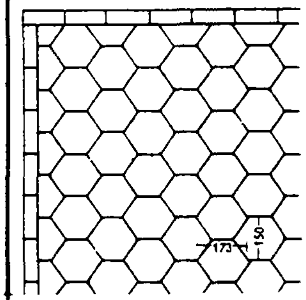

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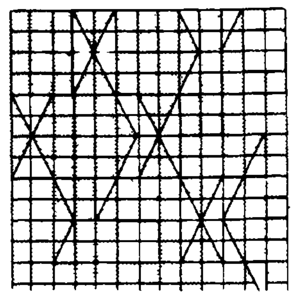
5 PVC, FLOORFLEX, LINOLEUM TILES

6 WOOD-PAVEMENT



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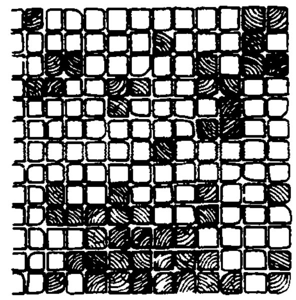
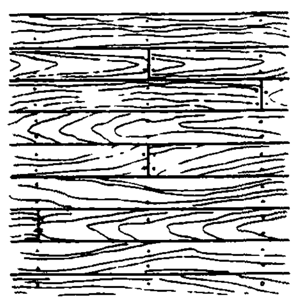


6

7 BOARDED FLOOR FINISH -tounged &. grooved

8 WOOD-BLOCKS



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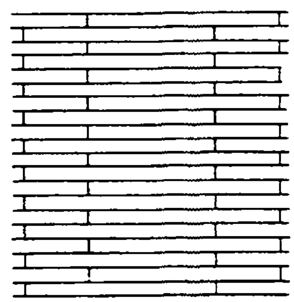

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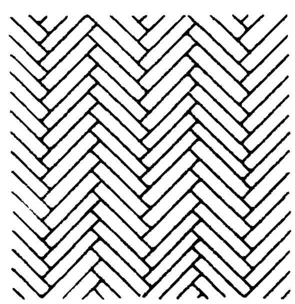
9 &.10 WOOD-MOSAIC



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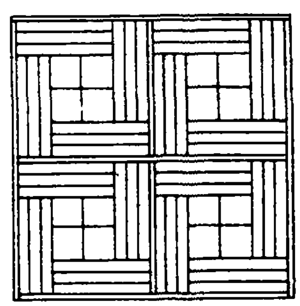

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7. FLOORS compiled: D.VOLKE OCT. '80	FLOOR FINISHES	BUILDING CONSTR. LECTURE CET 2031/1 7.5 27

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●REPETITION●exercises●●REPETITION●

Try to answer the following questions and practice sketching where ever necessary and possible.

1) Local Bylaws

Local Bylaws demand a certain capability of carrying load according to its destination.

a) Which minimum load a domestic floor is required to carry?

b) Which minimum load an industrial floor is required to carry?

2) Solid Ground Floors

Give explanations (if necessary by sketching) on solid ground floors, particularly on

a) Site Concrete: - thickness of concr. layers
- mixtures

b) Hardcore: - material, which can be used
- thickness of hardcore bed
- blinding

c) Waterproof Membran / DPC

3) Suspended Timber Ground Floors

a) What are the construction members of susp. timber ground floors?

b) How to protect susp. timber floors against droughts and dry rot?

c) Draw a sketch of an air brick

d) Show in a sketch the minimum dimensions required under B.R.C.4.

e) Draw the layouts of suspended timber floors with
- joists, parallel to a fireplace
- joists, at right angles to a fireplace

f) Discuss advantages and disadvantages of suspended timber ground floors.

4) Upper Floors

a) What are the main differences between Ground Floors and Upper Floors?

b) Sketch and explain the structure of an Upper Floor

c) List different types of Upper Floors

d) Explain the term (if necessary by sketching):
- Common Joist
- Trimming Joist
- Trimmer
- Trimmed Joist

e) Give explanations on "The Spacing of Joists":
   - Commonly used distances between joists
   - Maximum economical span
   - Use of "Double Floor Construction".

f) Sketch different "Strutting Arrangements", such as:
   - Herringbone strutting
   - Solid strutting : in line
   - Solid strutting : staggered

g) Explain three different ways of defining the Size of Floor Joists

h) Sketch and explain different methods of End Support of Floor Joists, such as:
   Built into or
   Supported against loadbearing walls

i) List different sorts of Floor Trimming Joints

j) Write notes on "Monolithic Reinforced Concrete Upper Floors" and describe:
   - Thickness
   - Reinforcement
   - Formwork
   - Advantages and Disadvantages

   if necessary by sketching

k) List and explain different types of "Precast Concrete Upper Floors"

l) Describe (if necessary by sketching) "Hollowblock and Waffle Floors"

6) Floor Finishes:

a) Explain the following terms:
   - Jointless Floor Finish
   - Cement/Sand Screed
   - Monolithic Construction
   - Seperate Construction
   - Unbonded Construction
   - Floating Construction
   - Granolithic Floor Finishes
   - Terrazzo

Use sketches!

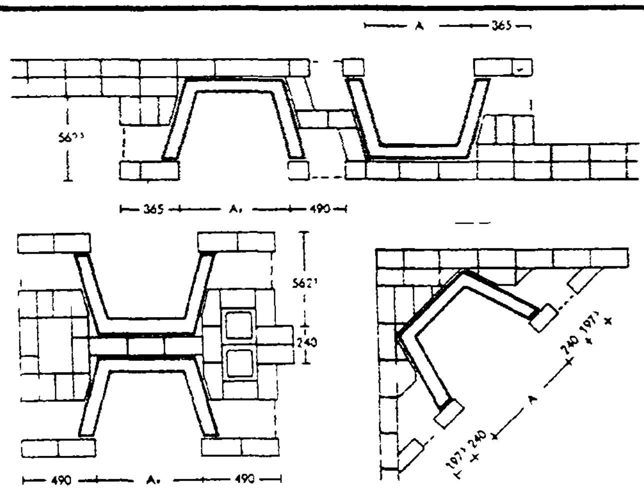
b) Give mix - designes

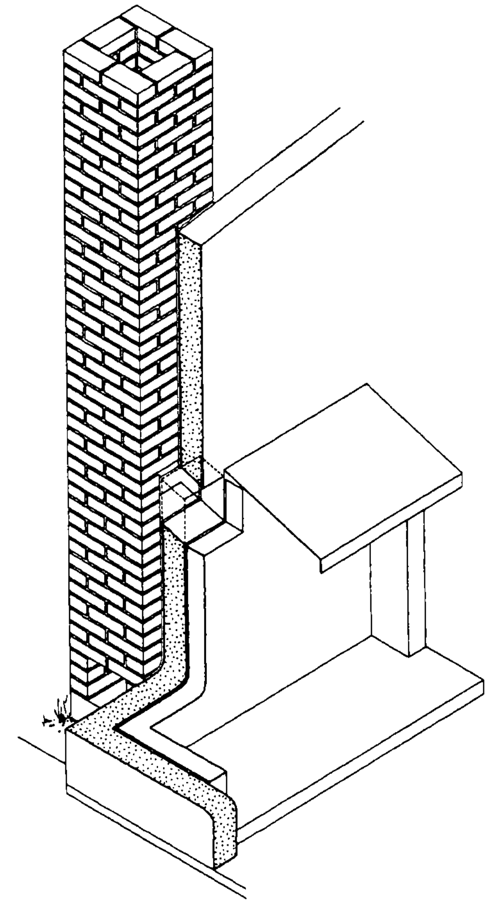
c) Explain different types of "Slab Floor Finishes"

d) List different types of "Sheet Floor Finishes"

e) Write notes on different types of "Wood Floor Finishes"

8.OPEN FIREPLACES, CHIMNEYS & FLUES





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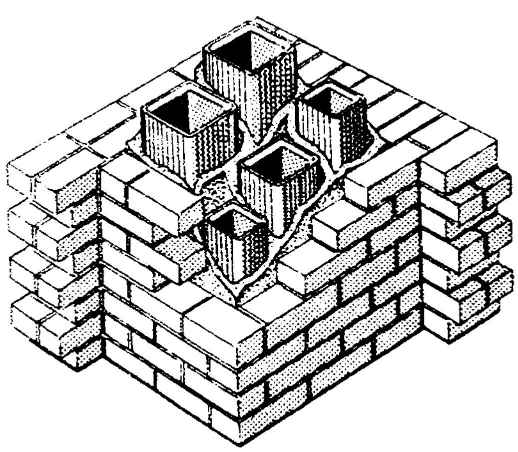

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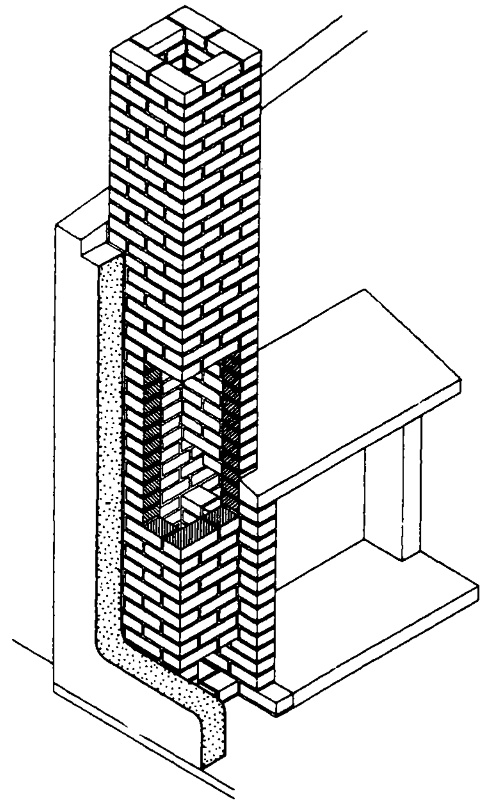
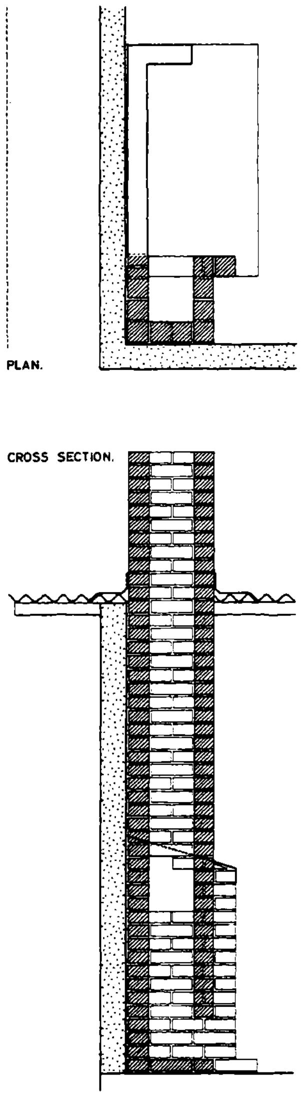
   Alexander Koch GmbH

8. FIREPLACES, CHIMNEYS & FLUES

8. FIREPLACES, CHIMNEYS and FLUES.
   - In Tanzania the open fire, burning solid fuel, is still widely used in houses as a means of space heating or for heating water for domestic purposes.





- A FIREPLACE is a space in a wall (or formed in a free-standing position) to accomodate an open fire from which the smoke and gases pass to the open air through a duct or FLUE.
- The structure enclosing a flue (or flues) is called a CHIMNEY.
- Where this rises above the roof it is called a CHIMNEY STACK.
- A projecting part of a wall which a fireplace and flues are constructed is called a CHIMNEY BREAST.
- A tall, freestanding chimney (usually required for large heating plants) is called a CHIMNEY SHAFT.

FUNCTION of FIREPLACES and FLUES

8.1 Function of Fireplaces and Flues

- The function of a fireplace is to burn fuel efficiently and safely, and to transfer the effectively the heat generated into the room.

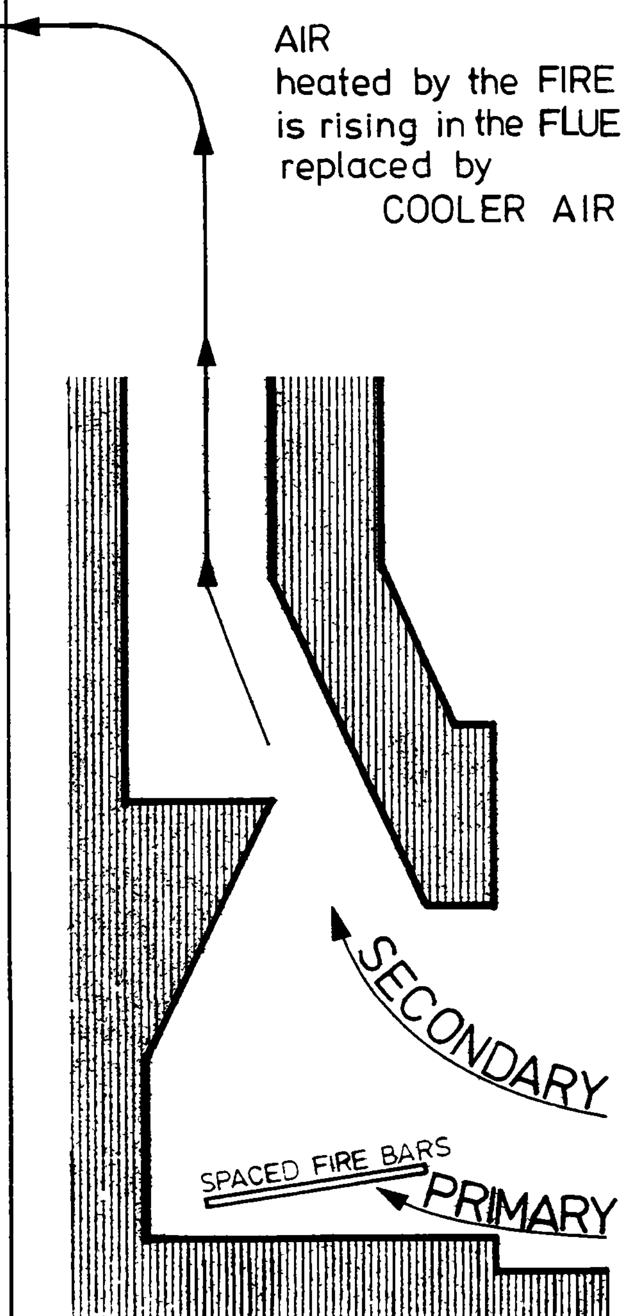
- An adequate supply of air is necessary for the efficient combustion of any fuel. The domestic fire, burning charcoal or timber, relies for its air supply on an upward air movement which is caused by cooler air flowing through and over the fire bed to replace a volume of heated air rising in a flue.

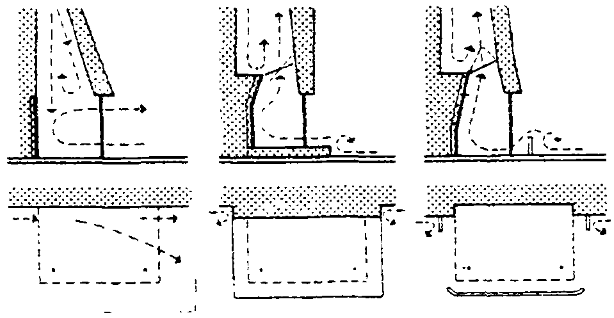
- This cooler air is made up by 2 components:
  . primary and
  . secondary (see fig.).
  The primary air supply is that air which feeds the fire bed and contains the oxygen nessary for combustion.

  The secondary air supply is that required to cause the column of air heated by the fire to rise up the flue carrying away with it the products of combustion.

- An efficient flue promotes this upward air movement, or 'DRAUGHT', and a suitably designed fireplace establishes a proper balance between the primary and secondary supplies so that efficient combustion may occur.

- Since the secondary air must be supplied to the fire via the room, which it enters through crack, windows doors or controlled vents, a measure of air change or ventilation results.





AIRMOVEMENT and AIRSUPPLY along FLOORS and WALLS to be interrupted (SMOKE!)

- THEREFORE:
The primary function of the flue is to contain the rising warm air and gases above a fire in a manner which will promote a natural upward flow of air (the power of which will depend on the difference in weight between the column of light, warmed air in the flue and a similar column of cool heavier external air.
The secondary function is to ventilate the room in which the fire is situated.

- In order that fireplaces and flues shall satisfactorily fulfil these functions a chimney and chimney breast (which are also structural parts of the building) must satisfy certain requirements such as:

REQUIREMENTS:

. WEATHER RESISTANCE
The prevention of wind and rain penetration is of particular importance because of the adverse affect on the function of the flue caused by the cooling of the flue gases.
Special care must be taken to prevent damp penetration at the point where a stack passes through a roof and flashings and damp-proof coarses are required at the junctions of the two.

The top part of the stack must also be protected to prevent saturation of the chimney.

WEATHER RESISTANCE

THERMAL INSULATION

. THERMAL INSULATION
Adequate thermal insulation must be provided to the flue by the chimney in order:

1. to avoid the cooling of the flue gases and the cousequent slowing down of the upward air flow or draught;
2. to prevent condensation of flue gases on the walls of the flue which (particularly with slow burning appliances) can cause considerable damage to the chimney.

FIRE RESISTANCE

. FIRE RESISTANCE
The construction of a fireplace and its chimney must be such that combustible materials within and outside the building cannot be ignited by the fire or hot flue gases.

THEREFORE:

Therefore an adequate thickness of noncombustible material around flues and fireplaces must be provided and all combustible materials to be kept away a sufficiant distance from a flue or a fireplace.

- Fireplaces must have a bottom or hearth of noncombustible material and extent on or above which the fire bed will rest.

- The outside surface of a chimney should not become hot enough to iquite timber or other combustible material which may be near it. A temperature of 65°C is considered to be a safe maximum(This is achieved by the use of e.g.100 mm c brickwork or concrete).

- The outlet of a flue should be well above the roof in order to avoid danger from sparks (outside the zones of wind pressure).
  Building regulations lay down require ments concerning heights of stacks, thickness of materials and proximity of combustible materials to flues and fireplaces.

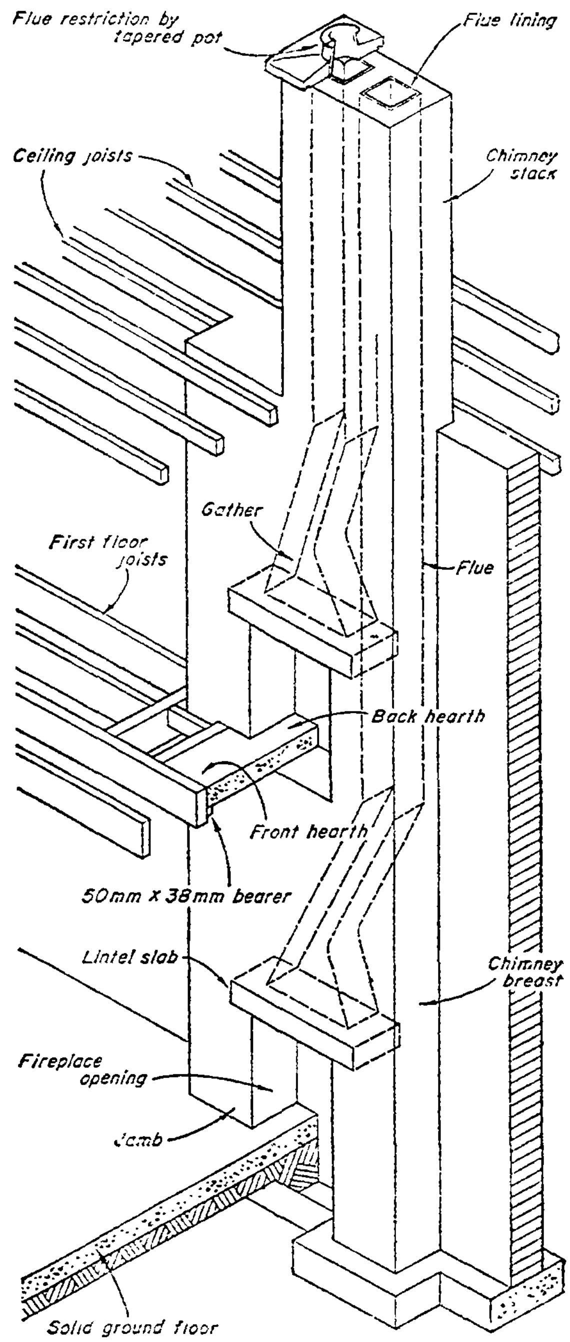
PRINCIPLES OF FIREPLACE DESIGN

8.2. PRINCIPLES OF FIREPLACE DESIGN.

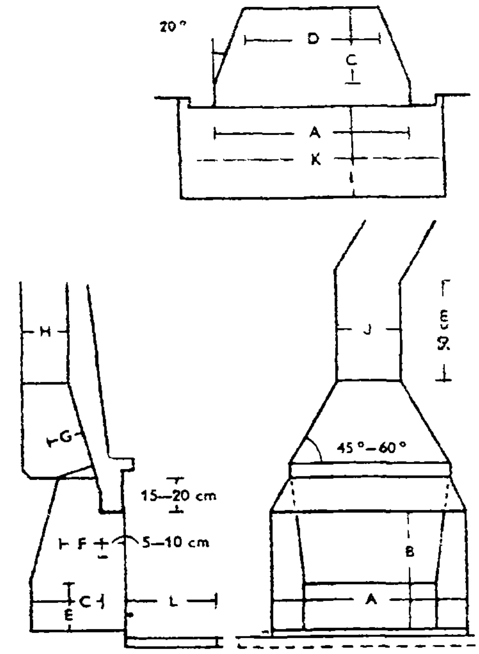
- The shape of the fireplace must be desingned to allow an adequate but not excessive supply of <u>primary air</u> to the fire bed and <u>secondary air</u> to the flue.

- To contain the fire safely and to transfer the heat generated into the room, the fireplace must be constructed of suitable materials, having high fire resistance but capable of storing and radiating heat.

- The fireplace consists basically of a rectangular recess - or FIREPLACE OPENING - of suitable height with means of supporting the chimney breast above and some means of reducing the width of the opening to that of its flue.
  The back and sides of the opening are formed of material capable of radiating heat and the base of the opening must be of fire-resisting material extending beyond the opening at front and sides.
  A SURROUND around the opening is often incorporated for aesthetic reasons or to increase the effective depth of the fireplace.



DIMENSIONING TABLE for OPEN FIREPLACES



TYPE of ROOM	ROOM SIZE		FIREOPENING			DEPTH	FIREBACK		THROAT		CHIMNEY			SURROUND	
			width	height	area		width	vert. part						width	leng
	m²	m³	cm	cm	cm²	cm	cm	cm	cm	cm	cm	cm	cm²	cm	cm
—	—	—	A	B	—	C	D	E	F	G	H	J	—	K	L
small rooms	16–22	40–60	60 65	50 55	3 000 3 580	34 35	36 40	25 25	20 20	12 12	20 20	20 20	400 400	100 105	50 50
medium rooms	22–30	60–90	70 75 80	58 60 63	4 060 4 500 5 040	36 37 38	44 49 53	25 25 28	20 20 20	12 12 12	20 20 20	20 20 26	400 400 520	110 115 120	50 50 50
larger rooms	30–40	90–120	85 90 95	66 68 71	5 610 6 120 6 750	38 40 40	58 62 66	28 28 30	20 20 20	12 12 12	20 20 26	26 26 26	520 520 676	125 130 135	50 50 50
large rooms	40–50	120–180	100 105 110	74 76 78	7 400 7 980 8 580	42 42 45	70 74 78	30 30 30	20 20 25	12 12 12	26 26 26	26 26 38,5	676 676 1 000	140 145 150	50 50 50
small halls	50–70	180–250	115 120 125	82 84 87	9 430 10 080 10 880	45 48 48	82 85 89	32 32 32	25 25 25	15 15 15	26 26 26	38,5 38,5 38,5	1 000 1 000 1 000	155 160 165	50 50 50
medium halls	70–90	250–350	130 135	90 92	11 700 12 420	51 53	93 97	32 32	25 25	15 15	26 26	38,5 38,5	1 000 1 000	170 175	50 50
large halls	üb. 90	üb. 350	140 145 150	95 97 100	13 300 14 070 15 000	54 55 58	100 105 109	35 35 35	25 25 25	15 15 15	38,5 38,5 38,5	38,5 38,5 38,5	1 480 1 480 1 480	180 185 190	50 50 50

TRADITIONAL OPEN FIREPLACE

8.2.1 TRADITIONAL OPEN FIREPLACE

- Originally fuel was burnt in a simple rectangular recess, but during the course of time scientific principles have been formulated to improve efficiency and reduce smokiness. These principles still remain basically sound and involve:

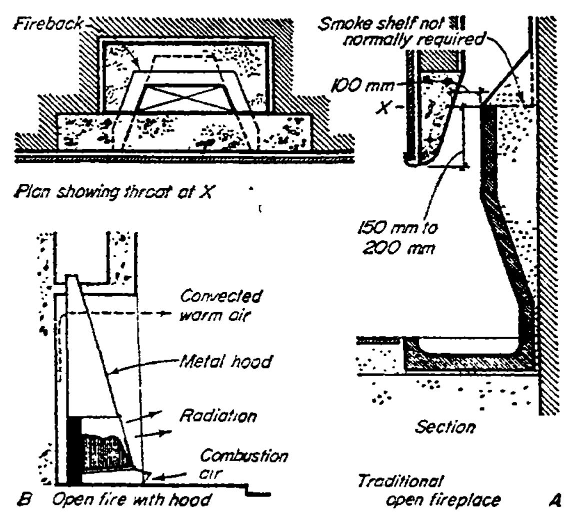
1\.
The correct design of the junction of fireplace and flue, called the THROAT. This should be 100 mm wide, 200 mm to 250 mm long and 150 mm to 200 mm deep, situated perpendicularly over the fire. The entrance to the throat should be rounded.

2\.
Splayed sides to the fireplace on plan to obviate eddies of smoke entering the room (This occurs with fireplaces having the back and the front of the opening equal in width.

3\.
Sufficient depth from the face of the chimney breast to the back of the fireplace to prevent smoking when a draught crosses the opening

4\.
The fireback sloping foreward to direct radiant heat into the room and raise the temperature of the fire, thus assisting combustion.

5\.
A smokeshelf level with the top of the throat although research has slown that this can be eleminated if all other features are properly designed and incorporated.



Traditional open fireplace

8. FIRE PLACES	FIREPLACE DESIGN	BUILDING CONSTR.
compiled: D·VOLKE		—— LECTURE ——
FEB 82		CET 4031 / 18.2 o7

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CIVIL ENGINEER. DEPARTMENT

The free arrangement of a fireplace in a room causes often several openings on 1, 2, or 3 sites of the OPEN FIREPLACE.

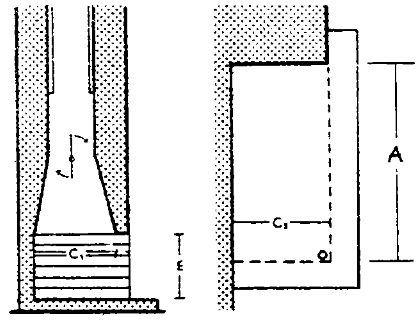
Dimensions of such fireplaces differ from comon ones with only one opening.

FOR DIMENSIONING REFER TO THE TABLE BELOW

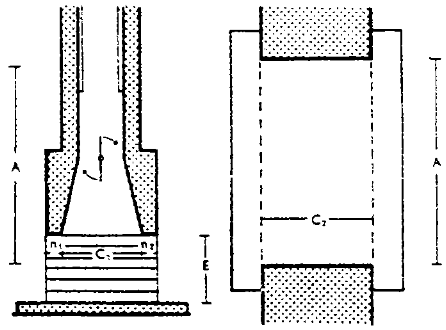
- Such fireplaces, however, remain uncontrolled and tend to consume large amount of fuel whilst promoting too large an air change. Control of the secondary air supply can be effected by a hood placed above the fire bed, in which case some heat transfer occurs by way of air circulating round the hot metal forming the hood, or preferably by an adjustable metal throat restrictor.
- When a stool grate to hold the fuel is used some control of the primary air supply to the fire can be effected by selecting a design with a solid front incorporating a variable inlet opening.

DIMESIONING —— TABLE

	C_1	C_2	Schornsteinquerschnitt
1	2/3 E—10 cm	C_1+n	1/12 E (A+C₂)
2	5/6 E—20 cm	$C_1+n_1+n_2$	1/12 E 2A
3	2/2 E—10 cm	C_1+n	1/12 E (A+2C₂)
4	5/6 E—20 cm	C_1+2n	1/12 E (2A+C₂)
5	⌀ min 81 5cm	C_1+2n	1/12 E 3 14 (C +20 cm)



1



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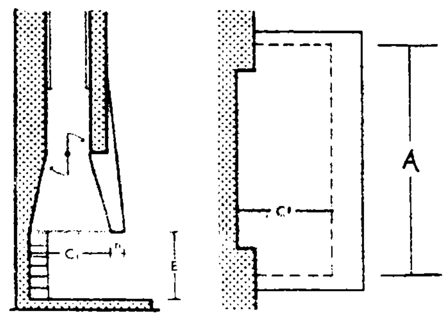

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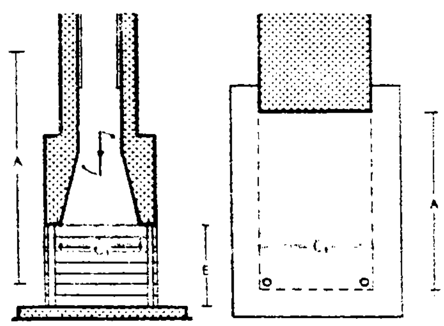

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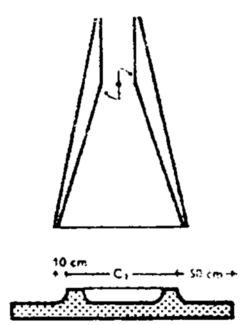


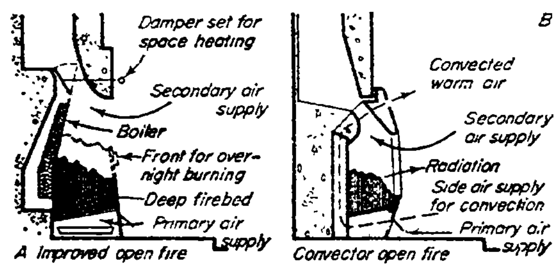
5

8 FIRE PLACES compiled: D·VOLKE FEB '82	FIREPLACE DESIGN	BUILDING CONSTR. —LECTURE— CET 4031/18.2o8
TCA TECHNICAL COLLEGE ARUSHA CHUO CHA UFUNDI ARUSHA	CIVIL ENGINEER. DEPARTMENT	8

IMPROVED SOLID FUEL APPLIANCES ●

8.22 IMPROVED SOLID FUEL APPLIANCES

- Normal open fires will burn a wide range of fuels including wood, charcoal, coal and peat but they are unsuitable for burning smokeless fuels such as coke and anthracite and they will not burn throughout the night.
- The improved appliances incorporate suitably spaced fire bars and provide increased vertical depth in the fire bed which permits smokeless fuels to be burnt.
- Often BACKBOILERS are incorporated which provide hot water for domestic use or may heat a limited number of radiators situated near the fire. A removable front anables an extra deep firebed to be laid for overnight burning.
- Some improved open fires incorporate a heat exchanger which provides heat by convection in addition to the radiant heat of the fire. They operate by passing air through a convection chamber round a metal fire container and returning the warmed air to the room in which the appliance is situated. These are called CONVECTOR FIRES and may be fitted with back boilers.



Improved solid fuel appliances

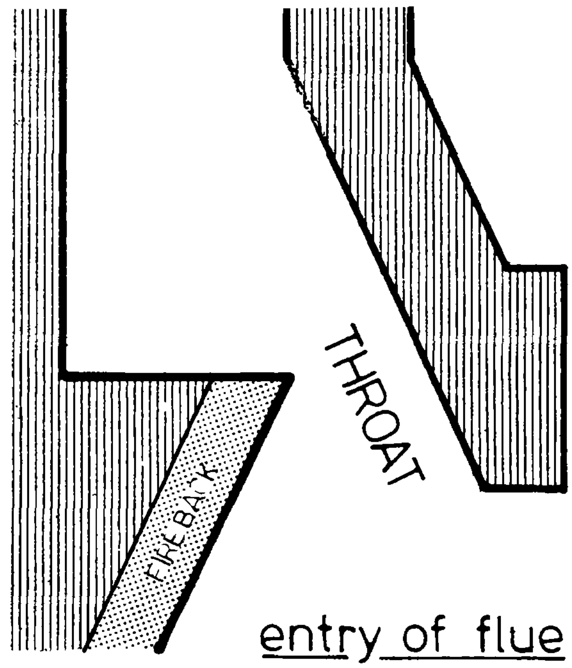
8.3. PRINCIPLES OF FLUE DESIGN

PRINCIPLES OF FLUE DESIGN

To ensure the proper function of a flue the following factors must be considered in its design:

1. SIZE and SHAPE

- Flues to domestic fires should be not less than 3,65m high measured vertically from the outlet of the appliance or fireplace to the top of the flue terminal in order to ensure an adequate difference in weight between the internal flue gases and the external air.
- The entry to the flue should be restricted to increase the inicial velocity of the gases and a further restriction at the flue terminal is desirable to increase the velocity at the outlet (This reduces the danger of down droughts.
- The cross-sectional area of a flue should be not less than 175 mm diameter. The normal 225 x 225 mm brick flue measures about 190 x 190 mm when lined. (For minimum sizes for various appliances refer to table).
- Where rectangular flues are used the longest side should not be more than one- and half times the shorter.
- Flues should be as straight as possible, any bends being near the top rather than just above the fireplace. Unavoidable bends should be at an angle of not less than 45 degrees and preferably not less than 60 degrees to the horizontal.



entry of flue

Appliance	114 mm internal diameter	150 mm internal diameter	225 mm × 225 mm or 175 mm to 200 mm internal diameter
Open and closeable fires, openable heaters, cookers	Heat storage cookers only, burning smokeless fuel	Smokeless fuels (up to 7325 W)	Bituminous fuels (minimum height of flue — 3 65 m)
Domestic boilers	Smokeless fuels (up to 7325 W). Maximum height 9·15m. Sweeping access every 3·0 m	Smokeless fuels (7325–14650 W). Sweeping access every 3·0 m	Bituminous fuels (all outputs). Smokeless fuels (14650–29300 W) — 200 mm diam. minimum

Notes
A closed heater should be provided with a flue of the same size as that of a boiler with the same rate of combustion.
Flues with bends making cleaning difficult should have a minimum diameter of 150 mm.
Smokeless fuels—include coke, anthracite, dry steam coal, coalite, etc.

Minimum flue sizes for solid fuel burning appliances

AIRTIGHTNESS

2. AIRTIGHTNESS

A flue must be airtight in order to maintain the strength of the draught at the fireplace and to prevent the escape of smoke. Air can enter through faulty jointing or faulty withes (controlled entry of air into the flue may however, be an advantage in certain circumstances).

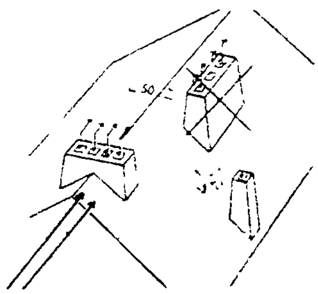
INSULATION

3. INSULATION

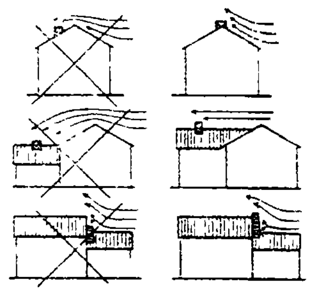
- Care must be taken to prevent the flue gases cooling, which might result in down draught and condensation. This precaution is particularly important where slow burning appliances are used.
- Flues should be constructed with 1/2 brick walls and liners. The use of brick thick walls in place of 1/2-brick thickness does not afford much increase in isulation value and has the disadvantage of offering more surface area to the atmosphere, with consequent cooling of the flue. It also has a high thermal capacity which requires a longer pre heating period before the flue is warm enough to encourage 'drought' action. The greater thickness may, however, be used for any external walls of flues to minimise damp penetration.
- Flues situated internally only need special consideration where they penetrate the roof and become exposed to the weather.
  Thickening of 1/2-brick flue walls to 1-brick thickness can be effected by corbelling out within the roof space, and perticular attention should be paid to the arrangement of the d.p.c. and flashings to the stack.

- A suitable capping should be provided to prevent saturation of the chimney. A projecting capping, in addition to throwing water clear of the chimney walls, helps to create a zone of low pressure at the flue outlet.

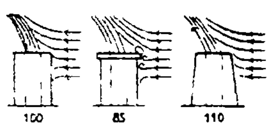
POSITION OF OUTLET



POSITION TO WINDDIRECTION AND RIDGE



EFFECT OF WIND TO THE DRAUGHT



FIGURES COMPARING THE EFFECTIVITY

INFLUENCE OF CHIMNEYHEAD AND AREA ON THE DRAUGHT

4. POSITION OF OUTLET

- For safety in terms of fire the outlet must be at least 1 m above the highest point of intersection of the chimney or flue pipe with the roof.
- The same distance above any adjacent opening light or ventilation opening which is not more than 2,50 m from the outlet, measured horizontally.
- When the chimney passes through the ridge of a pitched roof, or within 0,60 m of it, the outlet may be not less than o,60 m above the ridge.

These dimensions are exclusive of any chimney pot or other terminal.

- If the roof covering is of combustible material the outlet should be at least 1 m above the level of the ridge whatever the position of the stack.

These precautions do not, however, necessarily ensure the efficient functioning of a flue, the outlet of which must be positioned outside any potential zones of high wind pressure.
The positioning of a flue outlet in a potential suction zone will assist in the removal of the smoke and gases, but should occur in a high-pressure zone there is every likelihood of the gases being taken down the flue by air moving from this zone to an area of lower pressure within the room.

8.4 CONSTRUCTION OF FIREPLACES

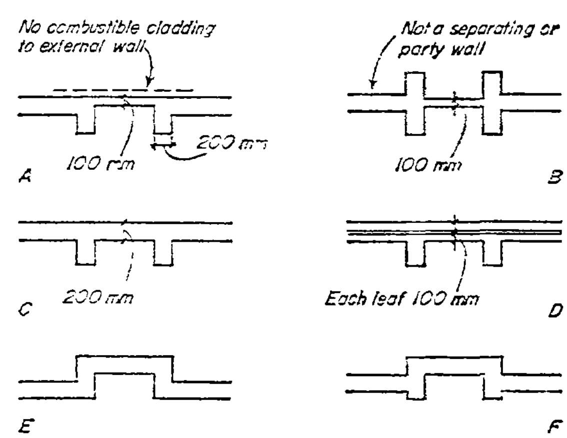
- The normal depth of the opening is 328 mm and the width 578 mm. This will take standard 406 mm and 457 mm wide fires. The height should be 585 mm to 600 mm from the finished hearth level to accommodate a standard 565 mm high fireback. If a projecting surround is to be incorporated this height should be increased to permit the proper formation of a throat.

Minimum thicknesses of material at sides and back of the opening are laid down in building regulations and are indicated in the figure. The jambs are required to be 200 mm thick. The back of the opening may be 100 mm thick when

1. It is set in an external wall and no combustible external cladding is attached behind it (A) or
2. it is common to two fireplaces set back-to back in a wall other than a party or separating wall (B)

In all other cases the back must be 200 mm of solid walling (C) or cavity walling with each leaf not less than 100 mm thick (D). (E) and (F) show alternative ways of setting the chimney breast in the wall of which it forms part.

Where a wide chimney breast is required for sake of appearance the jambs are made wider than 200 mm and where the jamb carries a flue as on an upper floor, a minimum width of 440mm is necessary.

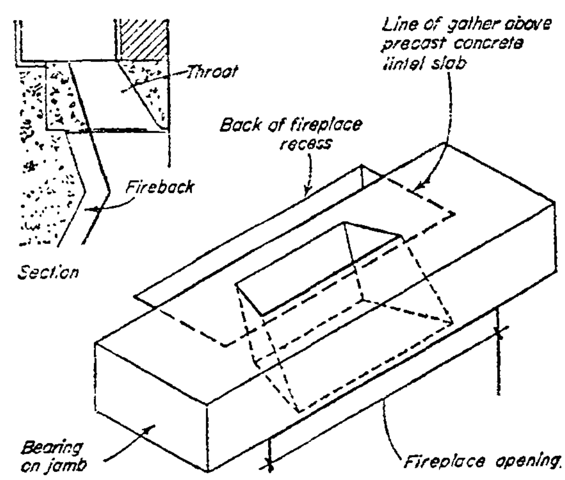


Thickness of material round fireplace openings

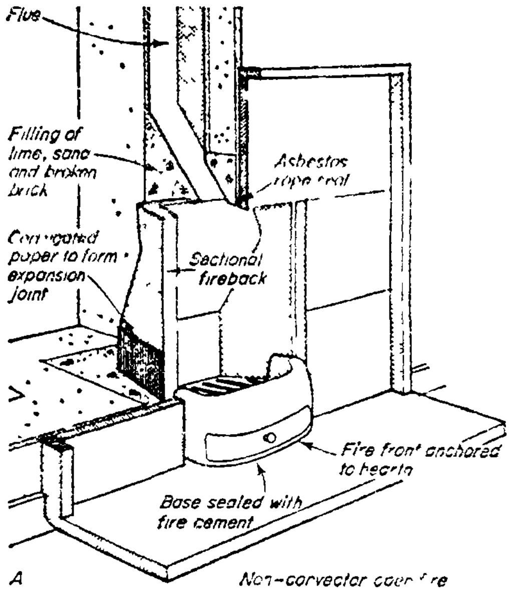
The traditional method of forming the head of the opening was by a segmental rough brick arch but the arch form presents some difficulty in forming a smooth narrow throat and a reinforced concrete lintel is preferable and is now normally used. Alternatively, a precast concrete lintel block or slab may be used in which the throat aperture is formed.

The junction between the relatively wide fireplace opening and the narrow flue is made by corbelling or 'gathering over' the brickwork or stone work of the chimney breast. The funnelshape produced is called the gather and provides a smooth flow from throat to flue.

The base of the fireplace opening is called the hearth. It is constructed of concrete and building regulations require a minimum thickness of 125 mm. The back hearth, within the recess, bears on the chimney breast. The front hearth must projekt at least 500 mm in front of the breast and 150mm beyond each side of the opening. The full 125 mm thickness of the front hearth must be taken into the recess.
In solid ground floors the floor slab itself forms the hearth of the fireplace. Timber ground floor construction requires the provision of a fender wall. This wall may be 102-5 mm thick, providing support to the floor joists, the space within being filled with hardcore which carries the concrete hearth or it may be 215 mm thick to provide also a bearing for the front and side edges of a reinforced concrete hearth, the back edge of which is supported on the breast.



Precast concrete lintel slab



8.41 NON-CONVECTOR OPEN FIRES

MODERN inset open fires or all-night burners comprise a grate with a front which is sealed into the fireplace opening and invorporates in its design some device for controlling the primary air supply such as a spin wheel or controllable flap. These grates are designed to fit British Standard fire backs which are made of firebrick or refractory concrete (aluminous cement and broken firebrick). The bend or knee at the back should be fairly high to permit the formation of a satisfactory throat (figure).

8.42 CONVECTOR OPEN FIRES

These are freestanding open fires in which the fire is contained in a metal enclosure surrounded by a second metal jacket to form an integral convection chamber. The flue penetrates the outer jacket. The junction of the front of the fire with the fireplace surround must be sealed with soft asbestos rope or string and the appliance must be screwed to the back hearth so that no movement takes place which might break the seal.

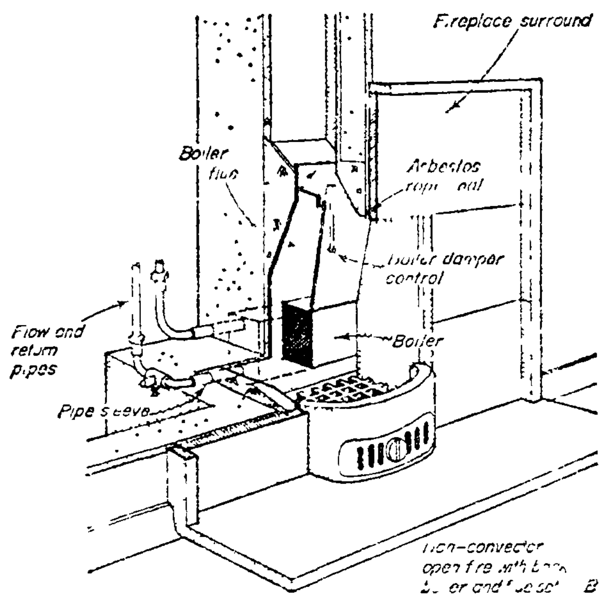
Back boilers

Non-Convector open fires with back boilers are cast iron units incorporating a water container, flue and damper which are installed in place of the normal fire back as shown in the figure. The same general methods of constructing the fireplace already described are used, but the height and depth of fireplace opening may need to be greater than for a normal open fire. Convector fires are also available with back boilers, the boiler being built into the appliances by the manufacturers. Flow and return pipes where they pass through the chimney breast, the gap between being caulked with asbestos string.

NON CONVECTOR OPEN FIRES

CONVECTOR OPEN FIRES

BACK BOILERS



CLEANING

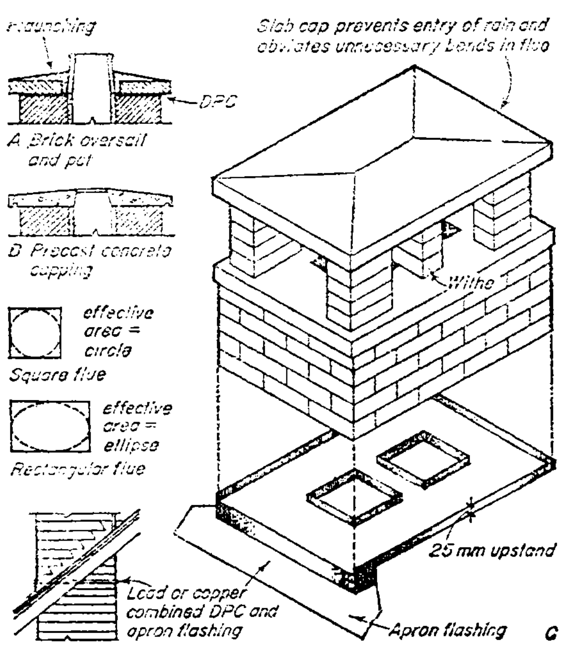
Chimney and flue cleaning

Most open fires are swept through the front. Where adjustable throat restrictors are installed, these are normally removable to allow cleaning brushes to be passed through the remaining opening.

CONSTRUCTION

OF CHIMNEYS

BRICK CHIMNEYS



Flues and chimney stacks

8.5 CONSTRUCTION OF CHIMNEYS

Brick chimneys

Domestic flues are mostly constructed in brickwork, with walls not less than 102-5 mm thick. Bends and slopes in the flue are formed by corbeling

The back of a flue in a party or separating wall, unless back to back with another flue, must be at least 200 mm thick, or be of cavity construction with each leaf not less than 100 mm thick, up to its intersection with the roof.

The chimney breast, immediately above the top ceiling is reduced in width to that required for the stack, allowing for at least 102-5 mm walls and withes, that is the walls between adjacent flues.

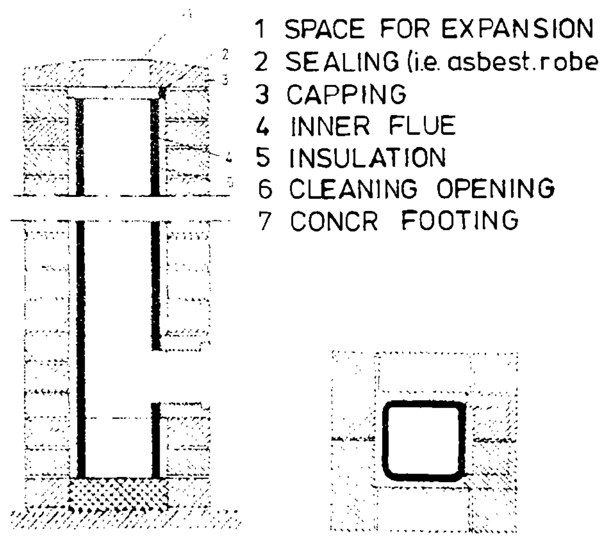
For safety in terms of stability the height of a stack, including any chimney pot or other terminal, above the highest point of intersection with the roof must not exceed six times the least horizontal dimension unless the stack is braced in some way or its stability under wind pressure is checked by calculation.

When a chimney breast or stack projects beyond the face of the wall below the total projection of the oversailing brickwork must not exceed the thickness of the wall below with a maximum projection of 50 mm in each course.

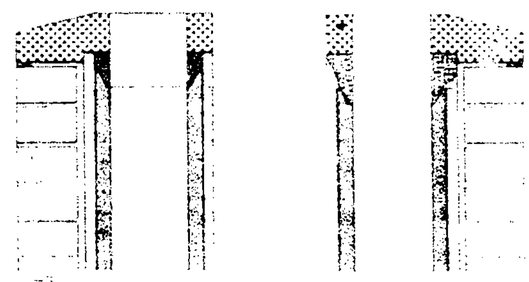
The top of a flue is usually terminated by a cylindrical fire-clay pot. Tapering pots provide the slight restriction at the flue outlet to increase the velocity of the rising flue gases. The pot is bedded in one or two courses of brickwork, or other type of capping, and the top of the stack round the pot is flaunched, that is weathered with mortar, to throw off water.

The use of a perforated and weathered stone or precast concrete cap (B) as a terminal has the advantage of dispensing with the need for flaunching which after a time, even with a cement-lime mortar, may crack and permit the penetration of rain.

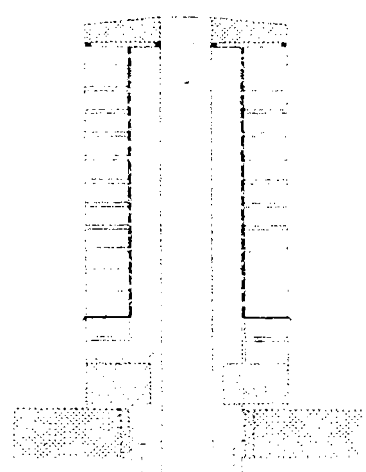
Any withes should be carried up to the underside of the top slab.
The top twelve courses of a stack should be laid in cement or cement-lime mortar of a strength not less than 1:1:6.
In order to ensure a smooth surface to the flue and to seal possible cracks in the brick joints the flue is parged or lined. Parging is the internal rendering of the flue with a weak cement-lime mortar,1:3:12, mix, not less than 13 mm thick, applied as the stack is built up. Flue liners, as well as ensuring a smooth airtight flue of uniform section, permit added insulation to be provided.
The Building Regulations, 1976, require flues for solid fuel and oil-burning appliances to be lined with rebated or socketed liners and make no provision for parging.
Liners may be made of fireclay, terra-cotta or acid - resisting concrete or they may be in the form of cast iron or vinyl-coated asbestos cement pipes (untreated asbestos cement is liable to disintegrate if heavy condensation accurs)(A,B)



CHIMNEY with PRECAST INNER FORM FLUE

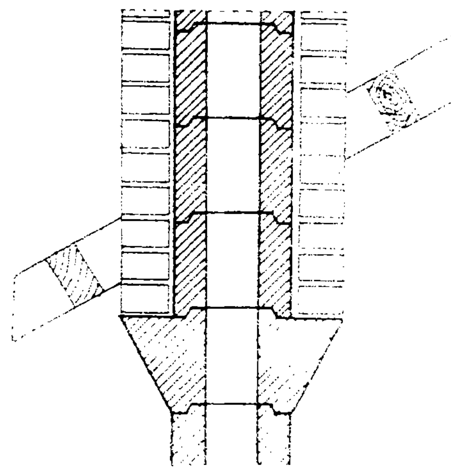


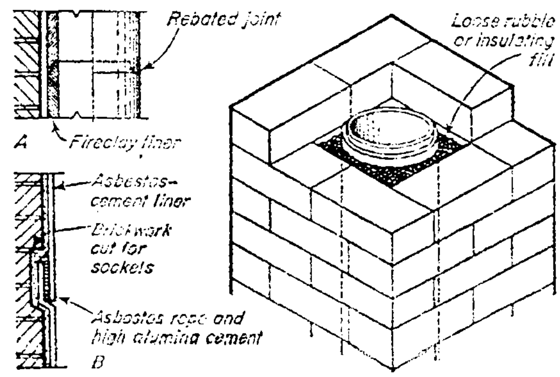
'PLEWA' 'BORA'
CHIMNEYHEAD with INNER FORM DUCT



PRECAST CHIMNEYSTACK

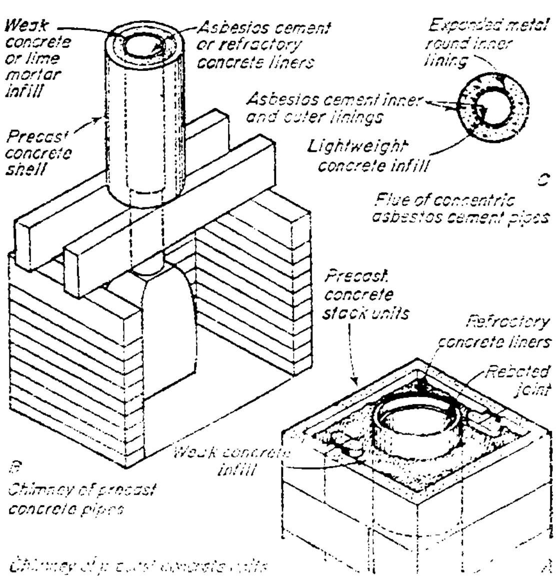
Where pipes are used the sockets should be uppermost and the joints made with asbestos rope and high alumina cement as shown in the figure.
The rope allows expansion and the cement is acid resistant.
The space between the lining and the chimney is usually filled with loose rubble flushed up with concrete or with an insulating material such as light weight concrete (C).
Alternatively, the space may be left unfilled but sealed at top and bottom to provide an insulating barrier of still air.
The gathering over of the flue above the fireplace opening, referred to under Fireplace construction, should be steep, not flat, with the entry to the flue itself, that is the top of the 'funnel' more ore less central with the fireplace unless the flue has to pass to one side in order to clear an upper fireplace. A 'dog-leg' bend once always formed in the gather is no longer considered essential.





Flue linings

STONE CHIMNEYS



Chimney construction

Stone chimneys

The temperatures encountered in a domestic flue are not likely to damage a good building stone, except in the immediate vicinity of the fire and in this position sandstone should be used or protection given by firebricks. The flue walls should be at least 215mm thick and if the stone is bakked with brick or concrete this should be maintained as the minimum overall thickness.
Coursed masonry may be corbelled out to a total projection not exceeding the thickness of the wall below. Each course may project a distance equal to half the thickness of the wall below it, provided the corbel stone is bonded into the wall a distance equal to twice its projection. Stone chimneys must be protected by liners.

Concrete chimneys

Concrete chimneys can be constructed in three ways:
1 With in situ concrete
2 With precast concrete units
3 By a combination of 1 + 2

Concrete for in situ work may be either plain or reinforced and where in contact with the flue gases should be of an acid-resisting refractory type. Lightweight concrete made with foamed slag or expanded clay aggregates, or no fines concrete, can also be used, provided protection is given by flue liners. The mix for dense concrete should not be too rich in order to reduce shrinkage and to resist the effects of heat satisfactorily crushed brick, slag, clinker or crushed limestone should be used as aggregate.

The concrete should be at least 100 mm thick and unless increased to at least 150 mm where penetrating the roof should be rendered to provide adequate protection against damp penetration.

Up to a height of seven times its least horizontal dimension the effect of wind pressure on a plain, dense concrete chimney need not be considered. Oversailing projections should form an angle of not less than 60 degrees with the horizontal unless the projection is reinforced. The height of in situ lightweight or no-fines concrete chimneys should be limited to four times their least horizontal dimension and all oversailing or projecting parts should be formed with dense concrete, reinforced as necessary. The open-textured internal surface of such chimneys should always be lined and the external surfaces should be rendered. With cast in situ chimneys of all types liners are invariably used as they form permanent shuttering.

Dampproof courses are not generally required if the outside is rendered and there are flue liners.
A veriety of precast units of dense or lightweight concrete are available for forming chimneys. There are two approaches to the construction of chimneys in this form:
One by precast blocks bonded to form the walls and the withes of the chimney as normal masonry,
another by forming the internal and external surfaces of the chimney with precast units and filling the intervening cavity with lightweight concrete.

Dense vibrated concrete blocks will generally withstand damp penetration without rendering the external surfaces, and such constructions automatically provide a sufficiently smooth surface to the flue.

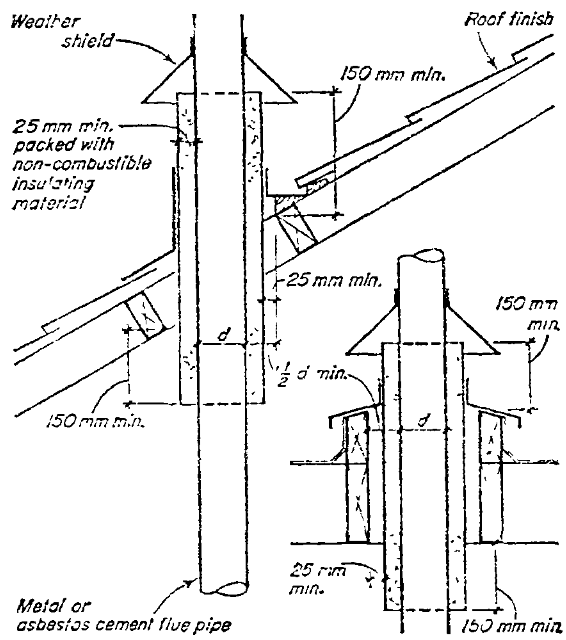
As with in situ cas flues of lightweight concrete flue liners are exxential with lightweight blocks, and these are incorporated in the manufacture.

METAL and ASBESTOS CEMENT FLUEs

Metal and asbestos cement flues
These materials have poor thermal insulation value and are not really suitable for external use unless insulated. They should generally be used only for flues within the room containing the appliance. Metal flues can be made of steel or cast iron. Asbestos cement flues are of heavy quality pipes. The pipes should be frequently supported, usually at every joint or at intervals not exceeding sixteen times the internal diameter.
The joints should be airtight and allowance should be made for the expansion and contraction of the pipes at the joints and at the supports.
Asbestos cement flues are not recommended for open fires or appliances using bituminous coal nor in situations where the internal flue temperature is likely to exceed 260°C since the material cracks when exposed to high temperatures or to flames impinging on its sureface. They must, therefore, be protected form flames by using a 1.8 m length of metal flue immediately above the fire.

Greater strength and insulation can be achieved by using asbestos cement pipes concentrically and filling the intervening cavity with lightweight insulating filling.

All combustible material in a roof or external wall through which the pipe passes must



Metal and asbestos cement flues

1. be kept a minimum distance of three times its external diameter away from the pipe,

or

2. be separated from the pipe by 200 mm of solid non-combustible material (300 mm if the combustible material is in an external wall above the pipe) or

3. the pipe must be enclosed with a sleeve of metal or asbestos cement. Such pipes must pass into a normal chimney within the same room or directly through an external wall or a roof structure, but not through a roof space, floor or internal wall.

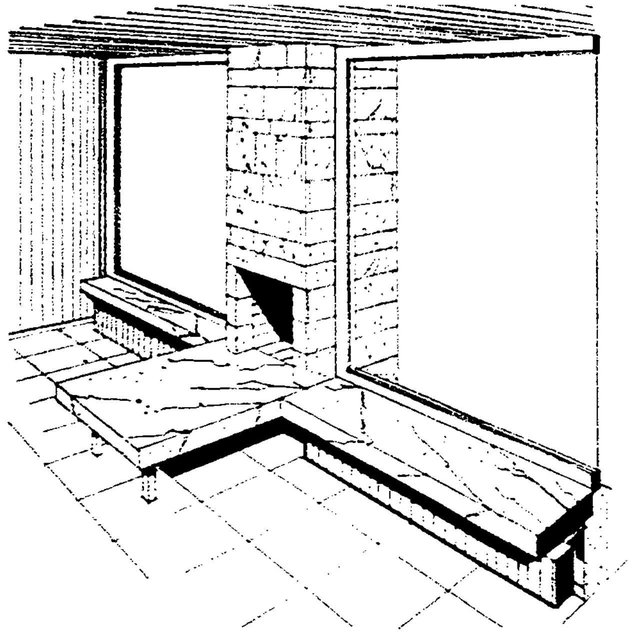
•REPETITION••exercises•REPETITION•••

Try to answer the following questions and practice sketching wherever necessary and possible:

1. Define briefly the term "FIREPLACE"
2. Name the structural members of a CHIMNEY
3. Describe briefly the function of Fireplaces and flues
4. Explain by means of sketches the PRIMARY and the SECONDARY AIR SUPPLY in a Fireplace and describe the differences.
5. A chimney and chimney breast must satisfy certain requirements, such as:
   - Weather Resistence
   - Thermal Installation and
   - Fire Resistance

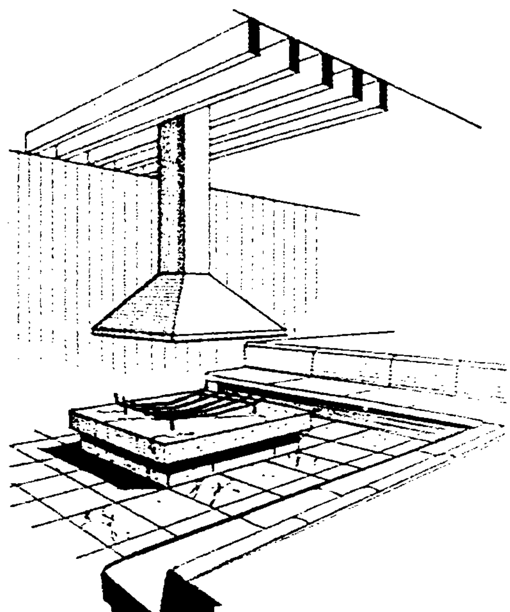
   Write notes on the above listed requirements.
6. Describe the principles of a traditional OPEN FIREPLACE and use sketches for illustration.
7. What are the characteristics of IMPROVED SOLID FUEL APPLIANCES? (use sketches for illustration)
8. Designing a flue properly the following factors must be considered.
   a Size and Shape
   b Airtightness
   c Insulation
   d Position of outlet

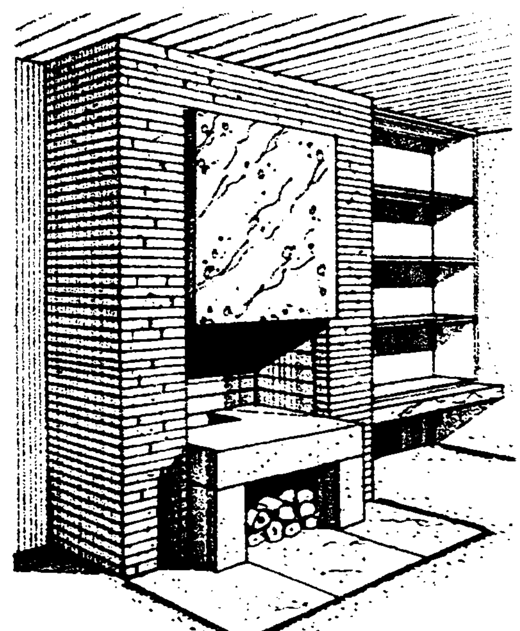
   Write notes on the above listed factors.
9. Draw a sketch, indicating depth, width and height of the opening of an open fireplace as well as the thickness of material at sides and back of the opening.
10. What is the traditional method of forming the head of the opening of a fire place?
11. What is an alternative to the traditional method?
12. Describe briefly (by using sketches for illustration)
    a How the junction between the fire place - opening and the flue is made (or HEARTH)
    b How the base (or HEARTH) of the fireplace opening is ctructed?

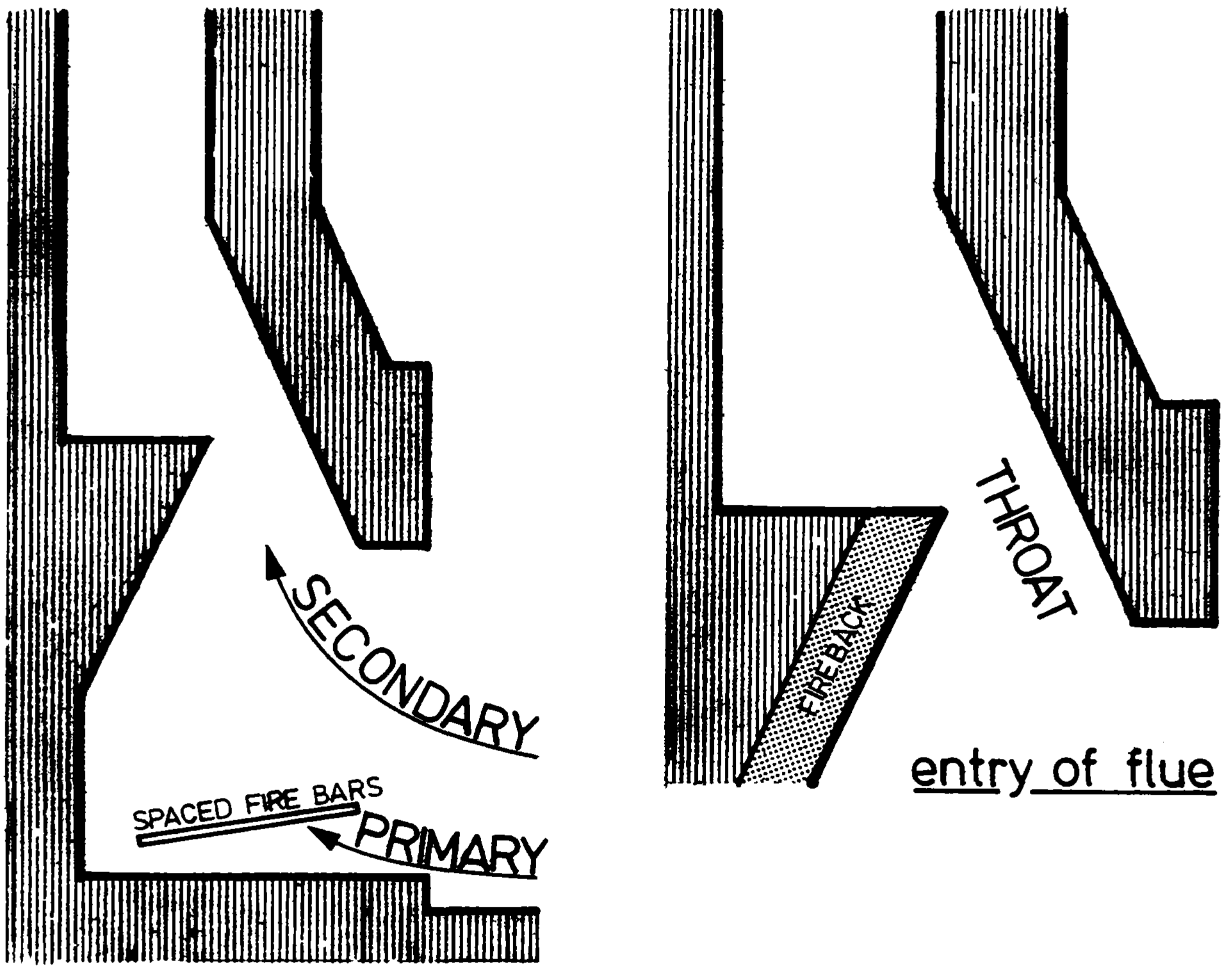


13. Explain briefly the terms:
    - Non-convector fires
    - Convector fires
    - Back boilers

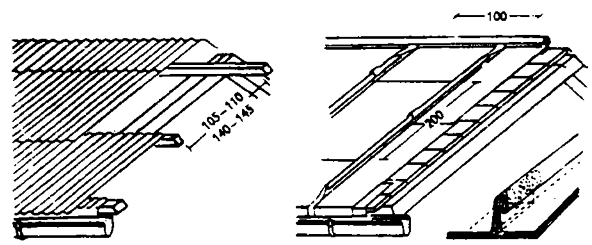
    and use sketches for illustration
14. List different types of chimneys (according to their building materials used for construction) and describe briefly (by means of heat sketches) the methods used for construction.

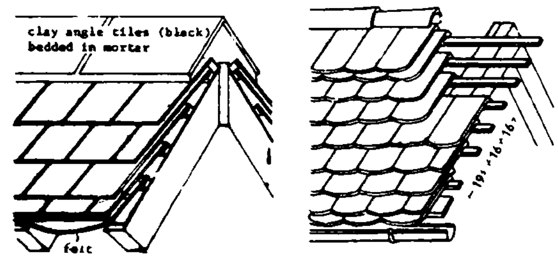





SECONDARY
SPACED FIRE BARS
PRIMARY
THROAT
FIREBACK
entry of flue

9. ROOFS





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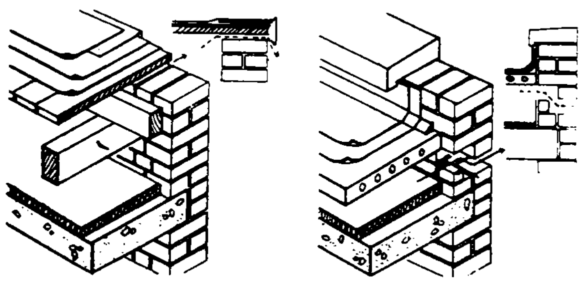

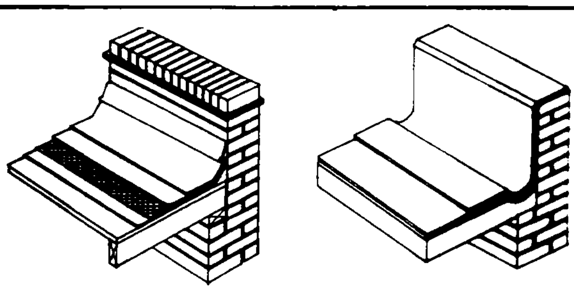

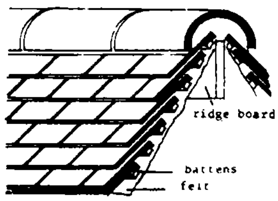

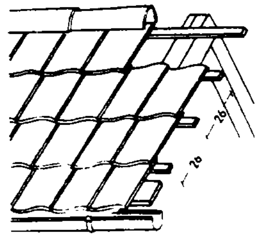

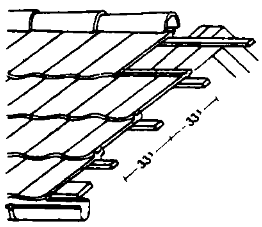

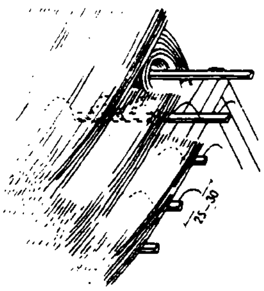

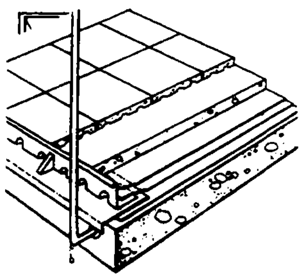

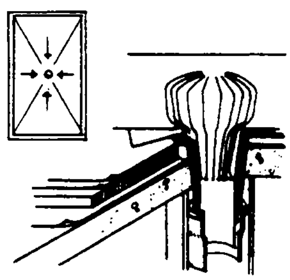

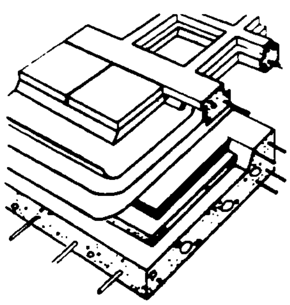

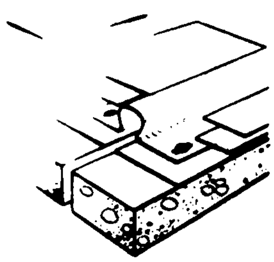

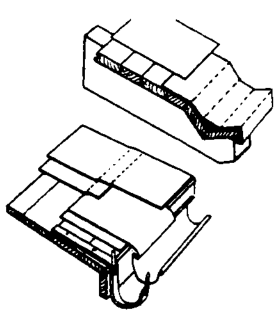

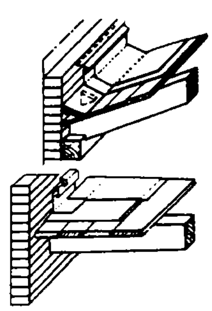

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9. ROOFS

FUNCTIONAL REQUIREMENTS

9. R O O F S

9.1 Functional Requirements

- The main function of a ROOF is to enclose space and to protect the space it coveres from the elements:
  RAIN
  WIND
  HEAT
- To fulfil its functions efficiently the roof normally must satisfy the same requirements as the walls:
  STRENGTH and STABILITY
  WEATHER RESISTANCE
  THERMAL INSULATION
  FIRE RESISTANCE
  SOUND INSULATION

STRENGTH and STABILITY

9.1.1 STRENGTH AND STABILITY are provided by the roof structure and a major consideration in the design and choice of the structure is that of a SPAN.
The wide variety of roof types in different materials which have been developed is - in main - the result of the search for the most economic means of carrying the roof structure and its load over spans of varying degrees.

DEAD WEIGHT

In all types of structures it is necessary to keep the DEAD WEIGHT to a minimum, so that the imposed loads can be carried with the greatest econom y of materials.

DEAD / LIVE LOAD RATIO

The degree of efficiency - in this respect - is indicated by the DEAD/LIVE LOAD RATIO, expressed in the terms of Loads per square metre of area covered
or
per metre run of roof structure

The structural problem in the design of WIDE SPAN ROOF STRUCTURES is - therefore - primarily that of achieving a DEAD/LIVE LOAD RATIO as low as possible.

CHARACTERISTICS of MATERIALS

- STRONG
- STIFF
- LIGHT

In solving this problem, two factors are important:
1) The characteristics of the materials to be used,
2) The form or shape of the roof

- if materials are STRONG less material is required to resist given forces.
- if materials are STIFF, they will deform little under load and the structure may be of minimum depth
- if materials are LIGHT, the self - weight of the structure will be small.

ALL OF THESE CONTRIBUTE TO A STRUCTURE OF SMALL DEAD WEIG

EFFECTS of WIND

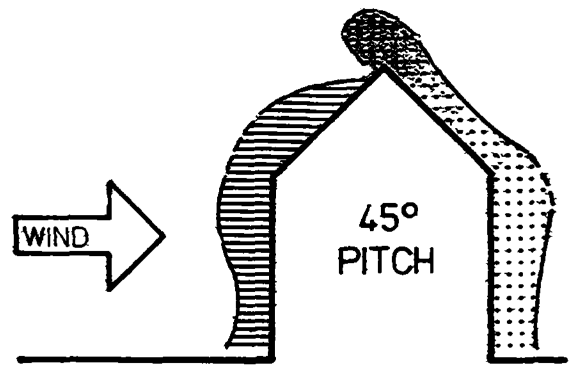
In addition to the dead load and the superimposed loads, the roof must resist the EFFECTS OF WIND.

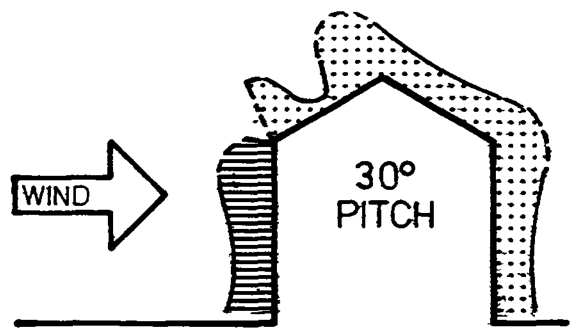
The pressure of wind varies with
- its velocity
- the height of the building, and
- the locality of the building.

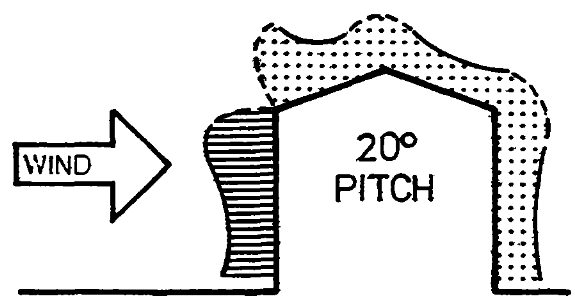
Wind may exert COMPRESSION on some parts of the roof and SUCTION on others, both in varying degrees at different points according to the pitch of the roof.

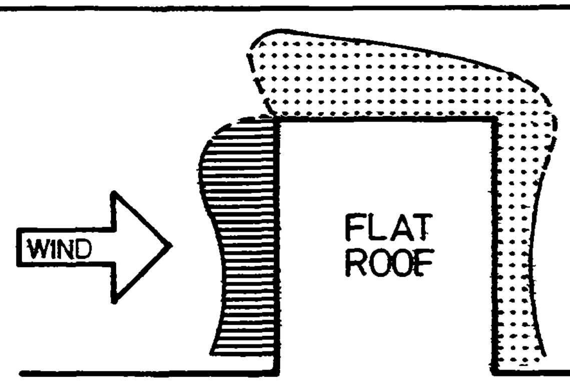
Higher suctions and compressions occure
- at the edges of the roof
- on flat roofs and
- on low pitched roofs the suction over the windward side can be considerable.

LIGHT ROOF COVERINGS: (alu-, g.c.i.-, asbestos sheets)
The supporting structure tends to be light and the weight of the cladding and roof structure as a whole may not be heavy enough to withstand the uplift of excessive suction during short periods of very high wind.
Therefore proper fastenings to the claddings and fixing of the roof structure to frames or walls are necessary to prevent them being stripped off.









9.1.2 WEATHER RESISTANCE
is provided by the roof coverings and the nature of these will effect the form and some details of the roof structure.

WEATHER RESISTANCE

THERMAL INSULATION

9.1.3 THERMAL INSULATION
In most buildings thermal insulation in the roof is either essential or increases the comfort
- <u>in hot areas</u> thermal insulation keeps the heat out of the building
- <u>in cold areas</u> thermal insulation prevents the building from greater heat loss.

Thermal insulation, however, is rarely a factor affecting the choice of the roof type, since the normal methods of providing it are generally applicable to all forms of roofs.
These methods vary and involve
- flexible
  or
- stiff insulation materials.

in or under the roof cladding or structure or the use of self-supporting insulation materials such as
- wood wool
- compressed straw slabs

which are strong enough to act as substructure to the covering.
In the case of concrete surface structurs, light weight aggregate concrete may be used (either fully or partly).

FIRE RESISTANCE

9.1.4 FIRE RESISTANCE

Adequate fire resistance is necessary in order to give protection against the spread of fire from and to any adjacent buildings and to prevent early collaps of the roof.
These matters will be discussed later under the topic"Fire protection".

SOUND INSULATION

9.1.5 SOUND INSULATION
Most forms of roof construction provide for the majority of buildings an adequate degree of insulation against sound from extern. Sources. Only in special cases, such as concert halls in noisy localities or hospitals along highways with heavy traffic, precautions might be necessary and might also affect the choice and design of the roof structure.

The fact, that weight and discontinuity of structure are important factors in sound insulating construction, makes this problem difficult in the case of roofs.

TYPES of ROOF STRUCTURES

9.2. TYPES OF ROOF STRUCTURS

- The area of the roof together with the roof coverings (which may be defined as the 'SKIN' of the roof and which can be constructed in many different ways) are carried by the ROOF STRUCTURE

- In order to drain the rainwater properly the 'SKIN' has to be more or less inclined.

- The better the 'SKIN' of the roof is able to protect the roof structures and the space enclosed from rain and wind, the flatter the roof can be constructed.

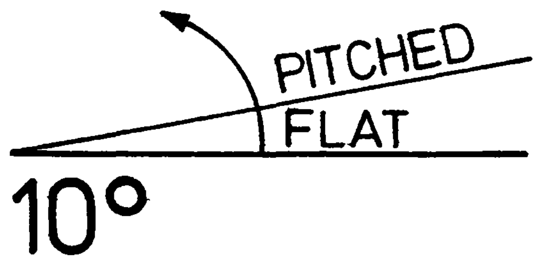
- The different types of roofs may be broadly classified in three ways:
  according to the
  1) shape of the roof
  2) structure of the roof
     (+building materials + span)
  3) coverings of the roof
     (+angle of in clination)

- shape, materials and colour of the 'skin' of the roof are most important for the appearance of the building.
  Therefore shape, degree of inclination as well als the covering material should be in accordance with local envirement.

FLAT and PITCHED ROOFS

9.2.1 FLAT AND PITCHED ROOFS

- Flat roof:
  outer surface horizontal or inclined at an angle not exceeding 10°.
- Pitched roof
  outer surface sloping in one or more directions at an angle more than 10°.



Climat and covering materials affect the choice between a flat or pitched roof.

- In hot, dry areas the flat roof is common (because there are no heavy rainfalls and the roof may form a useful out-of-door living room)
- In areas of heavy rainfalls, a steeply pitched roof quickly drains off rain.

Covering for roofs consist of

- unit materials, such as tiles and slates laid closed to and overlapping each other and
- membrane or sheet materials, such as asphalt, bitumious felt or metal sheeting, whith sealed or specially formed watertight joints.

STRUCTURE of the ROOF

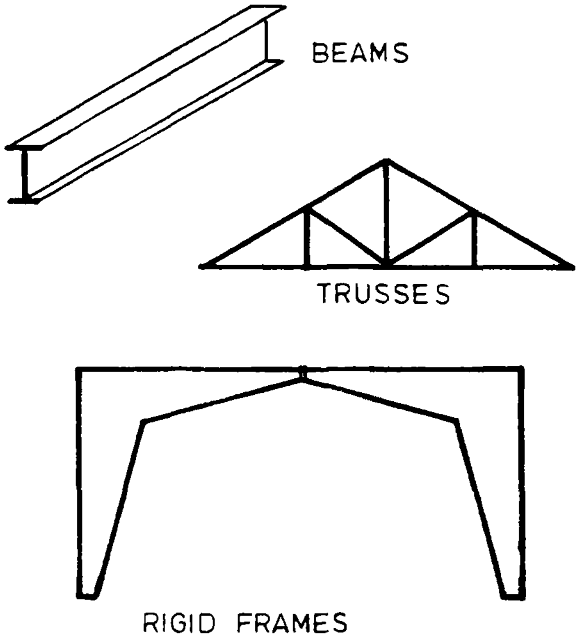
9.2.2 STRUCTURE OF THE ROOF

From a structural point of view roof structures may be considered broadly as

- two - or
- three - dimensional forms.

- Two - dimensional structures for practical purpose have LENGTH and DEPTH only and all forces are resolved in two dimensions with in a single vertical plane (only SPANNING FUNCTION).
- Three-dimensional structures have LENGTH, DEPTH and BREADTH, and forces are resolved in three dimensions within the structure. These forms can fulfil a COVERING and ENCLOSING FUNKTION as well als that of SPANNING. The general term is SPACE STRUCTURES.

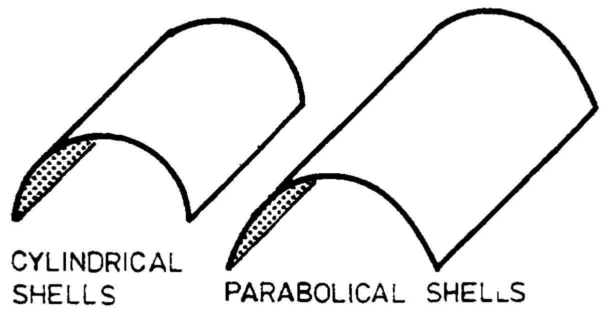
TWO-DIMENSIONAL ROOFS include :

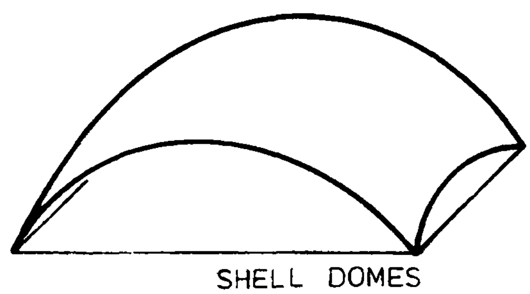


- beams
- trusses
- rigid frames of all types, including arch ribs

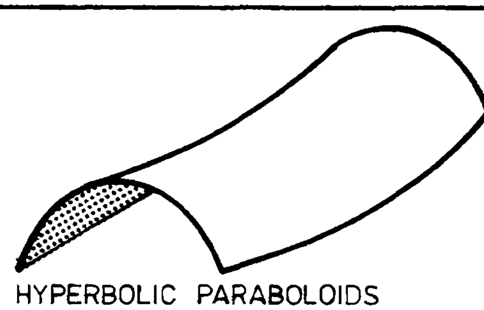
THREE DIMENSIONAL ROOFS include :

- cylindrical and parabolical shells and shell domes

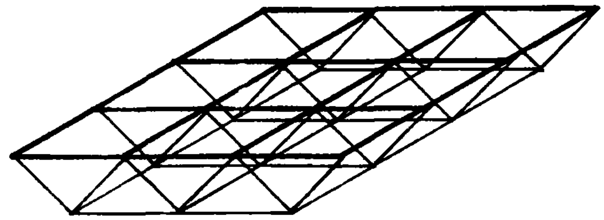




- doubly curved slabs, such as hyperbolic paraboloids and hyperboloids of revolution

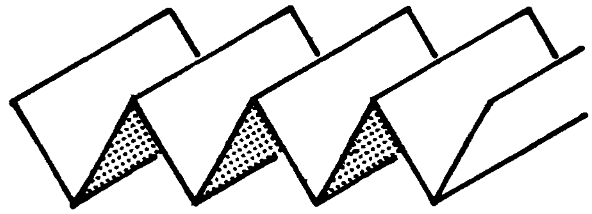


- grid structures, such as space frames, space grids, grid domes and barrel vaults



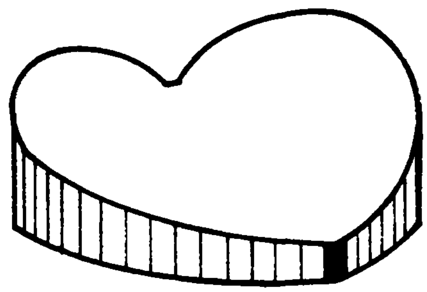
SPACE GRIDS

- folded slabs and prismatic shells

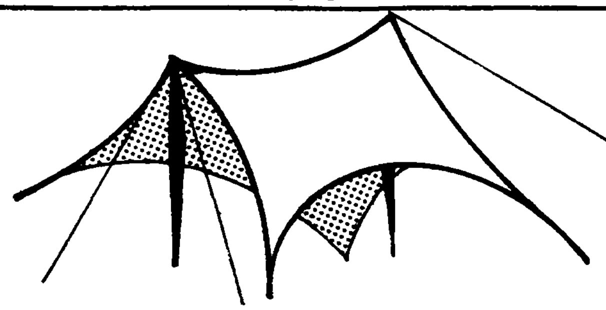


FOLDED SLABS

- suspended or tension roof structures.



SADDLE-ROPE-STRUCTURES



TENT STRUCTURES

SINGLE DOUBLE & TRIPLE ROOFS

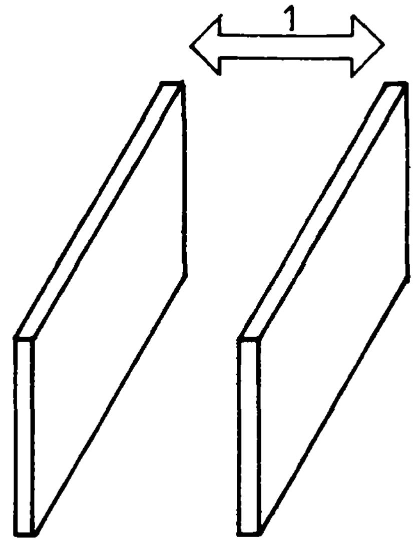
Roofs, constructed of two - dimensional members are classified as

- single
- double and
- triple rooefs

according to the number of horizontal stages necessary economically to transfer the loads to the supports.

SINGLE

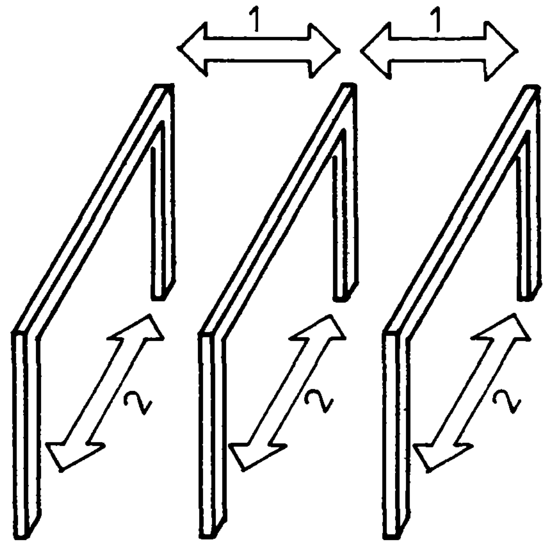
- in single roof construction the roofing system is carried directly by one set of primary members, spanning between the main supports



SINGLE ROOF

DOUBLE

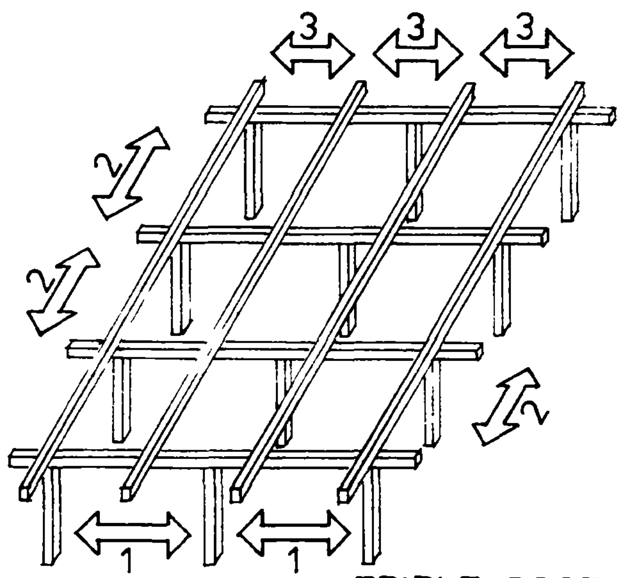
- As the span of the primary members increases a point is reached at which it becomes more economical to use larger members spaced further apart to support secondary members to carry the roofing system. This is known as double Roof Construction



DOUBLE ROOF

TRIPLE

- In some circumstances spans are such that three sets of members are required to produce an economic structure, resulting in three stages of support
  This is called Triple Roof Construction.
- This classification is applied to both flat and pitched roofs (as well as to floor construction).



TRIPLE ROOF

9· ROOFS compiled: D. VOLKE OCT. '79	TYPES OF ROOF STRUCTURES	BUILDING CONSTR — LECTURE — CET 5031 / 19·210

TCA TECHNICAL COLLEGE ARUSHA
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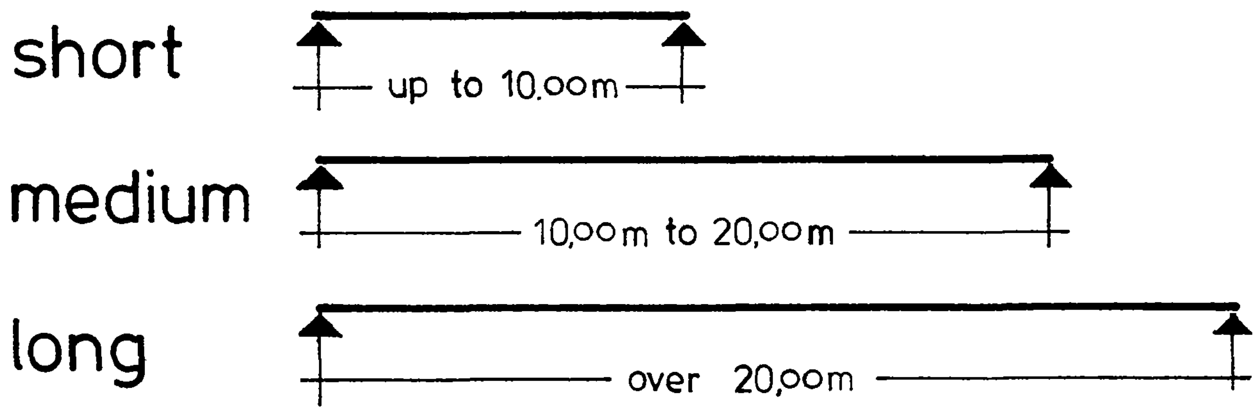
CIVIL ENGINEER. DEPARTMENT

LONG and SHORT SPAN ROOFS



9.2.3 LONG AND SHORT SPAN ROOFS

Roof structures are classified in terms of span as

- short span (up to 10.oom)
- medium span (10,oo to 20.oom)
- long span (over 20.oom)

- Short span construction will usually be cheapest
- As an increase in the distance between supports usually results in an increase in the cost - comparible with requirements of clear floor area should always be adopted in design.
- Three dimensional structures are normally not economic over short spans.

N.B.

N.B. All types of roof structures, which are introduced in the following, refer to the SHORT SPAN CONSTRUCTION only.

FLAT ROOFS

9.3 FLAT ROOFS

9.31 PHYSICAL AND STRUCTURAL PROBLEMS.

To design a building having a FLAT ROOF, seems to be very simple, because in a drawing using a scale of 1 : 100 or 1 : 200, it is just indicated as a double line and does not show the physical and structural problems behind.
Plenty of flat roofs (in Arusha and all over TAN) are leaking, because of

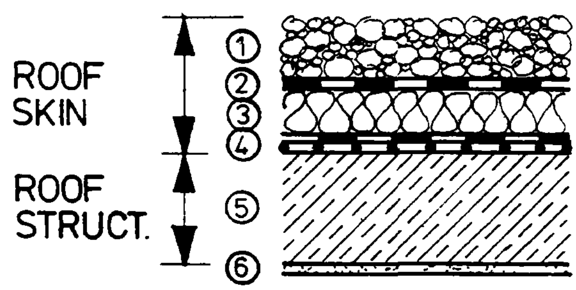
- insufficient (or wrong) construction, and
- lack of adequate building materials (expecially for thermal insulation and waterproof membranes).

9.32 STRUCTURE OF A FLAT ROOF

Flat roofs have to be drained through rainwateroutlets, such as:

- central <u>internal</u> rainwater inlet (special gully)
- tapering gutter discharging to an external rainwater downpipe or
- water spouts

STRUCTURE of a FLAT ROOF



① PROTECTION OF THE SKIN
② WATERPROOF MEMBRANE
③ THERMAL INSULATION
④ VENT. VAPOUR BARRIERE
⑤ ROOF STRUCTURE i.e. REINF. CONCRETE
⑥ CEILING

THERMAL INSULATION MATERIALS

9.33 THERMAL INSULATION MATERIALS

For most types of roofs (especially for flat roofs) thermal insulation is provided by NON-STRUCTURAL materials of two types with:

1) Low thermal conductivity
2) high thermal reflectivity.

Materials of low thermal conductivity have a <u>high percentage volume</u> of GAS or AIR VOIDS, which retard the transmission of heat.

Most efficient are materials with a CLOSED AIR or GAS CELL STRUCTURE, such as EXPANDET PLASTICS, used in board or granule form, a few mm thickness of which give insulation eaqual to a substantial thickness of brickwork, dense concrete or stone.

Typical of this class of insulators are :

QUILTS

a) QUILTS: consisting of
- glass fibre
- rock wool or slag wool (classified as MINERAL WOOL)

SLABS

b) SLABS : of
- wood wool
- straw boarded
- fibre boarded
- expanded plastics
- cork
- semi rigid glass fibre
- foamed glass
- thick, lowdensity soft wood strips (preferably 50 mm and above)

GRANULATED or NODULATED materials

c) GRANULATED or NODULATED materials used as loose fills, in layers on ceilings or fills in cavities:
- pelleted slag wool
- exfoliated vermicolite (a naturally occuring micaceous material which expands when its constained water is vaporized by heat).

FOAMED PLASTICS

d) PLASTICS FOAMED in - SITU and injected into cavities to fill them.
(note: The FOAM stabilizes the insulating air in the cavity by incorporating it as millions of very small cells within the materials.)

AIR or GAS CELLS

e) AIR or GAS CELLS within a basically higadensity material, as in foamed concrete or screed.

LIGHTWEIGHT AGGREGATES

f) LIGHTWEIGHT - AGGREGATE concrete and screeds which, to be effective, must be of adequate thickness, dried out and kept dry.

SPRAYED INSULATION

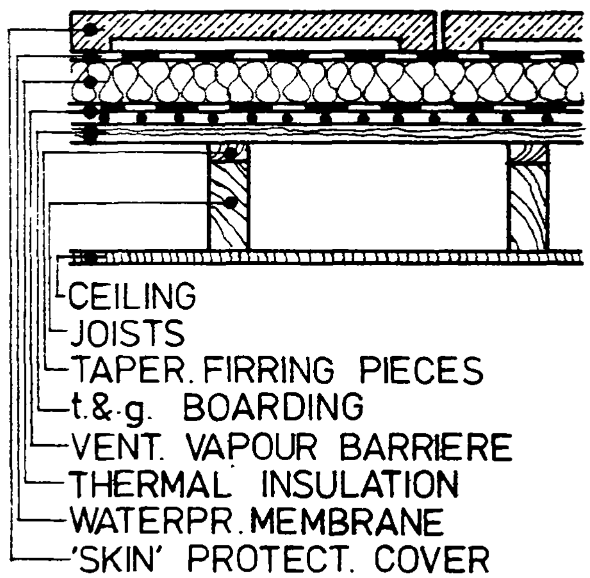
g) SPRAYED INSULATION, of asbestos fibre with water-activated binders, or lightweight plasters, applied to a thickness of 12 mm or more, on exposed protected internal surfaces.

NOTE: The presence of MOISTURE in an insulation material will REDUCE its efficiency.

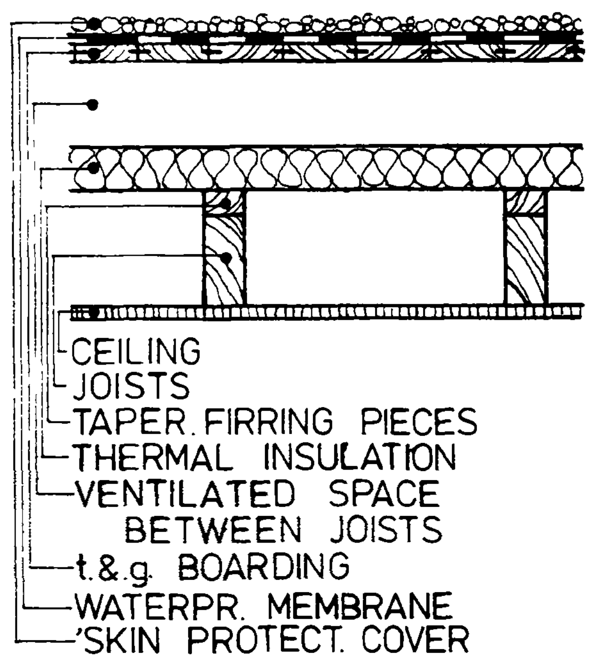
9.34 SINGLE AND DOUBLE FLAT ROOF CONSTRUCTION

The construction of a FLAT ROOF (in timber as well as in reinf. concr.) is comparable with that of an UPPER FLOOR.

SINGLE FLAT ROOF

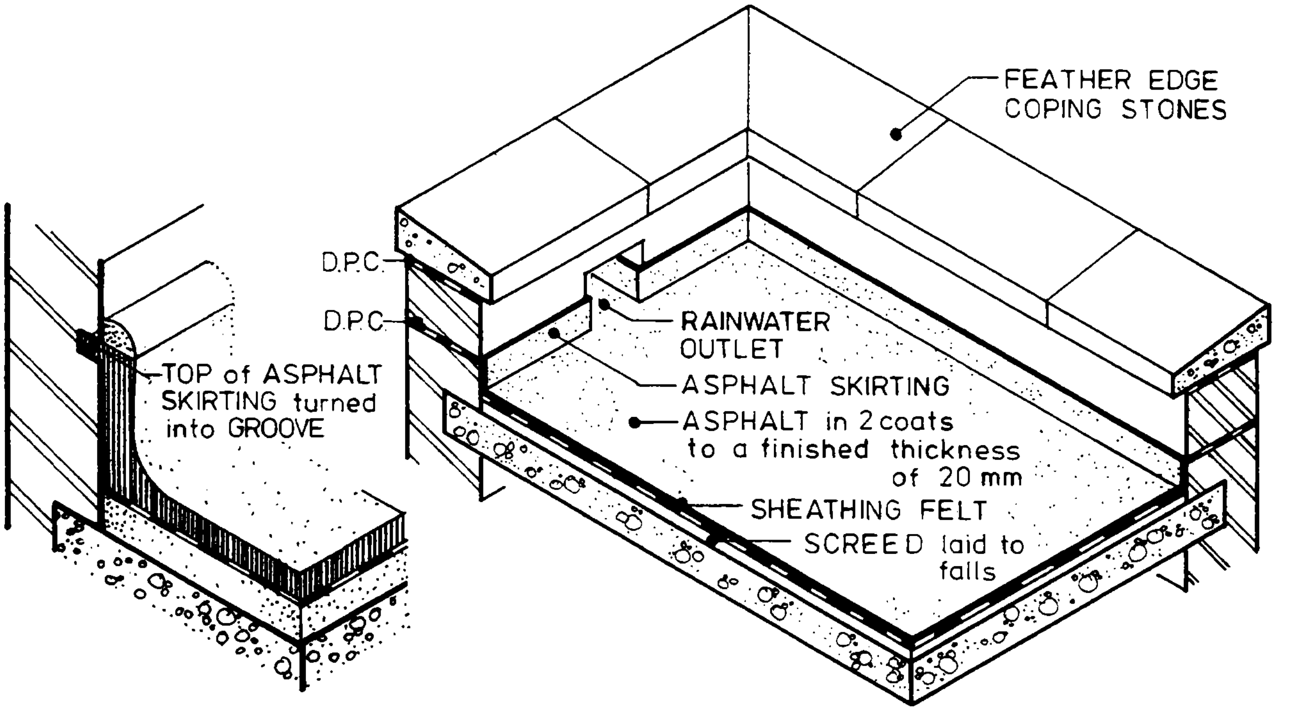


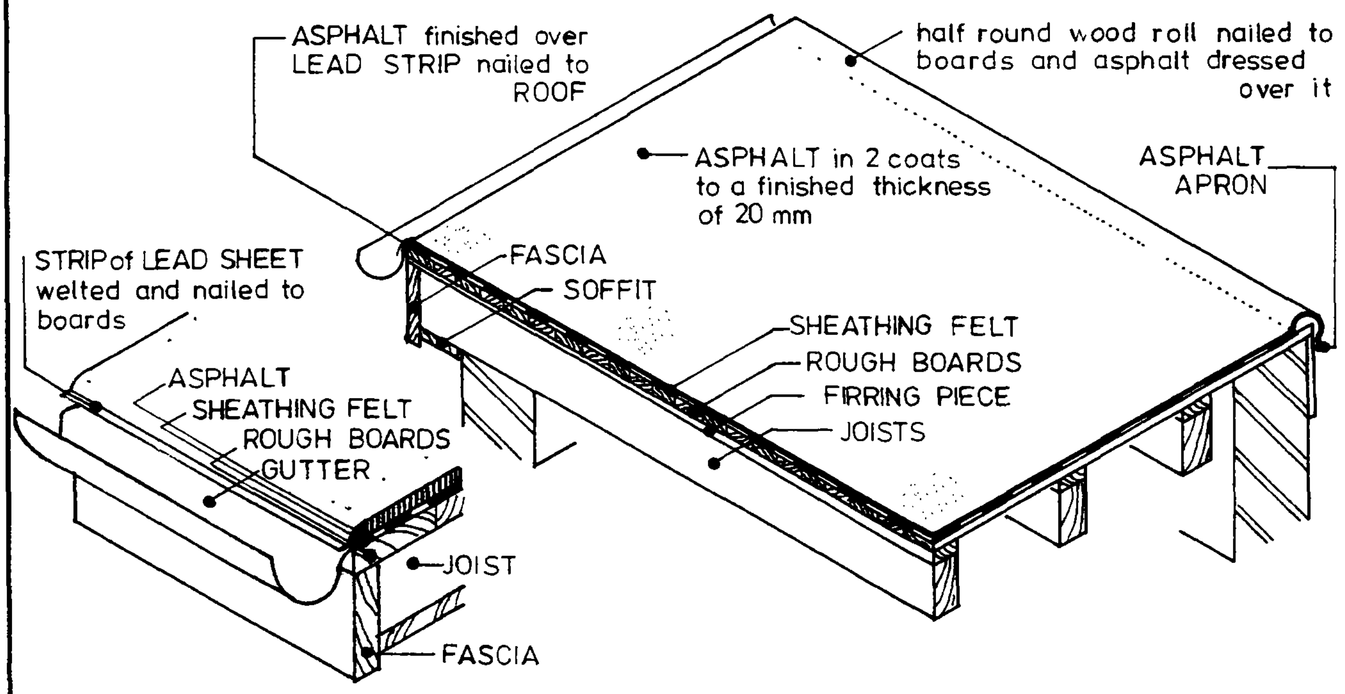
DOUBLE FLAT ROOF



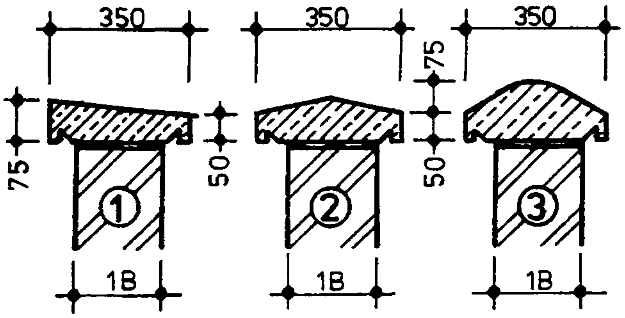
ASPHALT COVERED FLAT ROOFS

Is widely used but insufficient, because the roof skih is not properly ventilated and there is no protection cover against drying out of the asphalt by the sun. (ref. Fig.)





PARAPET WALLS



①
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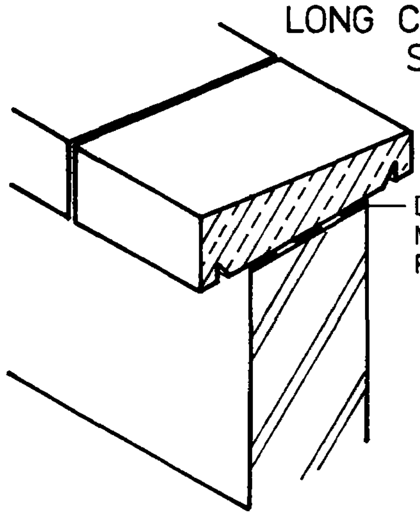
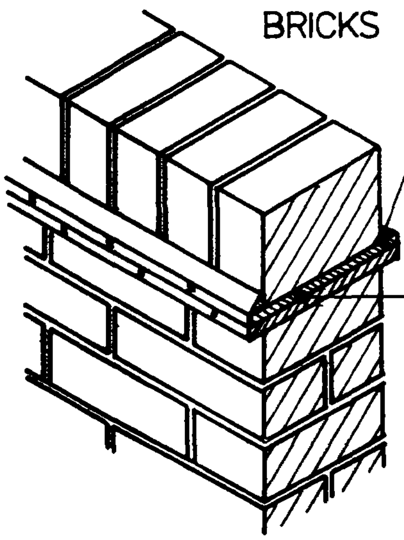
③





9.35 PARAPET WALLS
External walls of buildings are raised above the level of the roof as PARAPET WALLS for the sake of appearance of the building as a whole.

Parapet walls are <u>exposed</u> on all faces to driving rain and wind and are much more liable to damage than external walls below eaves level.

Parapet walls are <u>not weighted down</u> by floors and roofs and it is generally accepted that they should not be built above roof level higher than six times the least thickness of the parapet wall.

Parapet walls to be <u>covered or capped</u> with some non-absorbent material such as:

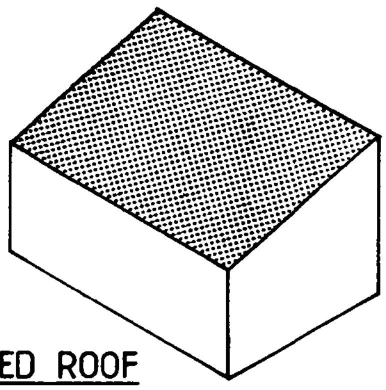
- natural stone (protective and decorative)
- artificial stone: Stones are made with a core of concrete faced with a mixture of crushed stone particles and cement.
- brick capping: Bricks are laid - on - edge on top of two coarses of creasing tiles laid-breaking joint-in cement mortar.
- D.P.C. beneath coping stones within the Parapet walls.

PITCHED ROOFS

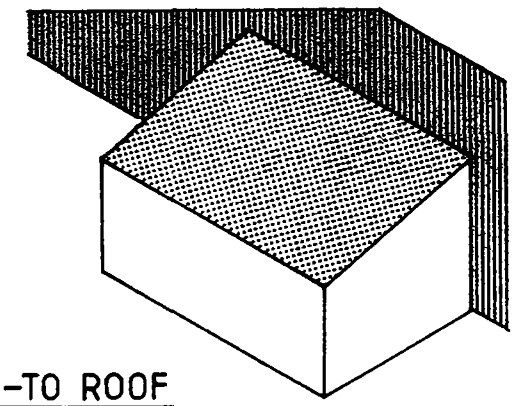
9.4 PITCHED ROOFS

9.41 SHAPES OF PITCHED ROOFS

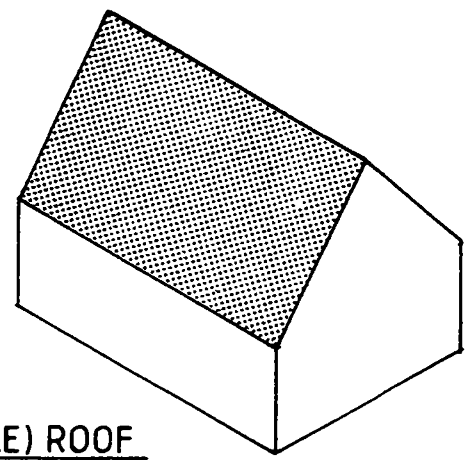
- Monopiched Roof
- Lean-to Roof
- Ridge (gable) Roof
- Hipped Roof
- Mansard Roof
- Butterfly Roof
- Shed Roof
- Tent Roof



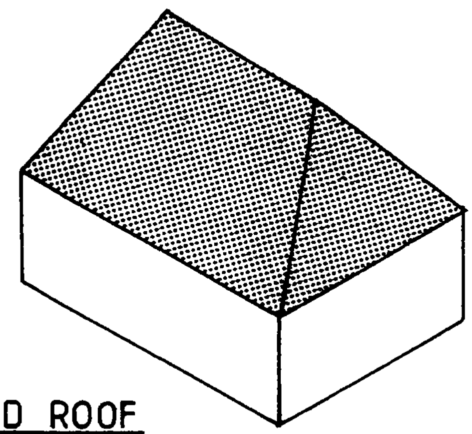
MONOPITCHED ROOF



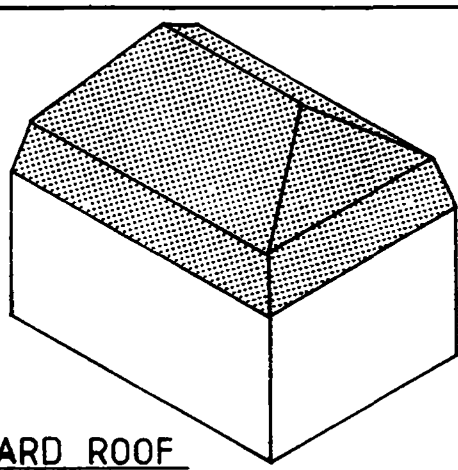
LEAN-TO ROOF



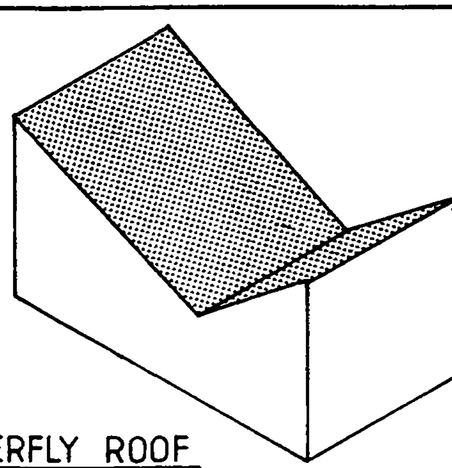
RIDGE (GABLE) ROOF



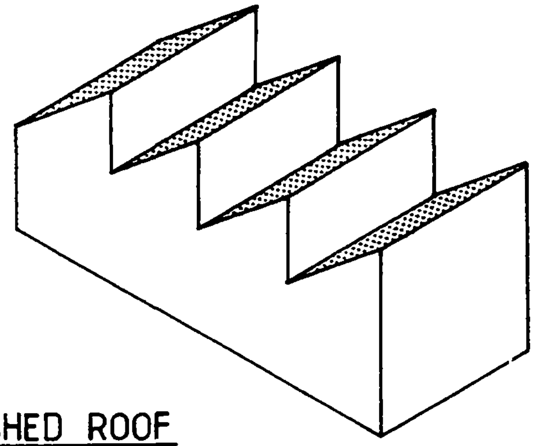
HIPPED ROOF



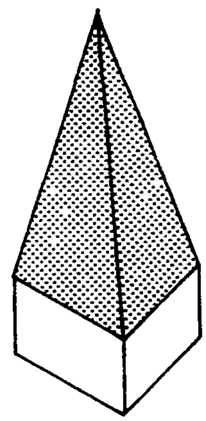
MANSARD ROOF



BUTTERFLY ROOF

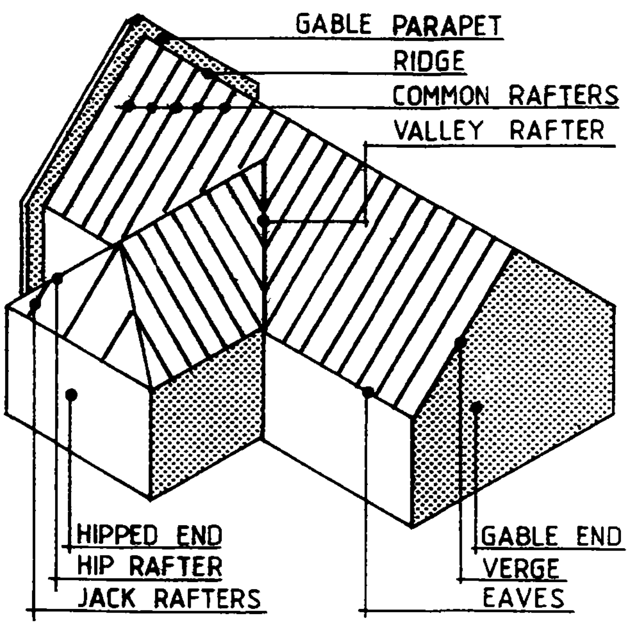


SHED ROOF



TENT ROOF

ROOFING TERMINOLOGY



9.42 TERMS

9· ROOFS compiled: D·VOLKE OCT '79	PITCHED ROOFS	BUILDING CONSTR — LECTURE — CET 5031 / 19.4 19
TCA TECHNICAL COLLEGE ARUSHA CHUO CHA UFUNDI ARUSHA	CIVIL ENGINEER. DEPARTMENT	19

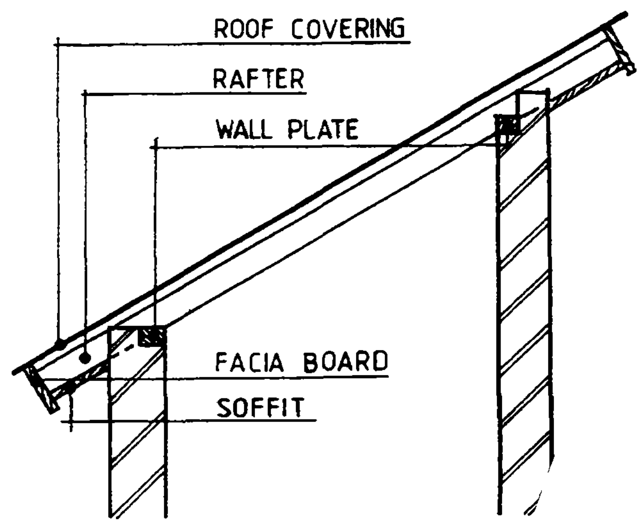
9.43 TYPES OF PITCHED ROOFS IN TIMBER (STRUCTURES)

1.

MONOPICHED ROOF

I. Mono-(single) pitched Roof:

Constructed similar to a timber flat roof or a timper upper floor (joists = rafters). Because of the pitch of the roof a BIRDS MOUTH at the end of the rafters has to be provided to avoid sliding off the wall plate. (ref. fig.)

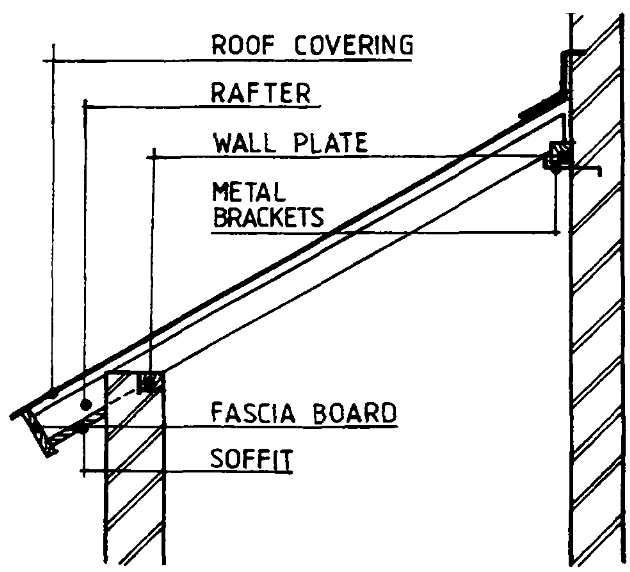


2.

LEAN-TO-ROOF

II. LEAN - TO ROOF

Is a monopitch roof of which the tops of the rafters are pitched against a wall. The feet of the rafters are birds mouthed over a wall plate as for a monopitched roof, and the upper ends over a plate supported on the wall by corbel brackets or by any means of supporting floor joists.



III. COUPLE ROOF

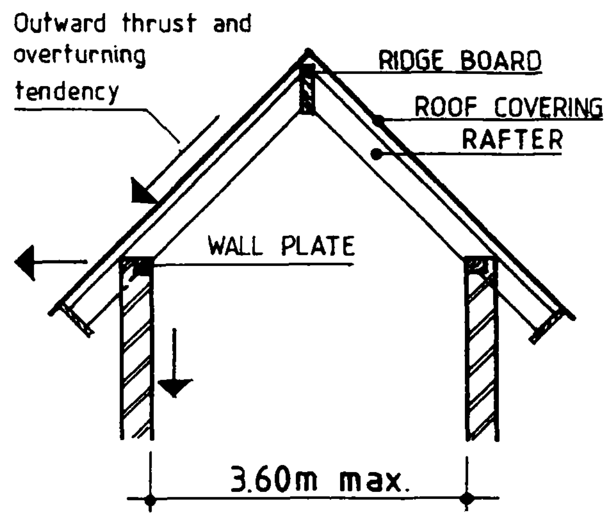
This ist the simplest, but not necessarily the most economic form of ridge roof sloping down in two directions from a central apex or ridge as it is technically termed. It consists of pairs, or couples, of rafters pitched against each other at their heads with their feet bearing on opposite walls.

When two spanning members are arranged in this way the junction at the ridge forms a mutual support so that the span of each is the distance between this point and its lower support. The depth of the rafters in a couple roof may, therefore, be considerably less than that of those in a flat or monopitch roof of the same overall span. This is an advantage from the point of view of economy of rafter material, but the arrangement of rafters results in a tendency for the ridge to drop under the roof load with a resultant outward spread of the rafter feet. In order to keep the roof stable this outward spread or thrust must be resisted by sufficiently heavy supporting walls. If the walls are tall they will, therefore, be thick and expensive. For 215 mm solid or 250 mm cavity walls of normal height the roof must be limited to a maximum clear span of about 3.oo m to keep the thrust within acceptable limits. The clear roof space given by this roof can, however, be used with advantage over wider spans than this if the roof pitch is steep and the eaves are low. This has the effect (1) of reducing the outward thrust of the rafters and (2) of reducing the height of any supporting walls and, therefore, their tendency to overturn, so that their thickness may be kept to a minimum.

The feet of the rafters are birdsmouthed over wallplates and the upper ends butt against a flat board called a ridge piece or board, to which they are nailed. This board facilitates fixing of the rafters and keeps them in position lateraly.

3.

COUPLE ROOF



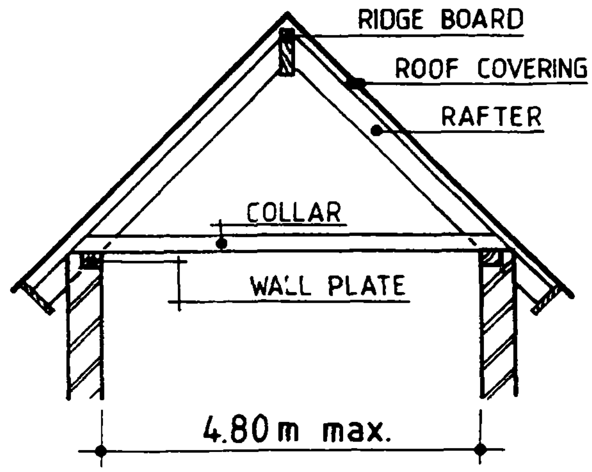
IV. CLOSE COUPLE ROOF

This roof results from the introduction of horizontal members to tie together the feet of each pair of rafters and prevent their outward spread. This forms a simple triangulated structure and produces vertical loads on the supports with no tendency to overturn the walls so that their thickness need take no account of this. These members, known as ties, are spiked to the feet of the rafters at plate level and if they are used to support a ceiling, as commonly is the case, they are called ceiling joists. The maximum economic span of this roof is about 6.10m, this being limited not by the spread of the rafters but by the economic sizes of the roof members. It is generally found most economic to restrict the depths of rafters to about 100 mm and, depending on the weight of the roof covering and the pitch and spacing of the rafters, this depth can be used over spans of about 4.60 m to 5,20 m

The function of ceiling joists as ties can be fulfilled by quite small sections but, as they act also as beams supporting their own weight and that of the ceiling, they tend to sag or deflect and they must be large enough to keep this within acceptable limits. For spans of the order given above quite large ceiling

4.

CLOSE COUPLE ROOF

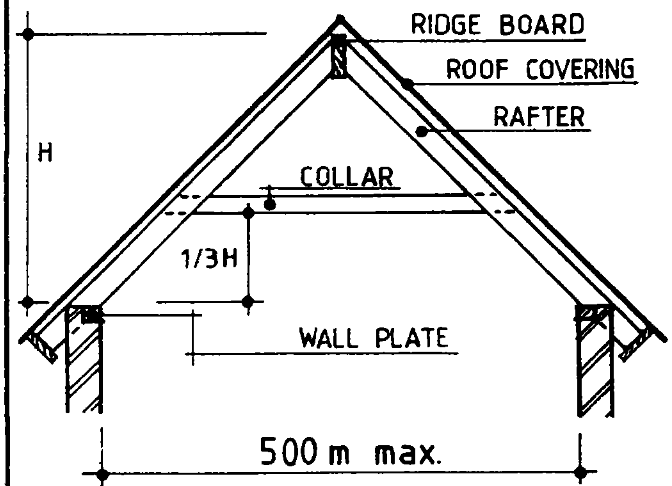


joists would be necessary and it is found more economic to reduce their effective span by suspending them from the ridge.
The longitudinal 75mmx50mm binder or runner skew nailed to the joists permits the hangers to be fixed to it at every third or fourth joist spacing rather than to each joist, thus economising in timber.

Fixing of hangers to runners should be deferred until the roof covering has been laid in order to avoid deflection of the ceiling joists due to the transfer through the hangers of any slight movement of the roof structure as it takes up the load.

5.

COLLAR ROOF

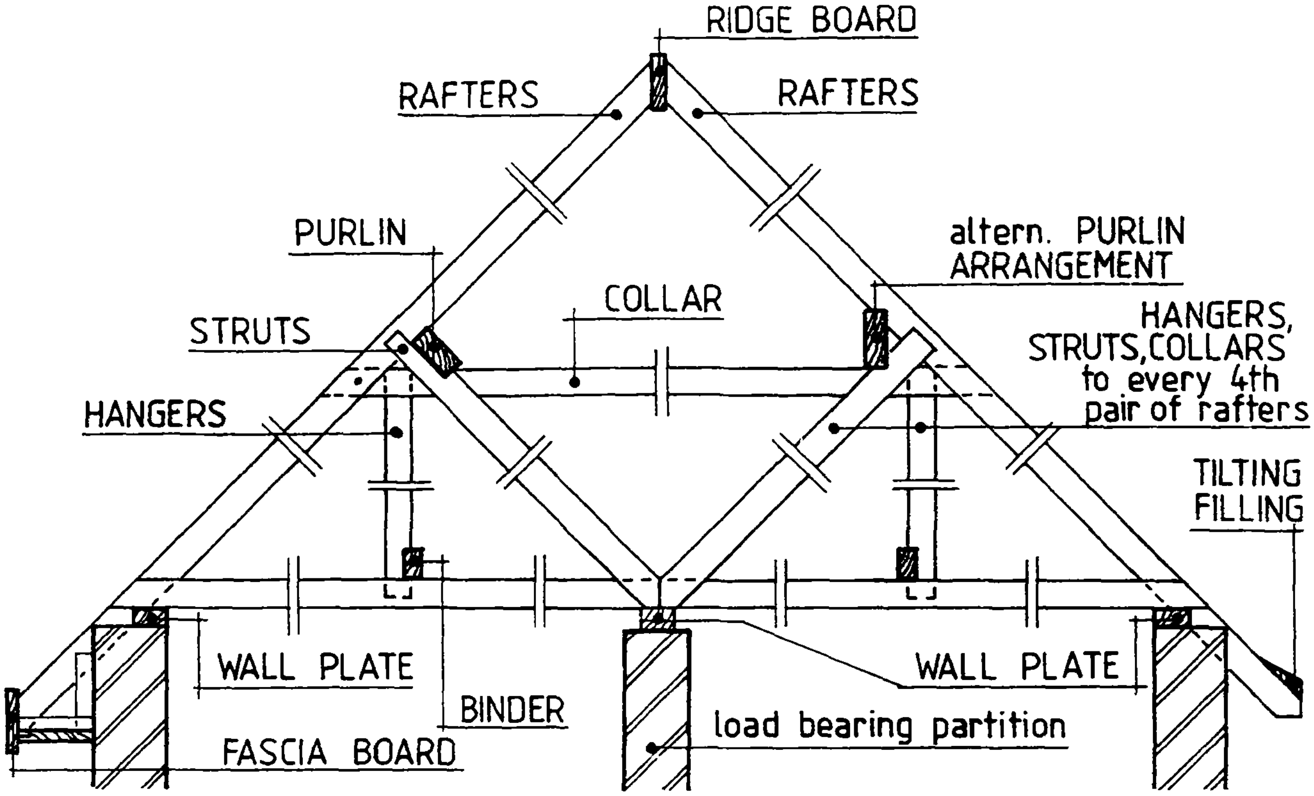


V. COLLAR ROOF

In this roof tie members are used but at a higher level than the feet of the rafters and they are called collars. It can be used for short spans not exceeding 4.90 m when it is desired to economise in walling, since the cailing will be raised and the roof may, therefore, be lowered on the walls to the same extent for a given height of room. The influence of the collar on the spread of the rafters is less marked the higher it is placed and half the rise of the roof is the maximum height at which it should be fixed. The size of the collars is the same as for close couple ties of an equivalent span. In the past a dovetail halved joint at the junction of collars and rafters was normal but this involves considerable labour and it is cheaper and stronger to use a bolt and timber connector.

6.

DOUBLE or PURLIN ROOF
for spans up to 7.20 m



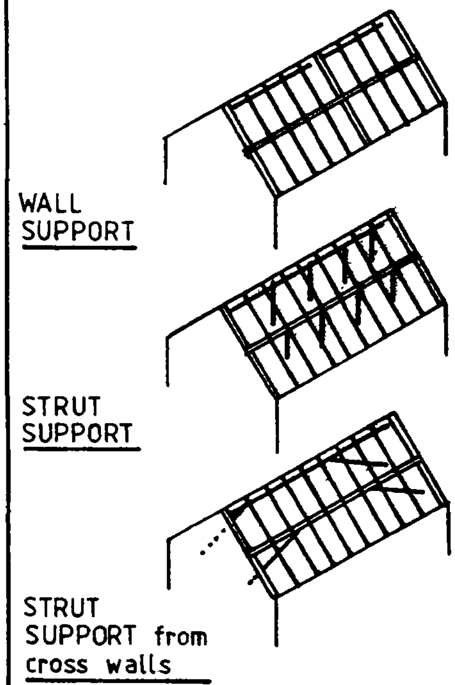
VI. DOUBLE OR PURLIN ROOF

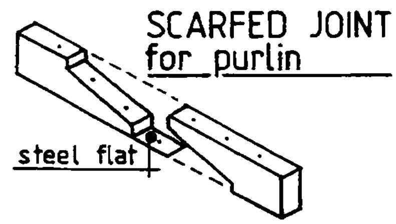
When the span of a roof is more than 6.10 m and requires in a couple type roof rafters much greater than 100 mm in depth it is cheaper to introduce some support to the rafters along their length, thus reducing their effective span, rather than to use large rafters. This support could be in the form of a strut to the centre of every rafter resting on a suitable bearing below, such as a partition or wall but, as in the case of ceiling joist hangers referred to above, it is more economical in timber to introduce a longitudinal beam on which all the rafters bear and to support this member at intervals greater than the rafter spacing. The introduction of this beam, or purlin as it is called, as a second stage of support brings the structure into the double roof classification. Although this introduces extra members into the construction the total cube of timber in the roof (and the weight of the roof) rises less with increase in span than if the rafters were increased in size.

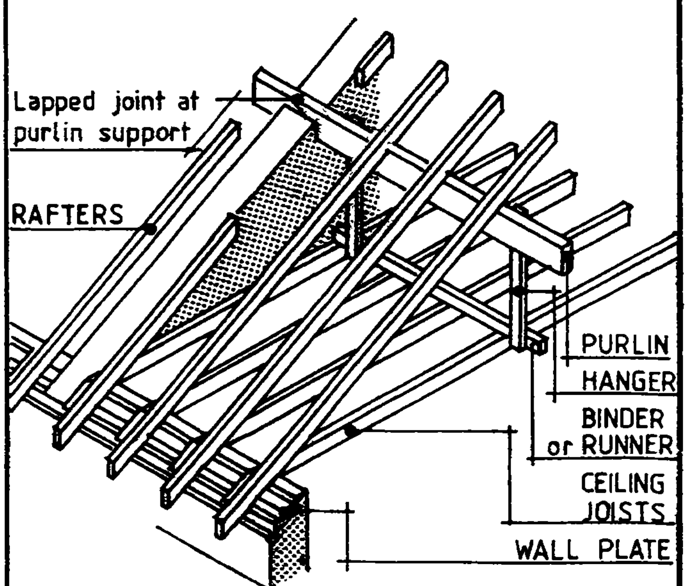
The purlins may be supported directly by cross walls or partitions at sufficiently close spacing along the length of the purlins or by struts off any suitably placed walls partitions or chimneys. The size of the purlins will be governed by the weight of the roofing system, the spacing of the purlins (if the length of rafter supported) and their span. As with rafters an increase in span results in increased size and cost of purlins and the span should, therefore, be kept within economic limits. Depending on the combination of weight and rafter length a 225 mm x 75 mm purlin will span from about 2.5o m to 3.7o m. If the spacing of available supports is such that purlins much larger than this are required it may be better to select an alternative method of construction.

Purlins may be placed vertically or normal to the rafters. The former ist preferable when the purlin bearing is directly on walls or on vertical struts, the latter is sometimes more convenient when inclined struts are used, which is the case when supports do not occur immediately under the purlins. Where possible inclined struts should be paired so that those to opposite purlins meet at the same point and bear against each other over the support. If this should result in struts at

PURLIN ROOF





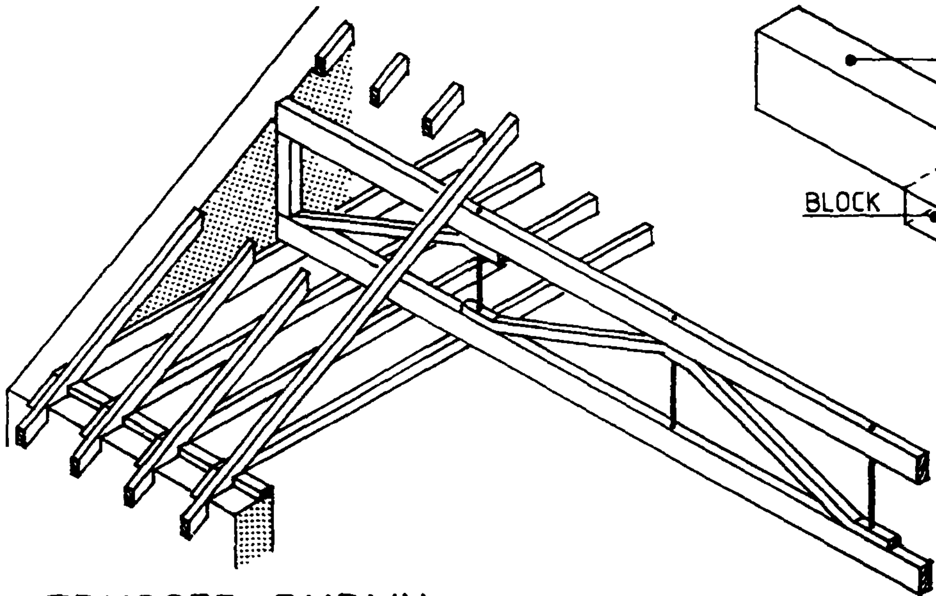


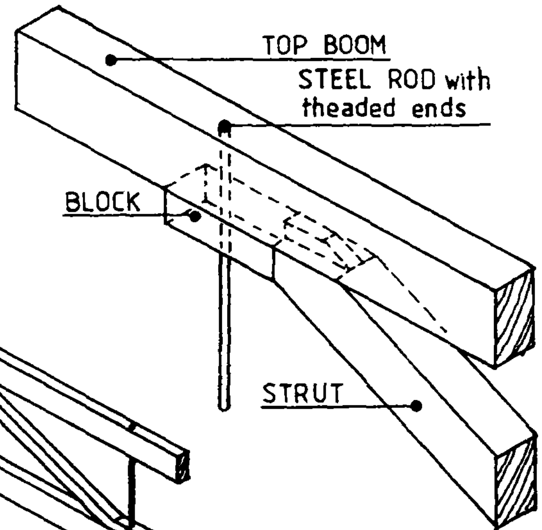
an excessively low angle a spreader piece nailed to the top of a ceiling joist may be used to increase the angle of the struts.

Joints required in the purlins should be made over supports wherever possible in the form of a lapped joint. Where joints must occ ur at points between bearings a stronger joint is necessary and a splayed scarf joint must be adopted.

As the span of the roof increases the size of the ceiling joists can be kept within economic limits by increasing the number of points of support and in a purlin roof hangers carrying binders can be suspended from the purlins. When the purlins are normal to the rafters the hangers are fixed to a rafter face immediately above the purlin.
Where no supports exist at intervals over which solid timber purlins of an economie size can span, but where suitable widely spaced cross walls exist, then deep beam purlins may be used. The maximum span over which they may be used in these circumstances depends to a large extent on the depth available for the beam. Two types are discussed below.

TRUSSED PURLIN





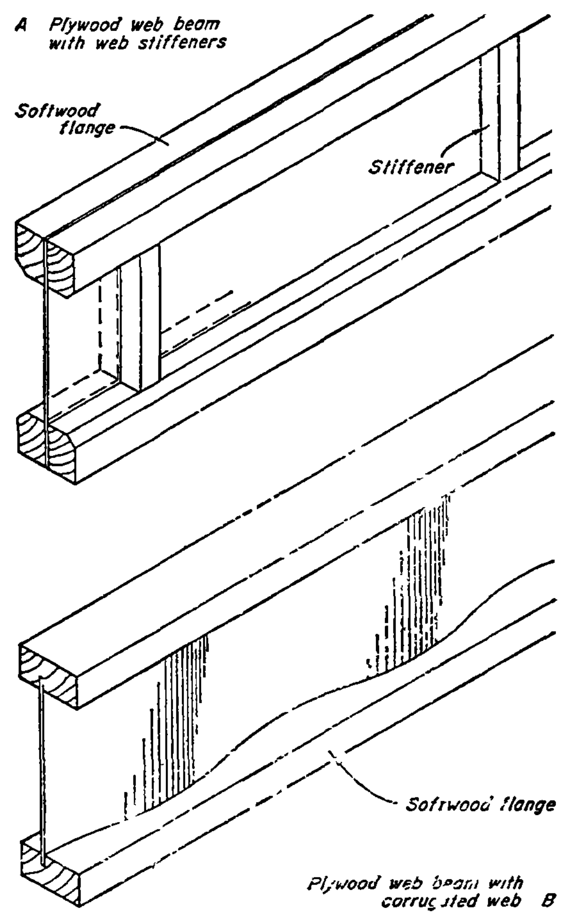
Trussed purlin

This ist a trussed, lattice or framed beam or girder all of which are synonymous terms for a beam built up of triangulated members. For a given load and span as the depth of a beam increases the bending stresses at top and bottom decrease and less material is required in the beam. This economy of material can be developed further by concentrating the majority of the material in the beam at the top and bottom where bending stresses are at a maximum. In the trussed beam structural depth is obtained with a minimum of material at the centre or web by means of relatively thin triangulating members which connect the top and bottom flanges or booms. For maximum economy bending stresses in the members should be avoided as far as possible

To this end the members should be arranged on the 'centre line' principle as far as is practicable that is to say at each junction of members their centre lines should intersect at one point. For the same reason loads should be applied only at the node points With trussed purlins however, the rafters are closely spaced along the top boom and do not all bear at a node point; some bending therefore occurs and the boom size must take account of this.

PURLIN BEAM

Purlin beam
The alternative to a trussed purlin is the thinwebbed timber beam, which may be specially fabricated or of which there are a number of mass-produced types on the market. This consists of a plywood web rebatted into and glued to top and bottom booms or glued at top and bottom between two timbers to form the booms. In deep beams of this type some stiffening against buckling of the thin web is required in the form of vertical stiffeners glued at intervals on each side of the web. In one proprietory beam this stiffening is obtained by using a vertically corrugated ply web instead of applied stiffeners.
A trussed purlin invariably makes use of the full depth between rafters and ceiling joists as shown, to provide direct support to the latter without hangers but when ply-webbed purlin beams are used they are unlikely to be as deep as this, exept in very low-pitched roofs, and hangers for the ceiling joists would be required.



135 Purlin beams

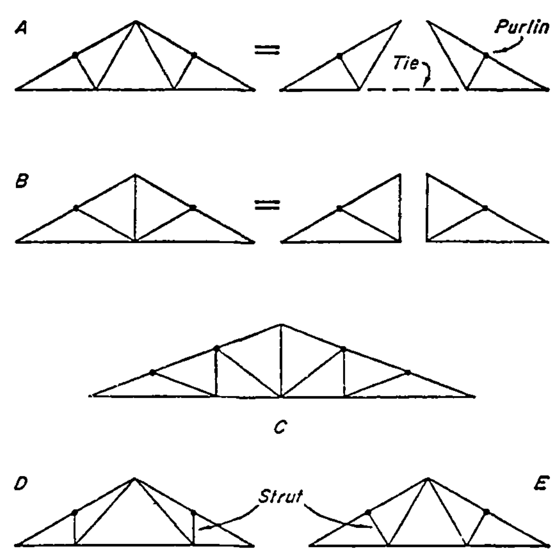
7. TRIPPLE or TRUSSED ROOFS

VII. TRIPPLE or TRUSSED ROOFS

The use of purlins as just described presupposes the presence of supporting elements at appropriate spacings. Where these do not exist or where, for some reason, this form of construction may not be suitable, for example, when the roof span is large and multiple purlins are necessary, an alternative method of supporting purlins is by structural members spanning the width of the roof at intervals along its length, the tops of which follow the pitch of the roof. These may be in the form of either a triangulated structure known as a roof truss or of deep rafters fixed at their feet rigidly to a pair of supporting columns to form one structural component. The latter are called rigid frames.

A ROOF TRUSS consists essentially of a pair of RAFTERS (or a single rafter in a monopitched roof) triangulated to provide support for the purlins, preferably at the node points.

For short span roofs two rafters lying in the same plane as their neighbours may be triangulated to carry purlins which are fixed immediately under them, so that the purlins are in the same relative position to the other rafters which they in fact support. These trusses are placed at relatively close centres. For wider spans resulting in large loads on the truss members, the size of a normal rafter is usually to small to be used in the truss and separate rafters are triangulated and carry the purlins on their backs. These rafters, therefore, lie below the level of the normal rafters and do not directly support the roof covering.
The rafters of the truss are called the PRINCIPAL rafters and the normal rafters the COMMON rafters.



TRUSS CONSTRUCTION in TIMBER

Truss construction in timber

- A roof truss must carry, via the purlins, the loads on a number of adjacent rafters.
- The forces on the joints between its members are, therefore, greater than those on the joints in a single or double roof structure and the use of one or two nails commonly used to secure members in the latter is insufficient in a truss.
- The detailed construction of a truss depends largely on the method adopted for joining the parts.
- Earlier methods involving mortice and tenon joints,necessitated relatively large amounts of timber at the junctions and, therefore, large heavy members (often larger than justified by the stresses in them) and the incorporation of large metal straps particularly at the tension points since the mortice and tenon joint is efficient only in compression.
- This type of truss is exemplified by the traditional king-post and queen-post trusses which, for these reasons, are now absolete.
- There are three modern methodes of joining the members:
  1 nailed joints
  2 bolt and connector joints
  3 glued joints and sometimes a combination of two.

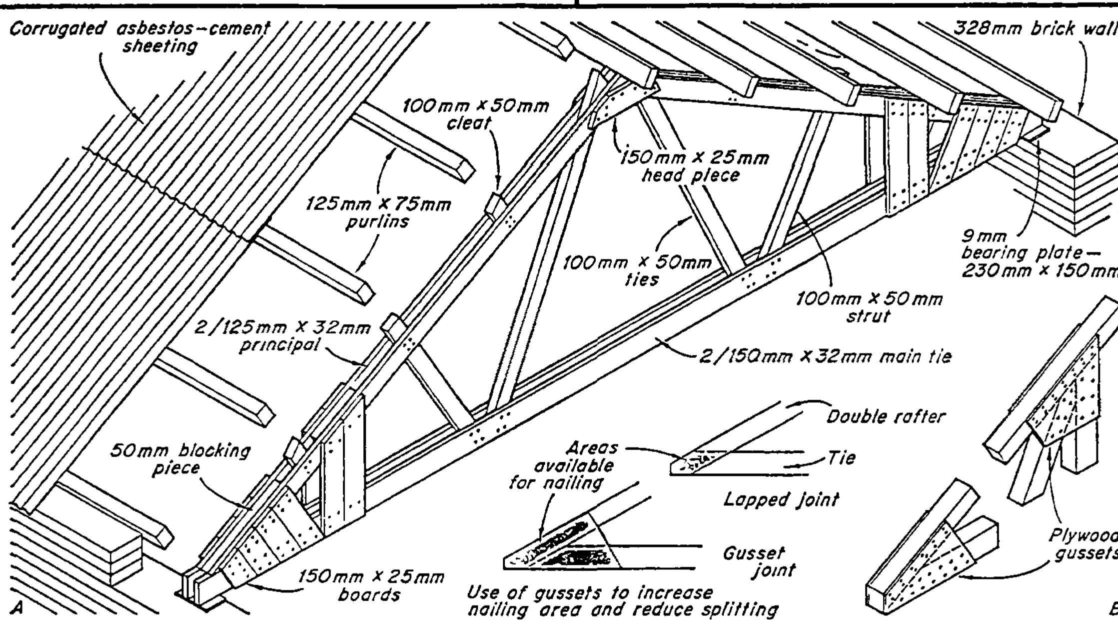
- These methods require the members to be laid one against the other, or LAPPED as it is termed, to make the joint or - alternatively - require the use of cover plates, or GUSSETS, when the members butt one against the other.
- If two members lap, the joint is called SINGLE LAP JOINT
  If one member lappes by two other members, it is called a DOUBLE LAP JOINT (also known as SANDWITCH CONSTRUCTION).
- In a single lap joint the joint is under eccentric loading. For small span trusses carrying light loads this is not significant but when the joints carry large loads eccentricity should be avoided by the use of double lap joints. Double members are also used in order to obtain a satisfactory arrangement of members in the truss as a whole for jointing purposes.

(1) NAILED TRUSSES:

(1) NAILED TRUSSES:

Jointing by nails is the least efficient of the three methods - but a traditional and simple method.
By preboring nail holes and using wide, thin members to provide ample fixing area, efficient structures may be obtained, particularly where light - weight roof coverings are used.
The arrangement of nails to be calculated.

An example of the application of nailing in this manner is shown in the figure, where sandwich construction is used to carry corrugated asbestos cement sheeting over spans up to 6.10m. The principal rafters and horizontal tie are each formed by two boards, 32 mm thick, and the struts and secondary ties are 100 mm x 50 mm seantlings sandwiched between, the joints at these points being made by direct nailing between the members. As the rafter und tie members lie in the same plane and butt against each other at the feet of the truss it is necessary to use gussets to effect a joint at these points. The gussets here are formed by 25 mm boards on each side set normal to the rafters and securely nailed to each member . The extension of the gusset by two vertical boards increases the rigidity of the whole truss.
The double members at the feet are blocked apart by 50 mm pakking pieces and at the ridge the rafters are secured to each other by a 25 mm board on each side.



137 *Nailed timber truss*

NAILED TRUSSES

Struts and secondary ties project beyond the rafters and 5o mm cleats are fixed at the intermediate purlin position to form seatings for the purlins. By joining them together the struts and cleats also serve to stiffen the thin rafter members which, being in compression are liable to buckle.
These trusses would be spaced 3.oo m to 3.6o m apart depending on the weight of the roof covering and the size of the purlins used. The point loads from the truss at its bearings are spread on to the walls by steel bearing plates as shown or by concrete templates built into the brickwork.

The purlin spacings shown in this exemplare are for small section corrugated sheeting. The intermediate purlins impose a point load on the rafters and, therefore, induce bending stresses. Since, however, the roof covering is light these stresses will be small and it is more economic to allow for them in the size of the rafters rather than to form nodes at these points by extra bracing members.

When self-supporting coverings such as these sheets are used they are laid directly on the purlins as in this example, but when the roofing requires a base such as battens, boarding or other roof decking needing support at closer intervals it is then cheaper to support the base on common rafters at the required spacings carried in the traditional way on purlins at the node positions only. This usually results in less timber content than if the purlins are placed at very close intervals.

When loading and span conditions require thicker members and where lapped joints do not provide sufficient nailing area, single thickness construction with gussets throughout may be used. By this means larger areas are available for nailing and all joints may be laid out on the 'centre line' principle.

(2) BOLTED and CONNECTORED TRUSSES

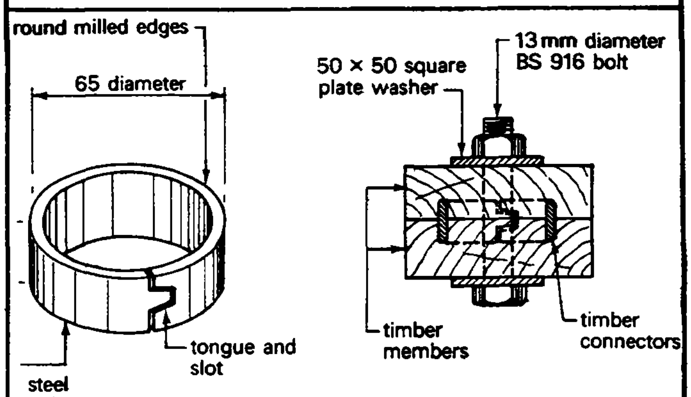
(2) BOLTED AND CONNECTORED TRUSSES

Timber connectors are metal rings or toothed plates used to increase the efficiency of bolted joints. They are embedded half in each of the adjecent members and transmit load from one to the other. There are many different types, of which the most commonly used for li_ght structures is the toothed plate connector, a mild steel plate cut and stamped to form triangular teeth projecting on each side which embed in the surfaces of the members on tightening the bolt which passes through the joint. For greater loads split ring connectors are used, but these require accurately cut grooves to be formed in each piece of timber.

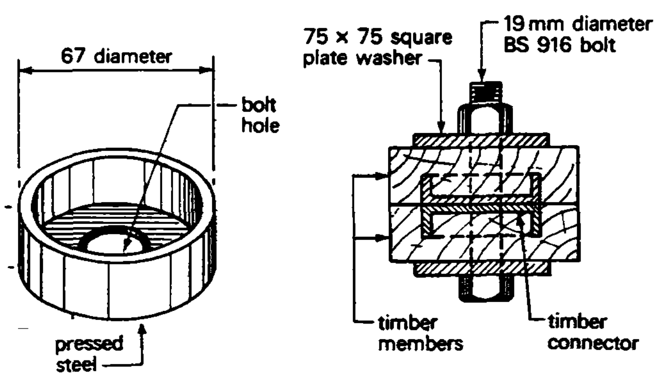
Jointing by connectors and bolts permits thicker timber to be used and its application is illustrated in the figure. This truss is for a span of 7.6o m and is designed to be spaced at 3.9o m centres and to carry large section corrugated asbestos cement sheeting, which is self-supporting over a span of 1.4o m and a ceiling.

Rafters and horizontal tie are of double members with single member secondary ties sandwiched between. Struts are of double members placed on the outside of rafters and tie. This arrangement permits 'center line' setting out at all joints where three members meet. It also permits a single bolt to effect the joint.

Gussets are required at feet and ridge, firstly because the main members do not overlap and, secondly, in order to obtain a greater fixing area for the number of bolts required at these joints.



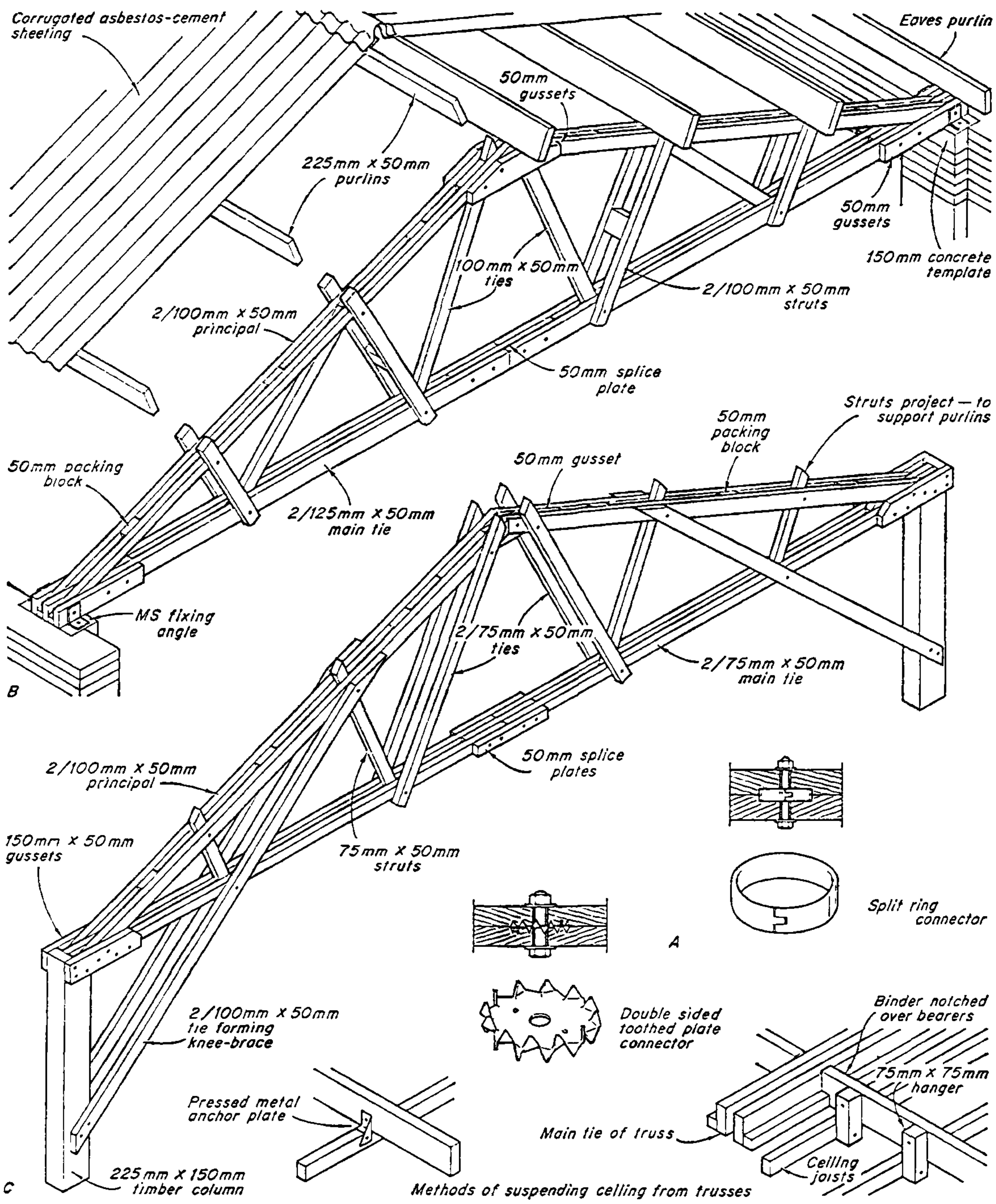
Parallel side split ring connector



Shear plate connectors

BOLTED and CONNECTORED TRUSSES

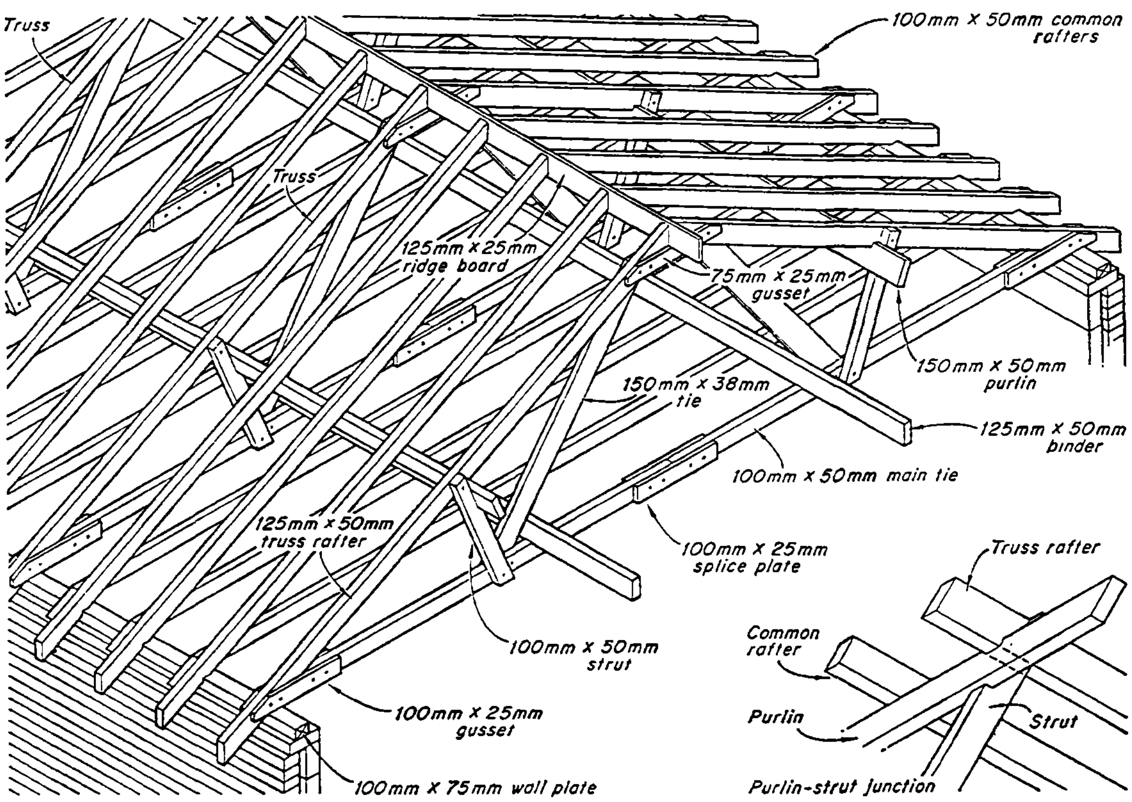
Since only one bolt is required at the foot of the rafter the gusset here need be no deeper than the tie, with a packing piece of the same size in the central space. To avoid the use of very long timbers the members of the main tie are joined or spliced at the centre using a central splice plate and four sets of bolts and connectors.



BOLTED and CONNECTORED TRUSSES

The joints in this truss are made with split ring connectors at each interface on 13 mm diameter bolts, with 5o mm square washers under bolt head and nut to prevent them sinking into the wood when the nuts are tightened. The projecting ends of struts and ties are necessary in order to obtain the minimum end distances beyond the connectors. It will be noted that the double members in the rafters and the long struts, which are compression members, are stiffened between the node points by 50 mm packing blocks securely spiked in position.

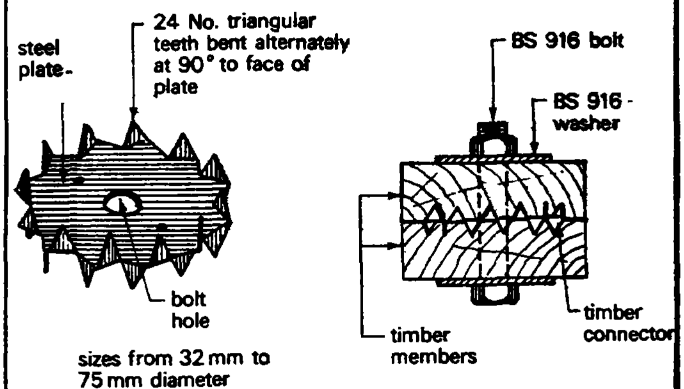
A variation of this type of truss is shown. This ist designed to be supported by columns the connection with which is stiffened against lateral movement by the triangulated and, therefore, stiff junction created by a knee-brace joining truss and column head. This is formed by extending the lower secondary tie to connect with the column some distance below the truss bearing thus rigidly uniting the two. In order to obtain a satisfactory junction with the column and to provide the necessary cross-sectional area for the knee-brace the secondary ties in this example are



made of double members placed on the outside faces of the truss, and the struts are single members. As this truss is not designed to take a ceiling load the struts and ties are smaller, except those forming the knee-braces which must resist wind stresses. To provide for the grater number of bolts required at the feet, due to wind loads transferred to the truss, larger gussets are necessary at these points. A single central gusset is provided at the ridge which also acts as a packing between the rafter members.

The two previous examples of bolted and connectored trusses are designed for self-supporting sheet coverings. Tiles, slates and similar coverings commonly used in domestic work require a substructure of battens supported by common rafters at 400 mm to 450 mm centres. A form of connectored truss for this type of work developed by the Timber Research and Development Association is illustrated and is essentially a pair of framed common rafters thus eliminating the need for separate principal rafters. The rafters of the truss therefore lie in the same plane as the adjacent rafters and the purlins, as a result of this, lie below the truss rafters and not on their backs as in a normal truss.

BOLTED and CONNECTORED TRUSSES



Double sided round toothed plate connectors

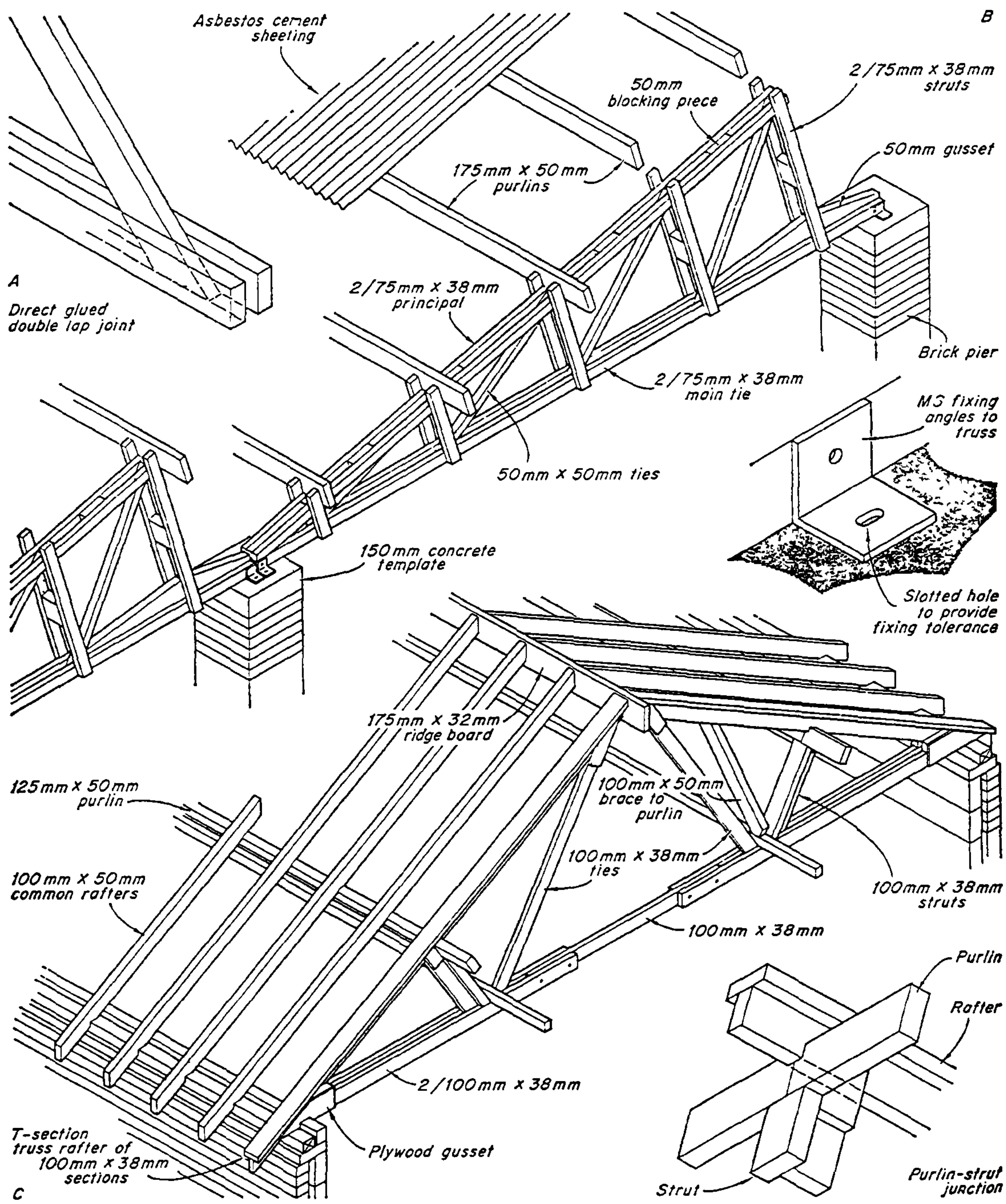
The truss is fabricated from single members, the joint between the rafters and main tie, which lie in the same plane, being made with gussets and the other joints by lapping the members. Binders to support the ceiling joists bear on the main tie near the lower nodes.

The trusses are designed to be placed not more than 1.8o m apart, that is at every fourth rafter where these are at 450 mm centres. The reactions at the feet are, therefore, not excessive and can be transferred adequately to the wall by the normal wall plate without a template or thickening of the wall. The example shown is for a span of 6.oo m.

(3) GLUED TRUSSES

Glues made from synthetic resins produce the most efficient form of joint, as strong as or even stronger than the timber joined, and many are immune to attack by dampness and decay. With this type of joint it is necessary to plane smooth all contact surfaces, and the necessary pressure during setting of the glue is provided by cramps or by bolts or nails which act as cramps. These are usually left in position.

(3) GLUED TRUSSES



9· ROOFS compiled: D·VOLKE OCT '79	PITCHED ROOFS	BUILDING CONSTR. — LECTURE — CET 5031 / 19.437
TCA TECHNICAL COLLEGE ARUSHA CHUO CHA UFUNDI ARUSHA	CIVIL ENGINEER. DEPARTMENT	37

GLUED TRUSSES

The members may be glued directly to each other using lapped joints or single thickness construction may be used by the adoption of gussets. As with nailed joints, in certain cases lapped members may not provide sufficient gluing area even with double lapped joints and gussets mast then be used to provide this.

An example of direct gluing is shown in the small 'nothlight' truss of 5.2o m span in figure in which single diagonal ties are sandwiched between double rafter and main tie members and the struts are formed by two thin members glued on the outside faces of the truss. This enables 'centre line' set-out of the members to be adopted. It should be noted that the two longest struts are packed out at the middle point to give increased stiffness to these compression members. Three nails driven in prebored holes act as cramps to each joint during setting of the glue.

Gluing not only produces very strong joints which result in quite small members, but also a very rigid structure which makes the truss easy to handle in transporting and fixing.

An example of a glued and gusseted truss is shown. This is a factory made, standardised truss framed from 38 mm thick members, fabricated in two halves and requiring only site holding of the main tie and site nailing to the ridge board. Rafters, struts and diagonal ties are single members joined by gussets, the compression members being formed into T-sections to stiffen them against buckling by the addition of 38 mm 'tables' glued and nailed on. Those to the struts form seatings for the purlins which lie below the rafters, so that the latter act also as common rafters.

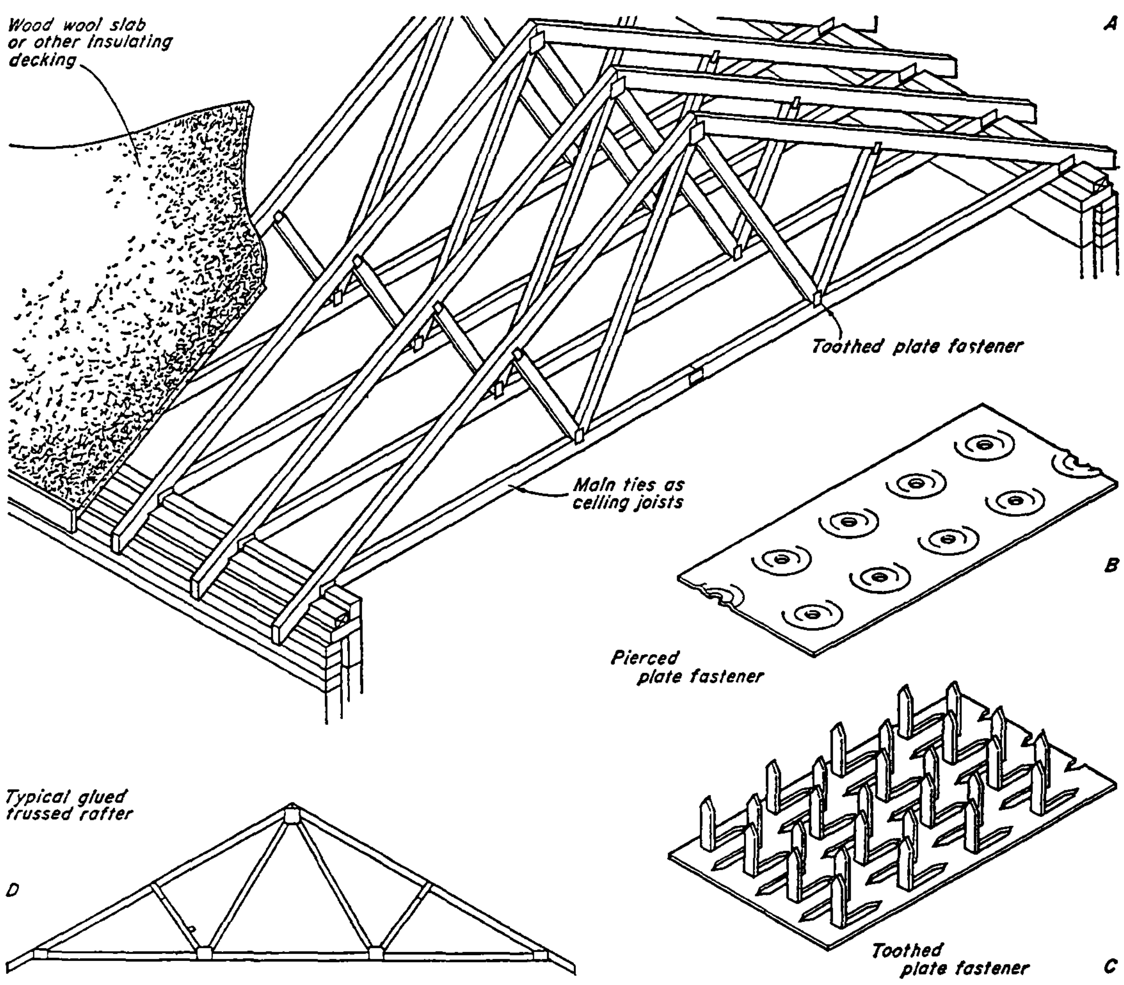
The main tie is partially of double members between which struts and diagonal ties are sandwiched and secured by direct gluing. To provide greater gluing area the lapped joints between rafter feet and tie are packed out to allow the application of plywood gussets on each side.

These trusses bear on the normal wall plate and are designed to be spaced up to 3.90 m apart for spans from 4.5 m to 9.om

8. TRUSSED RAFTERS

VIII TRUSSED RAFTERS

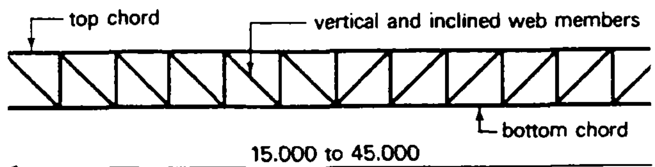
In recent years in domestic work there has developed the practice of triangulating or trussing every pair of rafters in roofs over spans which would normally require purlin construction, thus dispensing with purlins. There are a number of reasons for this, not the least of which has been the development of factory production for this type of component and the simplicity and speed with which this form of roof can be erected. The economic value of trussing every pair of rafters rests on these considerations together with the fact that many newer forms of roof coverings permit low pitches resulting in short bracing members and the fact that the use of insulating dekking such as wood wool or compressed straw slabs, or larger tiling or slating battens, permits the rafters to be placed



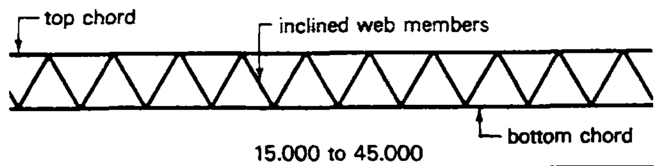
at 600 mm centres rather than the traditional 400 mm. This, together with the elimination of purlins and ridge board, reduces the timber content of the whole roof structure. These members are known as trussed rafters. It should be noted that since there are no purlins such a roof is a single roof construction.

Trussed rafters are fabricated from single thickness members jointed by gluing or nailing, using plywood or, in the case of nailing, punched metal plate gussets. Punched metal plate fasteners as they are usually called, fall into two groups.

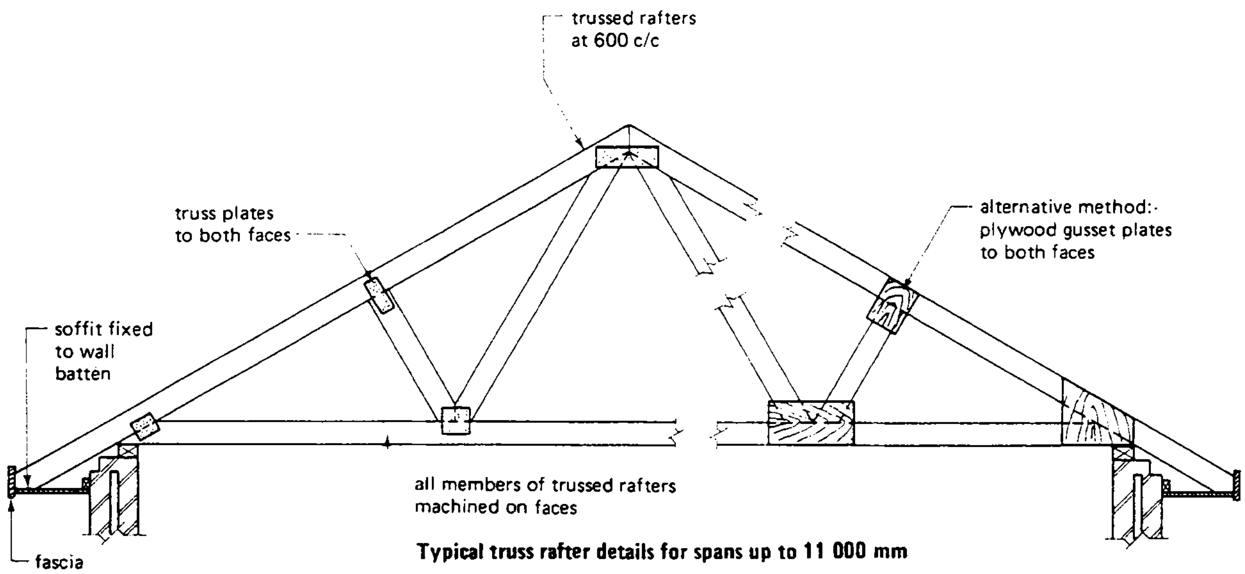
TRUSSED RAFTERS



Typical 'N' or Pratt truss



Typical Warren girder

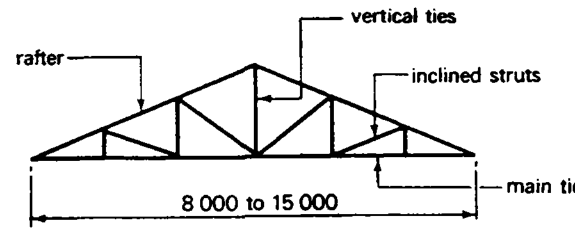


Typical truss rafter details for spans up to 11 000 mm

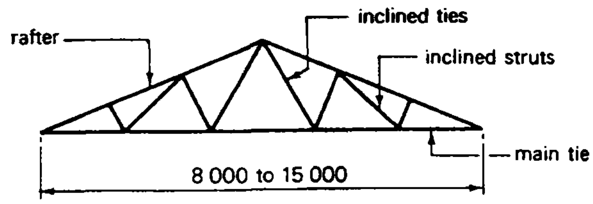
The use of low pitches, light-weight roof coverings and light-weight roof structures such as trussed rafters, by reducing the weight of the roof increases the danger of wind uplift and in these types of roof the necessity of adequate aucho-rages should be considered.

Firstly, a thin - gauge plate with holes punched regularly over its surface to receive nails, called a pierced plate fastener. Secondly a similar plate with teeth punched from the plate and bent over 90 degrees, called a toothed plate fastener, or connector. The latter, in which the teeth are an integral part of the plate, must be driven in by a hydraulic press or roller and are used in factory production since they are not suitable for site fabrication. The essential difference between a TRUSSED RAFTER and a ROOF TRUSS is that the former carries its own propartion of roof load directly on itself and only that load, wherease a truss carries the loads from a number of adjacent rafters via the purlins.

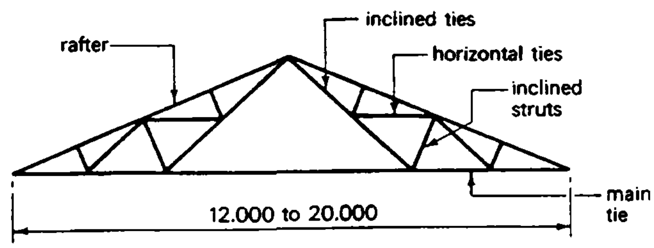
TRUSSED RAFTERS



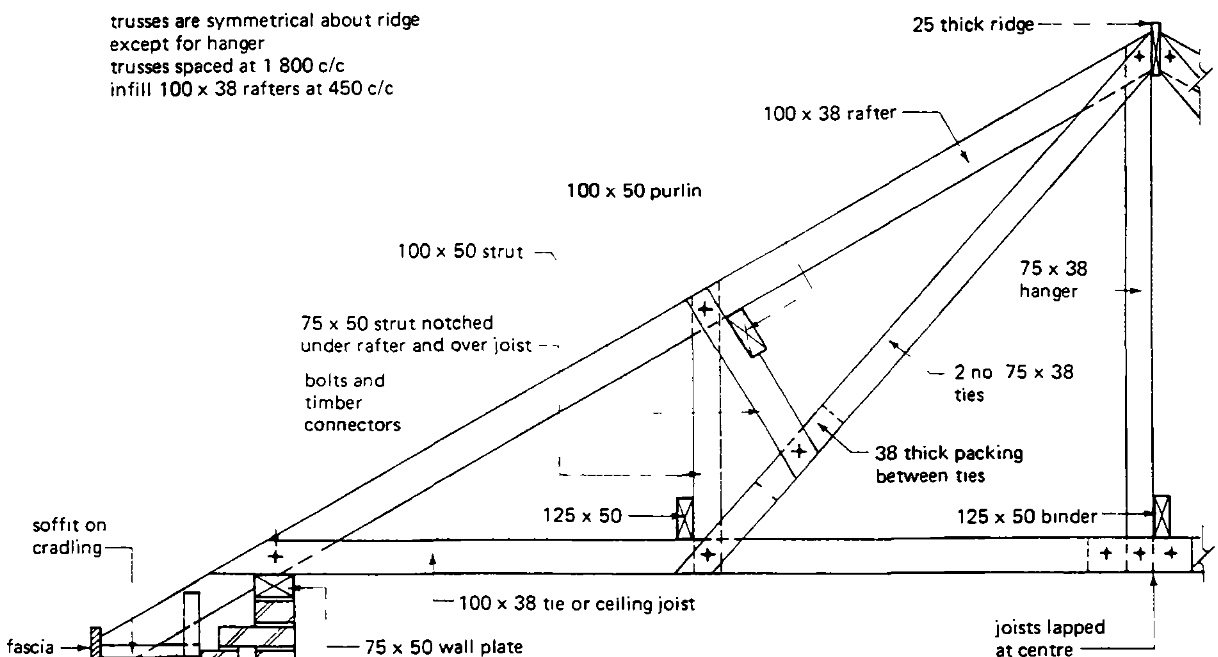
Typical Howe truss



Typical Fink or Belgian truss



Typical French truss



Typical truss detail for spans up to 8 000 mm

9.ROOFS compiled. D.VOLKE OCT. '79	PITCHED ROOFS	BUILDING CONSTR. LECTURE CET 5031/ 19.441
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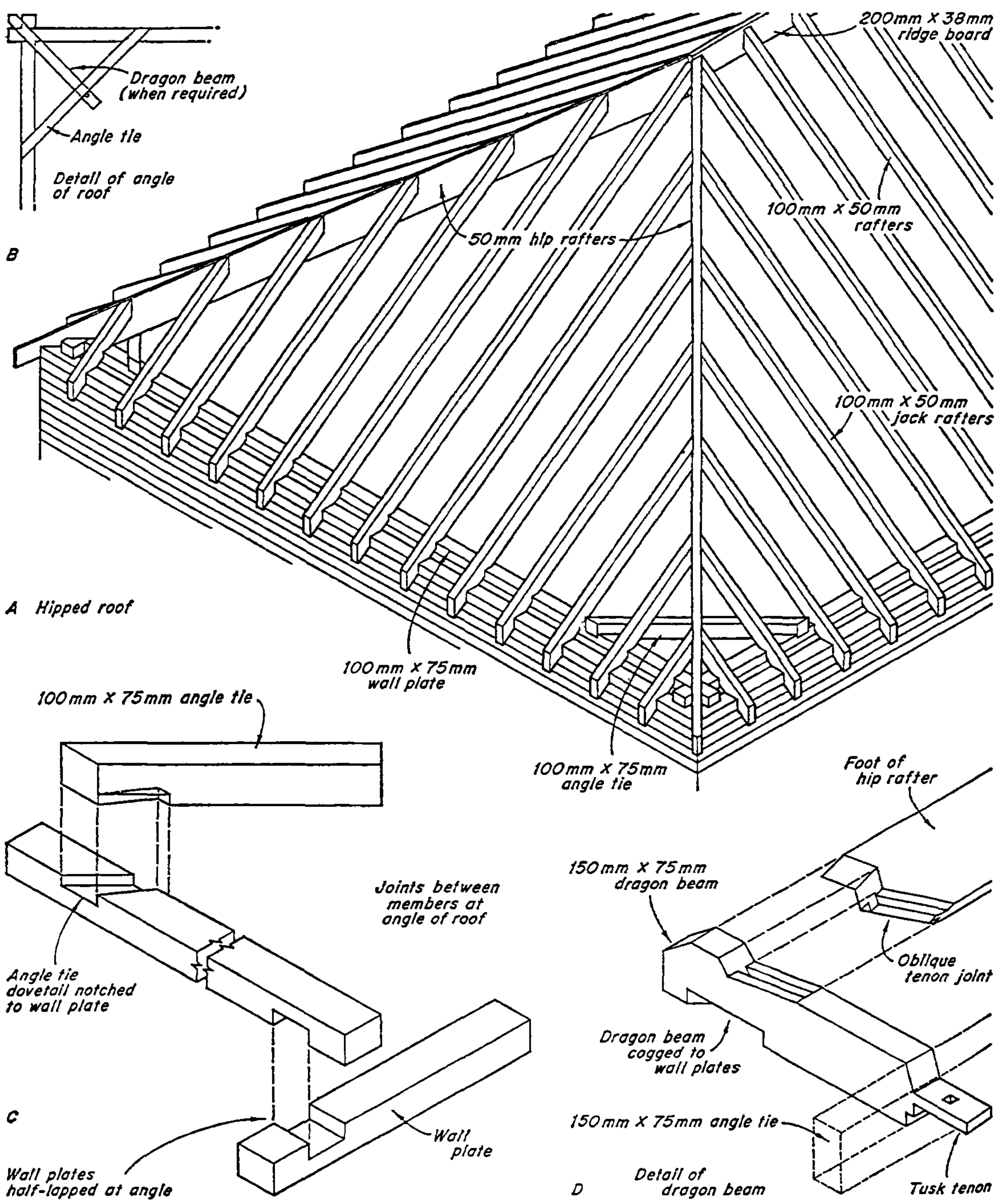
IX HIPPED ROOFS

A Hipped Roof is more complicated in its construction than a Gable Roof, necessiating SPLAY and SKEW cutting of all the shortened rafters at the intersections (called JACK RAFTERS) and the provision of a deep HIP RAFTER running from ridge



HIPPED ROOFS

to wall plate to carry their top ends (see fig.). The hip rafter transfers their loads to the wall plate and will, therefore, be 225 mm to 28o mm deep, depending upon its span and the depth of the rafters, and 38 mm to 5o mm thick. If the roof has purlins their ends will also be carried by the hip rafters which may then need to be 75 mm thick.

The tendency of the inclined thrust of the hip rafter to push out the walls at the quoin is overcome by tying together the two wall plates on which it bears by an angle tie dovetail notched or bolted to the plates (fig.). The foot of the hip rafter ist notched over the wall plates which are half-lapped to each other. If the rafter carries purlins causing a greater thrust more resistance to this is provided by the introduction of a dragon-beam as shown in the fig. linking the ends of the wall plates to the angle tie, which would be larger in size. The dragon-beam is cogged over the plates and tusk-tenoned to the tie. A dragon-beam will in any case be necessary to provide a bearing for the hip rafter when the eaves are sprocketed and the feet of the rafters terminate on the wall plate.

9.44 VALLEY

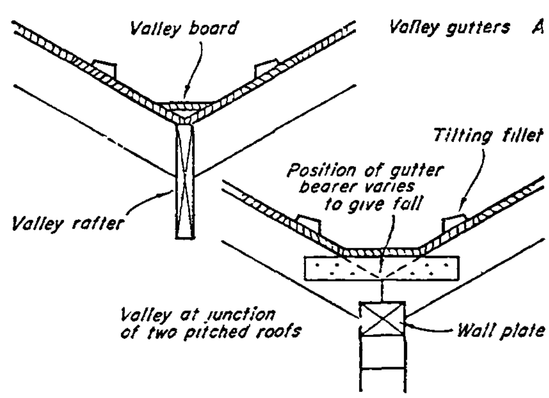
VALLEY

when the plan shape of the building breaks out or returns the intersection of the roof surfaces results in a junction having an external angle less than 180 degrees which is called a valley (the hip has an external angle greater than 180 degrees) As at a hip jack rafters occur. These run from ridge to valley and their feet are nailed to deep valley rafters the function and size of which are the same as those of the hip rafters

If returns and projections produce roof spans equal to that of the main roof the valley rafters will extend to the ridge where they will gain support as in. If, however, a projection is less in span the valleys will not meet the main ridge, and a support to the tops of the valley rafters and the lower ridge board must be provided in the roof space. If the width of the projection is small valley rafters may be omitted and all the rafters of the main roof be carried down full length on to a suitable bearing with boards laid on them to take the end of the ridge board and the feet of the jack rafters to the projection.

A valley is finished with a triangular timber fillet or a valley board, as shown in the fig. depending on the width required by the nature of the junction between the roof covering on the two slopes.

It will be seen that the plan shape greatly affects the roof construction and when designing a building which is to be covered with a pitched roof the implications of the plan in this respect must be borne in mind. The simple rectangular plan results in simple and relatively cheap roof construction; one in which breaks and returns accur, especially if they are numerous, may result in most expensive construction. This applies not only to the structure itself but also to the roof covereing



9.45 EAVES TREATMENT

EAVES TREATMENT

As with a monopitch roof, unless the roof is set behind a parapet. the eaves of a ridge roof may finish flush with or may project beyond the wall face, the former producing some economy in roof covering and timber, the latter providing some protection to the walls. Detailing of construction varies widely according to the pitch of the roof, the effect desired by the architect and whether an external or a hidden gutter is used. It is, therefore, possible to illustrate only some typical examples.

Examples of open projecting caves are shown in the figeres. With tile or slate coverings of any type the fascia projects as shown 19 mm oder so above the roofing battens in order to tilt the caves courses. Where no fascia is used as at a batten of greater depth than the boarding or battens, called a tilting - fillet, is used at this point.

Also closed projecting eaves are shown in the figure. The variation in detailing necessiated by increased projection can be seen. The ends of the rafters are cut horizontally to provide some fixing for the soffit boards (C), but as a considerable portion of the boarding is not supported by the rafter, soffit bearers are fixed to the rafter ends as shown. The back of the fascia should be grooved to take the edge of the soffit. Greater projections necessitat longer soffit bearers and brackets are then required to support heir inner ends as shown in (D). When plywood or asbestos cement sheet is used for the soffit, as is quite common, the fascia must be grooved to take the front edge and the back edge should be given continuous support by a fillet secured to the wall (E). In this case the soffit bearers can be fixed to this rather than to brackets from the rafters. If the roof pitch is not too great the soffit can be fixed direct to the rafters and, with a gable roof and projecting barge board, can continue up as the verge soffit. In this particular case the barge-board will be slightly less in depth than the fascia, but with a horizontal eaves soffit it must be deeper in order to cover the end of the eaves, in which case the outer and cantilever rafters which support it must be deeper than the common rafters or a thicker bargeboard must be used.

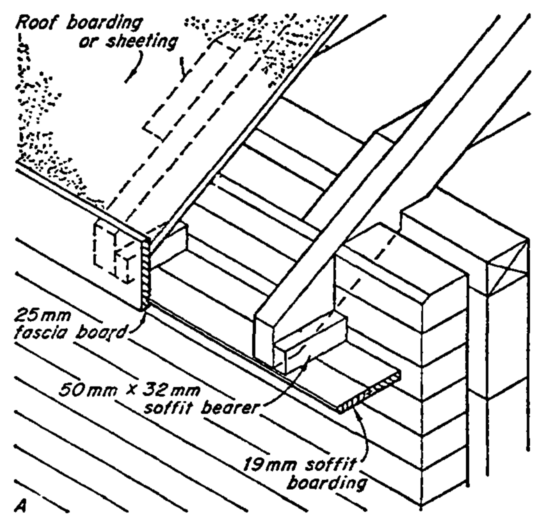
EAVES TREATMENT

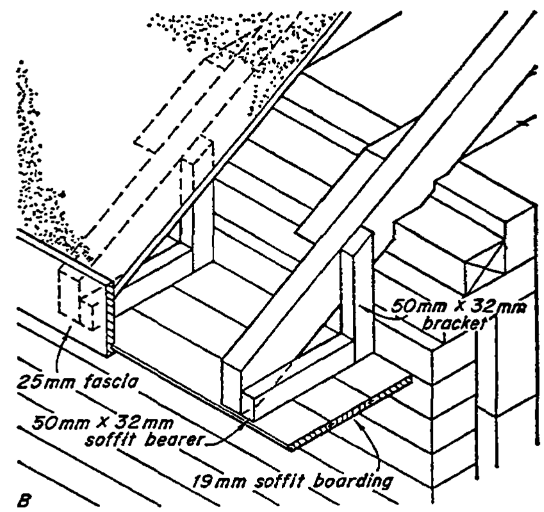
If a clear fascia, unobstructed by an external gutter, is desired an internal gutter may be formed. It is essential that the front edge of this type of gutter be at such a level that in the event of blockage of the outlet water will drain over the front rather than seep back into the roof structure and possibly into the building.

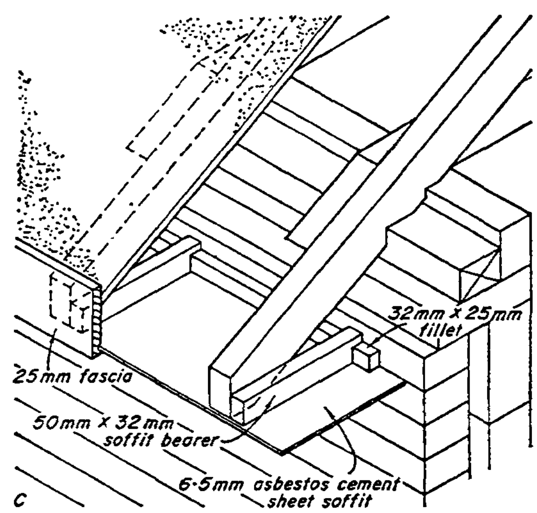
Roof ventilation should be ensured through closed eaves.

When a gable roof finishes with a plain verge, that is with no barge-board, the end of any form of closed projecting eaves must be boxed-in or be closed by the gable wall supported either on corbelling or on a springer. If the gable continues up as a parapet this is usually corbelled out for this purpose.

On wide, steeply pitched roofs the pitch may be reduced at the eaves in order to reduce the velocity of water during heavy rainfall and prevent overshooting of the gutter. This is done by means of sprockets which are short lengths of timber the same size as the rafters, fixed to the sides of the rafter feet as shown in figure or to the backs of the rafters if the latter run over the wall plate.



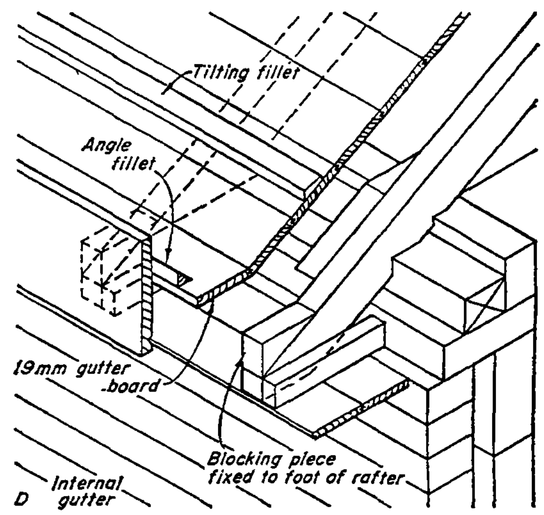


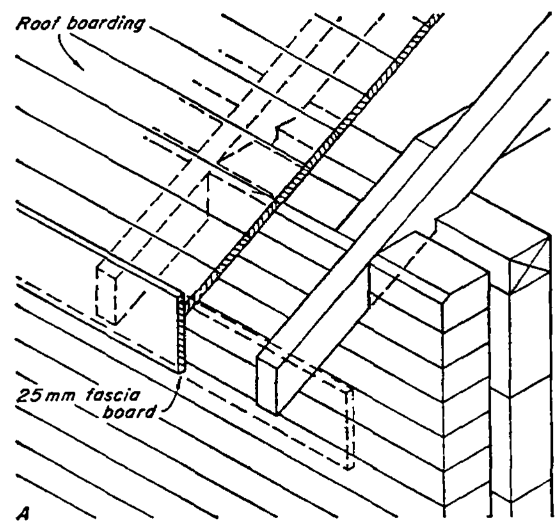


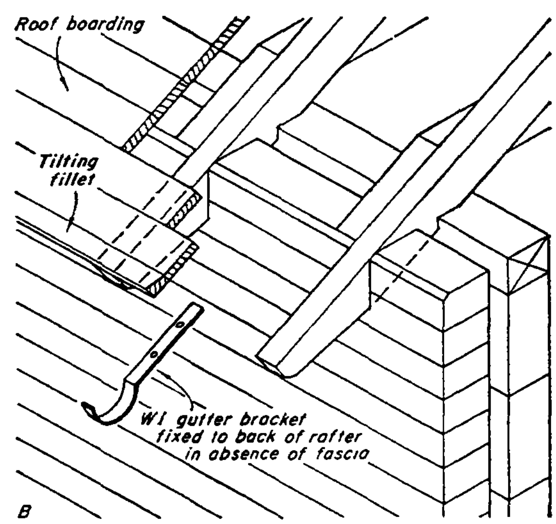
EAVES TREATMENT

The reduced pitch must, of course, not be less than the minimum angle necessary for the particular roof covering.

As an alternative to framing up a projecting eaves in the ways described above proprietary precast concrete eaves or gutter units may be used as for flat roofs, bedded on the head of the external walls. The shape of the unit spreads the roof load over both leaves of a cavity wall and over openings of limited span a back recess may be filled with concrete, together with reinforcing bars, to form a lintel. Behind a parapet wall a parapet gutter is framed up as shown in the figure by means of gutter bearers nailed to the rafters and carrying the gutter boards. The bearers are fixed at different levels along the wall to produce a fall to the gutter and as the level rises up the roof slope this results in a gutter which tapers in width on plan from a maximum at the highest point and is, therefore, termed a tapered gutter in contrast to the parallel or box gutter.





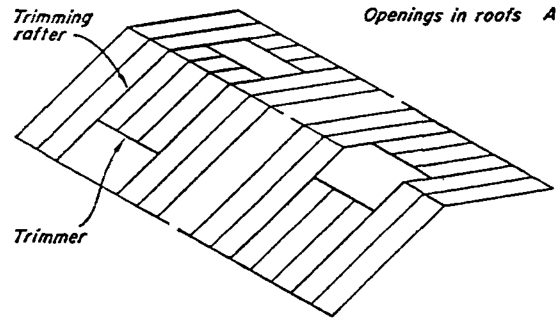


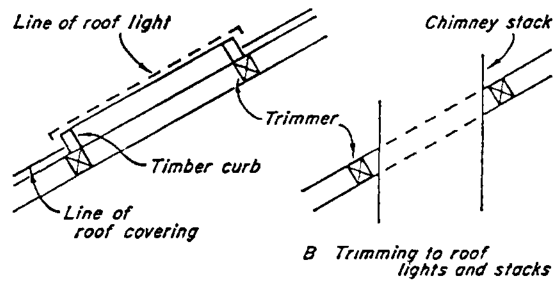
OPENINGS IN TIMBER ROOFS

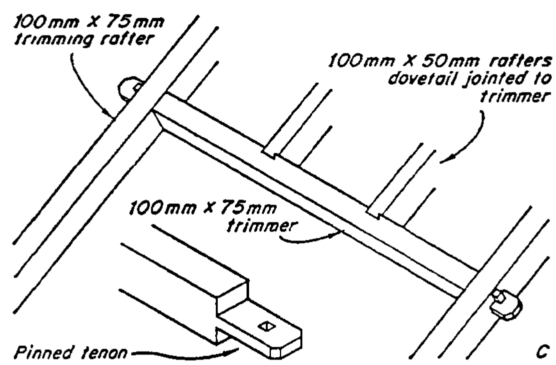
9.46 OPENINGS IN TIMBER ROOFS

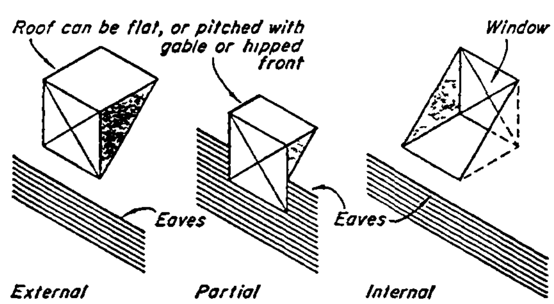
Roofs may be penetrated by chimney stacks and various forms of roof lights and, in pitched roofs, by dormer windows, for all of which openings in the roof must be formed. As in the case of floors and in a similar manner the roof is framed or trimmed to form such openings. Details of trimming to flat roofs are normally identical with those for floors.
In pitched roofs openings may be required at any point between eaves and ridge, or at the ridge, as shown in the figure. For stacks and skylights the trimmers are placed normal to the roof slope and are fixed to the trimming rafters by pinned tenons. This joint has an extended tenon and is secured with a wedge. The trimmed rafters are fixed to the trimmers by any of the methods described for floors.

Openings for roof lights are finished with a timber upstand or CURB as indicated in the figute which in a pitched roof, raises the light above the level of the roof covering and permits a watertight junction to be formed all round, and in a flat roof provides for a 150 mm upturn of the roof finish.









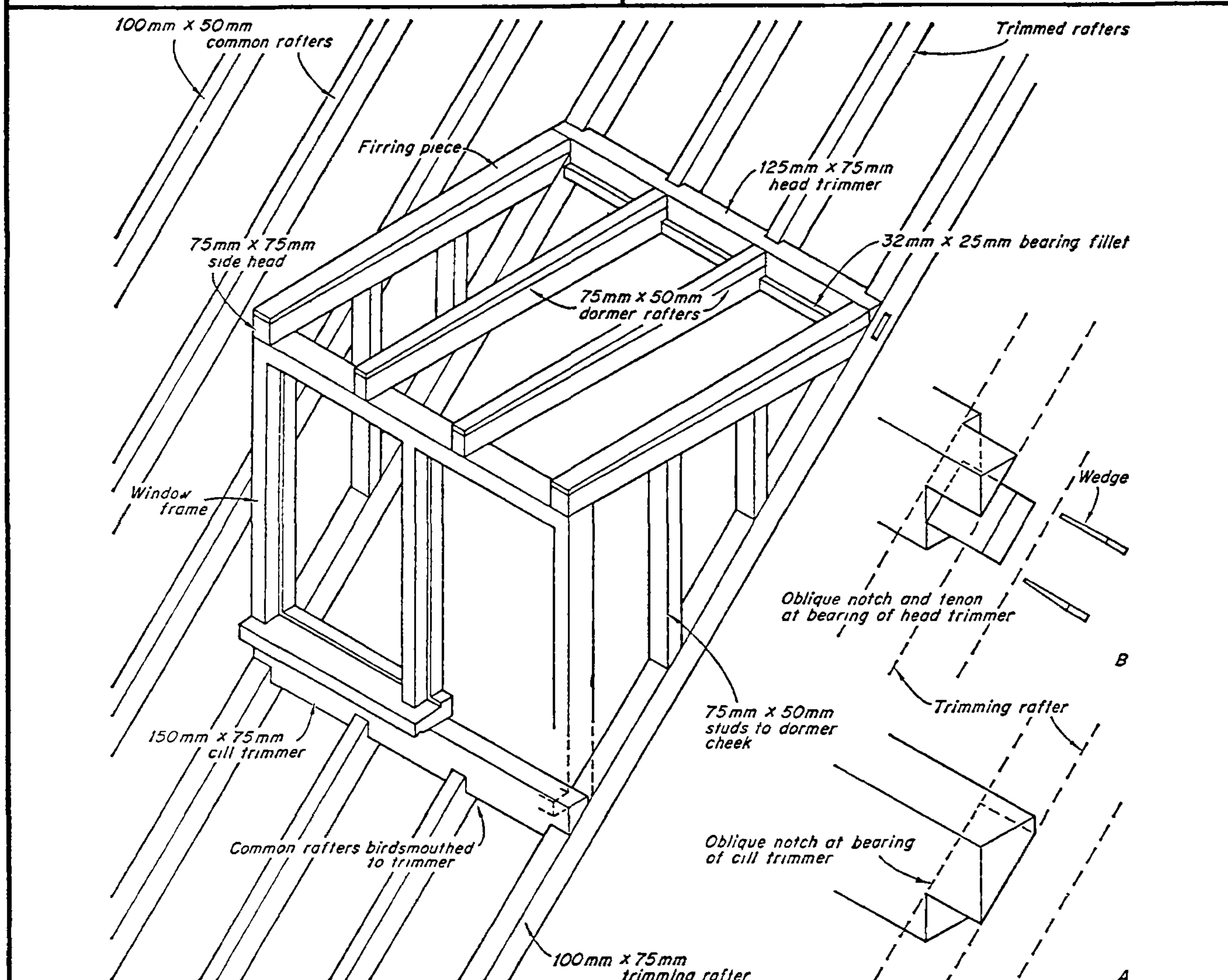
The positioning of trimmers for dormer windows varies according to framing requirements and is descussed below.

DORMER WINDOWS

DORMER WINDOWS

The dormer window is a vertical window set in the slope of a roof as distinct from a skylight which is parallel to the slope. It may take various forms as shown in the figure. The internal dormer which avoids a projection above the roof slope is less common and involves a small flat roofed area in front of the window.

For external dormer windows the lower or cill trimmer is fixed vertically to provide a seating for the dormer framework and window and to raise the window cill clear of the roof covering. It is 75 mm or 100 mm wide and its depth will vary with the roof pitch and the tape of roof covering. The top or head trimmer may be fixed vertically or normal to the slope. If the dor-



mer roof is flat a vertical trimmer provides a fixing surface for the boarding or other decking; if it is pitched a trimmer normal to the slope may be used and this simplifies jointing to the trimming rafters. The sill trimmer is oblique notched over the trimming rafters and nailed in position.
The vertical head trimmer is oblique notched and tenoned to them, the tenon being necessary here in order to resist the thrust from the feet of the upper trimmed rafters. In the case of a partial dormer there is no sill trimmer since the window sits directly on the wall below.

The traditional method of forming the dormer front was to frame up 100 mm by 75 mm side posts and head on the cill trimmer, the posts being tenoned or dowelled to the trimmer, and within this to set the window. Nowadays, unless the dormer is large, it is usual to make the head and mullions of the window frame large enough to act structurally to support the dormer roof and cheeks as shown in the figure. The cheecks are formed by a 75 mm x 75 mm side head running from the dormer front back to the trimming rafter against which it is splay

DORMER WINDOWS

cut and nailed, the spandrels thus formed being filled with 75 mm x 50 mm studs to which 19 mm t and g boarding is fixed externally. If the cheek is small studs can be omitted, the spandrel being covered with 25 mm boarding nailed to corner post and side head, running parallel with the roof slope.
The framing of an internal dormer varies slightly from this. The lower trimmer would be set vertically to form a front bearing for the flat roof below the window and the top trimmer set similarly to form a head over the window. Since neither may be notched over the trimming rafters, in order not to obstruct the roof covering, both must be tenoned into them. Two posts under the bearings of the top trimmer and running from floor to trimming rafters would support a cross bearer carrying the window and the members forming the flat roof.

9.5 ROOF COVERINGS

9.51 FUNCTION OF ROOF COVERINGS

ROOF COVERINGS

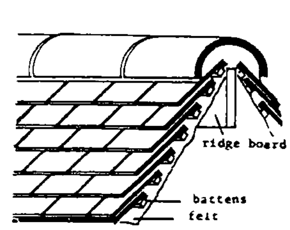
The function of the Roof Covering is that of a 'SKIN' - protection against weather.
In addition to that function the Roof covering has to be fire resistant and has to provide an adequate thermal insulation.

9.52 TYPES OF ROOF COVERINGS

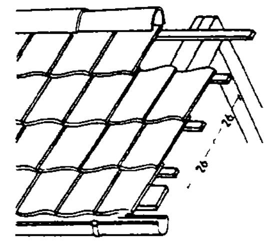
In accordance with the structure of the roof and the above mentioned functions there are different types of Roof Coverings.
A broad classification, comprising 5 groups, is:

1 Roof sealing
2 Table covering
3 Sheet covering
4 Scalloped covering
5 Thatch covering

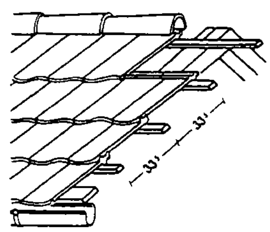
Depending on the SLOPE of the roof the type of Roof Covering has to be choosen. The above mentioned types of Roof coverings are comprising the following material:



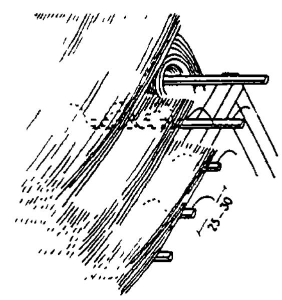
(5) Plain tile roof



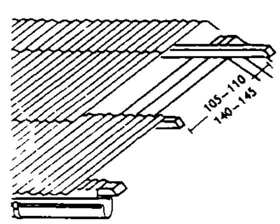
(6) Pantile roof (clay) 43 kg/m²



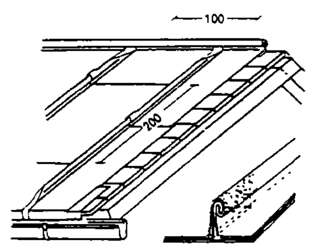
(7) Interlocking tile roof 42 kg/m²



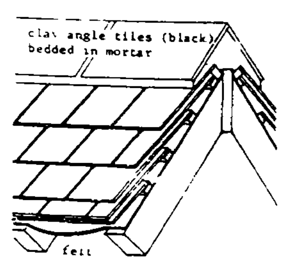
(8) Thatch roof 10 kg/m²



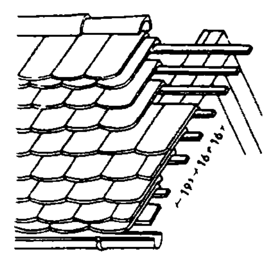
(9) Corrugated Eternit roof 17 kg/m²



(10) Metal roof 5.5-6.5 kg/m² (aluminium 2-3 kg/m²)



(11) Slate roof



(12) Double roof ('Doppeldach') 63 kg/m²

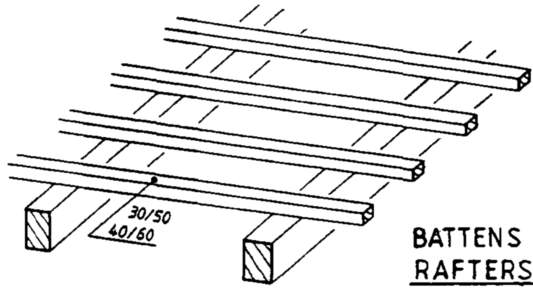
1 Roof sealing: - heat sealed plastic foils; - roofing felts, glued in different layers, sealed with bitumious paints. - reinforced with metal fails, etc.	ROOF SEALING
2 Table covering: - asphaltic or bitumious felts, glued or nailed in 1,2,or 3 layers. They are colled according to the weight of the raw-materials (333 g/m^2 or 500 g/m^2). The raw-felt is soaked with tar or bitumen and coated. Sand or chippings may be pressed on the surface of the felt as protection against mechanical loads and weather.	TABLE COVERING
3 Sheet covering: - Sheet metal (coated or galvanized) - galvanized corrugated iron sheets - corrugated aluminium sheets - corrugated asbestos sheets.	SHEET COVERING
4 Scalloped coverings: - Roofing (clay) tiles - Concrete tiles - Slates - Asbestos plain tiles (in different forms and shapes) - shingles.	SCALLOPED COVERING
5 Thatch coverings: - straw - dry grass, or hey - reed	THATCH COVERING

9.53 SUBSTRUCTURES

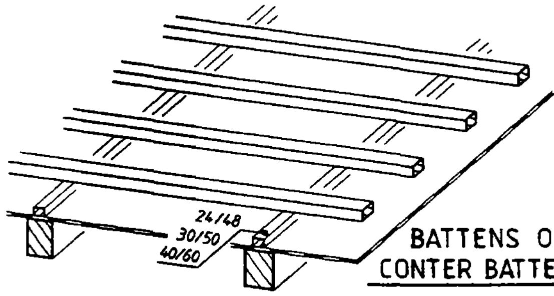
SUBSTRUCTURES

The Roof covering - 'the SKIN' - has to have an adequate substructure and has to be fixed on it, in order to avoid sliding or being taken away by the wind.

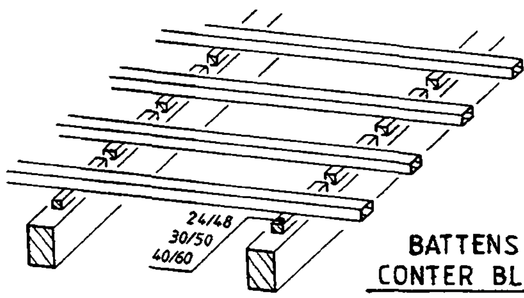
There are different types of substructures depending on the 'SKIN', covering the roof:



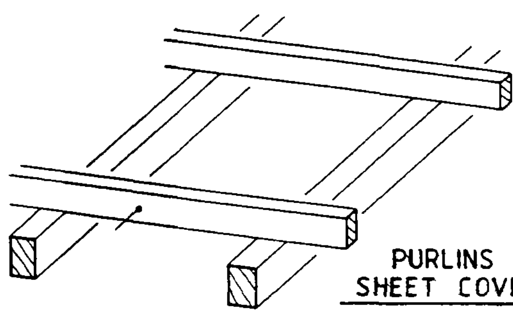
BATTENS ON RAFTERS



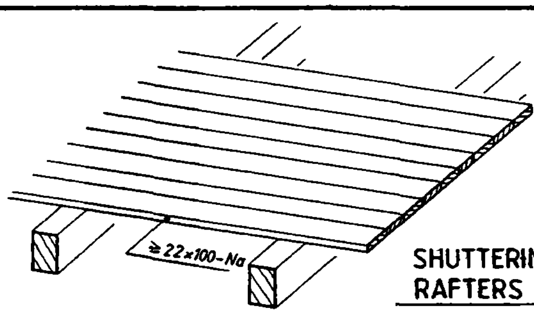
BATTENS ON CONTER BATTENS



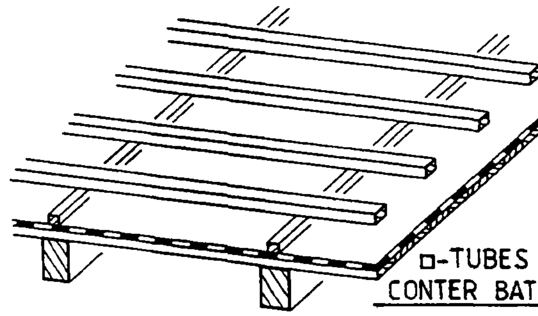
BATTENS ON CONTER BLOCKS



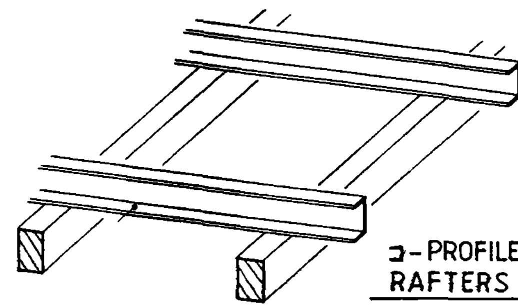
PURLINS FOR SHEET COVERINGS



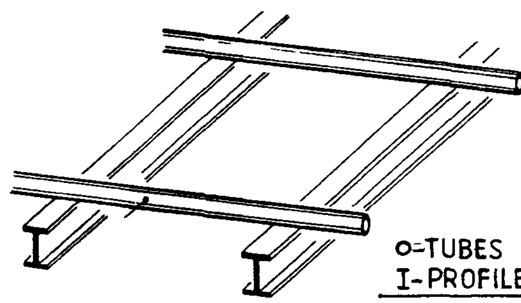
SHUTTERING ON RAFTERS



□-TUBES ON CONTER BATTENS



⊐-PROFILES ON RAFTERS

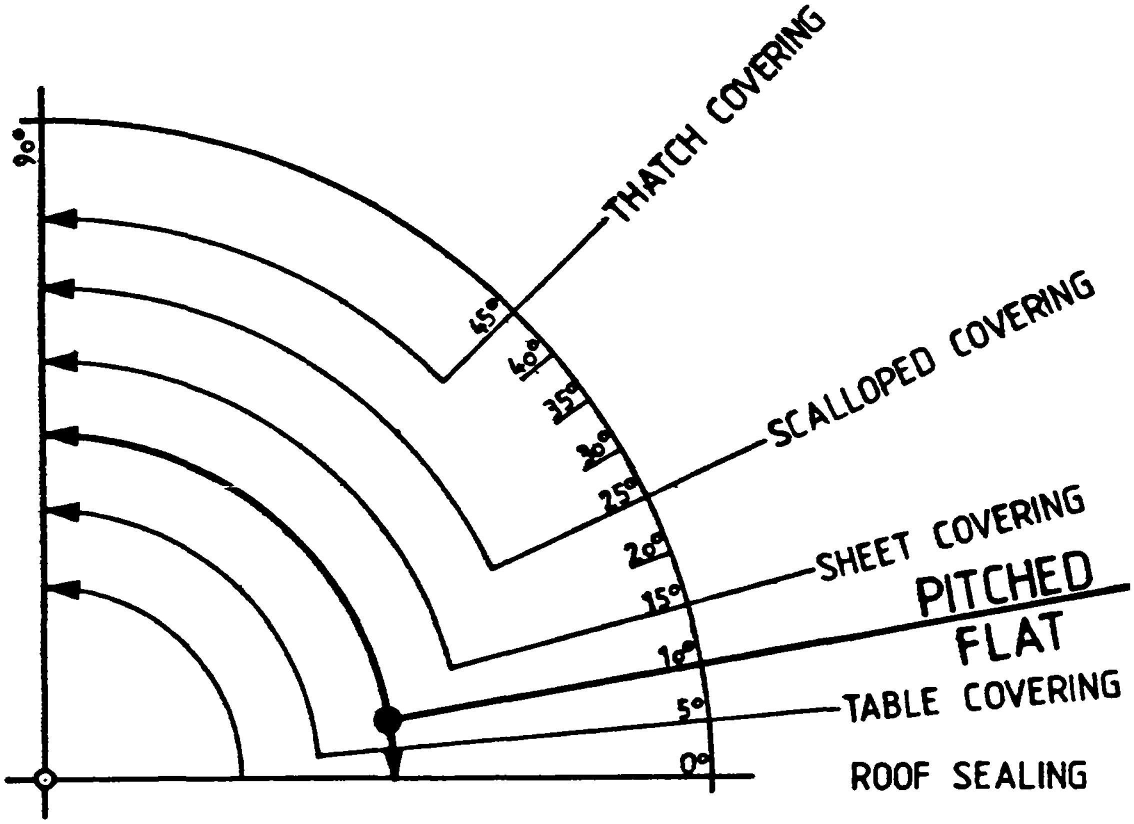


O-TUBES ON I-PROFILES

An additional provision to seal flat inclined roofs is the use of fibre-reinforced roofing felt or special plastic foils.

- The overlapp of such materials to be - 15 cm
- In order to get a proper cross-ventilation the material should hang loose between the fields of the battens.

9.54 CHOICE OF ROOF COVERINGS



9.55 MATERIALS AND COVERING METHODS

○ TABLE COVERING :

ASPHALTIC OR BITUMIOUS FELTS,
GLUED OR NAILED IN
1-, 2-, OR 3-LAYERS

1-LAYER TABLE COVERING

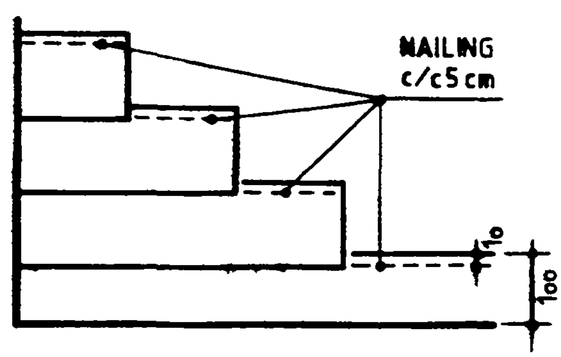
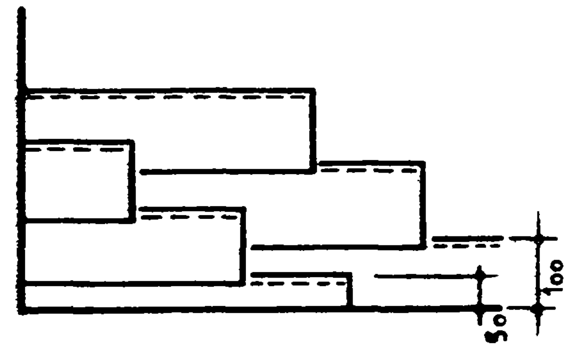
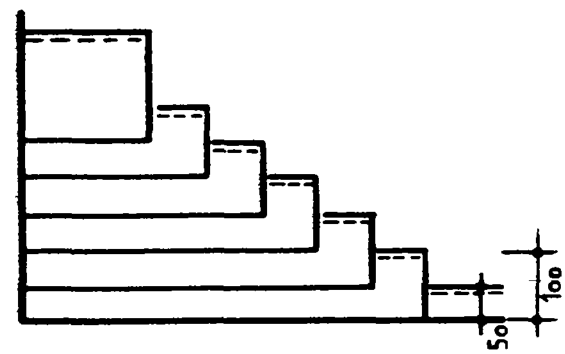
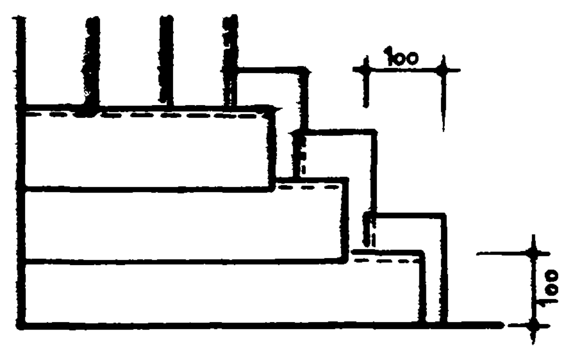


TABLE COVERING

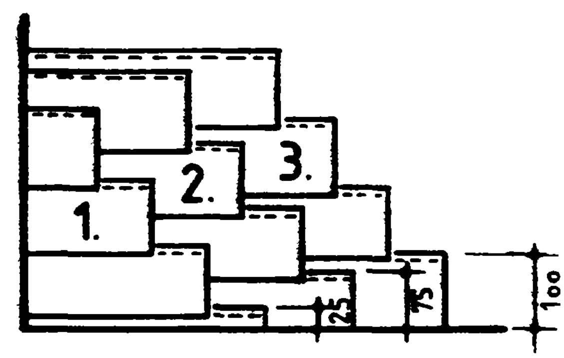
2-LAYER TABLE COVERING







3-LAYER TABLE COVERING



○ SHEET COVERINGS :

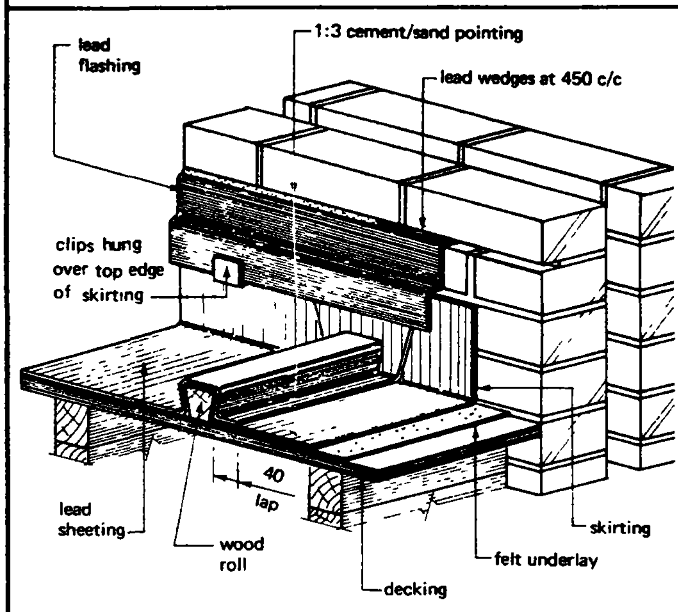
SHEET METAL COVERINGS

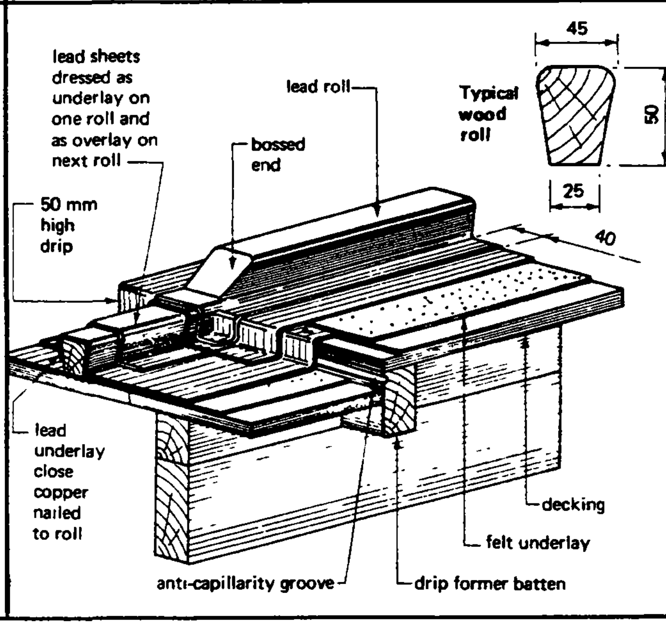
- Sheet metal coverings provide an excellent protection against wind and rain, is durable and lighter in weight than tiles, slates or asphalts.

  Metal roofs are noisy.

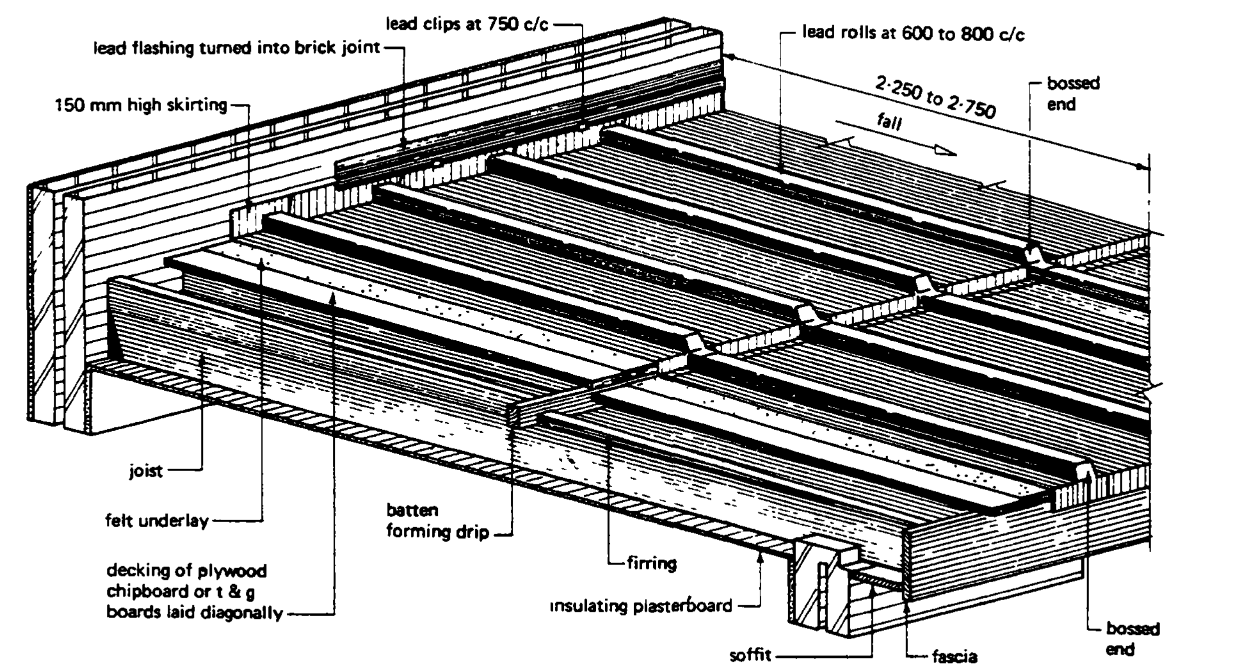
Four types of metals are used for sheet coverings:

1 Lead
2 Copper
3 Zinc
4 Aluminium

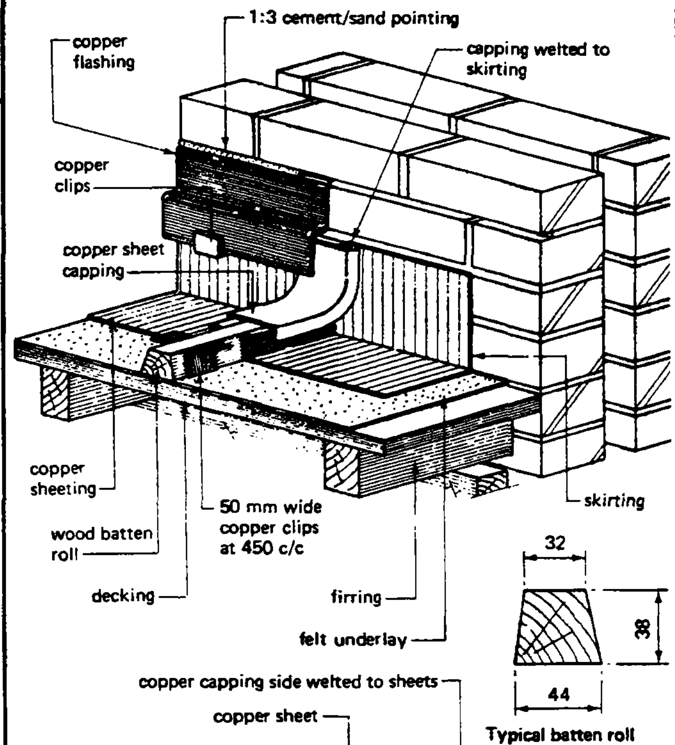


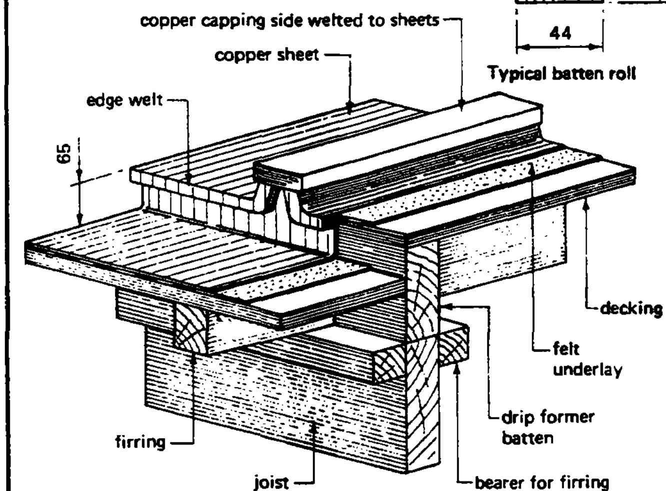


Lead

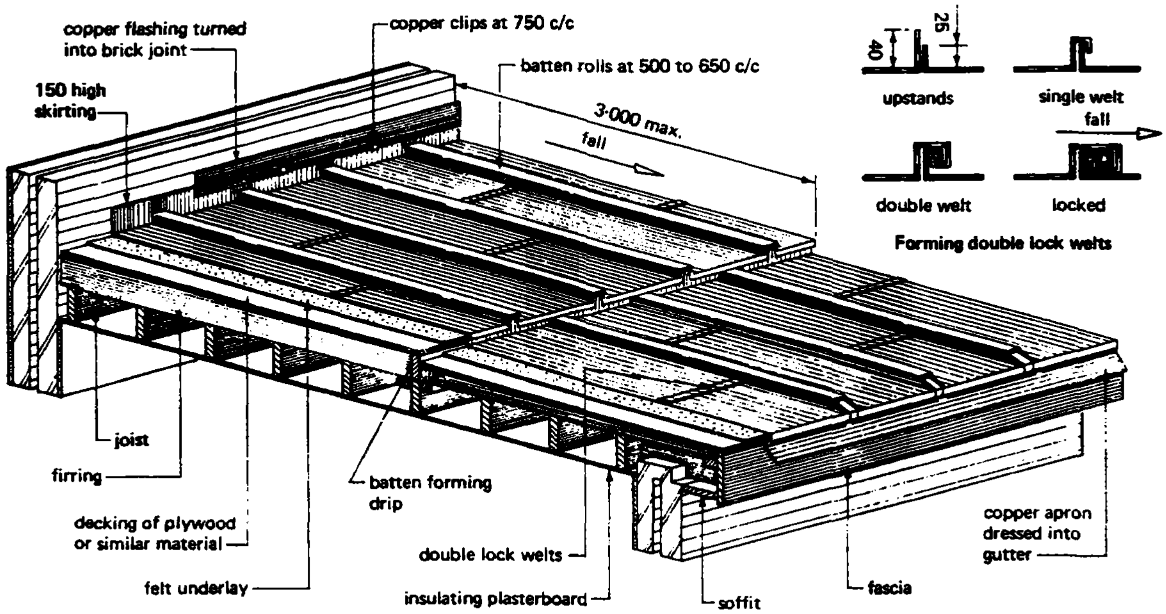


SHEET COVERING





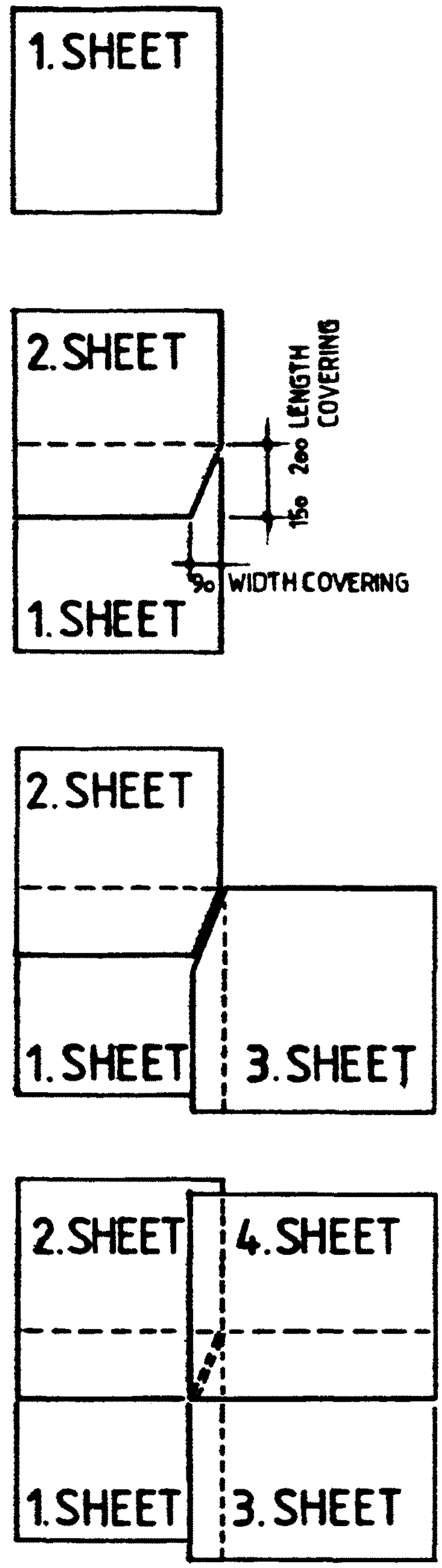
Copper



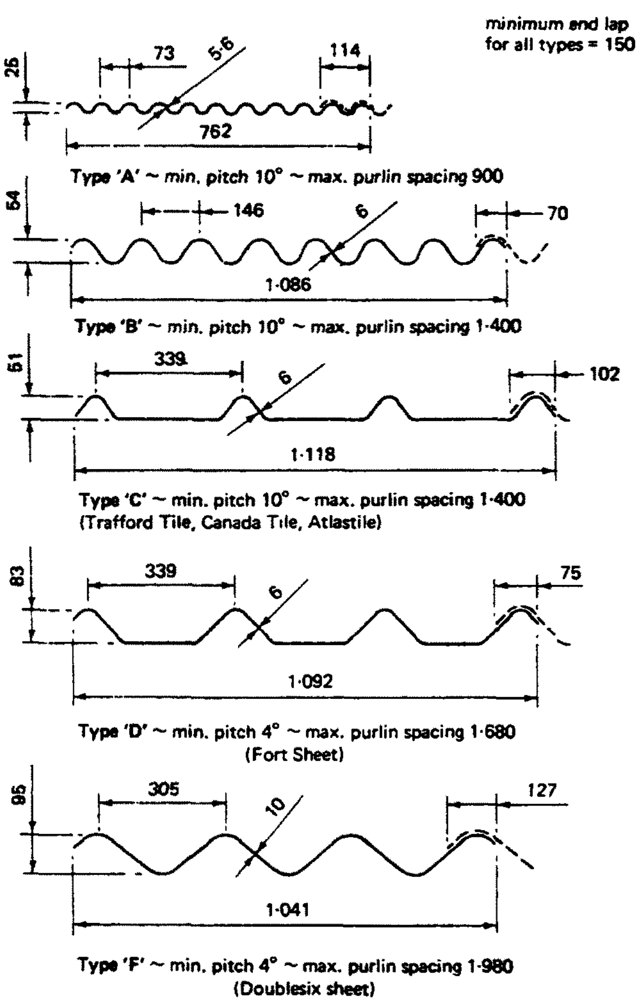
9. ROOFS compiled: D.VOLKE OCT. '79	ROOF COVERINGS	BUILDING CONSTR. —LECTURE— CET 5031/1 9.557
TCA TECHNICAL COLLEGE ARUSHA CHUO CHA UFUNDI ARUSHA	CIVIL ENGINEER. DEPARTMENT	57

SHEET COVERING

ASBESTOS SHEET COVERING :
LAYING OF THE
2. AND 3. SHEET
WITH CORNERCUT

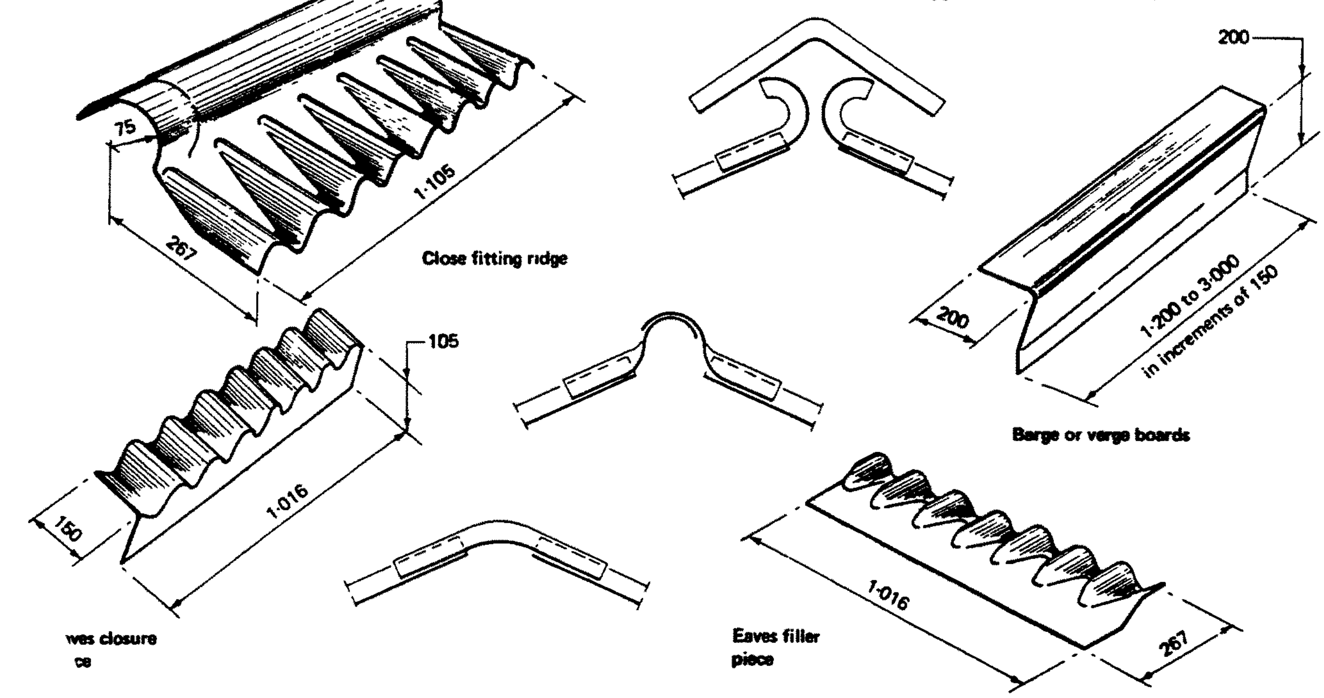


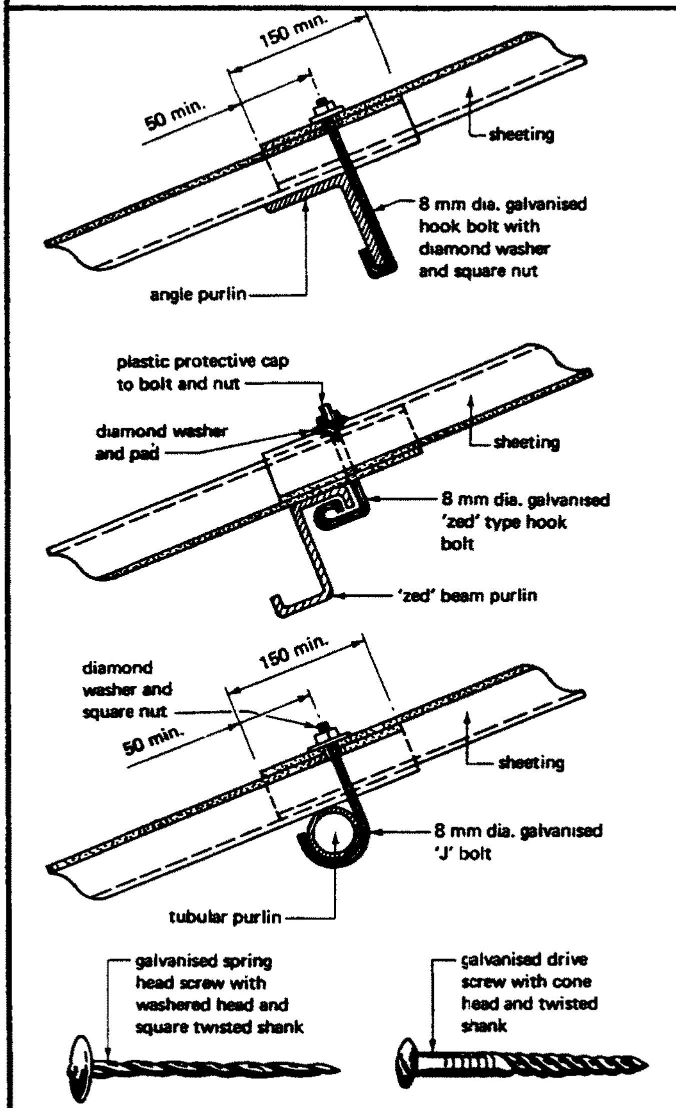
Typical asbestos cement sheet profiles



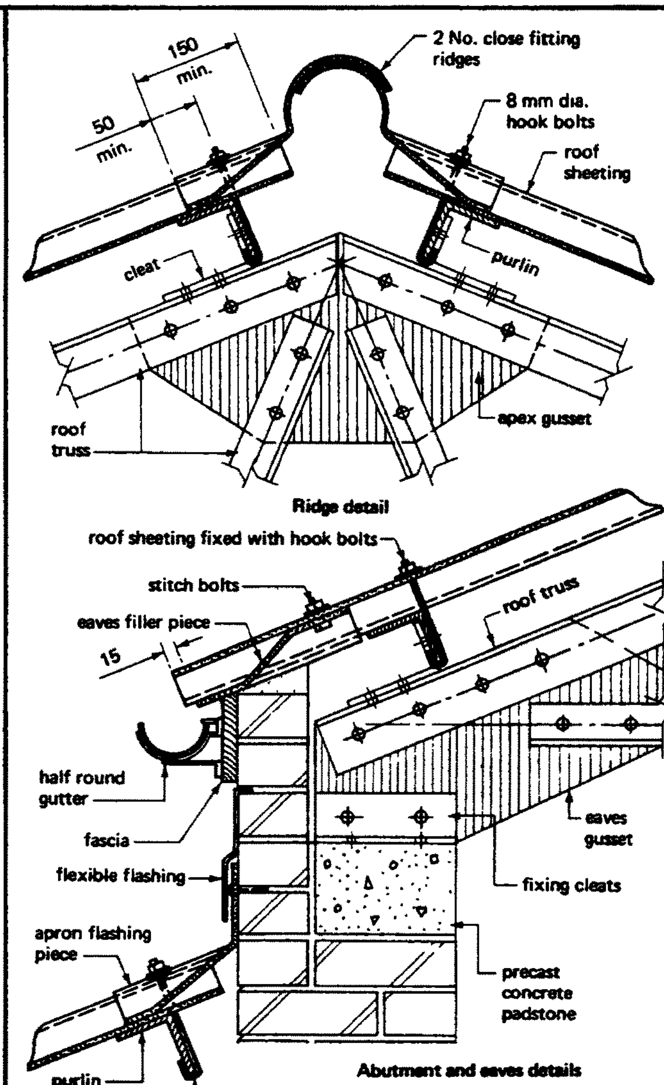
All sheets are available in lengths from 900 to 3·000 in 150 mm increments
For other profiles see BS 690

Typical fittings for type 'B' sheeting





Fixings for timber purlins



Typical asbestos cement roofing details

9. ROOFS	ROOF COVERINGS	BUILDING CONSTR.
compiled: D.VOLKE		LECTURE
OCT. '79		CET 5031/1 9.5 59

TCA TECHNICAL COLLEGE ARUSHA
CHUO CHA UFUNDI ARUSHA

CIVIL ENGINEER.
DEPARTMENT

o SCALLOPED COVERINGS

- Roofing tiles

a Clay tiles: Hand-made
machine-pressed

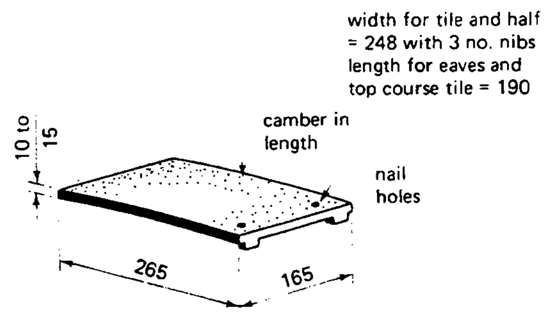
b Plain concrete tiles:(sand/cement/water, compressed in a mould) are uniform in texture, shape and colour.

<u>Nibs:</u>
either projecting nibs at one end of the tiles, or one continous nib, in order to secure the tiles to the sloping surface of the roof.

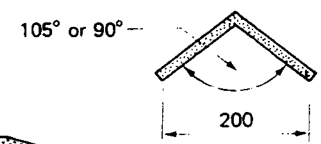
<u>Camber</u>:
the tiles are not perfectly flat, but have a slight rise or CAMBER in the back, to prevent water being drawn up between the tiles by capillary action.

<u>Gauge and Lap</u>:
plain tiles are hung so that at every point on the roof there are at least two thicknesses of a tile.
The sides butt together and these joints are bonded up the slope of the roof.
The tiles in every 4th course are nailed to the battens.
In very exposed positions every tile should be nailed to the battens.

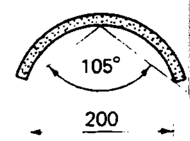
ROOFING TILES



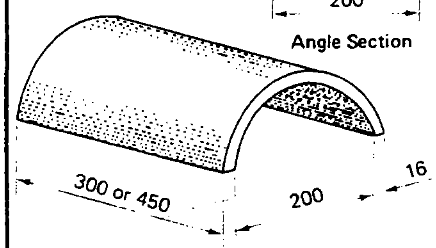
Standard Plain Tiles



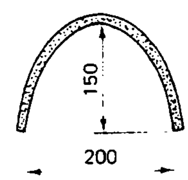
Angle Section



Segmental Section

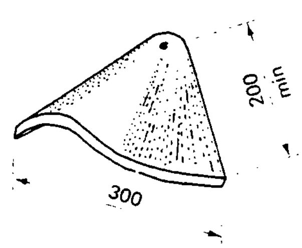


Half Round Ridge Tile

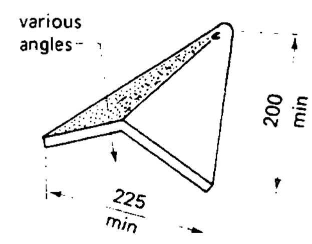


Hog Back Section

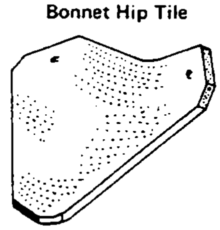
Typical Ridge Tiles

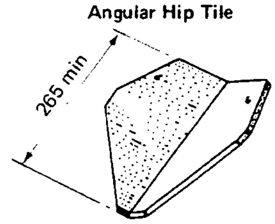


Bonnet Hip Tile



Angular Hip Tile


Curved Valley Tile

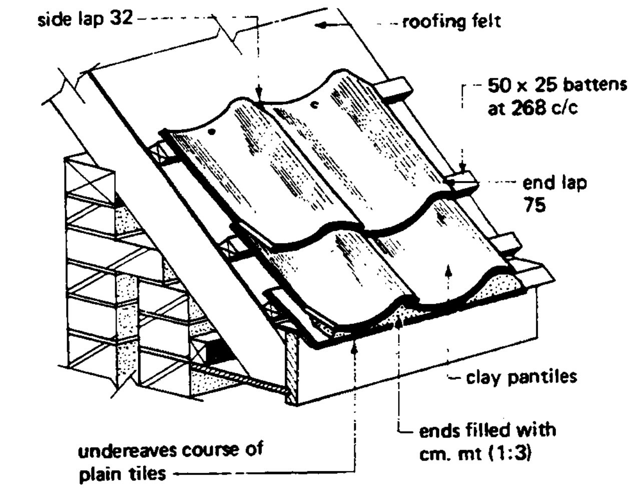


Angular Valley Tile

9 ROOFS compiled D VOLKE OCT '79	ROOF COVERINGS	BUILDING CONSTR LECTURE CET 5031/19560

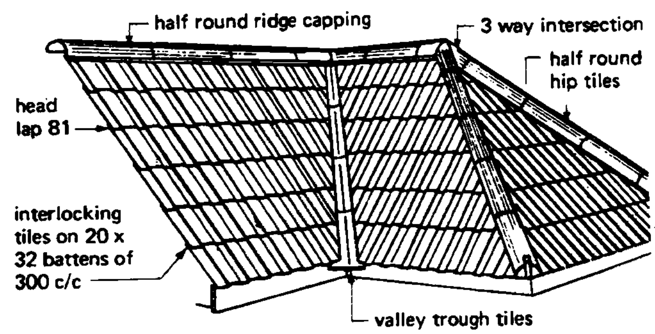
ROOFING TILES

PLAIN TILES ARE LAID TO DOUBLE LAP



Eaves:

A double coarse overhangs the fascia board some 40 mm. (in order to shed water into the eaves gutter)

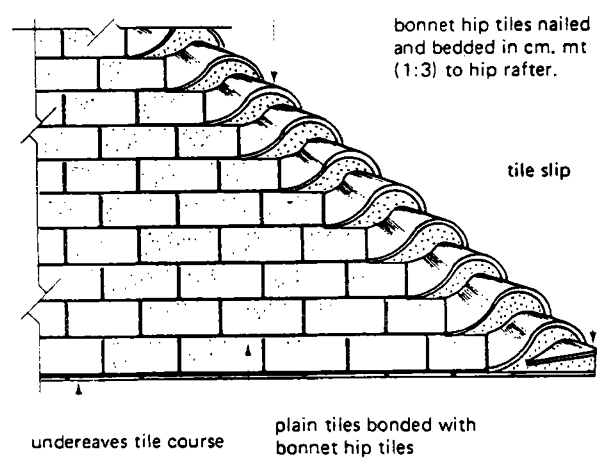


Ridge:

There are 4 standard sections of clay ridge tiles.

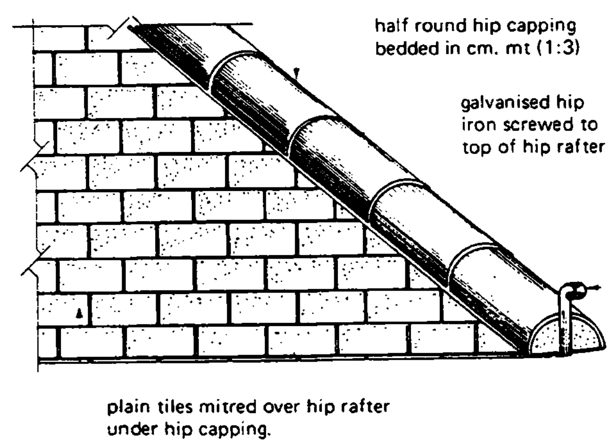
- Half round ridge tile
- Seginental ridge tile
- Angle ridge tile
- Hog back ridge tile

All ridge tiles have their edges bedded in fillets of cement mortar spread on the back of the top course tiles.



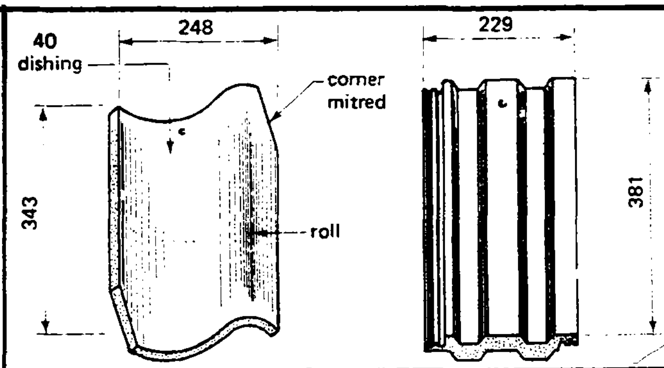
Hips:

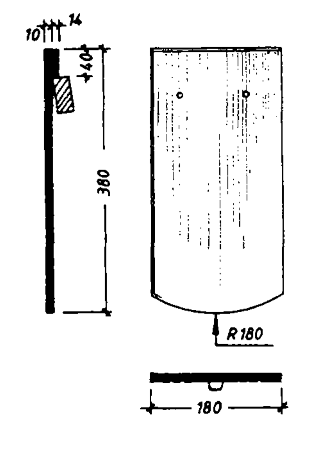
May be covered with ridge tiles bedded in exactly the same way as on ridges.
To prevent the tiles from slipping down, a galvanized iron or wrought-iron hip iron is fixed to the hip or fascia.
The tiles next to the hip have to be cut to fit against the side of the hip rafter so that they lie under the hip tiles.

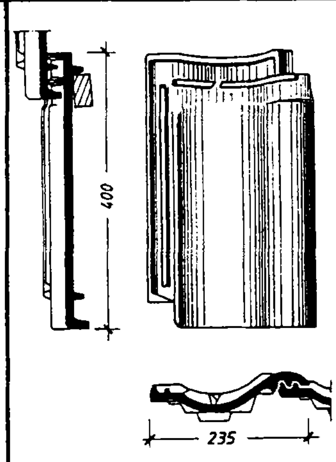


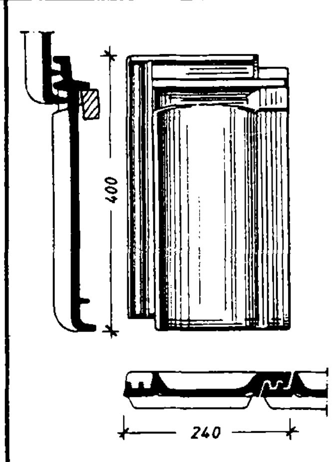
ROOFING TILES
DIFFERENT TYPES

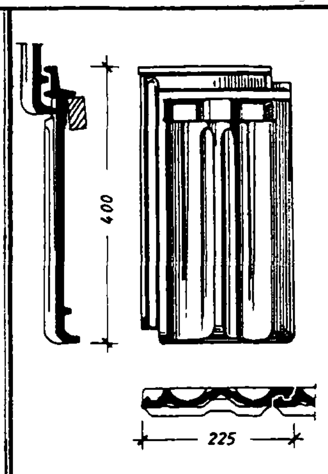
1 PANTILE
2 INTERLOCKING TILE
3 PLAIN TILE

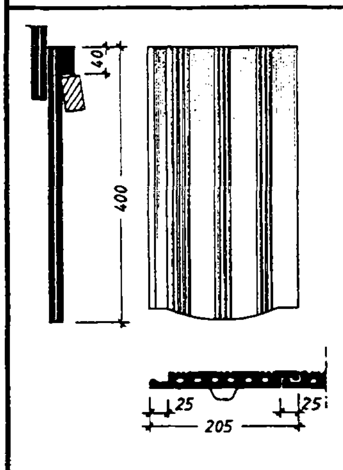


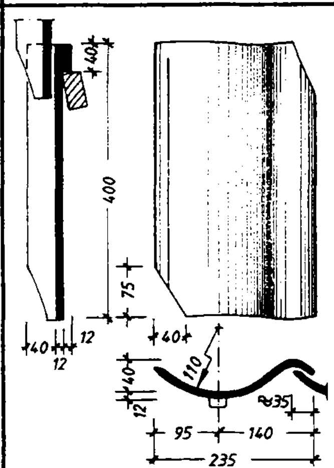


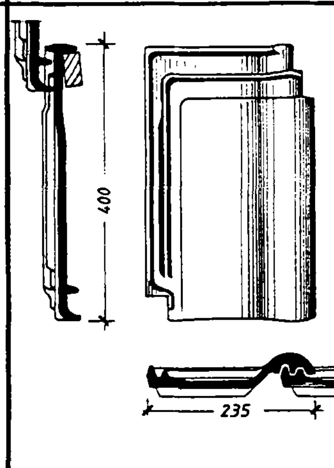


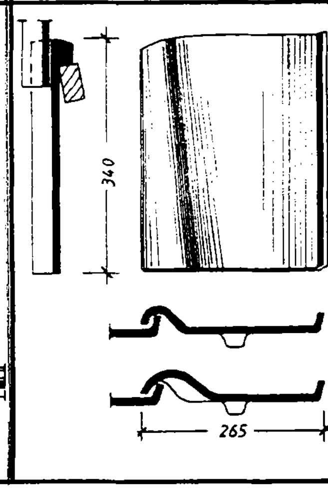


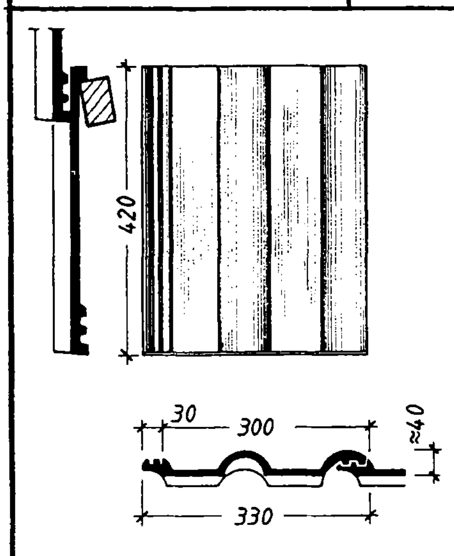


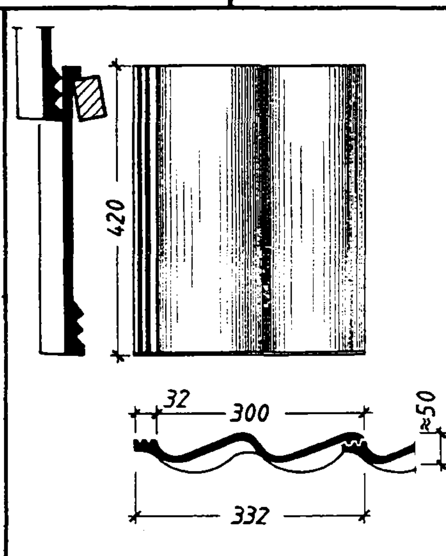






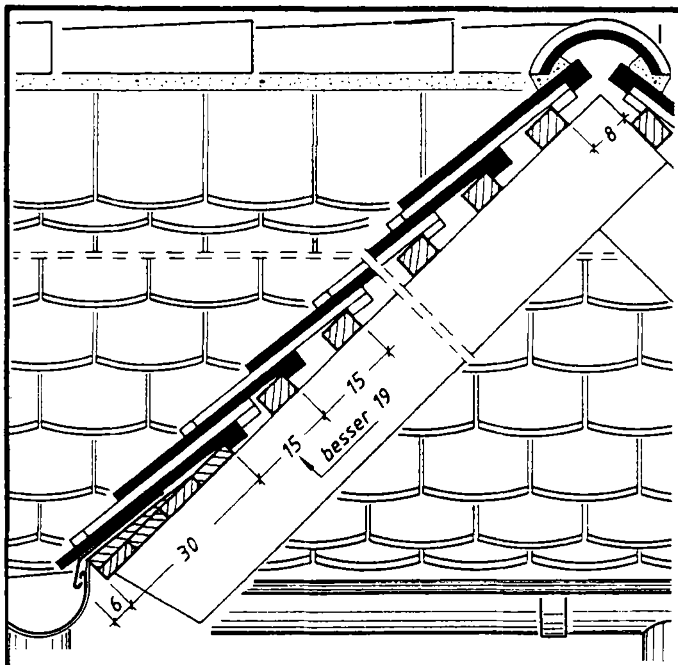




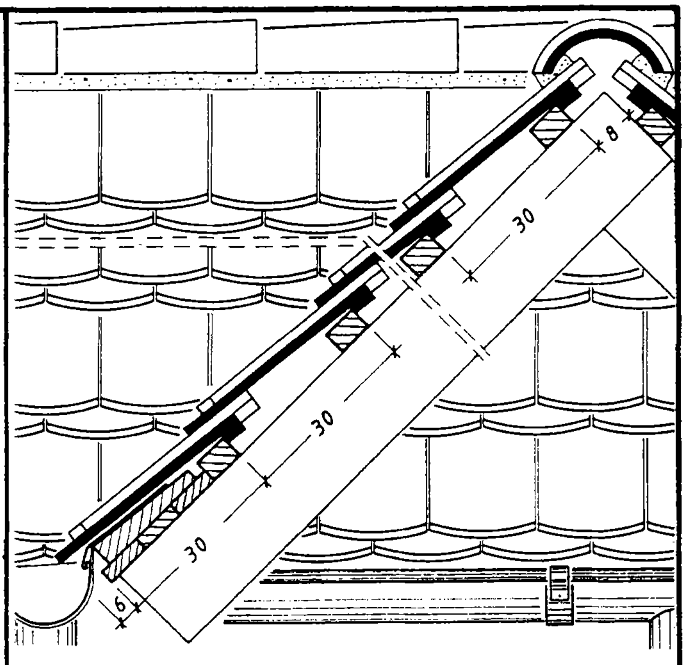


4 INTERLOCKING PAN
5 -- --
6 -- TILE
7 PLAIN TILE, INTERLOCKING
8 PANTILE (german)
9 FLATROOF PAN
10 S-TILE
11 'FRANKFURTER' PAN (concrete)
12 DOUBLE-S PAN (concrete)

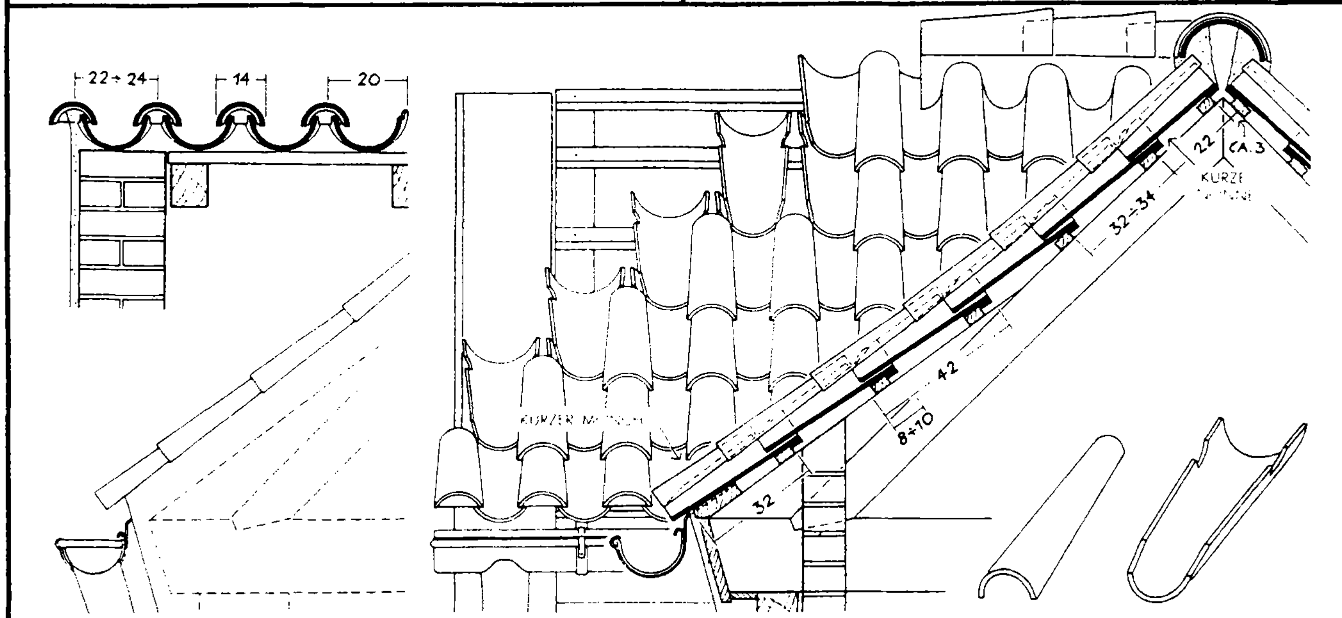
9. ROOFS compiled : D.VOLKE OCT. 79	ROOF COVERINGS	BUILDING CONSTR — LECTURE — CET 5031/1 9.562



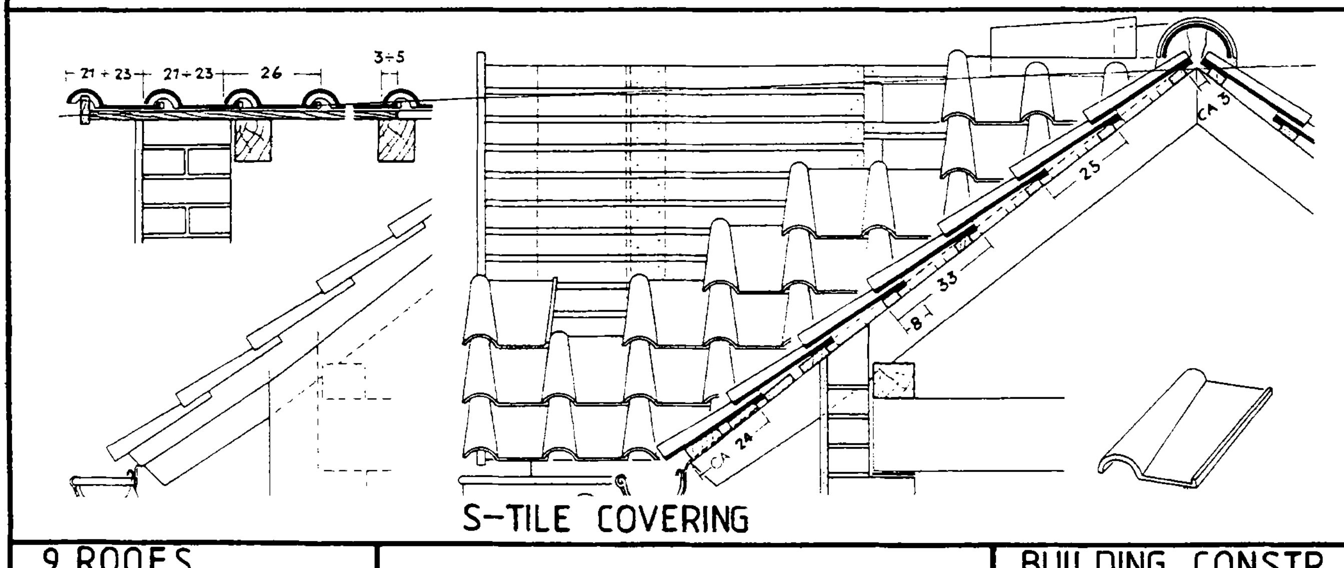
BEAVERTAIL DOUBLE COVERING



BEAVERTAIL CROWN COVERING



ROMAN TILE COVERING



S-TILE COVERING

9. ROOFS		BUILDING CONSTR.
compiled: D.VOLKE		LECTURE
OCT. '79		CET 5031 / 1 9.563

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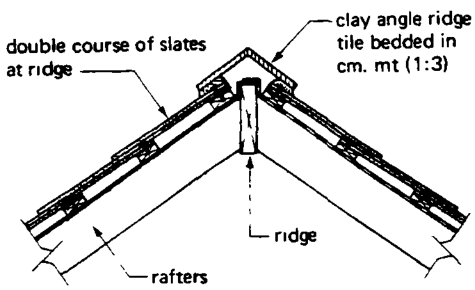
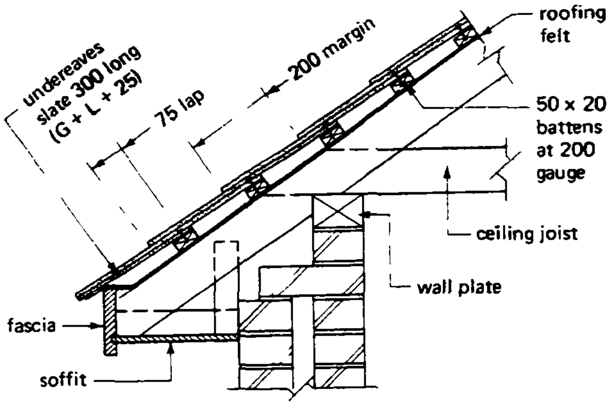
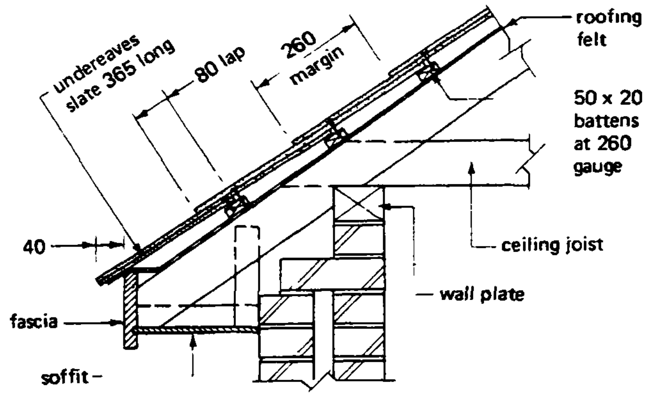
SLATES



Typical Ridge Detail

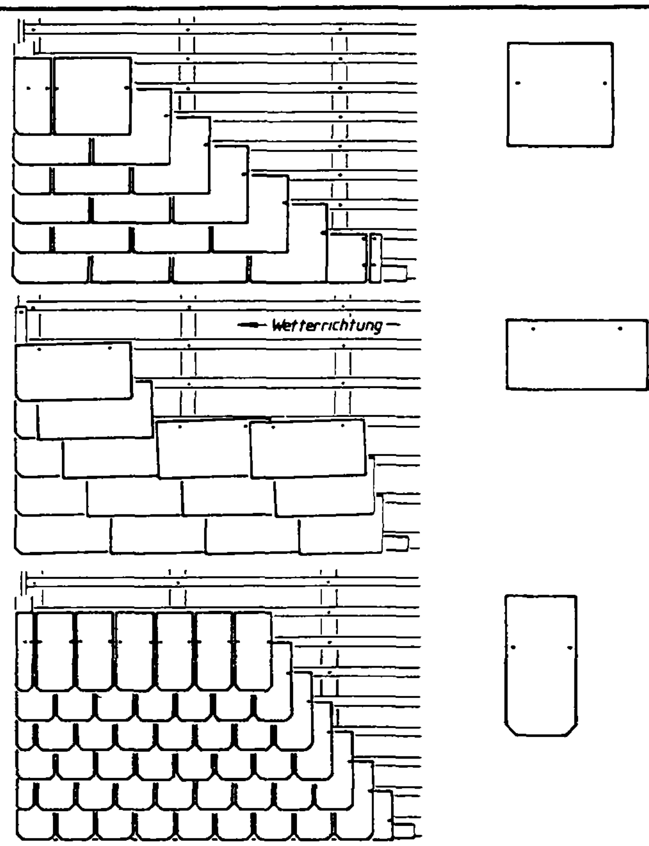


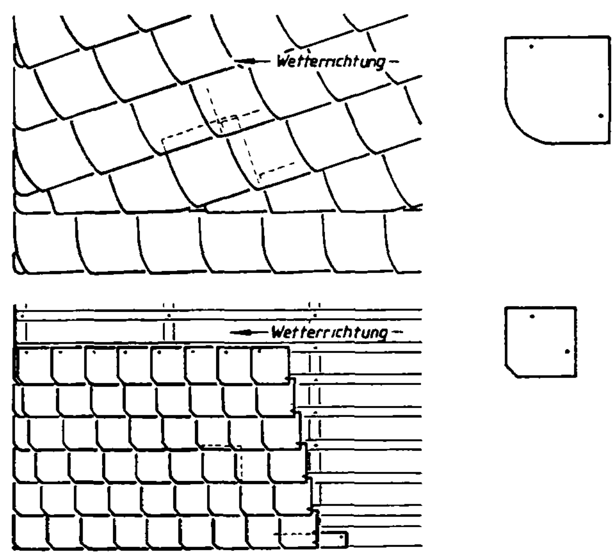
Head Nailed Slating Using 500 x 250 slates



Centre Nailed Slating Using 600 x 300 slates

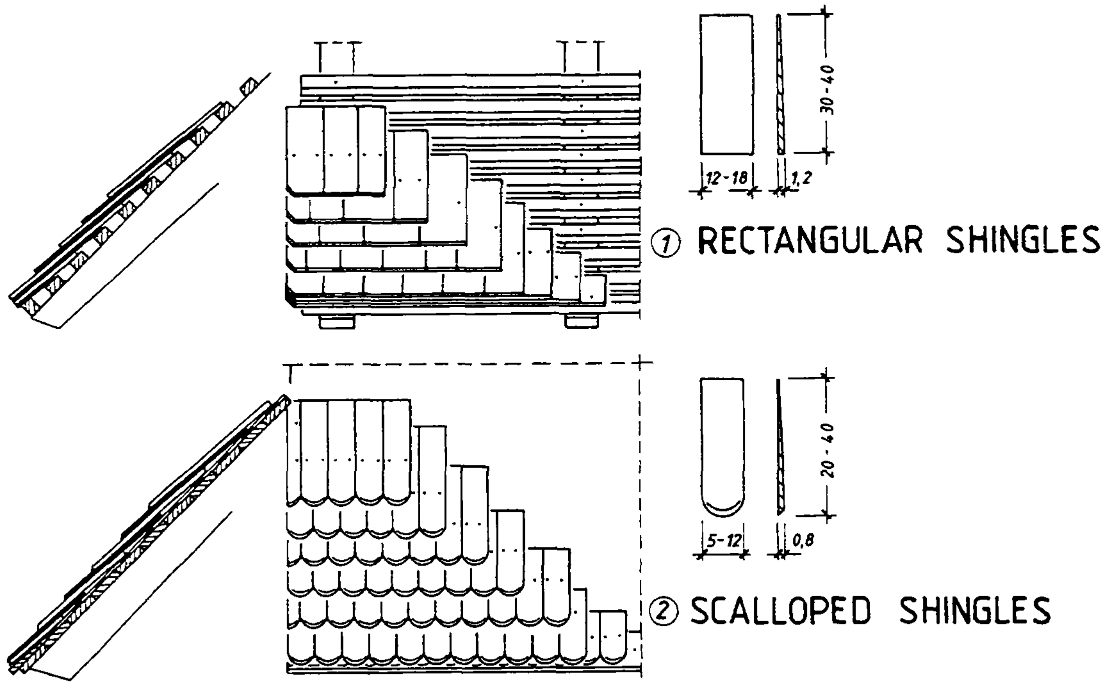
ASBESTOS SLATES



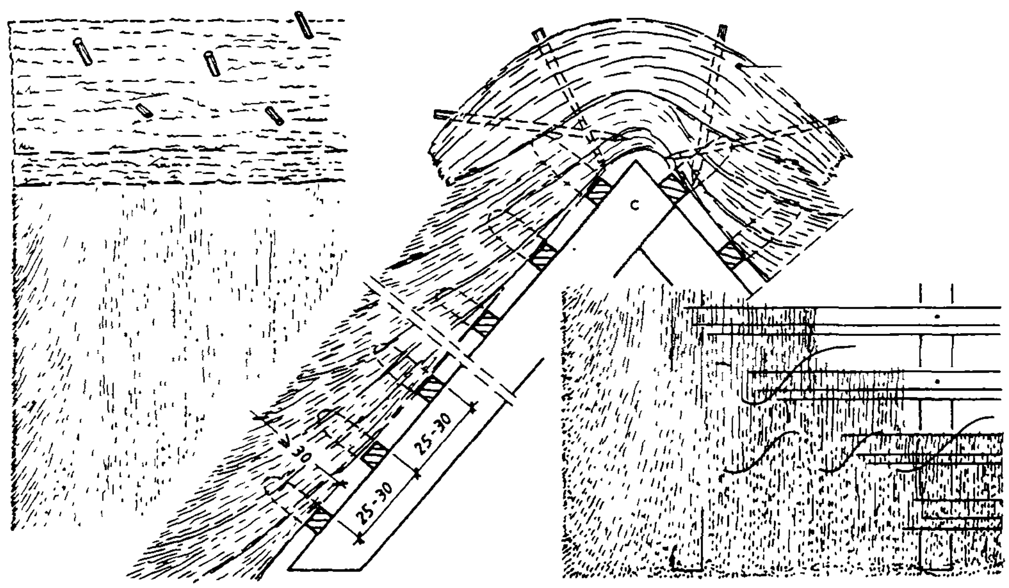


9. ROOFS	ROOF COVERINGS	BUILDING CONSTR.
compiled: D.VOLKE		LECTURE
OCT. '79		CET 5031/ 19.564

SHINGLES



○ THATCH COVERINGS



9 ROOFS	ROOF COVERINGS	BUILDING CONSTR.
compiled : D.VOLKE		LECTURE
OCT. '79		CET 5031 / 1 9.565

●●REPITITION ● exercises ● REPITITION●●

Try to answer the following questions and use sketches where ever necessary and possible

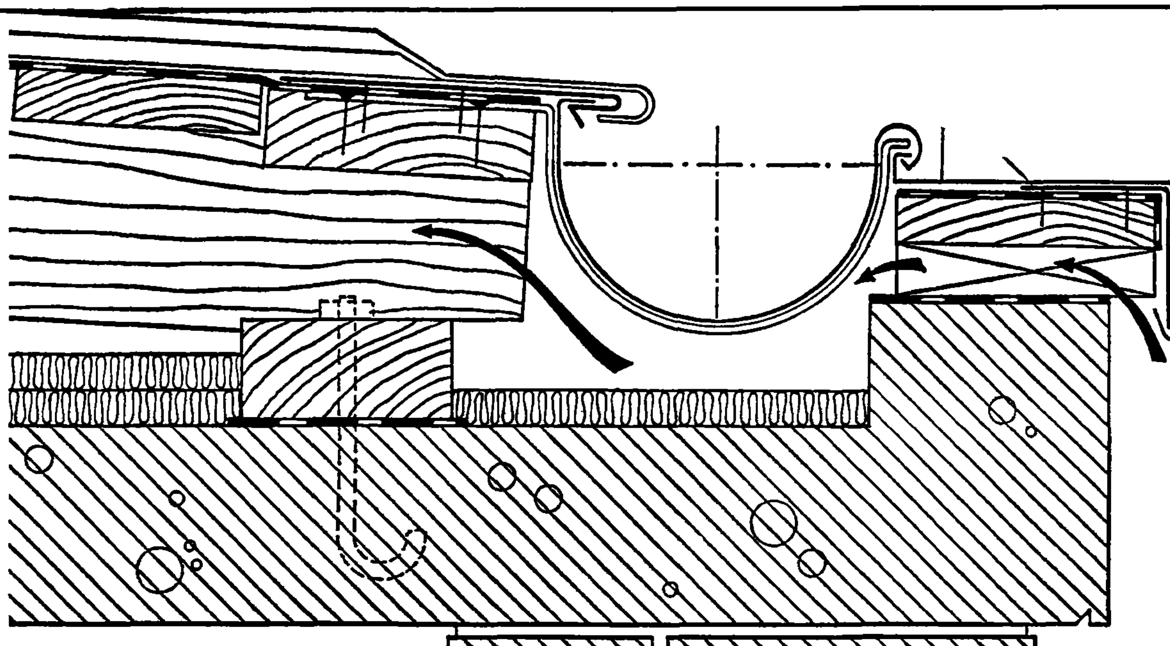
9.1 What are the main functions of a roof?

List the requirements the roof must satisfy to fulfil its functions efficiently and explain briefly the importance of these requirements.

9.2 Explain the terms:
- Roof structure, and
- 'Skin' of the Roof

Classify the different types of roofs in three different ways

Define the following terms:
- Flat roofs
- pitched roofs
- two-dimensional roof structures
- three - dimensional roof structures
- single roof construction
- double roof construction
- triple roof construction
- long span roofs
- medium span roofs
- short span roofs.



9.3 Write notes on <u>Flat Roofs</u>, explaining
- the structure of a flat roof
- thermal insulation materials
- single and double roof construction
- reinforced concrete flat roofs
- timber flat roofs
- parapet walls

and use sketches for illustration.

9.4 Write notes on <u>Pitched Roofs</u>, explaining
- the types of pitched roofs according to the shape of the roof
- the types of pitched roofs according to the structure of the roof

and use sketches for illustration.

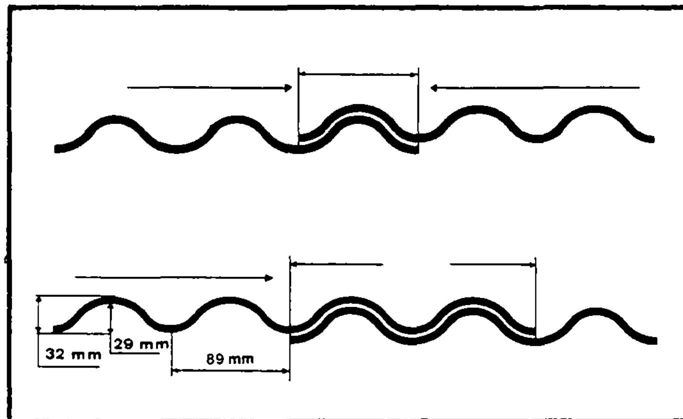
Explain the following terms briefly:
- gable
- gable parapet
- verge
- hip
- hipped end
- vally
- ridge

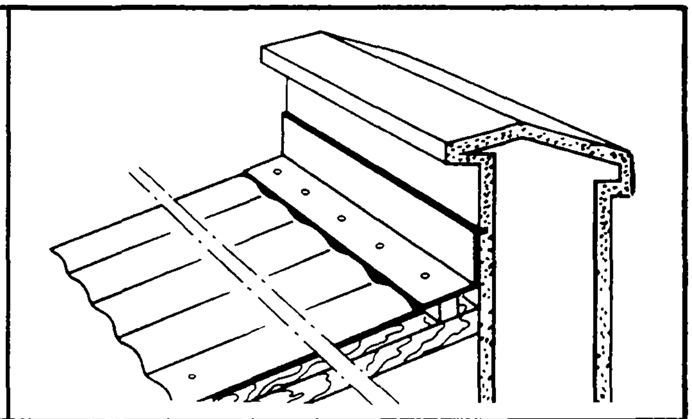
Referring to truss construction in timber, compare the three modern methods of joining the members:
- nailed joints
- bolt and connector joints
- glued joints

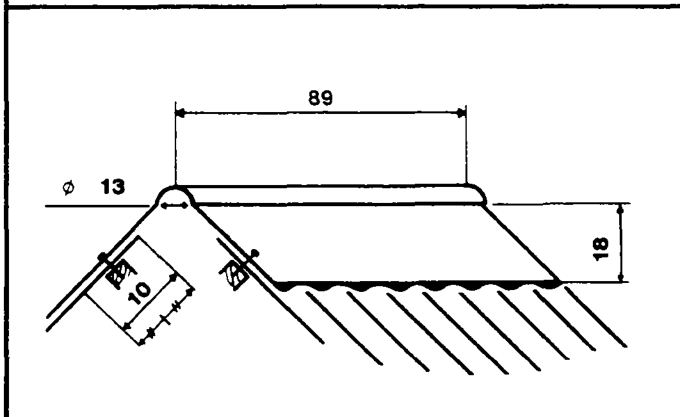
and describe their advantages and disadvantages.

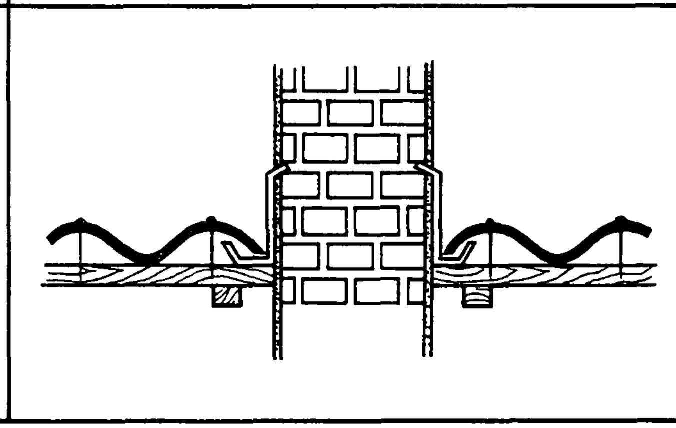
Show by means of neat sketches examples of
- open projecting eaves and
- closed projecting eaves

Write notes on Openings in timber roofs, including DORMER WINDOWS. Use sketches for illustrations.









9.5 Classify the different types of roof coverings
What sort of covering materials may be used for the above listed types of roof coverings?

Explain - by means of sketches - different types of sub-structures depending on the 'skin' covering the roof.

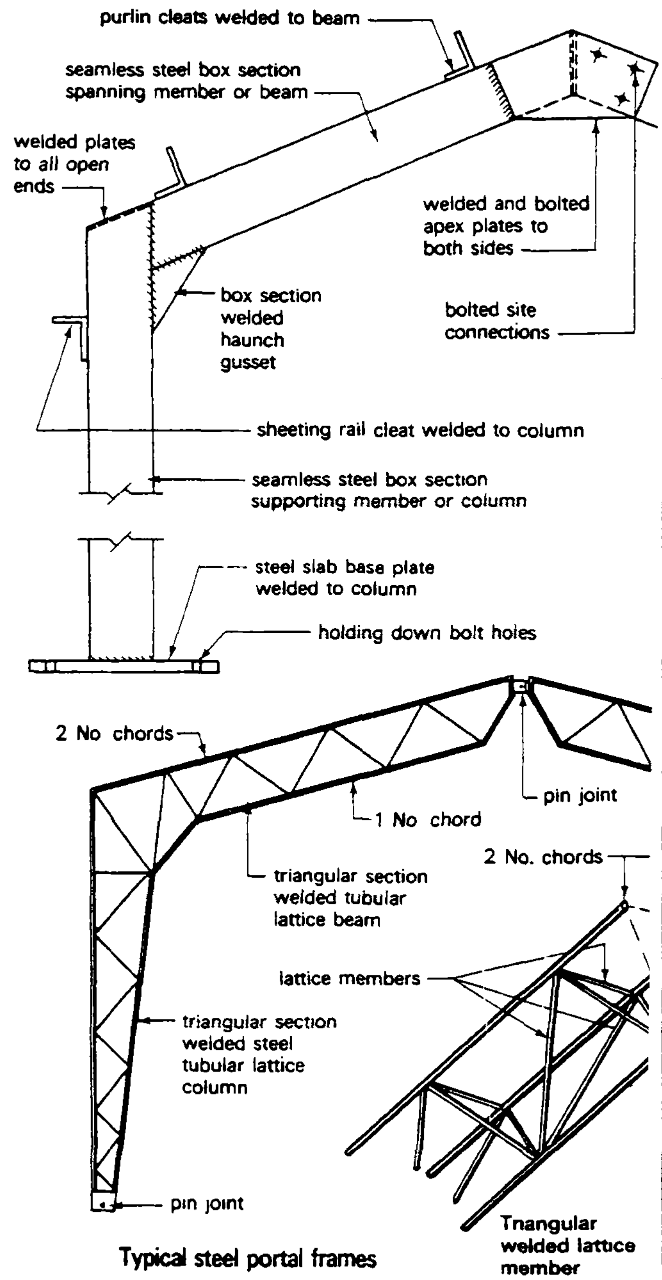
Write notes on the choice of roof coverings and explain in the form of a diagram the interdependency of the pitch of the roof and the covering material.

Show - by using sketches for illustration - covering methods for different sorts of materials, such as:

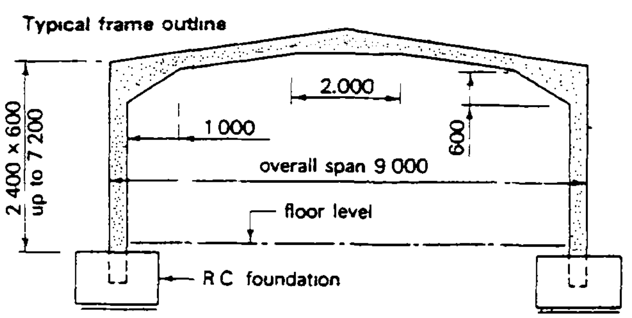
- one -, two-, three-, layer table covering
- asbestos sheet covering
- covering with roofing tiles
- covering with slates
- covering with asbestos plain tiles
- covering with shingles
- thatch covering
- sheet metal covering

10.FRAMED STRUCTURES

CONTENTS:



Typical steel portal frames



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1. R. Chudley
   'Construction Technology'
   Vol. 2 and 3

2. Jack Stroud Foster
   Mitchell's Building Contruction
   'Structure and Fabric'
   Part 1 and 2

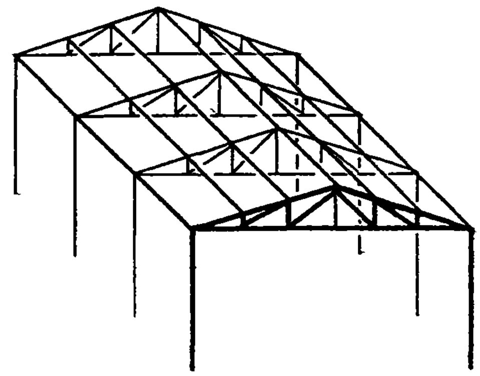
10.FRAMED STRUCTURES

10.1

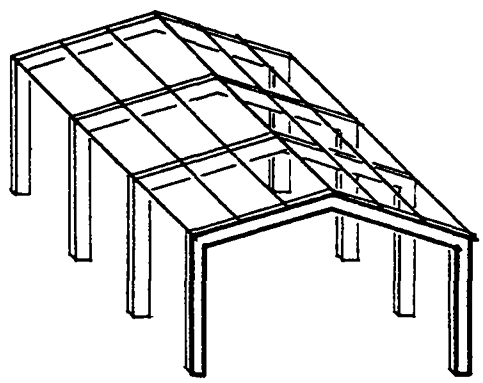
10.1. Structural Concept:

- A framed structure (or skeleton structure) consists essentially of a skeleton or framework which supports all the loads and rsists all the forces acting on the building and through which all loads are transfered to the soil on which the building rests.
- The elements of such framework are pairs of uprights, supporting some form of spanning members.
  These are spaced apart and tied together by longitudinal members to form the volume of the building.
  They are classified as:
  - BUILDING FRAMES of columns and horizontal beams for single and multi-storey buildings.
  - SHED FRAMES, of columns and roof trusses for single-storey buildings, and
  - PORTAL or RIGID FRAMES, of columns and horizontal or pitched beams for single-storey buildings.
- In these frames the vertical supports are in compression.
  SUSPENDED (or SUSPENSION) STRUCTURES have been developed in which the floos are suspended from the top of the building by vertical supports which are therefore in tension.

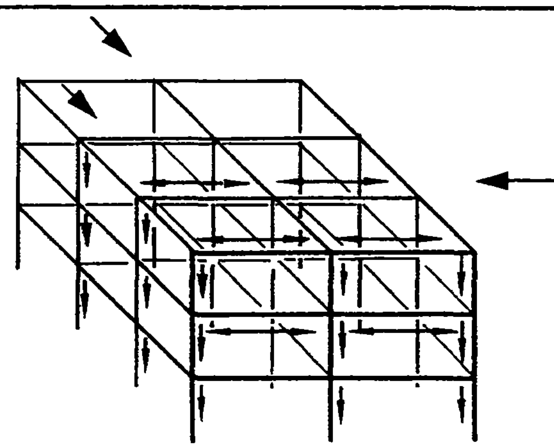
  Other forms of skeleton structures are the frameworks of interconnected members, known as GRID STRUCTURES.
- By its nature the skeleton frame connot enclose the space within it. Therefore other enclosing-elements must be assosiated with it.



SHED FRAME



PORTAL FRAME



BUILDING FRAME

STRUCTURAL CONCEPT

- The significance of this clear destinction between the supporting element and the enclosing element is that the enclosing element can be made relatively light and is not fixed in its position relative to the skeleton frame or may fit into the panels of the frame.

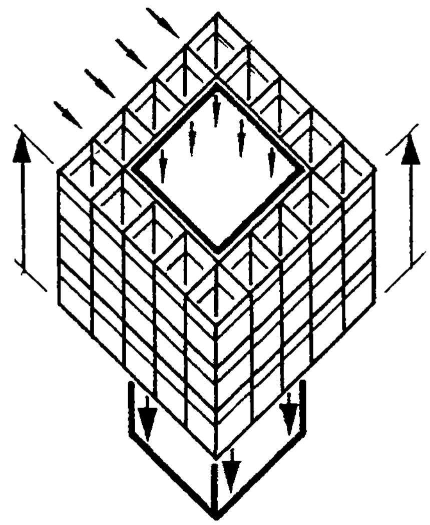
The advantages of framed structures are:

1) Saving in floor space (particularly when internal structural supports must be provided)
2) Flexibility in plan and building operations because of the absence of load bearing walls at any level.
3) Reduction of dead weight.

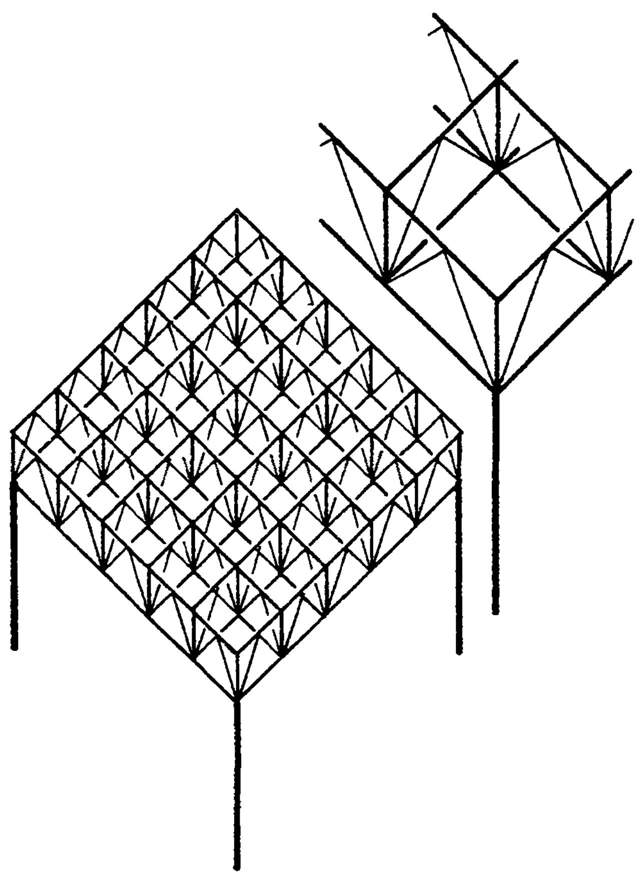
These advantages do not necessarily make a framed structure economically advantageous in every circumstances, i.e. in the case of individual small-scale buildings where the plan area is divided into rooms by walls and partitious.

In general it can be said that framed structures become logical and economical:

1. When the span of roof or floor becomes great enough to necessiate double construction involving beams or truses applying heavy concentrated loads at certain points on the supporting structure.
2. In the case of industrialised system building, the framed structure can be economic even for small-scale building types. (Due to largescale production and to the reduction in erection time and of labour on site which should accompany the use of prefabricated components.



SUSPENSION STRUCTURE



GRID STRUCTURE

10.2 Functional Requirements

Strength and stability: Are ensured by the use of appropiate materials in suitable forms applied with regarding to the manner in which a structure and its parts behave under load.

- Building frames may be classified according to the stiffness or rigidity of the joints between the members, especially between columns and beams.

A NON-RIGID (or pin-jointed) frame is one, in which the nature of the joints is such that the beams are assumed to be simply supported and the joints non-rigid.

Rigidity in the framed structure as a whole is ensured by the inclusion of some stiffing elements in the structure often in the form of triangulating members.
Steel and timber frames are commonly joined together in this manner and sometimes precast concrete frames.

A SEMI-RIGID frame is one in which some (or all) joints are such that some rigidity is obtained. A technique usually limited to steel frames and which effects some saving in materials. In

A FULLY - RIGID frame.all joints rigid. This results in considerable economics in material in the frame.
Depending upon the nature of the structure the joints alone may provide the stiffness necessary to prevent the frame as a whole from deforming under lateral wind pressure, although additional stiffening elements are often required. This type of building frame can be constructed in steel and concrete.

NON-RIGID
SEMI-RIGID
FULLY-RIGID

Fire - resistance: An adequate degree of fire-resistance in the frame is essential in order that its structural integrity may be maintained in the event of fire, either for the full period of a total burn-out or for a period at least long enough to permit any occupants of the building to escape.

- Concrete is highly fire resistent but steel in many circumstance requires the provision of fire-protection, of which a number of forms exist such as en - sure by concrete or by asbestos board. Timber, although a combustable material (which will easily burn in the form of thin boards) burns less readily when in thicknesses greater than about 15 cm. Its combusibility may also be reduced by the application of fire retardants.

10.3 STRUCTURAL MATERIALS

- Materials which are commonly used for framed structures are:
  - Steel
  - Concrete (reinforced or prestressed).
  - Timber
  - Aluminium alloys.
- Material for framed structures - particularly when these are *TALL OR WIDE IN SPAN* need to be:
  - Strong
  - Stiff.
  - Light in weight.

The stronger the material the smaller the amount which will be required to resist a given force.

The stiffer the material the less will the structure and its members deform under load.

The relationship of the depth of a spanning member or structure to its span is expressed as the DEPTH/SPAN RATIO, and is useful as a basis of comparison of the effects of using material and forms of structure of different degrees of stiffness. A small depth / span ratio indicats the achievement of adequate stiffness with minimum depth of spanning member.

The lighter the material (provided the strength is adequate) the lower the self-weight of the structure. The self or dead weight of a structure, as well as the load which the structure is to carry, contributesto the stresses set up within it.
Low dead weight is an important economic factor (especially in structures carrying light loads)

The smaller the self (or dead) weight of a structure relative to the load to be carried, the more economic the structure.

This relationship is expressed as the *DEAD/LIVE LOAD RATIO.*

STRONG
STIFF
LIGHT
IN WEIGHT

The raltionship of the weight of a material to its strength provides on indication of its efficiency in terms of the weight required to fulfil the structural function. This is expressed as the STRENGTH/WEIGHT RATIO, a high value indicating high strength with low self weight resulting in a minimum weight of material to fulfil a particular structural purpose.

DEPTH/SPAN RATIO
DEAD/LIVE LOAD RATIO
STRENGTH/WEIGHT RATIO

STEEL

STEEL is a material strong in both: compression and tension, and it is stiff.
A steel structure is therefore relatively economic in material because a small amount can carry a relatively large load and because it is stiff, the structure and its members will not easily deform under load.
It has a high strength/weight ratio. These characteristics make it suitable for both: low-rise and high-rise building frames and roof structures of all spans.

TIMBER

TIMBER varies its bending strength from about 1/28 to 1/23 that of mild steel (according to the specis and to the presence or absence of knots and faults in the timber). Compared with other materials its stiffness is low but in relation to is own weight, which is quite light, it is relatively very stiff. Thus in structural applications compensation for its lack of stiffness can be made without excessive increase in weight of structure.

It has a relatively high strength /weight ratio, and is suitable for lightly or moderately loaded low-rise building frames and for shed and rigid frames (particularly where the span and weight of these are large).

CONCRETE

CONCRETE varies in strength according to mis.
The compressive strength of normal structural concrete is about 1/16 that of steel, but its tensile strength is only about 1/10 of its compressive strength. Its stiffness is low compared with steel and its strength/weight ratio is low.
To overcome this weakness, structural members are REINFORCED in their tension zones with steel bares or PRESTRESSED in the same zones (usually by means of steel wires or cables).

In reinforced form concrete is suitable for SHORT-SPAN low- and high-rise building frames.
In pressed form for wide-span building and rigid frames.
Prestressed concrete may also be applied to shed frames using precast roof trusses.

ALUMINIUM

ALUMINIUM varies in strength according tothe particular alloy, from about 3/4 that of mild steel to strengths somewhat greater than that of steel. Although stiffer than either concrete or timber, aluminium alloys are only about 1/3 as stiff as steel but they are only about 1/3 its weight. These characteristics make them suitable for roof structures (which carry only light imposed loads); particularly those of long span, and less so for normal building frames. The high cost of aluminium usually precludes its structural use for other than very wide span roof structures.

10.4 Layout of Frames

- As a general rule: Space columns as closely as the nature of the building will permit. This resulting in short span beams or trusses will be cheaper than one with widely spaced columns. With smaller spans the beams reduce in size and cost and - similarly - the columns, because of the reduced loads they carry.

- The SPACING of the frames is influenced largely by the economic span of the floor or roofing system which they support and this will vary with the imposed floor or roof loading and the type of floor or roofing system.

In the case of building frames and rigid frames it can be shown, that as the frame beams increase in span (or frame columns increase in height) there comes a point at which it may be more economic to increase the spacing between the frames, rather than to maintain them at the most economic span of particular floor or roofing system.

In the case of shed frames, a close spacing of the frames usually gives the cheapest structure.

The layout of a skeleton structure should be based on a regular structural grid because:

- loads on the structure are transmitted evenly to the foundations (minimising relative settlement and standardising the sizes of foundation slabs).
- It results in regularity in beam depths and column sizes and in the position of columns and beams relative to walls. This avoids the use of 'waste' material to bring beams and columns to similar dimensions either because they are exposed to view or, in the case of reinforced concrete, to standardise formwork. It also standardises the size of dividing and enclosing walls or panels.
- In reinforced concrete work the regular slab and beam spans minimise the variations in rod sizes.
- It permits greater re-use of formwork, both in precast and in situ concrete construction.

10.5 BUILDING FRAMES

- Building frames are basically a series of rectangular frames, placed at right angles to one another so that the loads are transmitted from member to member until they are transferred through the foundations to the subsoil.
- Building frames can be economically constructed of
  - Concrete
  - Steel or a combination of the two and
  - Timber.

10.5.1 Funktions of building frame members

Main beams:
Span between columns and transfer the live and imposed loads placed upon them to the columns.
Secondary beams:
Span between and transfer their loadings to the main beams. Primary function is to reduce the spans of the floors or roof being supported by the frame.
Tie beams:
Internal beams spanning between columns at right angles to the direction of the main beams and have the same function as a main beam.
Edge beams:
As tie beam but spanning between external columns.
Columns:
Vertical members which carry the loads transferred by the beams to the foundations.
Foundation:
The base(s), to which the columns are connected and serve to transfer the loadings to a suitable load-bearing subsoil.

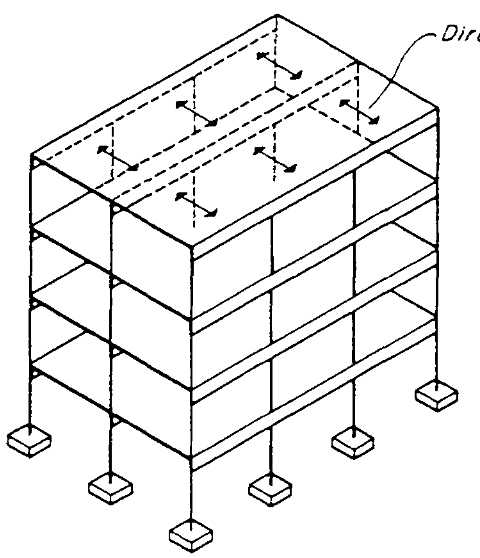
Floors:
May or may not be an integral part of the frame; they provide the platform on which equipment can be placed and on which people can circulate. Besides transmitting these live loads to the supporting beams they may also be required to provide a specific fire resistance, together with a degree of sound and thermal insulation.
Roof:
Similar to floors but its main function is to provide a weather-resistant covering to the upper most floor.
Walls:
The envelope of the structure which provides the resistance to the elements, entry of daylight, natural ventilation, fire resistance, thermal insulation and sound insulation.

REINF. CONCRETE FRAMES

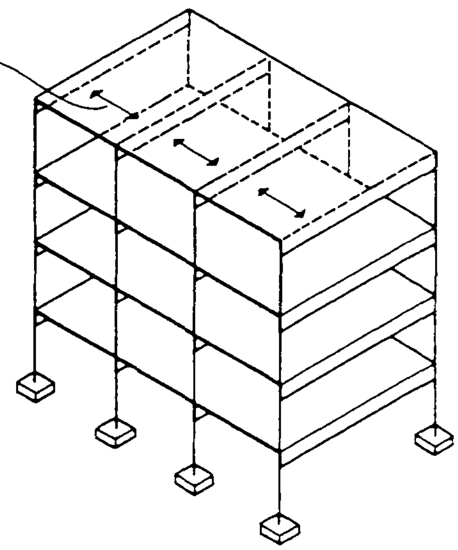
10.5.2 Reinforced concrete frames

Reinforced concrete, because of its particular characteristics, can be formed into walls as well as into beams and columns to form a skeleton frame and the designer's freedom to cast concrete in almost any shape is only limited by the cost of the formwork or shuttering into which the concrete must be poured. This forms a large proportion of the total cost of a reinforced concrete structure as can be seen from the following approximate percentage breakdown:

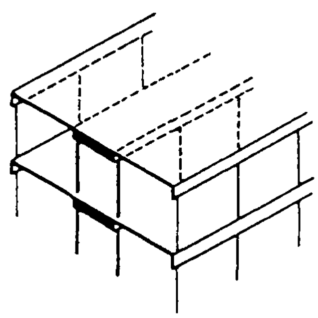
- Concrete		40%
Materials	28%	
Labour	12%	
- Shuttering incl. errection and stripping		32%
Materials	12%	
Labour	20%	
- Reinforcement		28%
Materials	10%	
Labour	18%	



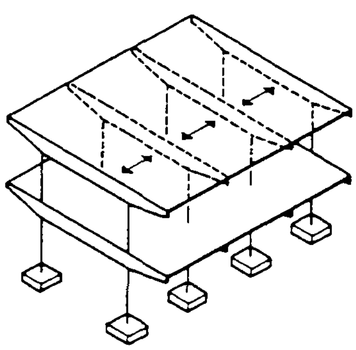
Beams parallel to external wall



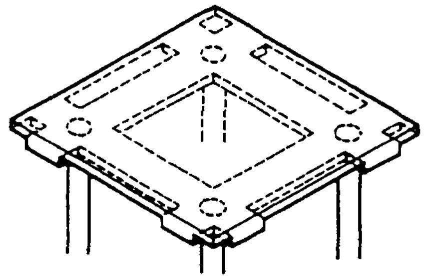
Beams at right angles to external wall

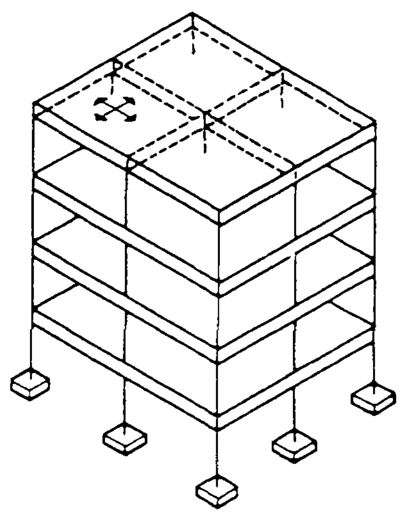


B Stiff inner structure



Cantilever beam frames



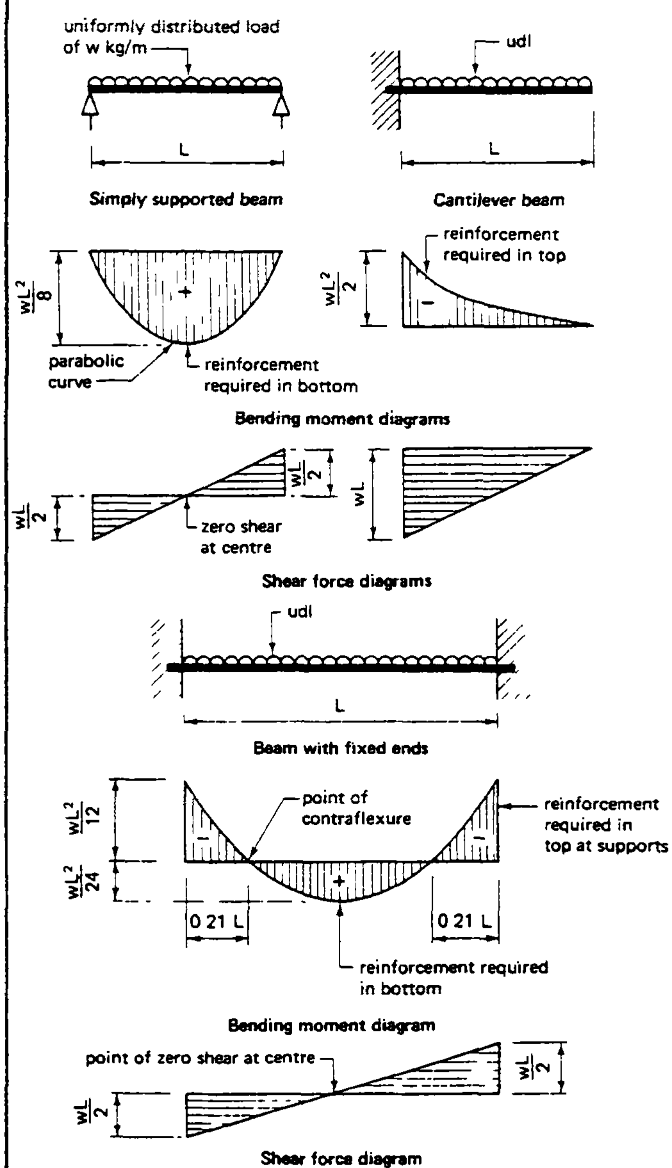


10.5.2.1 Reinforced concrete beams

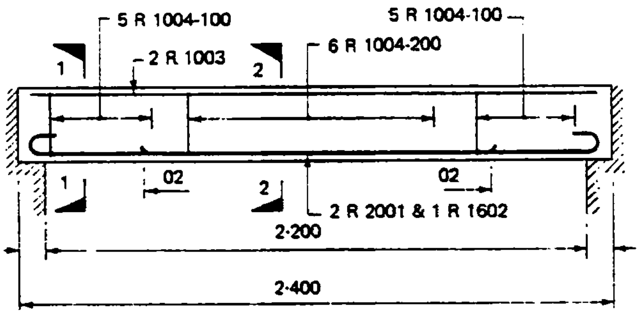
Beams can vary in their complexity of design an reinforcement from the very simple beam formed over an isolated opening to the more common form encountered in frames where the beams transfer their loadings to the columns.
When tension is induced into beam the fibres will lengthen until the ultimate tensile strength is reached, when cracking and subsequent failure will occur.
With a uniformly distributed load the position and value of tensile stress can easily be calculated, but the problem becomes mor complex when heavy point loads are encountered.

The concrete design of a r.c. beam will ensure, that it has sufficient strength to resist both the compression and tensile forces encountered in the outer fibres, but it can still fail in the 'web' connecting the compression and tension areas. This form of failure is called SHEAR failure and is in fact diagonal tension.
Concrete has a limited amount of resistance to shear failure and if this is exceeded reinforcement must be added to provide extra resistance.
Shear occurs at or near the supports as a diagonal failure line at an angle of approximately 45^0 to the horizontal and sloping downwards towards the support (A useful fact to remember is that zero shear occurs at the point of maximum bending.).
Reinforcement to resist shearing force may be either stirrups or inclined bars, or both. The total shearing resistance is the sum of the shearing resistances of the inclined bars and the stirrups, calculatet seperately if both are provided.

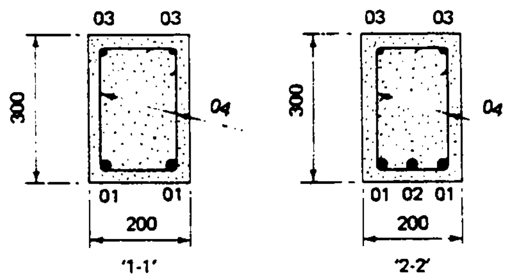
Bending moment and shear force diagrams



REINF. CONCRETE BEAMES



Elevation—beam 1-3 No. thus

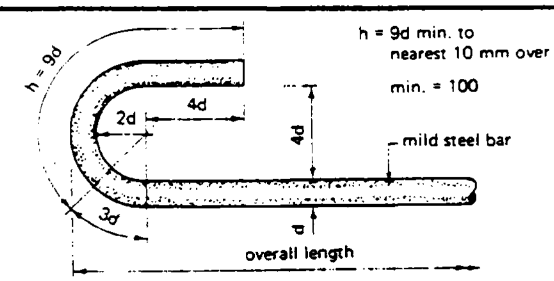


Typical R.C. beam details and schedule

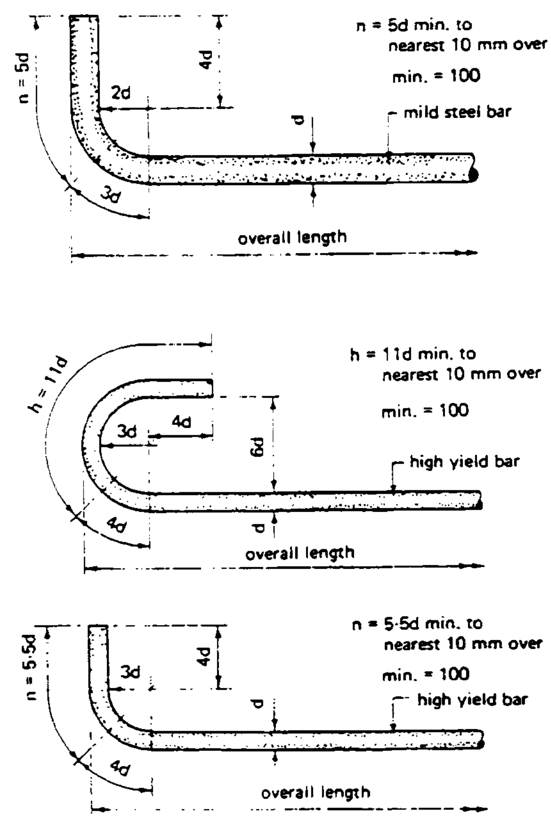
Member	Bar mark	Type & size	No. of mbrs	No. in each	Total No.	Length of each bar†	Shape. All dimensions* are in accordance with BS 4466
Beam 1	1	R20	3	2	6	2660	2300
	2	R16	3	1	3	1400	straight
	3	R10	3	2	6	2300	straight
	4	R10	3	16	48	1000	250 150

† specified to nearest 25 mm * specified to nearest 5 mm

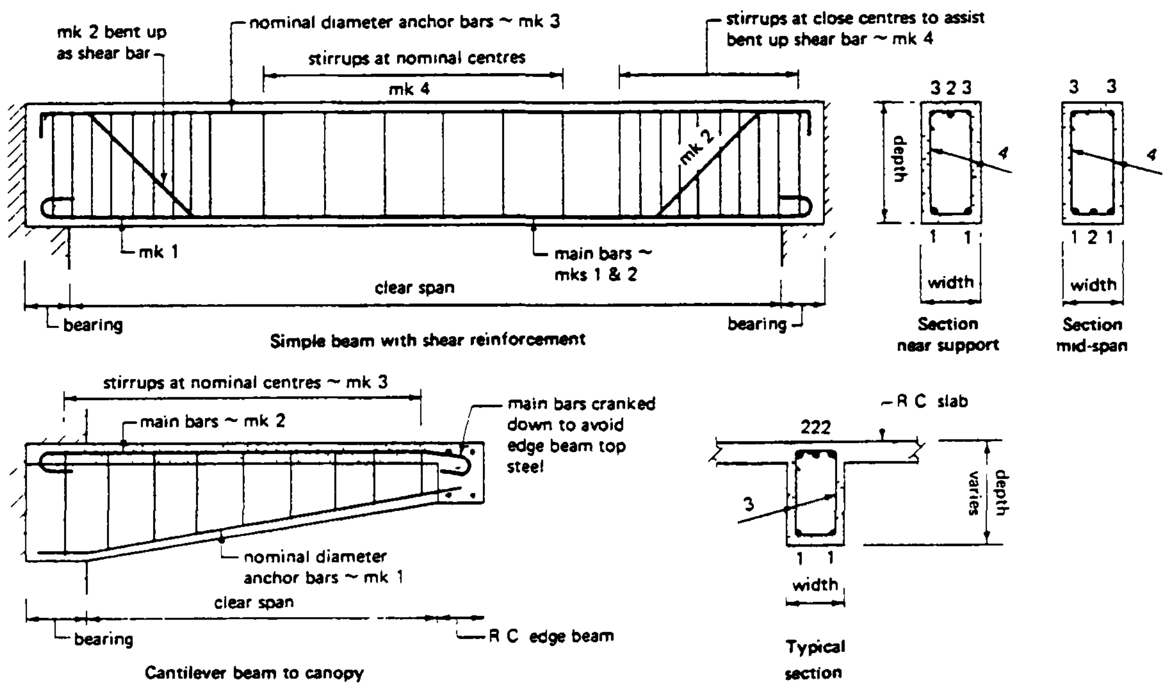
Inclined or bent up bars should be at 45° to the horizontal and positioned to cut the anticipated shear failure plane at right angles. These may be separate bars or alternatively main bars from the bottom of the beam which are no longer required to resist tension which can be bent up and carried over or onto the support to provide the shear resistance Stirrups or binders are provided in beams, even where not required for shear resistance, to minimise shrinkage cracking and to form a cage for easy handling. The nominal spacing for stirrups must be such that the spacing dimension used is not greater then the lever arm of the section, which is the depth of the beam from the centre of the compression area to the centre of the tension area or 0.75 times the effective depth of the beam, which is measured from the top of the beam to the centre of the tension reinforcement. If stirrups are spaced at a greater distance than the lever arm it would be possible for a shearing plane to occur between consecutive stirrups, but if the centres of the stirrups are reduced locally about the position at which shear is likely to occur several stirrups may cut the shear plane and therefore the total area of steel crossing the shear plane is increased to offer the tensile resistance to the shearing force.



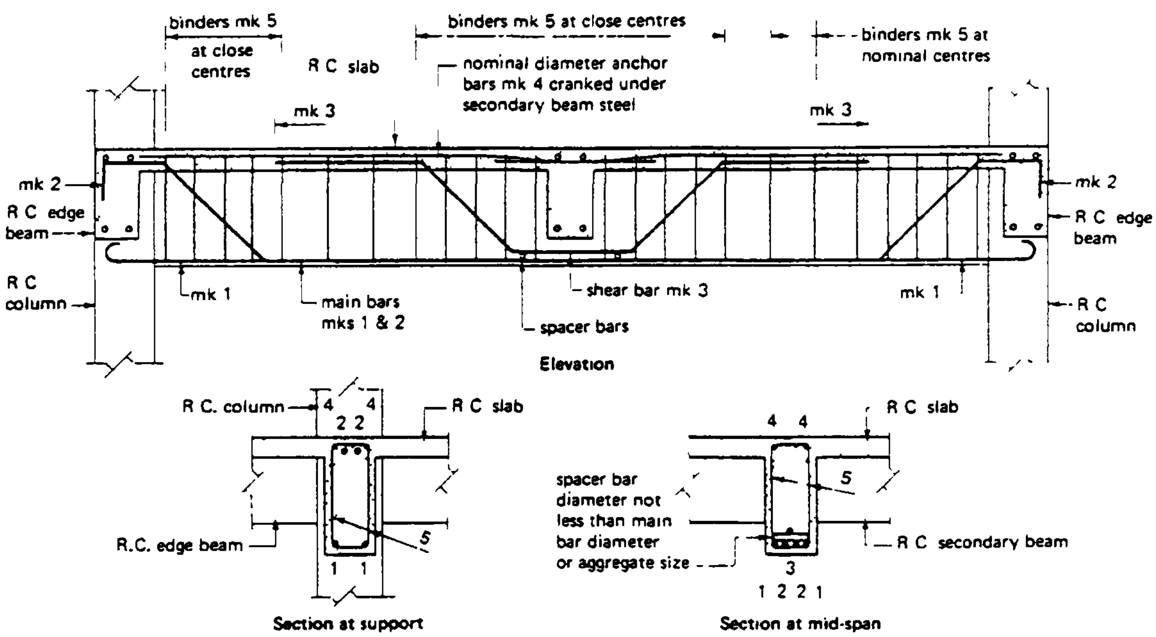
Standard hooks and bends



REINF. CONCRETE BEAMS



Simple reinforced concrete beams



R.C. beam with heavy reinforcement

10.5.2.2 Reinforced concrete columns

A column is a vertical member carrying the beam and floor loadings to the foundation and is a compression member. Since concrete is strong in compression it may be concluded that provided the compressive strength of the concrete is not exceeded no reinforcement will be required. For this condition to be true the following conditions must exist:

1. Loading must be axial.
2. Column must be short, which can be defined as a column where the ratio of its effective height to its thickness does not exceed 12.
3. Cross section of the column must be large.

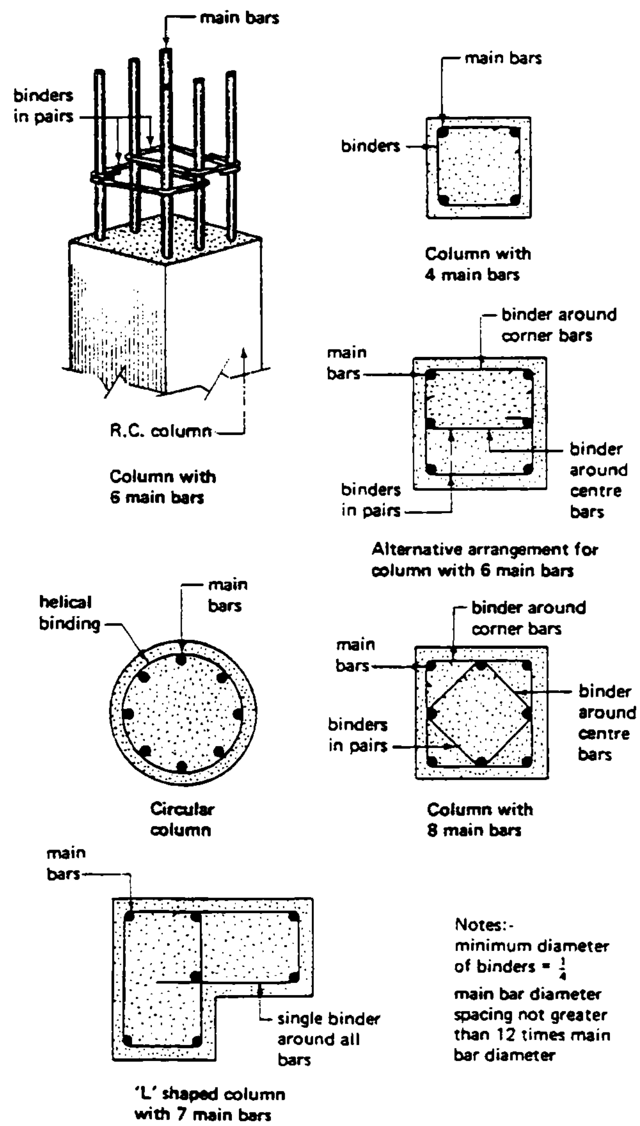
These conditicns rarely occur in framed buildings, consequently bending is induced and the need for reinforcement to provide tensile strength is apparent. Bending in columns may be induced by one or more of the following conditions:

1. Load coupled with the slenderness of the column; a column is considered to be slender if the ratio of effective height to thickness exceeds 12.
2. Reaction to beams upon the columns, as the beam deflects it tends to pull the column towards itself thus inducing tension in the far face.
3. The reaction of the frame to wind loadings both positive and negative.

The minimum number of main bars in a bolumn should not be less than four for rectangular columns ans six for cicular columns with a total cross section area of not less than 1% of the cross sectional area of the column and a minimum diameter of 12mm. To prevent theslender main bars from buckling and hence causing spalling of the concrete, links or binders are used as a restraint.

REINF. CONCRETE COLUMNS

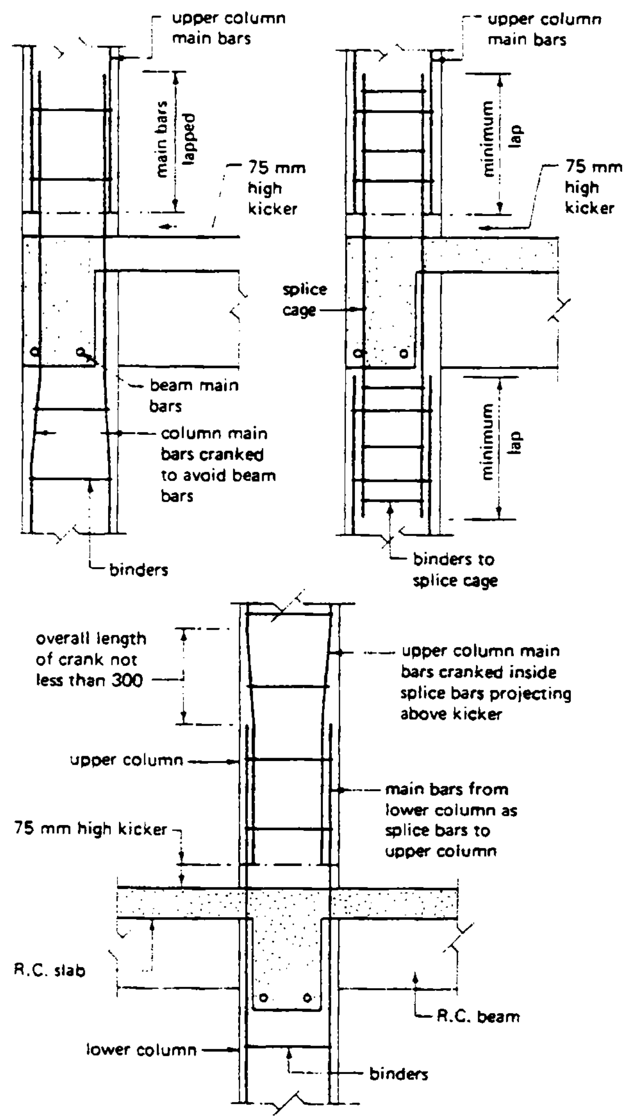
R.C. column binding arrangements

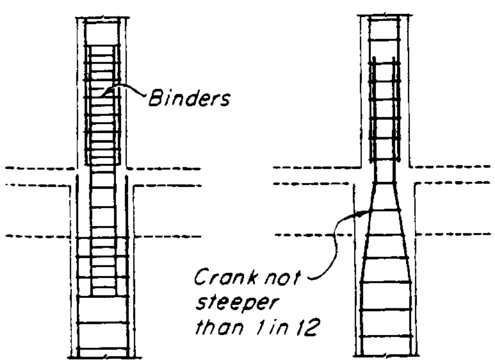


These should be at least one-quarter of the largest main bar diameter and at a pitch or spacing not greater than twelve times the main bar diameter. All bars in compression should be tied by a link passing around the bar in such a way that it tends to move the bar towards the centre of the column.

Where the junction between beams and columns occur there could be a clash of steel since bars from the beam may well be in the same plane as bars in the columns. To avoid this situation one group of bars must be bent or cranked into another plane; it is generally considered that the best practical solution is to crank the column bars to avoid the beam steel.

R.C. column and beam junctions





Alternative column splices

10.5.2.3 Reinforced concrete slabs

A reinforced concrete slab will behave in exactly the same manner as a reinforced concrete beam and it is therefore designed in the same manner. The designer will analyse the loadings, bending moments, shear forces and reinforcement requirements on a slab strip 1.000 m wide. In pratice the reinforcement will be fabricated to form a continuous mat.For light loadings a mat of welded fabric could be used.

There are three basic forms of reinforced concrete slabs, namely:

1. Flat slab floors or roofs.
2. Beam and slab floors or roofs.
3. Ribbed floors or roofs - see 7. FLOORS.

1) Flat slabs

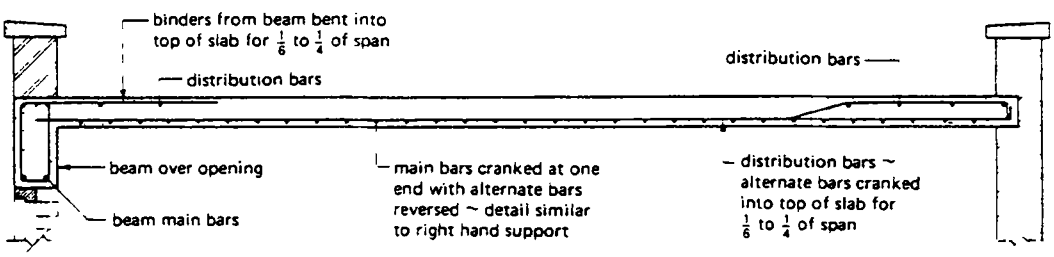
These are basically slabs contained between two plain surfaces and can be either simple or complex. The design of the complex form is based upon the slab acting as a plate in which the slab is divided into middle and column strips; the reinforcement being concentrated in the latter strips.

Simple flat slabs can be thick and heavy but have the advantage of giving clear ceiling heights since there are no internal beams.

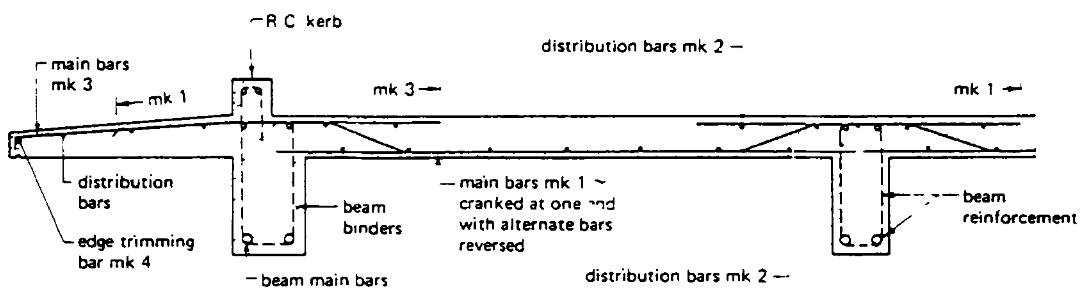
REINF. CONCRETE SLABS

They are generally economic up to spans of approximately 9.000 m and can be designed to span one way, that is across the shortest span, or to span in two directions. These simple slabs are generally designed to be simply supported, that is, there is no theoretical restraint at the edges and therefore tension is not induced and reinforcement is not required. However, it is common practice to provide some top reinforcement at the supports as anti-crack steel should there, in practice, be a small degree of restraint. Generally this steel is 50 % of the main steel requirement and extends into the slab for 0.2 m of the span. An economic method is to crank up 50% of the main steel or every alternate bar over the support since the bending moment would have reduced to such a degree at this point it is no longer required in the bottom of the slab. If there is an edge beam the top steel can also be provided by extending the beam binders into the slab.

Typical R.C. slab details



Typical R.C. flat slab



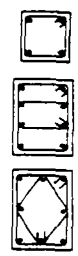
Typical R C beam and slab with cantilever

REINF. CONCRETE SLABS

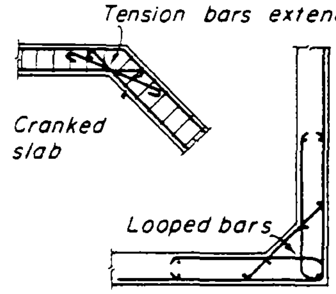
2) Beam and slab

By adopting this method of design large spans are possible and the reinforcement is generally uncomplicated. A negative moment will occur over the internal supports necessitating top reinforcement; as with the flat slabs, this can be provided by cranked bars Each bar is in fact cranked but alternate bars are reversed thus simplifying bending and indentification of the bars. Alternatively a separate mat of reinforcement supported on chairs can be used over the supports.

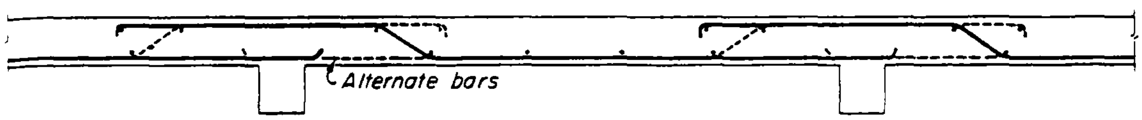
REINFORCEMENT



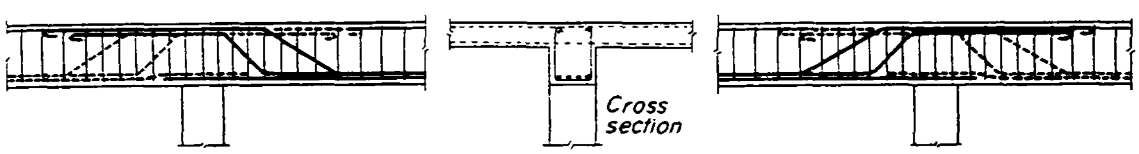
Column reinforcement



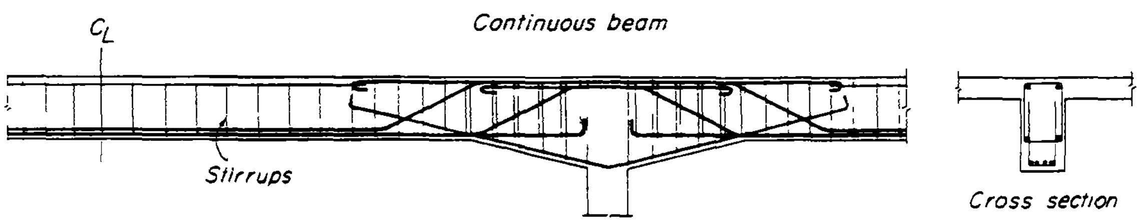
Angle of wall



Continuous slab



Continuous beam

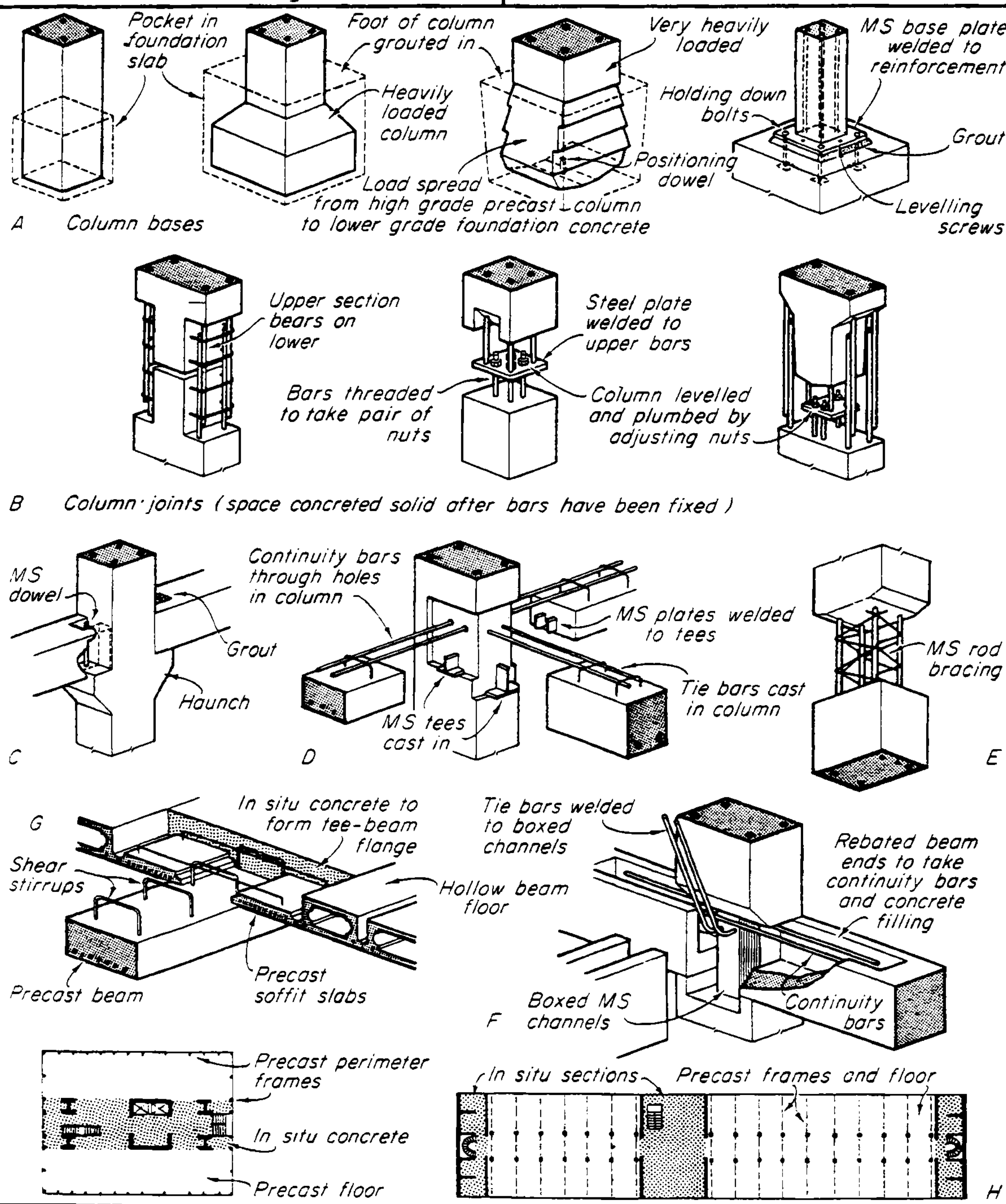


Haunched beam

10.5.3 Precast concrete frames

The overall concept of a precast concrete frame is the same as any other framing material. Single or multi-storey frames can be produced on the skeleton or box frame principle. Single and two-storey buildings can also be produced as portal frames, a method generally reserved for advanced level study. Most precast concrete frames are produced as part of a 'system' building and therefore it is only possible to generalise in an overall study of this method of framing.

PRECAST CONCR FRAMES



10 FRAMED STRUCT.	BUILDING FRAMES	BUILDING CONSTR.	
compiled: D.VOLKE		LECTURE	
DEC. '82		CET 6031 / 1 1o.516	
TCA TECHNICAL COLLEGE ARUSHA CHUO CHA UFUNDI ARUSHA		CIVIL ENGINEER. DEPARTMENT	16

PRECAST CONCR. FRAMES

Advantages

1. Mixing, placing and curing of the concrete carried out under factory-controlled conditions which results in uniform and accurate units.
   The casting, being an 'off site' activity, will release site space which would have been needed for the storage of cement and aggregates, mixing position, timber store and fabrication area for formwork and the storage, bending and fabrication of the reinforcement.
2. Repetitive standard units reduce costs: it must be appreciated that the moulds used in precast concrete factories are precision made, resulting in high capital costs. These costs must be apportioned over the number of units to be cast.
3. Frames can be assembled on site in cold weather which helps with the planning, programming and progressing of the building operations. This is important to the contractor since delays can result in the monetary penalty clauses, for late completion of the contract, being invoked.
4. In general the frames can be assembled by semi-skilled labour. With the high turnover rate of labour within the building industry operatives can be recruited and quickly trained to carry out these activities.

Disadvantages

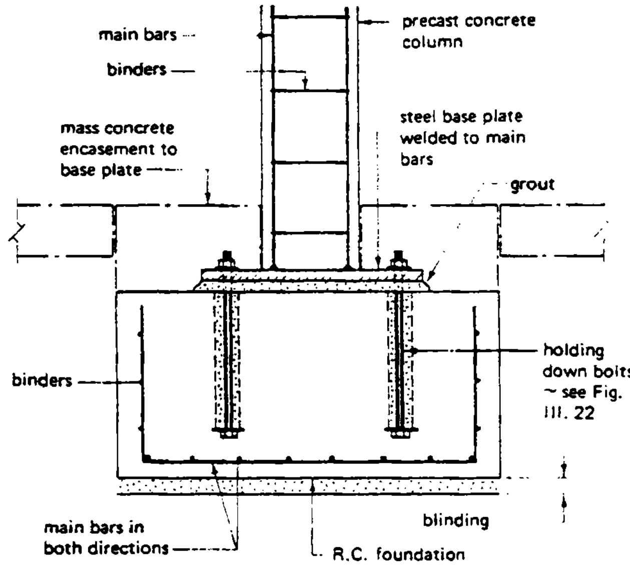
1. System building is less flexible in its design concept than purposemade structures. It must be noted that there is a wide variety of choice of systems available to the designer, so that most design briefs can be fulfilled without too much modification to the original concept.
2. Mechanical lifting plant will be needed to position the units; this can add to the overall contracting costs since generally larger plant is required for precast concrete structures than for in situ concrete structures.
3. Programming may be restricted by controls on delivery and unloading times laid down by the police. Restrictions on deliveries is a point which must be established at the tender period so that the tender programme can be formulated with a degree of accuracy and any overtime payments can be included in the unit rates for pricing.
4. Structural connections between contractual problems. The major points to present both design and contractual problems. The major points to be considered are protection against weather, fire and corrosion, appearance and the method of construction. The latter should be issued as an instruction to site, setting out in detail the sequence, temporary supports required and full details of the joint.

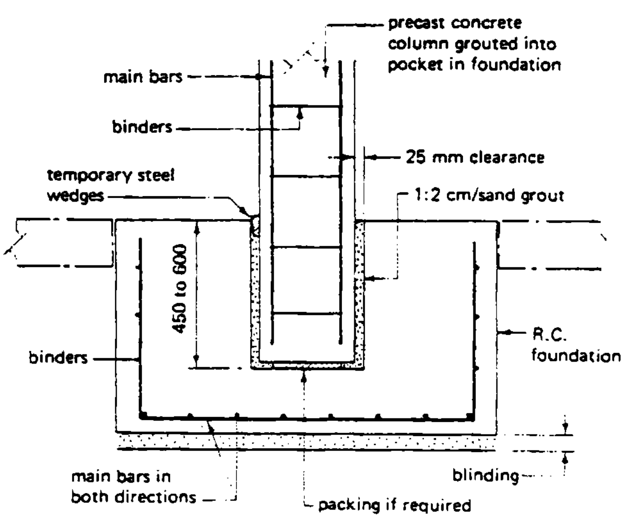
ADVANTAGES | DISADVANTAGES

10.5.3.1 Methods of connections

Foundation connections

Precast columns are connected to their foundations by one of two methods, depending mainly upon the magnitude of the load. For light and medium loads the foot of the column can be placed in a pocket left in the foundation. The column can be plumbed and positioned by fixing a collar around its perimeter and temporarily supporting the column from this collar by using raking adjustable props. Wedges can be used to give added rigidity whilst the column is being grouted into the pocket. The alternative method is to cast or weld on a base plate to the foot of the column and use holding down bolts to secure the column to its foundation in the same manner as described in detail for structural steelwork.



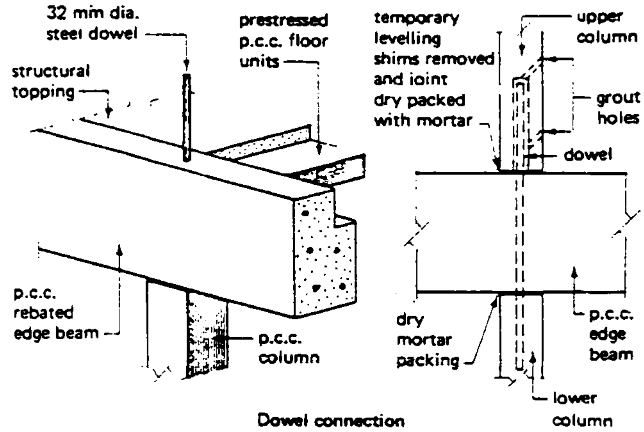


P.C.C. column to foundation connections

Column connections

The main principle involved in making column connections is to ensure continuity and this can be achieved by a variety of methods. In simple connections a direct bearing and grouted dowel joint can be used, the dowel being positioned in the upper or lower column. Where continuity of reinforcement is required the reinforcement from both upper and lower columns left exposed and either lapped or welded together before completing the connection with in situ concrete. A more complex method is to use a stud and plate connection where one set of theaded bars are connected through a steel plate welded to a set of bars projecting from the lower column; again the connection is completed with in situ concrete. Column connections should be made at floor levels but above the beam connections, a common dimension being 600 mm above structural floor level. The columns can be of single or multi-storey height, the latter having provisions for beam connections at the intermediate floor levels.

METHODS of CONNECTIONS



Dowel connection

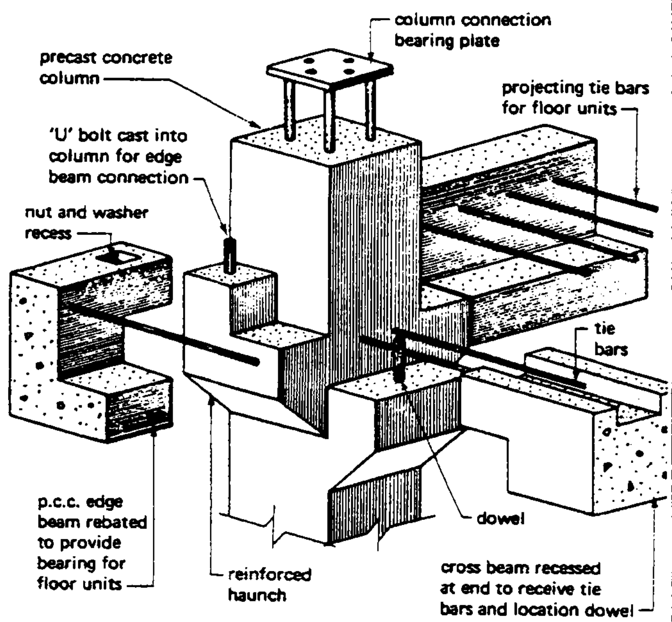
Beam connections

As with columns, the main emphasis is on continuity within the joint. Three basic methods are used:

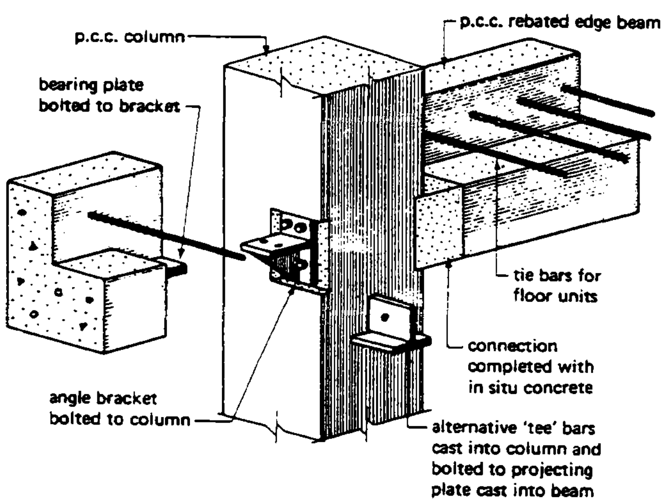
1. A projecting concrete haunch is cast on to the column with a locating dowel or stud bolt to fix the beam.
2. A projecting metal corbel is fixed to the column and the beam is bolted to the corbel.
3. Column and beam reinforcement, generally in the form of hooks, are left exposed. The two members are hooked together and covered with in situ concrete to complete the joint.

With most beam to column connections lateral restraint is provided by leaving projecting reinforcement from the beam sides to bond with the floor slab or precast concrete floor units.

Typical precast concrete beam connections



NB beam recess filled with cement grout to complete connection



Precast concrete column connections

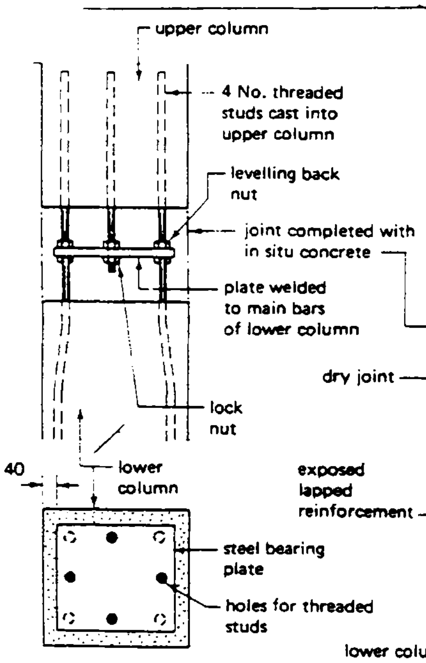
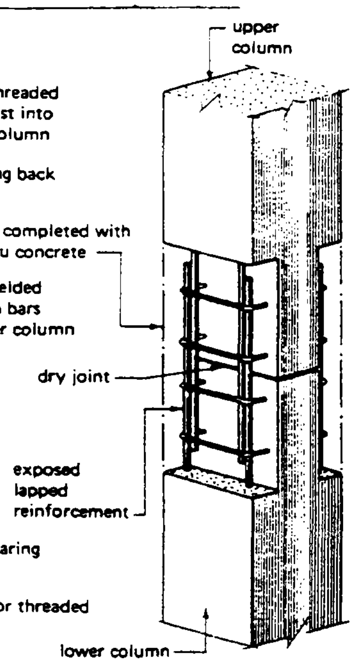


Plate and stud connection

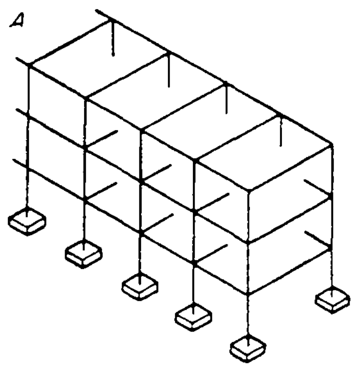


Exposed reinforcement connection

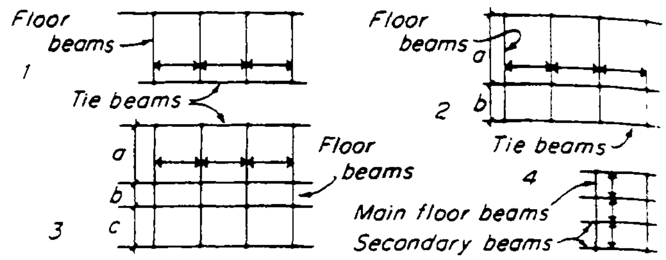
10.5.4 Structural steelwork frames.

STRUCT. STEELWORK FRAMES

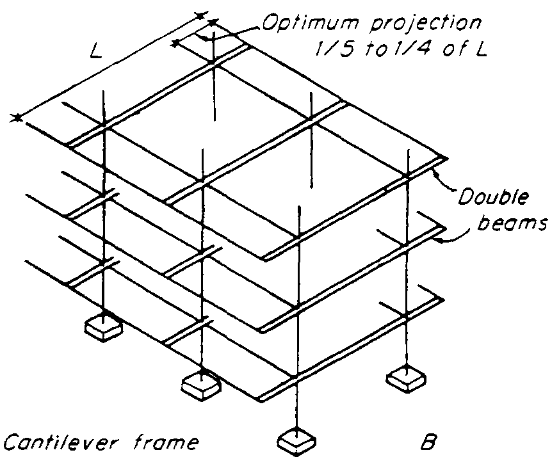
Structural steel as a means of constructing a framed building has been used since the beginning of the twentieth century. Structural steel as well as reinforced 'insitu' and precast concrete are used and this means a comparison must be made before any particular framing medium is chosen. The main factors to be considered in making this choice are:



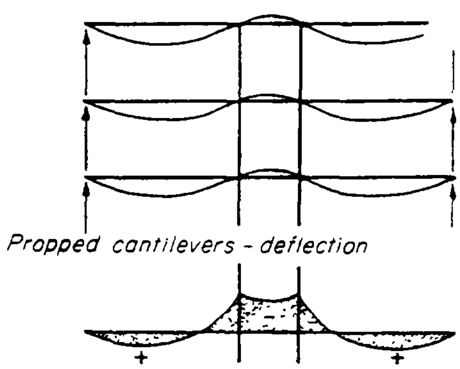
Simple 'cage' frame



Layout	Member	SPANS Practicable range (m)	Economic range (m)
1	Floor beams	3 65 to 15.25	4 25 to 6 00
	Slab	2 40 to 7 30	300 to 4 25
2	Floor beams	3 00 to 15 25; for economy 'a' should not be more than 1 1/5 x 'b'	4 25 to 5 50
	Slab	As for 1 above	
3	Floor beams	a c 3 to 15 25; b 1 8 to 15.25; for economy 'b' should be from 1/8 to 2/3 of (a + c)	4.25 to 5 50; 2 40 to 3 00
	Slab	As for 1 above	
4	If spacing of floor beams is greater than 5 50 m secondary beams may be used to keep slab span within the economic limits		

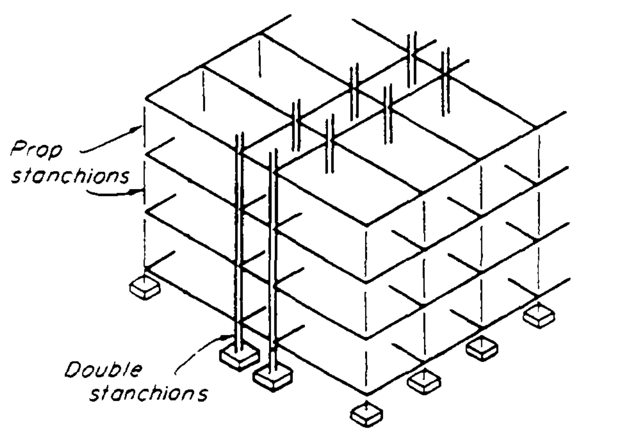


Cantilever frame



Propped cantilevers - deflection

Propped cantilevers - bending moments



Propped cantilever frame

COSTS :

Site costs:
The use of a steel or precast concrete frame will enable the maximum amount of prefabrication off site, during which time the general contractor can be constructing the foundations in preparation for the erection of the frame. To obtain the maximum utilisation of a site the structure needs to be designed so that the maximum amount of floor area is achieved. Generally prefabricated section sizes are smaller than comparable in situ concrete members, due mainly to the greater control over manufacture obtainable under factory conditions and thus these will occupy less floor area.

Construction costs:
The main factors are design considerations, availability of labour, availability of materials and site conditions. Concrete is a flexible material which allows the designer to be more creative than working within the rigid confines of standard steel sections. However, as the complexity of shape and size increases so does the cost of formwork and for the erection of a steel structure skilled labour is required, whereas activities involved with precast concrete structures can be carried out by the more readily available semi-skilled labour working under the direction of a competent person. The availability of materials fluctuates and only a study of current market trends can give an accurate answer to this problem. Site condiditions regarding storage space, fabrication areas and manoeuvrability around and over the site can well influence the framing method chosen.

Maintenance costs:
These can be considered in the short or long term but it is fair to say that in most framed buildings the costs are generally negligible if the design and workmanship is sound. Steelwork, because of its corrosive properties, will ned some form of protective treatment but since most steel structures have to be given a degree of fire resistance the fire protective method may well perform the dual function.

STRUCT. STEEL FRAMES

10.5.4.1 Structural steel frames

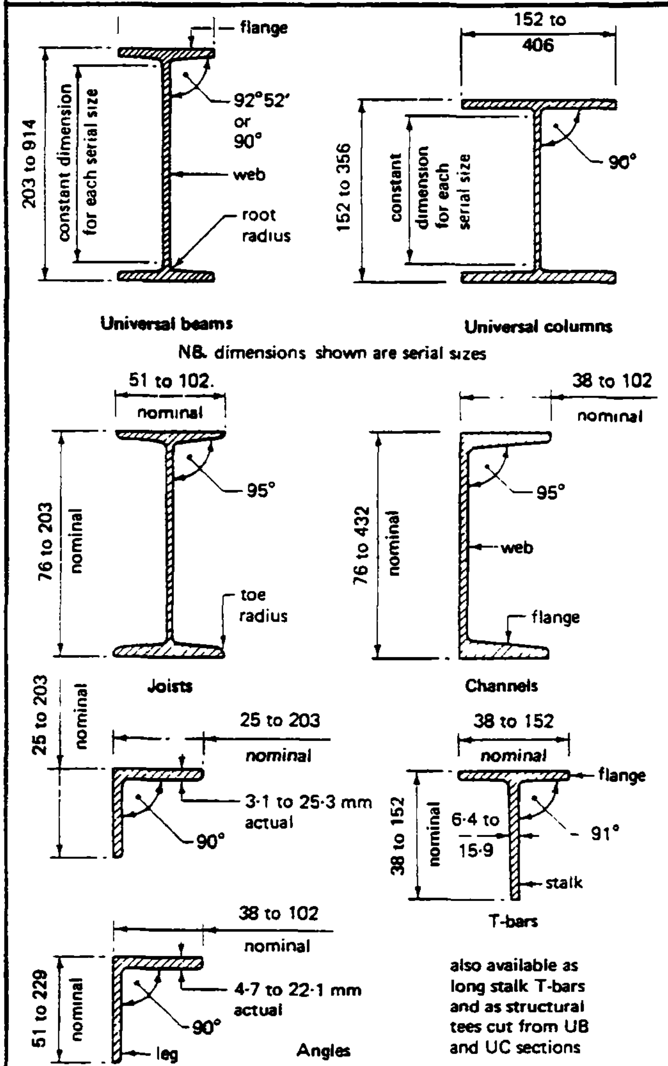
The design, fabrication, supply and erection of a structural steel frame is normally placed in the hands of a specialist sub-contractor. The main contractor's task is to provide the foundation bases in the correct positions and to the correct levels with the necessary holding down fixing bolts. The designer will calculate the loadings, stresses and reactions in the same manner as for reinforced concrete and then select a standard steel member whose section properties meet the design requirements. Standard steel sections are given in BS 4, Part 1 and in the Handbook on Structural Steelwork published jointly by the British Constructional Steelwork Association Ltd. and the Constructional Steel Research and Development Organisation, which gives the following section types:

Universal beams: These are a range of sections supplied with tapered or parallel flanges and are designated by their serial size x mass in kilograms per metre run. To facilitate the rolling operation of universal beam sections the inner profile is a constant dimension for any given serial size. The serial size is therefore only an approximate width and breadth and is given in millimetres.

Joists: A range of small size beams which have ta pered flanges and are useful for lintels and small frames around openings. In the case of joists the serial size is the overall nominal dimension.

Universal columns: These members are rolled with parallel flanges and are designated in the same manner as universal beams. It is possible to design a solumn section to act as a beam and conversely a beam section to act as a column.

Channels: Rolled with tapered flanges and designated by their nominal overall dimension x



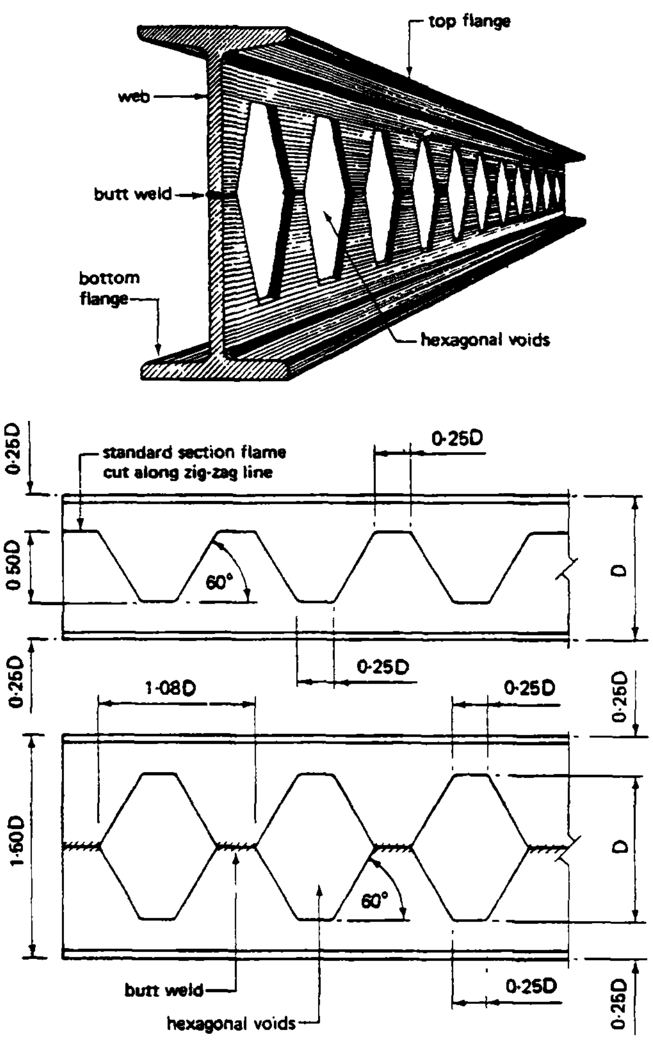
mass per metre run and can be used for trimming and bracing members or as a substitute for joist sections.

Angles: Light framing and bracing sections with parallel flanges. The flange or leg lengths can be equal or unequal and the sections are designated by the nominal overall leg lengths x nominal thickness of the flange.

T-bars: Used for the same purposes as angles and are available as rolled sections with a short or long stalk or alternatively they can be cut from a standard universal beam or column section. Designation is given by the nominal overall breadth and depth x mass per metre run.

CASTEL. UNIVERSAL SECTIONS

Castellated beams



NB castellated joists, universal columns and zed sections also available

10.5.4.2 Castellated universal sections

These are formed by flame cutting a standard universal beam or column section along a castellated line; the two halves so produced are welded together to form an open web beam. The resultant section is one and a half times the depth of the section from which it was cut. This increase in depth gives greater resistance to deflection without adding extra weight but will reduce the clear headroom under the beams unless the overall height of the building is increased. Castellated sections are economical when used to support lightly loaded floor or roof slabs and the voids in the web can be used for housing services. With this form of beam the shear stresses at the supports can be greater than the resistance provided by the web; in these cases one or two voids are filled in by welding into the voids metal blanks.

10.5.4.3 Connections

Connections in structural steelwork are classified as either shop connections or site connections and can be made by using bolts, rivets or by welding.

Bolts

Black bolts: The cheapest form of bolt available, the black bolt can be either hot or cold forged, the thread being machined onto the shank. The allowable shear stresses for this type of bolt are low and therefore they should only be used for end connections of secondary beams or in conjunction with a seating cleat which has been designed and fixed to resist all the shear forces involved. The clearance in the hole for this form of bolt is usually specified as 1.6 mm over the diameter of the bolt. The term black bolts does not necessarily indicate the colour but is the term used to indicate the comparatively wide tolerances to which these products are usually made. BS 4190 gives recommendations for black bolts and nuts for a diameter range of 5 to 68 mm inclusive.

Bright bolts: These have a machined shank and are therefore of greater dimensional accuracy fitting into a hole with a small clearance allowance. The stresses allowed are similar to those permitted for rivets. Bright bolts are sometimes called turned and fitted bolts.

High strength friction bolts:
Manufactured from high tensile steels and are used in conjunction with high tensile steel nuts and tempered washers. These bolts have generally replaced rivets and black bolts for both shop and site connections since fewer bolts are needed and hence the connection size is reduced. The object of this form of bolt is to tighten it to a predetermined shank tension in order that the clamping force thus provided will transfer the loads in the connecting members by friction between the parts and not by shear in or bearing on the bolts. Generally a torque controlled spanner or pneumatic impact wrench is used for tightening; other variations to ensure the correct torcue are visual indicators such as a series of pips under the head or washer which are flattened when the correct amount of shank tension has been reached. Nominal standard diameters available are from 12 to 36 mm with lengths ranging from 40 to 500mm, as recommended in BS 4395.

The holes to receive bolts should always be drilled in a position known as the back mark of the section. The back mark is the position on the flange where the removal of material to form a bolt or rivet hole will have the least effect upon the section properties. Actual dimensions and recommended bolt diameters are given in the Handbook on Structural Steelwork.

Rivets:
Made from mild steel to the recommendations of BS 4620 rivets habe been generally superseded by bolted and welded connections for structural steel frames. Rivets are available as either cold or hot forged with a veriety of head shapes ranging from an almost semi-circular or snap head to a countersunk head for use when the projection of a snap, universal or flat head would create an obstruction. Small diamter rivets can be cold driven but the usual practice is to drive rivets whilst they are hot. Rivets, like bolts, should be positioned on the back mark of the section; typical spacings are 2 1/2 diameters centre to centre and 1 3/4 diameters form the end or edge to the centre line of the first rivet.

Welding:
Primarily considered as a shop connection since the cost together with the need for inspection, which can be difficult on site, generally makes this method uneconomic for site connections. The basic methods of welding are oxy-acetylene and electric arc. A blowpipe is used for oxy-acetylene which allows the heat from the burning gas mixture to raise the temperature of the surfaces to be joined. A metal filler rod is held in the flame and the molten metal from the filler rod fuses the surfaces together. In the alternative method an electric arc is struck between a metal rod connected to a suitable low voltage electrical supply and the surface to be joined which must be earthed or resting on an earthed surface. The heat of the arc causes the electrode or metal rod to melt and the molten metal can be deposited in layers to fuse the pieces to be joined together.

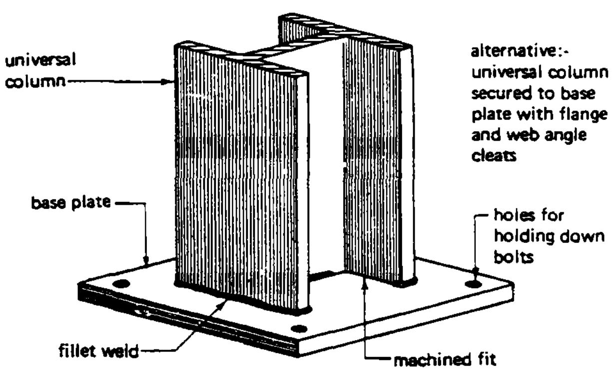
With electrical arc welding the temperature rise is confined to the local area being welded whereas oxy-acetylene causes a rise in metal temperature over a general area. Welds are classified as either fillet or butt welds. Fillet welds are used to the edges and ends of members and forms a triangular fillet of welding material. Butt welds are used on chamfered end to end connections.

STRUCT. STEEL CONNECTIONS

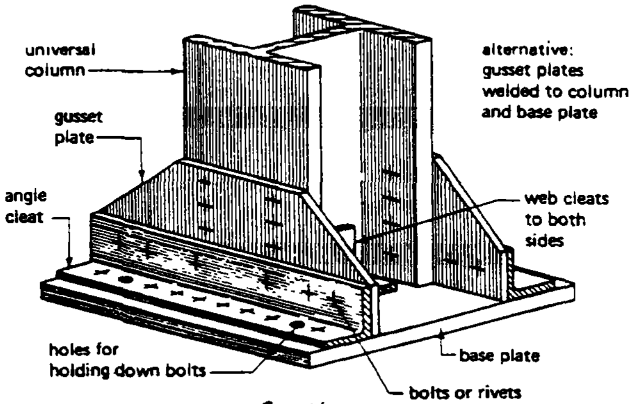
10.5.4.4 Structural steel connections

Base connections:
Are of one or two forms, the slab or bloom base and the gusset base. In both methods a steel base plate is reauired to spread the load of the column on to the foundation. The end of the column and the upper surface of the base plate should be machined to give a good interface contact when using a bloom base. The base plate and column can be connected together by using cleats or by fillet welding.

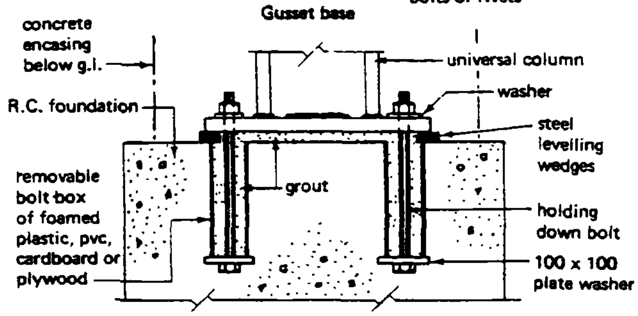
The gusset base is composed of a number of members which reduce the thickness of the base plate and can be used to transmit a high bending moment to the foundations. A machined inferface between column and base plate will enable all the components to work in conjunction with one another, but if this method is not adopted the connections must transmit all the load to the base plate. The base is joined to the foundation by holding down bolts which must be designed to resist the uplift and tendency of the column to overturn. The bolt diameter, bolt length and size of plate washer are therefore important. To allow for fixing tolerances the bolts are initially housed in a void or pocket which is

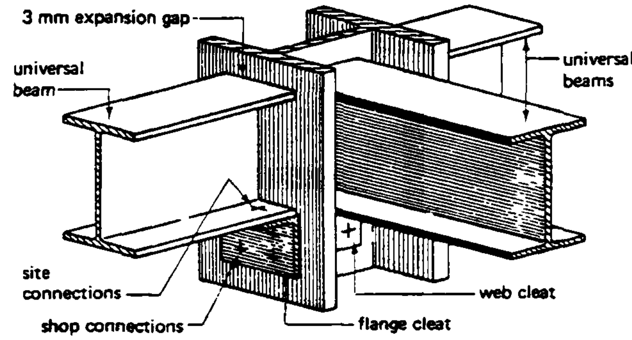


Slab or bloom base

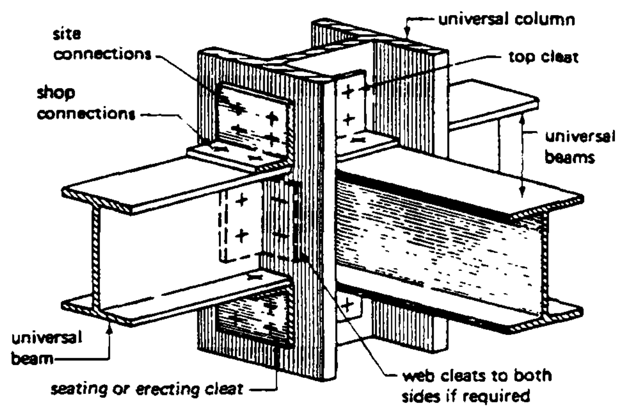


Gusset base

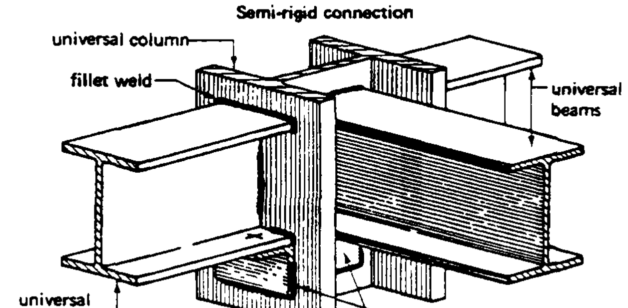




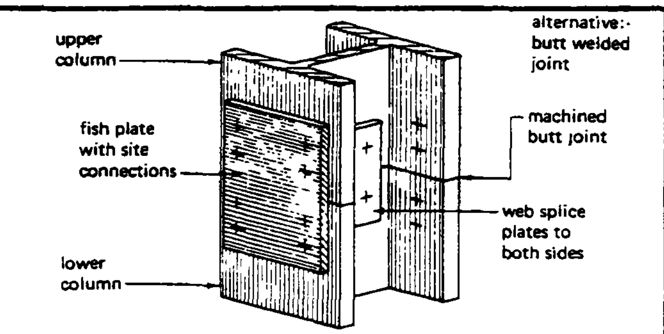
Simple connection



Semi-rigid connection

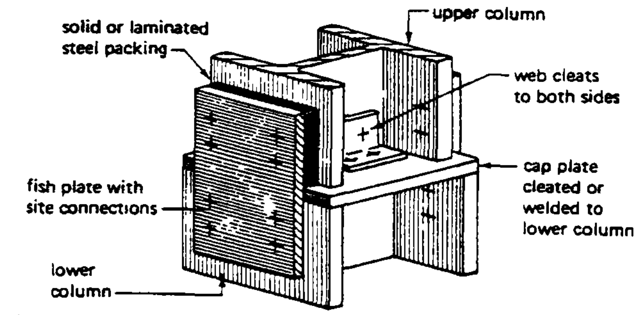


Rigid connection

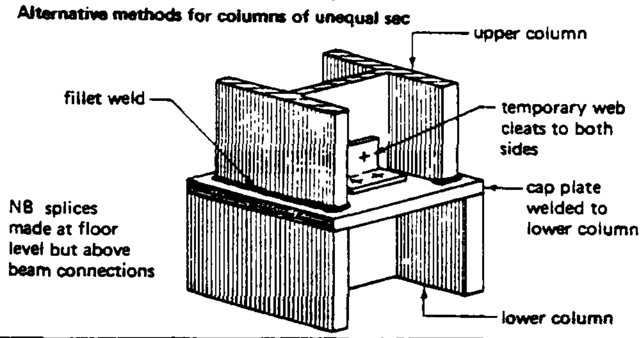


Columns with equal sections

NB for columns of same serial size but of different sections splice is made using 4 No. fish plates fixed on the inside of flanges



Alternative methods for columns of unequal sec

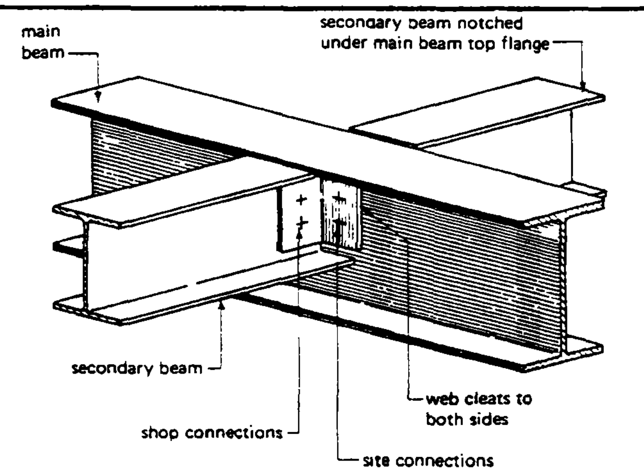


filled with grout at the same time as the base is grouted on to the foundation. To level and plumb the columns steel wedges are inserted between the underside of the base plate and the top of the foundation.

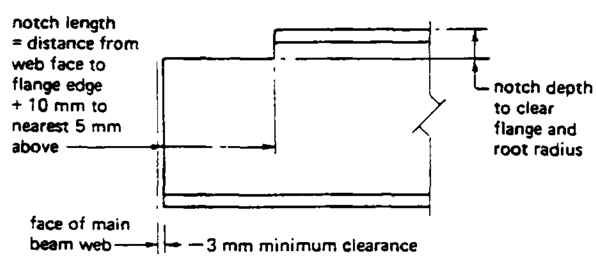
Beam to column connections:
These can be designed as simple connections where the whole of the load is transmitted to the column through a seating cleat. This is an expensive method requiring heavy sections to overcome deflection problems. The usual method employed is the semi-rigid connection where the load is transmitted from the beam to the column by means of top cleats and/or web cleats; vor ease of assembly an erection cleat on the underside is also included in the connection detail. A fully rigid connection detail, which gives the greatest economy on section sizes, is made by welding the beamt to the column. The uppermost beam connection to the column can be made by the methods described above or alternatively a bearing connection can be used, which consists of a cap plate fixed to the top of the column to which the beams can be fixed either continuously over the cap plate or with a butt joint.

Column splices: These are made at floor levels but above the beam connections. The method used will depend upon the relative column sections.

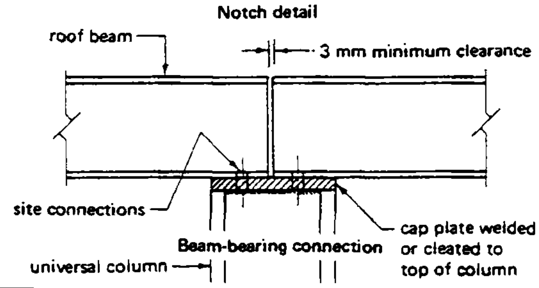
Beam to beam connections:
The method used will depend upon the relative depths of the beams concerned. Deep beams receiving small secondary beams con have a shelf angle connection whereas other depths will need to be connected by web cleats.



Beam to beam connections



Notch detail



Beam-bearing connection

10. FRAMED STRUCT.	BUILDING FRAMES	BUILDING CONSTR.
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10.5.4.5 Frame erection

This operation will not normally be commenced until all the bases have been cast and checked since the structural steelwork contractor will need a clear site for manoeuvring the steel members into position. The usual procedure is to erect two storeys of steelwork before final plumbing and levelling takes place.
The grouting of the base plates and holding down bolts is usually left until the whole structure has been finally levvelleo and plumbed. The grout is a neat cement or cement/sand mixture depending on the gap to be filled:

12 to 25mm gap -	stiff mix of neat cement;
25 to 50mm gap -	fluid mx of 1:2 cement/sand and tamped;
over 50mm gap -	stiff mix of 1:2 cement/sand and rammed.

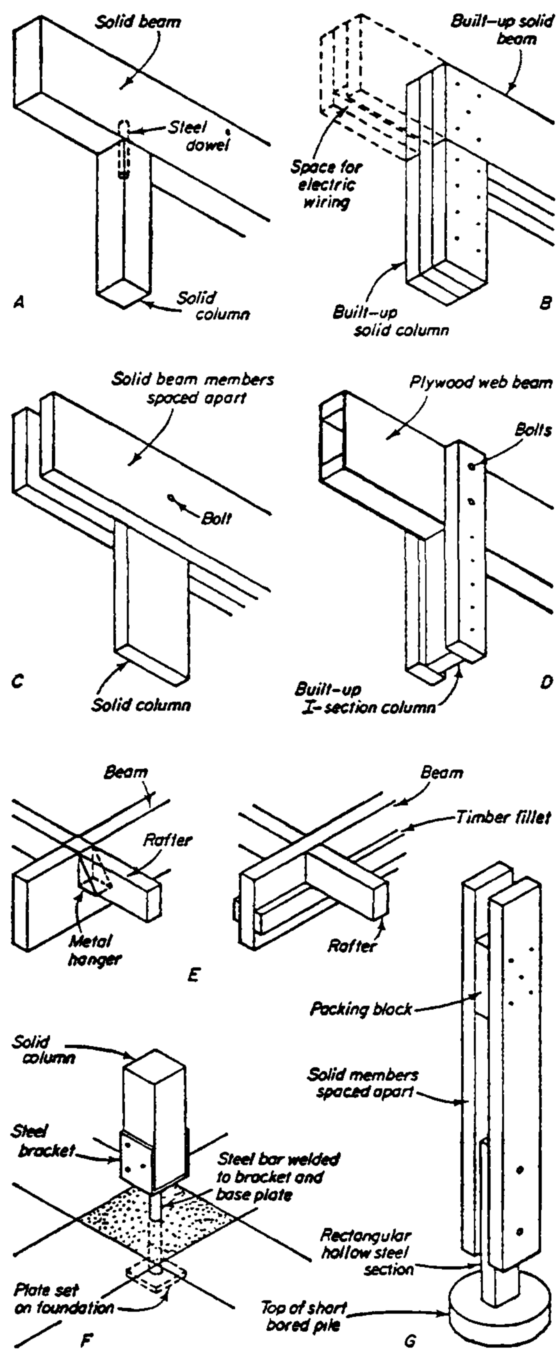
With large base plates a grouting hole is sometimes included but with smaller plates three sides of the base plate are sealed with puddle clay, bricks or formwork and the grout introduced through the open edge on the fourth side. To protect the base from corrosion it should be encased with concrete up to the underside of the floor level giving a minimum concrete cover of 75mm to all the steel components.

10.5.4.6 Fire protection of steelwork

Part E of building regulations together with Schedule 8 gives the minimum fire resistance periods and methods of protection for steel structures according to the purpose group of the building and the function of the member. The traditional method is to encase the steel section with concrete, which requires formwork and adds to the loading of the structure. Many 'dry' techniques are available but not all are suitable for exposed conditions.

10.5.5 Timber frames

Skeleton frames constructed in timber may be fabricated from solid timber sections, built-up sections or glued and laminated sections.



Timber beams and columns

10.5.5.1 Clumns and beams

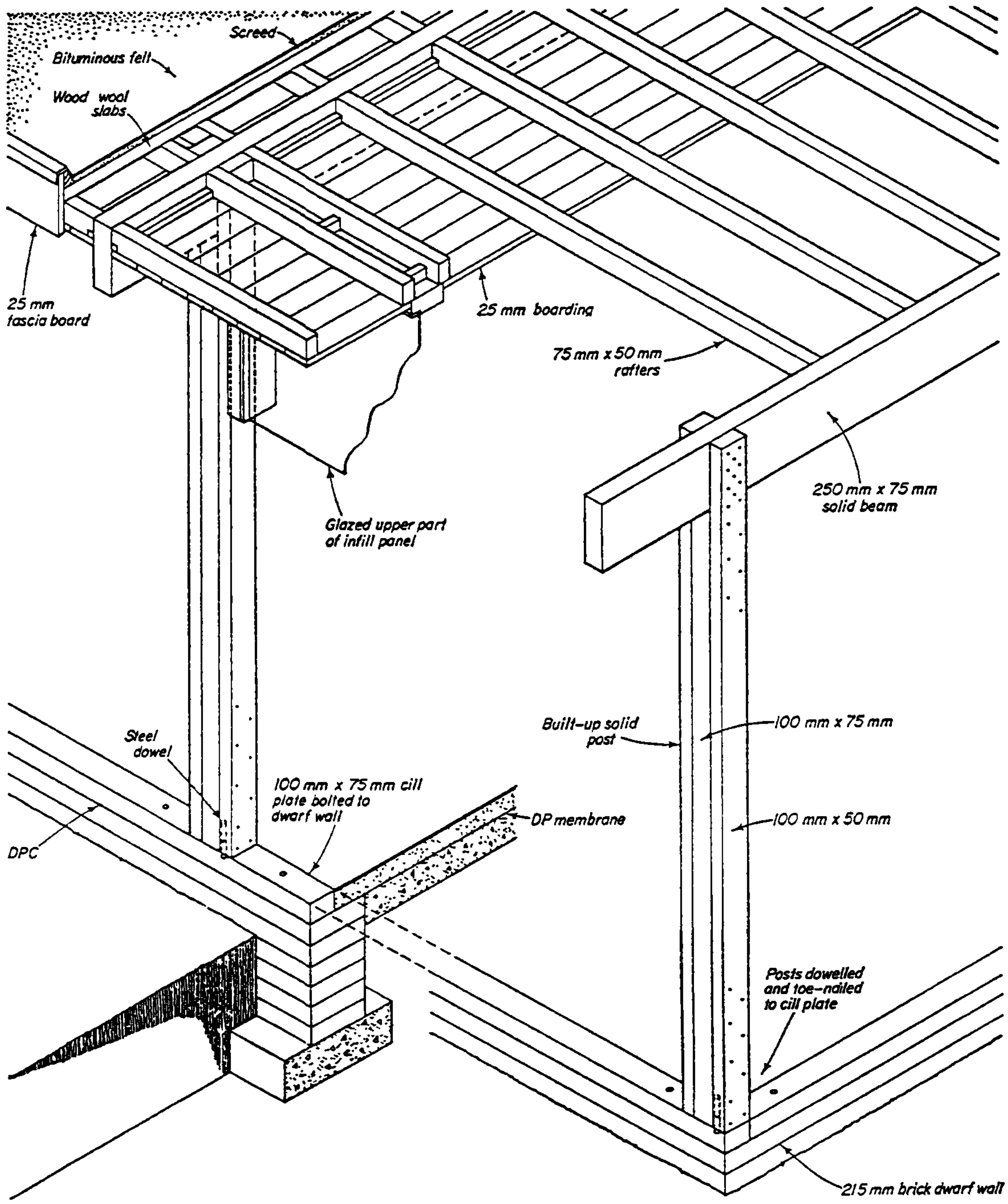
Solid square or rectangular sections are generally the most economical in cost, but where members beyond the available sizes and lengths of solid timber are required it is necessary to form them by combining a number of smaller sections of timber. This may be accomplished by nailing or bolting together several pieces to form built-up solid sections. Apart from obtaining the required sizes for large members there are advantages in building up solid sections from smaller pieces since these are easier to obtain and to season properly without checking and they may be built-up in ways that minimise warping and permit rigid connections between columns and beams.

In the case of built-up column sections involving butt joints in the length it is essential that the abutting faces be carefully machined and the joints staggered. Built-up box and I-sections used as columns are stiffer than a solid section for a given timber content and are particularly suitable for tall columns. Another method of increasing the stiffness of lightly loaded columns is to provide the bearing area in two parallel members spaced apart by packing blocks at intervals and connected by nails, bolts or glue.

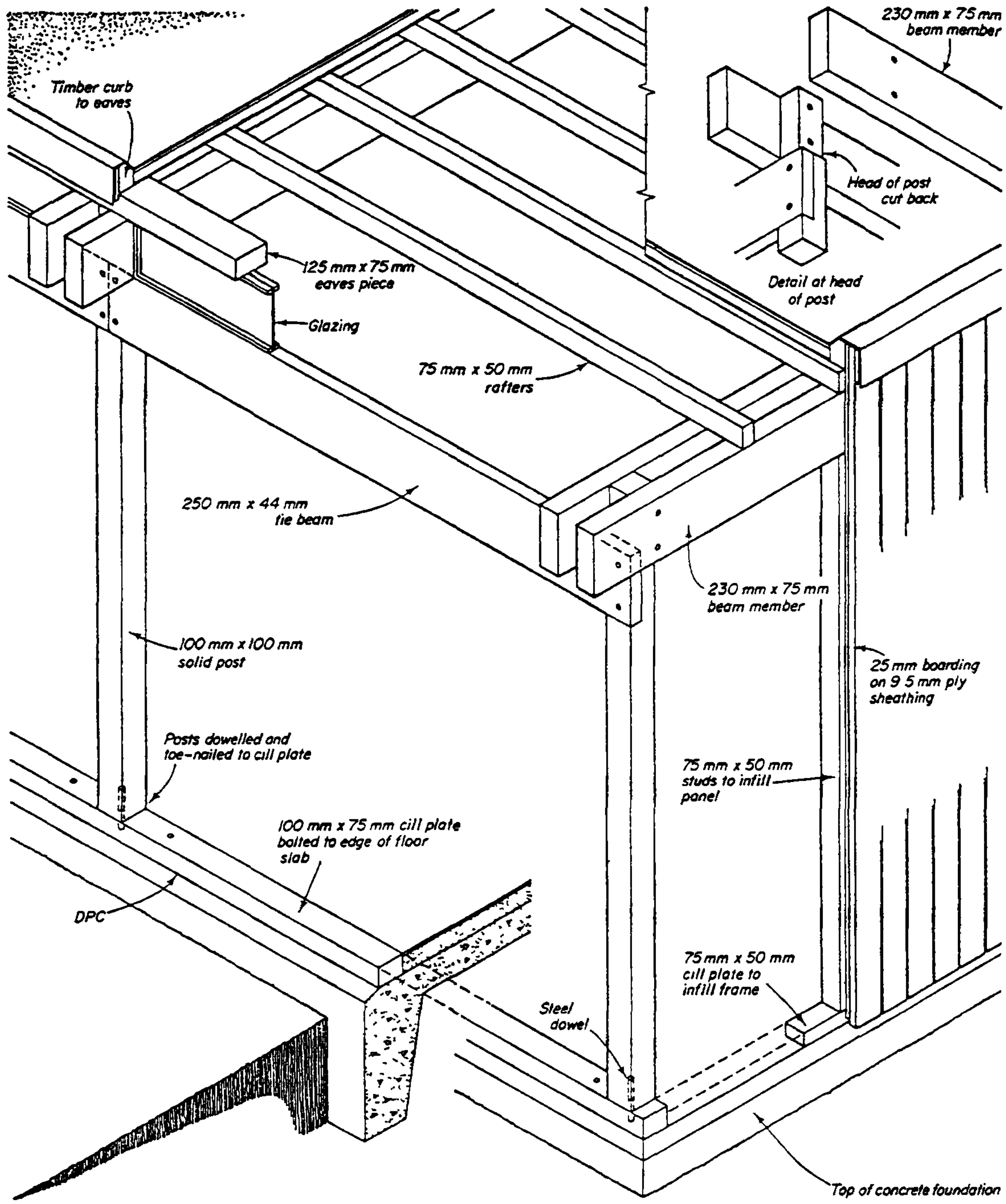
Built-up solid beams are normally built up of vertical pieces nailed or bolted together, nailing being satisfactory for beams up to about 250mm in depth, although these may require the use of bolts at the ends if shear stresses are high. Where the imposed loading is light beams may be built up with solid flanges and plywood webs nailed or glued, or glued and nailed, together. Such web beams, compared with solid beams, are very stiff relative to the amount of timber in them, especially those with two webs forming a box section and result in low

TIMBER FRAMES

dead/live load ratios. The thin webs necessitate stiffeners at intervals along the length of the beam. Increased shear resistance near the supports may be obtained by closer spacing of the stiffeners at the ends of the beam. The fire resistance of



Timber frame with built-up solid posts and solid beams

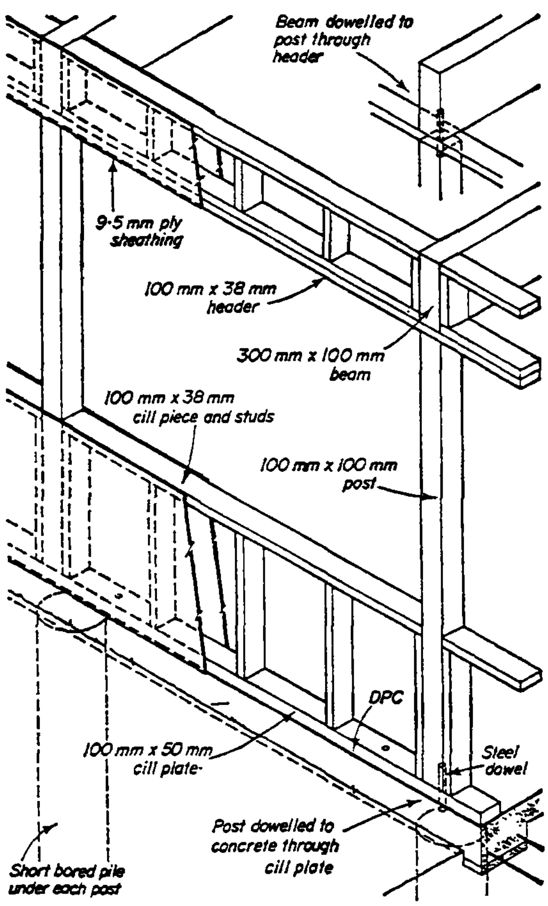


Timber frame with solid posts and spaced solid beams

web beams such as these is very much lower than that of solid or glued and laminated timber beams by reason of the thinness of the parts. If exposed to the weather the surface veneer of the plywood webs of this type of beam tends to check. Glued and laminated sections, commonly called glulam sections, consist of timber laminations glued together to form square or rectangular sections and, for large span beams, I-sections. They are more expensive than solid or built-up sections but permit the use of higher permissible stresses in their design and are, therefore, suitable where loads are great or spans are large.

10.5.5.2 Connections
Connections between beams and columns are made with nails, bolts, dowels and cleats according to the type of members.

Those between solid and glulam beams and columns are made by metal dowels with or without side fixing plates, the latter providing a stiffer connection, or simply by side-nailing the beam to the column. Built-up members are connected by nails, bolts or bolts and timber connectors. Built-up solid sections or spaced solid members permit rigid connections to be made by passing one member, or part of it, through the other.

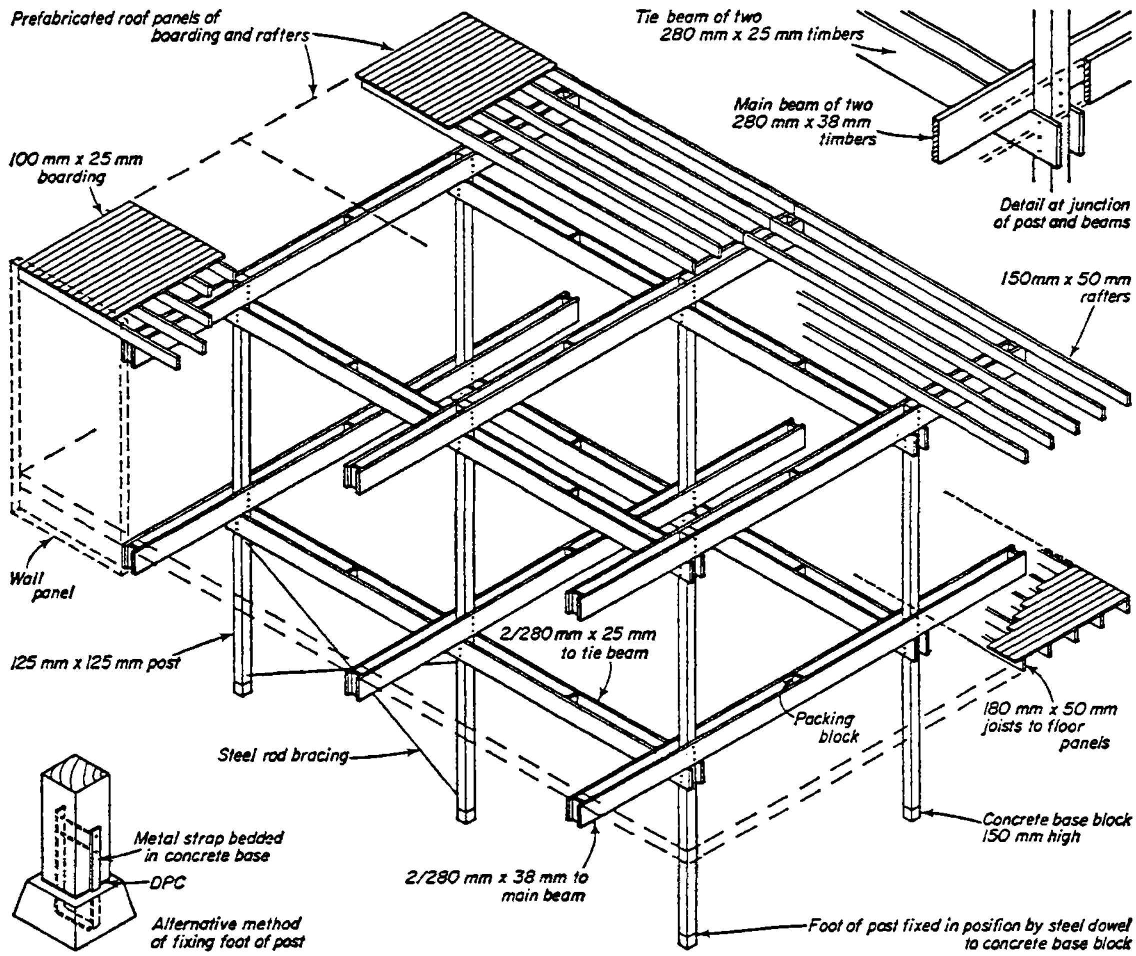


Timber frame with solid posts and beams

Spaced beams permit the use of smaller sections than would be required for a single solid member. The solid built-up beam, however, has the advantage that one piece restrains the warping of the others.
Beam to beam connections are made by means of metal hangers or by metal cleats bolted or screwed to the beams, Rafters and joists may be supported by hangers or timber fillets.
Column base connections are made in various ways depending on the relation of the column to the remainder of the building fabric. Free standing external columns normally are raised of the ground to isolate them from ground moisture. This may be done by means of a concrete stool or block with a damp-proof layer between the timber and concrete, the column being fixed in position by a steel dowel or by straps and bolts. Alternatives to this which isolate the timber from the ground and also fix the column in position are shown in the figure. These three methods also hold the post against wind uplift, the effect of which can be considerable when the roof is flat and the structure is light. External perimeter columns normally bear on a continuous timber cill plate which is bolted to the concrete floor slab or perimeter dwarf wall and which also carries the infilling wall panels. If the loading on the column and the nature of the soil necessitates it a small pier and foundation slab or a short bored pile must be constructed under the column position. Internal columns usually bear directly on the floor slab, thickened to form a base if necessary, and are secured in position by a metal dowel.

10.5.5.3 Building frames in timber.

Most small-scale timber framed structures take the form of post and beam construction in which resistance to racking distortion of the frame under working load is provided by the infill panels. A proportion of solid or near-solid wall panels is, therefore, necessary to ensure stability and can normally be provided. The choice of connection and form of junction between the members of the frame in most cases thus depends largely on the degree of rigidity required for erection purposes before the panels are fixed.
The figure shows post and beam frames constructed with built-up solid posts and single solid beams, the latter passing between the outer column pieces, to which they are secured by nailing, and bearing on the centre piece. The foot of each post bears on the timber cill plate bolted to the dwarf wall as for frame wall construction. Bearings for the rafters are provided by fillets nailed to the beam sides. The roof extends beyond the wall panels the heads of which are secured to noggings between two closely spaced rafters.
The frames are constructed with solid posts and spaced solid beams. The latter bear on shoulders formed at the head of the posts and are secured by two bolts to produce a rigid connection. In this example some lateral rigidity results from the provision of a deep tie beam immediately below the bearings of the main beams, this also being set into the face of the posts and bolted to them. This tie, together with the substantial member fixed to the paired beams above the glazing and some solid panels under some windows in the wall panels, would provide lateral rigidity to the structure.
Since a dowelled connection does not produce a rigid post to beam junction rigidity must be provided by wall panels parallel to the beams. The header running over the tops of the posts provides some rigidity to the frames during erection and ultimate structural rigidity is provided by the top and bottom solid panels forming an opening for glazing. In this example the foundations are short bored piles placed under each post.
The figure shows a double height house frame with the single floor raised above ground level.
The posts are solid and the main bearing beams and lateral tie beams are formed as spaced beams with pairs of deep but relatively thin solid members. The depth of the junction between posts and beams and the use of three bolts at each connection produces stiff joints and rigidity in both directions. Packing blocks at the ends and centre of all beams provides the necessary stiffening against lateral buckling of the thin members. Further stiffening of the frame would be provided by enclosing one of the ground level bays on all four sides with solid panels.
The floor and roof consist of boarded timber joists and rafters made up into prefabricated panels bearing on top of the beams. Prefabricated wall panels are secured to the edges of roof and floor.



Two-storey timber frame

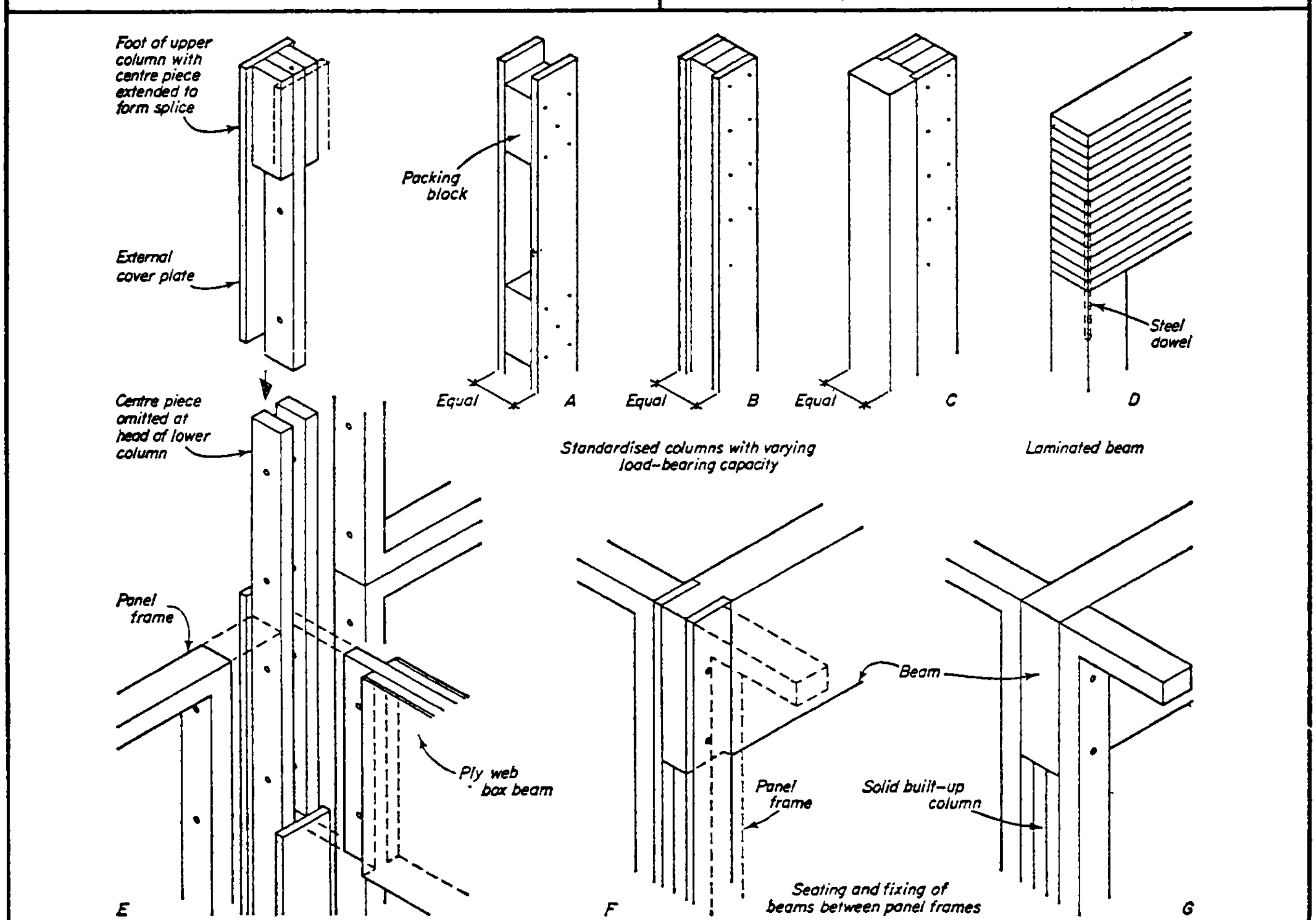
PREFABRICATION

10.5.5.4 Prefabrication

The design of the last structure and its panel components permits full prefabrication of the parts and assembly by nut-and-bolt is simple and rapid. It is, however, a 'one-off' building. In any form of system building for alarge market provision must be made for the variety of situations produced by arying spans and loading of beams and by single or two-storey buildings, by designing ranges of components with a minimum of variations in construction and dimensions which may be applied to a maximum number of building situations. The figure shows solutions to some aspects of the problem which have been worked out in practice. (A,B, and C) illustrate column types in the same system, all of standard width. (A) is for the light loads and consists of two relatively thin but identical members of sufficient cross-sectional area to take the maximum design load for which they are intended, blocked apart to prevent them buckling. (B) is a built-up solid version with increased bearing area to take greater loads, the outer members and the overall dimensions being the same as in (A). (C) is an extension of (B) to provide further bearing area by the addition of a solid piece glued to (B), to receive which the rebate in the latter is formed. Thus by this means provi-

PREFABRICATION

sion is made for a range of loading conditions by a minimum number of component parts with a standard width dimension.
Variations in span and loading of beams may be met by increased depth and by change of form while maintaining a standard width. Normal timber sizes set a limit to the depth of solid timber beams but deeper beams may be formed as plywood box beams as in (E) where imposed loads are light or by laminating thin boards in glulam construction as in (D).
The three-piece built-up solid column shown in (E) permits a splice connection to be formed for two_story construction, by a simple variation of standard storey-height column components.
The recess to accommodate the beam at the head of a standard column, formed by the omission of the centre piece at that point, is extended by the use of longer outer members. This receives the splice formed at the foot of the upper column by the use of shorter outer members. In this example the end of the ply box-beam is formed as a deep tenon which is accomodated by the column recess and bears on top of the centre piece. The connection is secured by bolts which pass through the edge members of the infill panels to hold them in position.
In single-storey framed systems the seating and fixing of beams may be accomplished by making the column shorter than the adjacent infill panels and using the latter to fix the beam in position as in (G) which requires the fixing of the panels prior to setting the beam in position. In (F) the built-up column has two thinner outer pieces which carry up the full height and serve to hold the beam in position by nailing until the infill panels are offered up and bolted in position.



10. FRAMED STRUCT.	BUILDING FRAMES	BUILDING CONSTR.
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CIVIL ENGINEER DEPARTMENT

10.6 PORTAL FRAMES

10.6.1 Theory

- A portal frame may be defined as a continous or rigid frame.
- The basic characteristic is that of a rigid or restrained joint between the supporting member (column) and the spanning member (beam).
- The object of this continuity is to reduce the bending moment in the spanning member by allowing the frame to act as one structural entidy, thus distributing the stresses throughout the frame.
- In a conventional simply supported beam (over a large span) an excessive bending moment occurs at mid-span.

This necessiates a deep heavy beam or a beam shaped to give a large cross section at mid-span. Alternatively a deep cross member of lattice struts and ties could be used. The main advantage of a simply supported frame lies in the fact that the column loading is axial and therefore no bending is induced into the supporting members

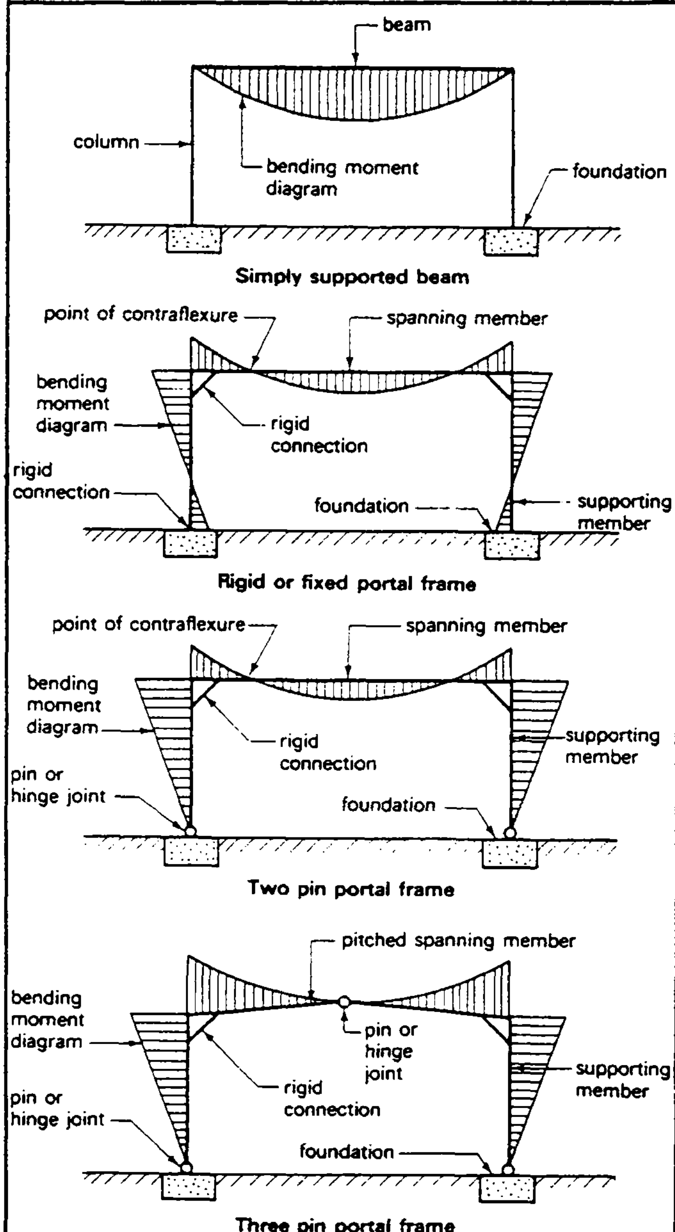
This may ease design problems (since it would be statically determinate), but does not necessarily produce an economic structure.

Furthermore the use of a portal frame eliminates the need for a lattice of struts and ties within the roof space, giving a greater usable volume to the structure and generally a more pleasing internal appearance.

- In a RIGID FRAME the transfer of stresses from the beam to the column will require special care in the design of the joint between the members.

Similarly the horizontal thrust and/or the rotational movement at the foundation connection needs careful consideration. Methods to overcome excessive forces at the foundation are:

1. Reliance on the PASSIVE PRESSURE of the soil surrounding the foundation.
2. Inclined foundations so that the curve of pressure is normal to the upper surface thus tending to induce only compressive forces.
3. A tie bar or beam between opposite foundations.
4. Introducing a hinge or pin joint where the column connects to the foundation.



Portal frames - comparison of bending moments

- HINGES

  Portal frames are usually connected directly to their foundation bases, forming rigid or unrestrained joints.

The rotational movement caused by wind pressures, tending to move the frames and horizontal thrusts of the frame loadings are generally resisted by the size of the base and the passive earth pressures. When the frames start to exceed 4 m in height and 15 m in span the introduction of a hinged or pin joint at the base connection should be considered.

A hinge is a device which will allow free rotation to take place at the point of fixity but at the same time will transmit both load and shear from one member to another.

They are sometimes colled: pin joints, unrestrained joints, nonrigid joints.

Since no bending moment is transmitted through a hinged joint the design is simplified by the structural connection becoming statically deteminate.

(In practice it is not always necessary to provide a true PIVOT where a hinge is included but to provide just enough movement to ensure the rigidity at the connection is low enough to overcome the tendency of rotational movement.)

Hinges can be introduced into a portal frame design at the base connections and at the centre or apex of the spanning member, giving three basic forms of portal frames:

1. Fixed or rigid portal frames- all connections between frame members are rigid.
   - The bending moment will be of lower magnitude and more evenly distributed than other forms.
   - Used for small to medium size frames where the moments transfered to the foundations will be excessive.
2. Two pin portal frame - hinges are used at the base connection to eleminate the tendency of the base to rotate.
   - The bending moments resisted by the supporting members will be greater than those in the rigid portal frame.
   - Main use is where high base moments and weak ground conditions are encountered.
3. Three-pin portal frames - this form has hinged joints at the base connections and at the centre of the spanning member.
   - The effect of the third hinge is to reduce the bending moment in the spanning member but to increase deflection.
   - To overcome this latter disadvantage a deeper beam must be used or alternatively the spanning member must be given a pitch to raise the apex wall above the eaves level.

THEORY

Two other advantages of the three-pin portal frame are that the design is simplified since the frame is statically determinate and on site they are easier to erect, particularly when preformed in sections.

Most portal frames are made under factory controlled conditions - off site - which gives good dimensional and quality control but can create transportation problems.

To lessen this problem and that of site erection splices may be used. These can be positioned at the points of contraflexure, junction between spanning and supporting members and at the crown or apex of the beam.

Portal frames can take the form of the usual roof profiles for single or multispan buildings.

The frames are generally connected over the spanning members with purlines designed to carry lightweight roof coverings or deckings.

The walls can be of similar material fixed to sheeting rails attached to the supporting members or alternatively clad with brick or infill panels.

CONCRETE PORTAL FRAMES

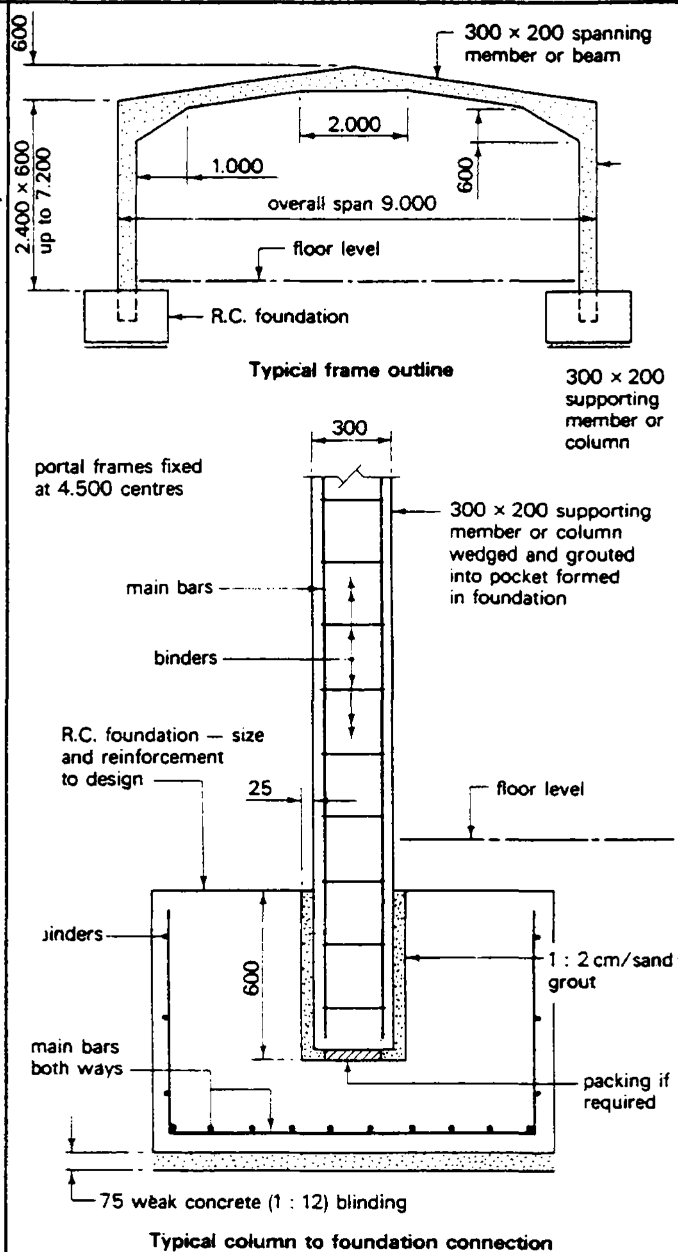
10.6.2 Concrete portal frames

Concrete portal frames are invariably manufactured from high quality precast concrete suitably reinforced.
In the main the use of precast concrete portal frames is confined to low pitch (4° to 22 $1/2^{\circ}$) single span frames but two storey and multi-span frames are available, giving a wide range of designs from only a few standard components.

The frames are generally designed to carry a lightweight (34 kg/m^2 maximum) roof sheeting or decking fixed to precast concrete purlins.

Wall finishes can be varied and intermixed since they are non-load bearing and therefore have to provide only the degree of resistance required for fire, thermal and sound insulation, act as a barrier to the elements and resist positive and negative wind pressures. Sheet claddings are fixed in the traditional manner, using hook bolts and purlins, sheet wall claddings are fixed in a similar manner to sheeting rails of precast concrete or steel spanning between or over the supporting members. Brick or block wall panels either of solid or cavity construction can be built off a ground beam constructed between the foundation bases or alternatively they can be built off the ground floor slab. It must be remembered that all such claddings must comply with any relevant Building Regulations.
Foundations and fixings.
The foundations for a precast concrete portal frame usually consist of a reinforced concrete isolated base or pad designed to suit loading and ground bearing conditions. The frame can be connected to the foundations by a variety of methods:

1. Pocket connection - the foot of the supporting member is located and housed in a void or pocket formed in the base so that there is an all round clearance of 25 mm to allow for plumbing and final adjustment before the column is grouted into the foundation base.
2. Base plate connection - a steel base plate is welded to the main reinforcement of the supporting member, or alternatively it could be cast into the column using fixing



Typical single span pcc frame

lugs welded to the back of the base plate. Holding down bolts are cast into the foundation base; the erection and fixing procedure follows that described for structural steelwork.

3. Pin joint or hinge connection - a special base or bearing plate is bolted to the foundation and the mechanical connection is made when the frames are erected.

CONCRETE PORTAL FRAMES

The choice of connection method depends largely upon the degree of fixity required and the method adopted by the manufacturer for his particular system.

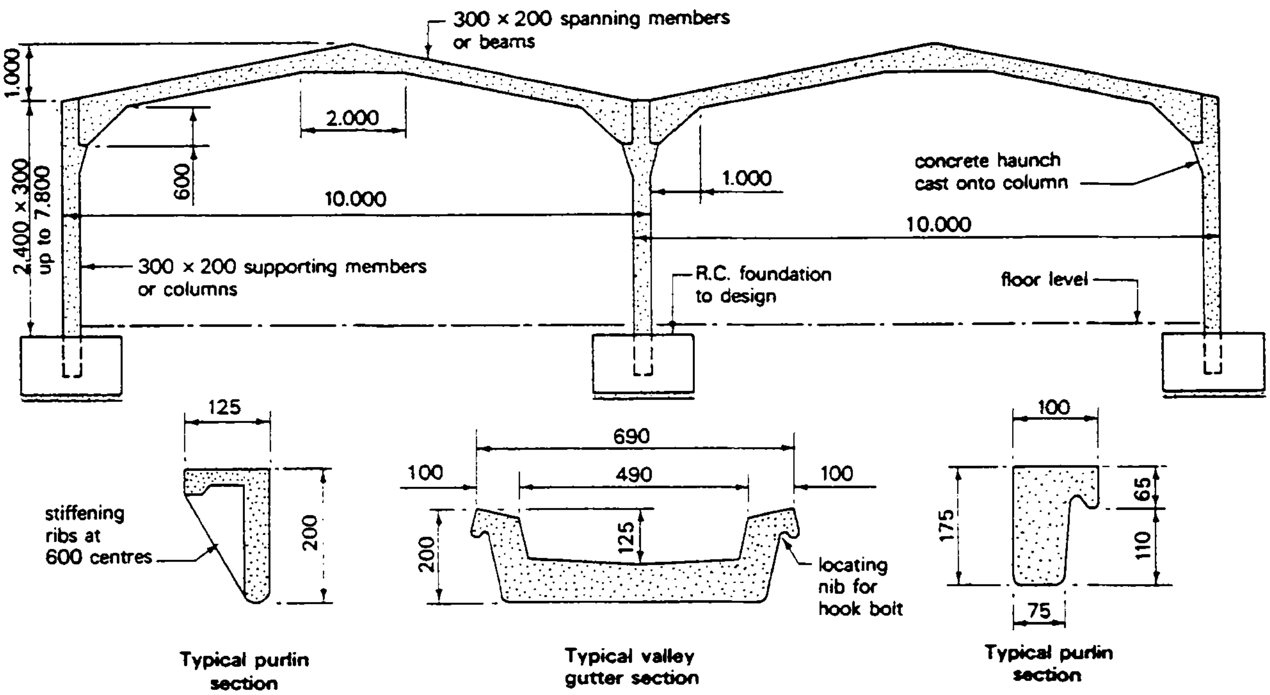


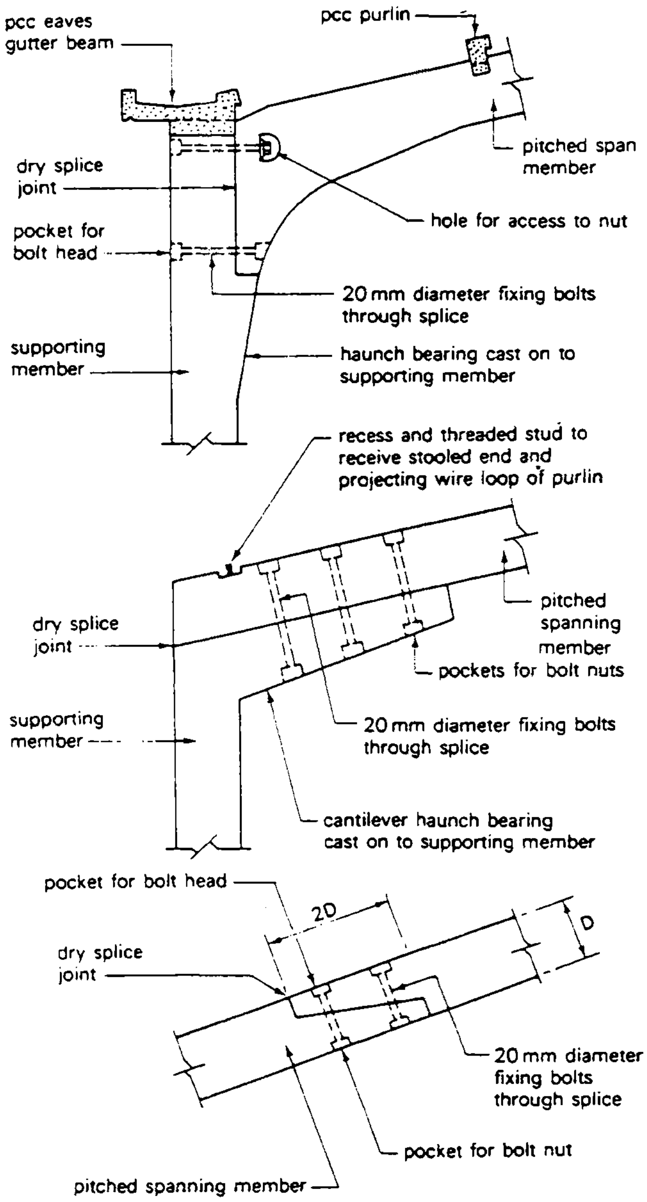
Fig III.3 Typical multi-span precast concrete portal frame

Advantages
The main advantages of using precast concrete portal frames can be enumerated thus:

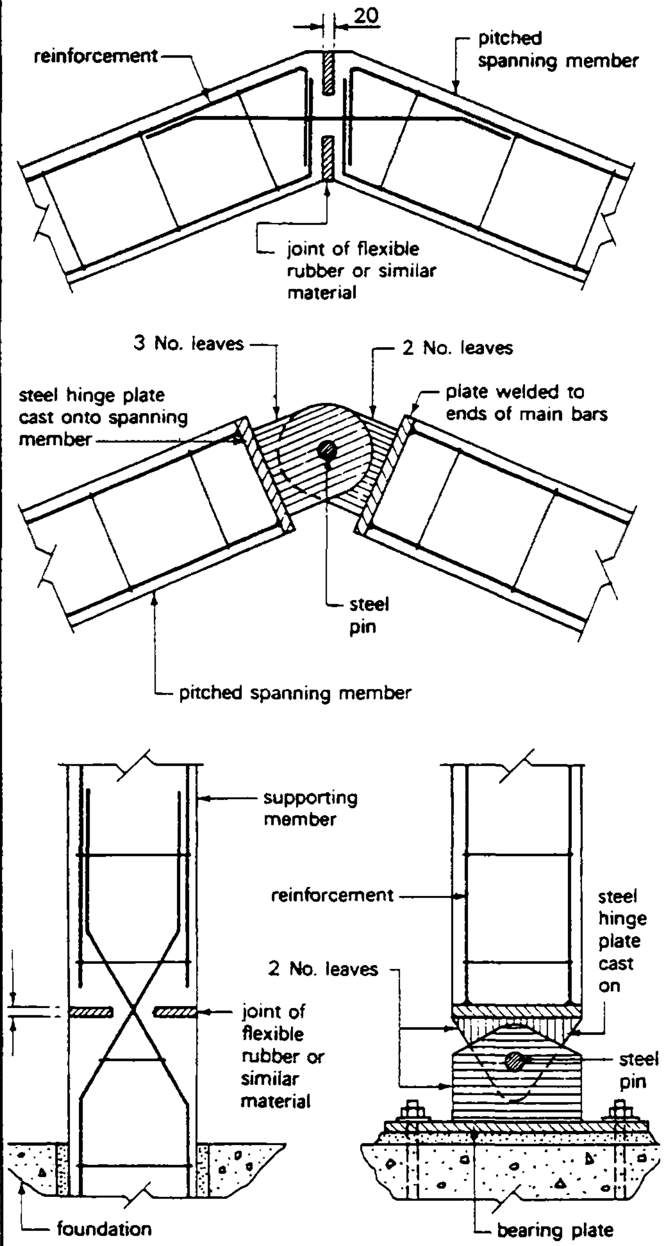
1. Factory production will result in accurate and predictable components since the criteria for design, quality and workmanship recommended in CP 110 can be more accurately controlled under factory conditions than casting components in situ.
2. Most manufacturers produce a standard range of interchangeable components which, within the limitations of their systems, gives a well-balanced and flexible design range covering most roof profiles, single span frames, multi-span frames and lean-to roof attachments. By adopting this limited range of members the producers of precast portal frames can offer their products at competitive rates soupled with reasonable delivery periods.
3. Maintenance of precast concrete frames is not usually required unless the building owner chooses to paint or clad the frames.

ADVANTAGES

4. Precast concrete products have their own built-in natural resistance to fire and therefore no fire-resistant treatment is required. By varying the cover of concrete over the reinforcement most frames up to 24.000 m span are given a 1-hour fire resistance and frames exeeding this span are rated at 2-hour fire resistance.
5. The wind resistance of precast concrete portal frames to both positive and negative pressures is such that wind bracing is not usually required.



Typical splice details for pcc portal frames



Typical hinge details for pcc portal frames

6. Where members of the frame are joined or spliced together the connections are generally mechanical (nut and bolt) and therefore the erection and jointing can be carried out by quickly trained semi-skilled labour.
7. The clean lines of precast concrete portal frames are considered to be aesthetically pleasing.
8. In most cases the foundation design, setting out and construction can be carried out by the portal frame sub-contracting firm.

10.6.3 Steel portal frames

Steel portal frames can be fabricated from standard universal beam, column and box sections. Alternatively a lattice construction of flats, angles or tubulars can be used. Most forms of roof profiles can be designed and constructed giving a competitive range when majority of systems employ welding techniques for the fabrication of alternative system uses special knee joint, apex joint and base joint column sections supplied by the main contractor or by the manufacturer producing the jointing pieces.

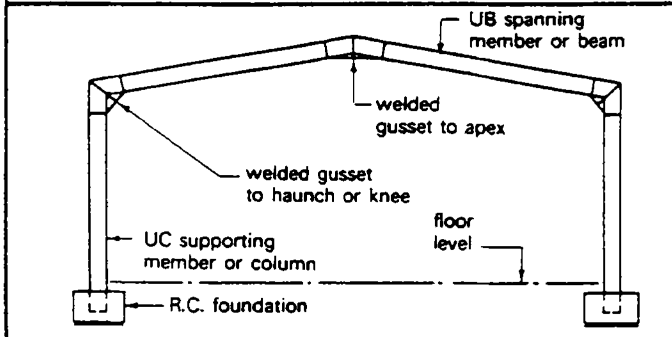
The frames are designed to carry lightweight roof coverings of the same loading conditions as those given previously for precast concrete portal frames. Similarly wall claddings can be of the same manner.

Foundations and fixings.

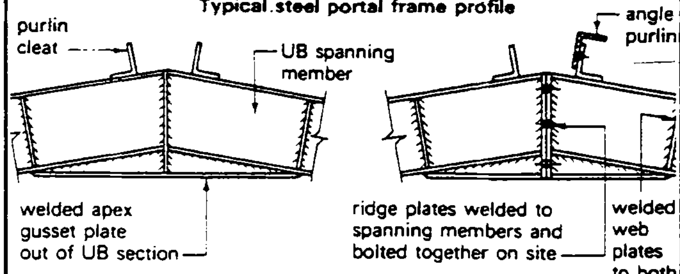
The foundation is usually a reinforced concrete isolated base or pad foundation designed to suit loading and ground bearing conditions. The connection of the frame to the foundation can be by one of three basic methods:

1. Pocket connection -
   The foot of the supporting member is inserted and grouted into a pocket formed in the concrete foundation as described for precast concrete portal frames. To facilitate levelling some designs have gussets welded to the flanges of the columns.
2. Base plate connection -
   traditional structural steelwork column to foundation connection using a slab or a gusset base fixed to a reinforced concrete foundation with cast in holding down bolts.
3. Pin or hinge connection -
   special bearing plates designed to accomodate true pin or rocker devices are fixed by holding down bolts to the concrete foundation to give the required low degree of rigidity at the connection.

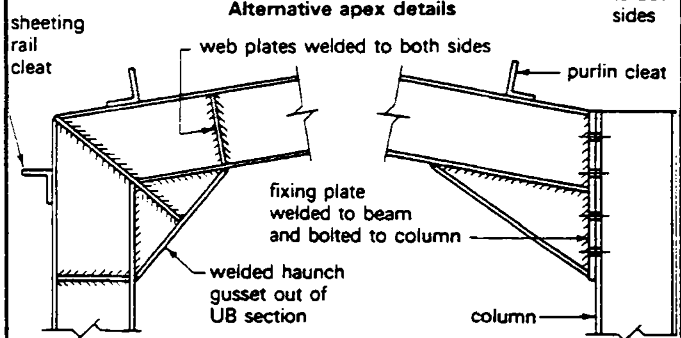
STEEL PORTAL FRAMES



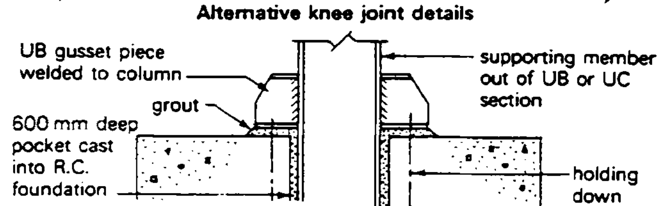
Typical steel portal frame profile



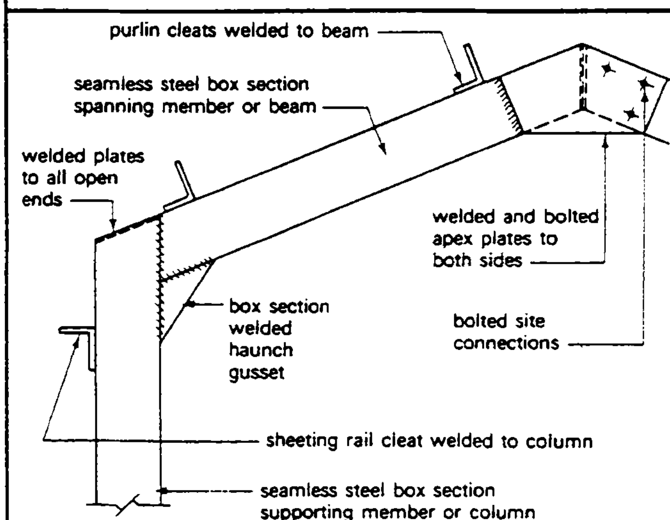
Alternative apex details



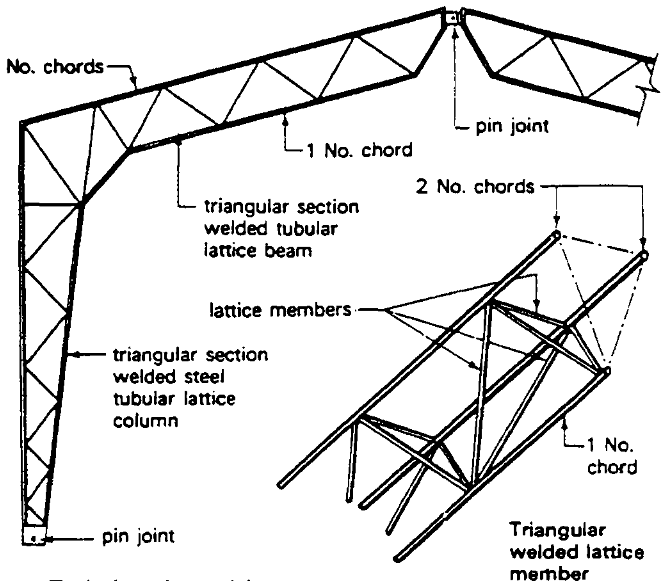
Alternative knee joint details



Pocket foundation connection



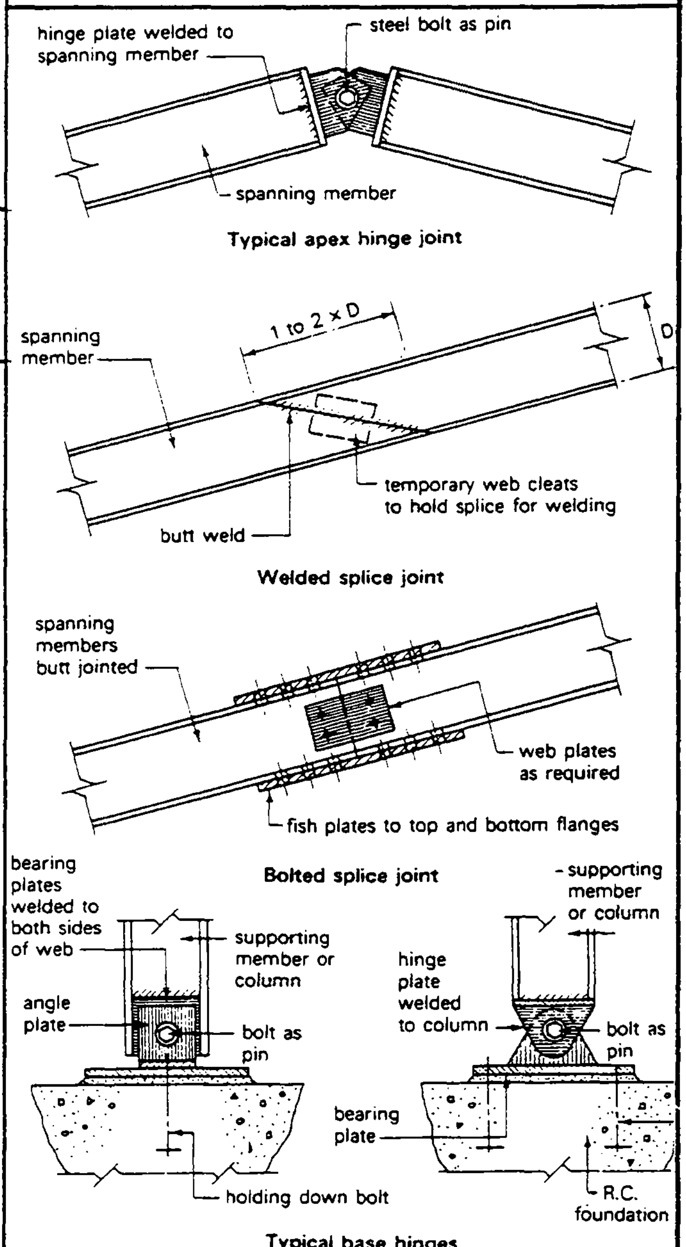
STEEL PORTAL FRAMES



Typical steel portal frames

ADVANTAGES

Advantages
The main advantages of factory controlled production are: a standard range of manufacturer's systems, a frame of good wind resistance and the ease of site assembly using quickly trained semi-skilled labour attributed to precast concrete portal frames can be equally applied to steel portal frames. A further advantage of steel is that generally the overall dead load of a steel portal frame is less than a comparable precast concrete portal frame. However, steel has the disadvantage of being a corrosive material which will require a long life protection of a patent coating or regular protective maintenance generally by the application of coats of paint. Steel has a lower fire resistance than precast concrete but if the frame is for a single storey building structural fire protection may not be required under the Building Regulations (see Building Regulation E5(4)).



Steel portal frames - splices and hinges

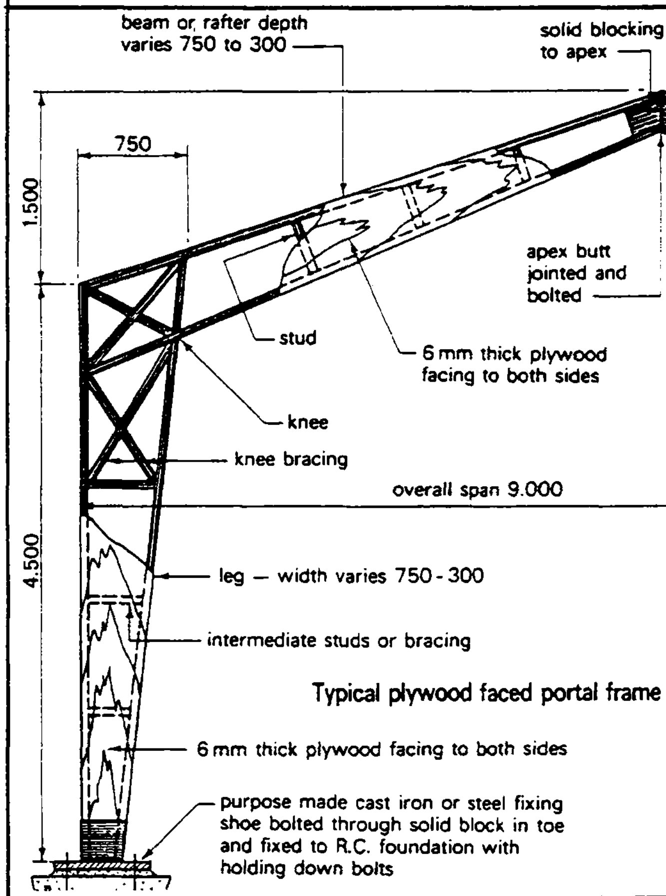
10.6.4 Timber portal frames

Timber portal frames can be manufactured by several methods which produce a light, strong frame of pleasing appearance which renders them suitable for buildings such as churches, halls and gymnasiums where clear space and appearance are important.
The common methods used are glued laminated portal frames, plywood faced portal frames and timber portal frames using solid members connected together with plywood gussets.

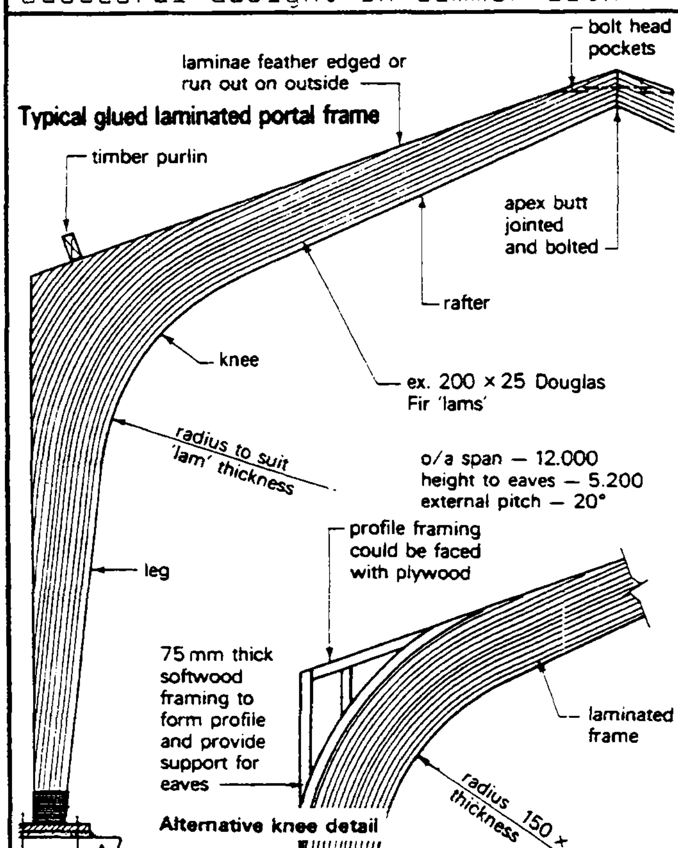
Glued laminated portal frames.

The main objective of forming a laminated member consisting of glued layers of thin section timber members is to obtain an overall increase in strength of the complrete component over that which could be expected from a similar sized solid section of a particular species of timber. This type of portal frame is usually manufactured by a specialist firm since the jigs required would be too costly for small outputs.
The selection of suitable quality softwoods of the right moisture content is also important for a succesful design. In common with other timber portal frames, these can be fully rigid, 2pin or 3 pin structures.
Site work is simple, consisting of connecting the foot of the supporting member to the metal shoe fixing or to a pivot housing bolted to the concrete foundation and connecting the joint at the apex or crown with a bolt fixing or a hinge device. Most glued laminated timber portal frames are fabricated in two halves which eases transportation problems and gives maximum usage of the assembly jigs. The frames can be linked together at roof level with timber purlins and clad with a light-weight sheeting or decking; alternatively, they may be finished with traditional roof coverings.
Any form of walling can be used in conjunction with these frames provided such walling forms comply with any of the applicable Building Regulations.

TIMBER PORTAL FRAMES



Typical plywood faced portal frame



Typical glued laminated portal frame

Plywood faced portal frames.

These frames are suitable for small halls, churches and schools with spans in the region of 9.000 m. The portal frames are in essence boxed beams consisting of a skeleton core of softwood members faced on both sides with plywood which takes the bending stresses. The hollow form of the construction enables electrical and other small services to be accommodated within the frame members. Design concepts, fixing and finishes are as given above for glued laminated portal frames.

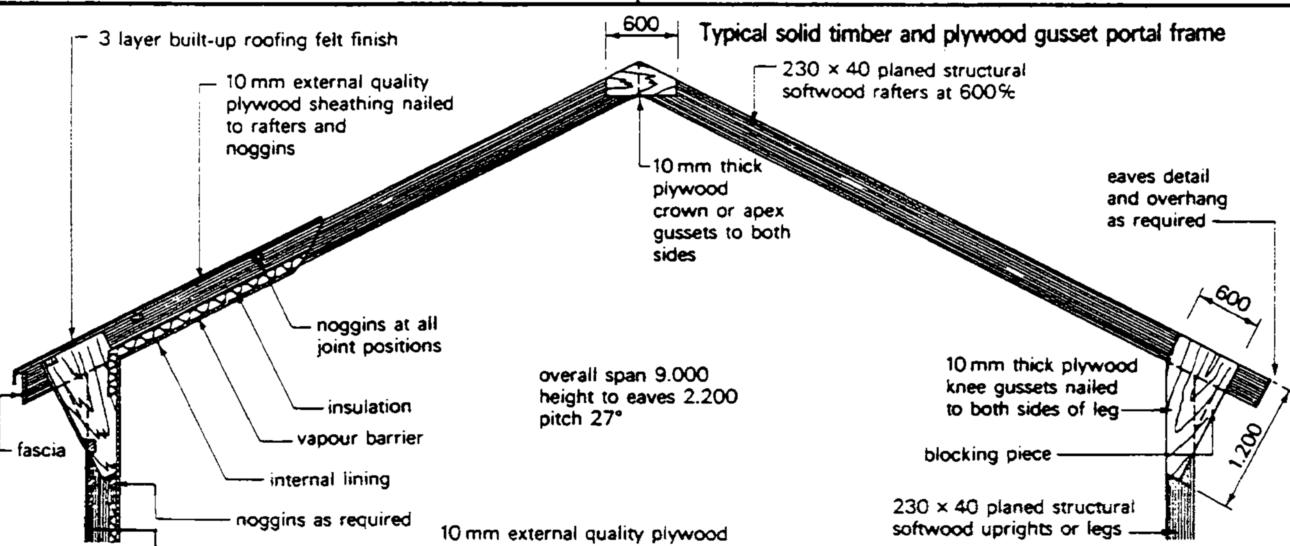
Solid timber and plywood gussets.

These frames were developed to provide a simple and economic timber portal frame for clear span buildings using ordinary tools and basic skills. The general concept of this form of frame veries from the two types of timber portal frames previously described in that no glueing is used, the frames are spaced close together (600, 900 and 1200 mm centres) and are clad with a plywood sheath so that the finished structure acts as a shell giving a lightweight building which is very rigid and strong. The frames can be supplied in two halves and assembled by fixing the plywood apex gussets on site before erection or alternatively they can be supplied as a complete frame ready for site erection.
The foundations for this form of timber portal frame consists of a ground beam or alternatively the frames can be fixed to the edge of a raft slab. A timber speader or sole plate is used along the entire length of the building to receive and distribute the thrust loads of the frames.

Connection to this spreader plate is made by using standard galvanised steel joists hangers or by using galvanised steel angle cleats. Standard timber windows and doors can be inserted into the side walls by trimming in the conventional way and infilling where necessary with studs, noggins and rafters.
The advantages of all timber portal frame types can be enumerated as follows:

1. Constructed from readily available materials at an economic cost.
2. Light in weight.
3. Easy to transport and erect.
4. Can be trimmed and easily adjusted on site .
5. Protection against fungi and/ or insect attack can be by impregnation, or surface application.
6. Pleasing appearance either as a natural timber finish or painted.

Typical solid timber and plywood gusset portal frame



●●REPETITION●exercises●REPETITION●●

Try to answer the following questions and practice sketching whereever necessary and possible

1) Structural Concept

a) Explain the term FRAMED STRUCTURE, and name the elements of a frame work!

b) Classify different types of FRAMED STRUCTURES! (use sketches for illustration!)

c) When is it logical and economical to use FRAMED STRUCTURES?

2) Functional Requirements

a) Explain the difference between

- Non-rigid frames
- Semi-rigid frames and
- Fully-rigid frames

3) Structural Materials

a) List materials which are commonly used for framed structures!

b) Explain the following terms:

- Depth/span ratio
- Dead/live load ratio
- Strength/weight ratio

4) Layout of frames

a) Write notes on SPACING of frames!

b) Why should the layout of a SKELETON STRUCTURE be based on a regular STRUCTURAL GRID?

5) Building Frames

a) What are BUILDING FRAMES?

b) List different frame members and give brief explainations on each!

c) Write notes on reinforced concrete frames and explain their members:

- reinforced concrete beams
- reinforced concrete columns
- reinforced concrete slabs

(use sketches for illustration!)

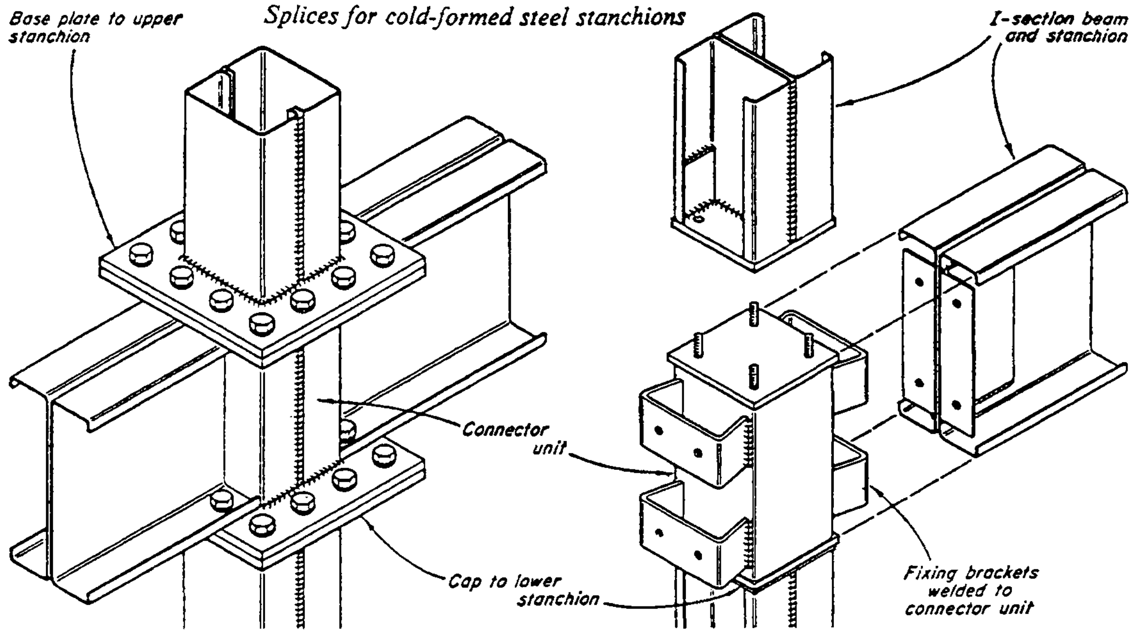
d) Write notes on PRECAST CONCRETE FRAMES and their methods of connections! (use sketches for illustration!)

e) Compare structural steel, reinforced 'in situ' and precast concrete as a material in frame construction!

f) Write notes on STRUCTURAL STEEL FRAMES! (use sketches for illustration!)

g) What are CASTELLATED UNIVERSAL SECTIONs and why are they used?

h) Explain the terms SHOP CONNECTIONS and SITE CONNECTIONS and how they can be made by using bolts, rivets or by welding!



i) Write notes on structural steel connections!

k) Describe the erection of structural steel frames!

l) What do you know about FIRE PROTECTION of STEELWORK?

m) Write notes on TIMBER FRAMES, explaining their members COLUMNS and BEAMS, and their method of CONNECTIONS! (use sketches for illustration!)

n) Explain, by using sketches, the ways of construction of BUILDING FRAMES in TIMBER.

o) What do you know about the PREFABRICATION of timber frames?

6) Portal frames

a) Characterize PORTAL FRAMES

b) What are the methods to overcome excessive forces at the foundation?

c) What are HINGES?

d) Explain the three basic forms of portal frames and show - by using sketches - the position of their hinges.

e) Write notes on CONCRETE PORTAL FRAMES, and their FOUNDATION and FIXINGS! (use sketches for illustration!)

f) What are the ADVANTAGES of concrete portal frames?

g) Write notes on STEEL PORTAL FRAMES, and their FOUNDATIONS and FIXINGS! (use sketches for illustration!)

h) What are the ADVANTAGES of steel portal frames?

i) Write notes on TIMBER PORTAL FRAMES and explain the differences between:

. GLUED LAMINATED PORTAL FRAMES

. PLYWOOD FACED PORTAL FRAMES and

. SOLID TIMBER and PLYWOOD GUSSETS.

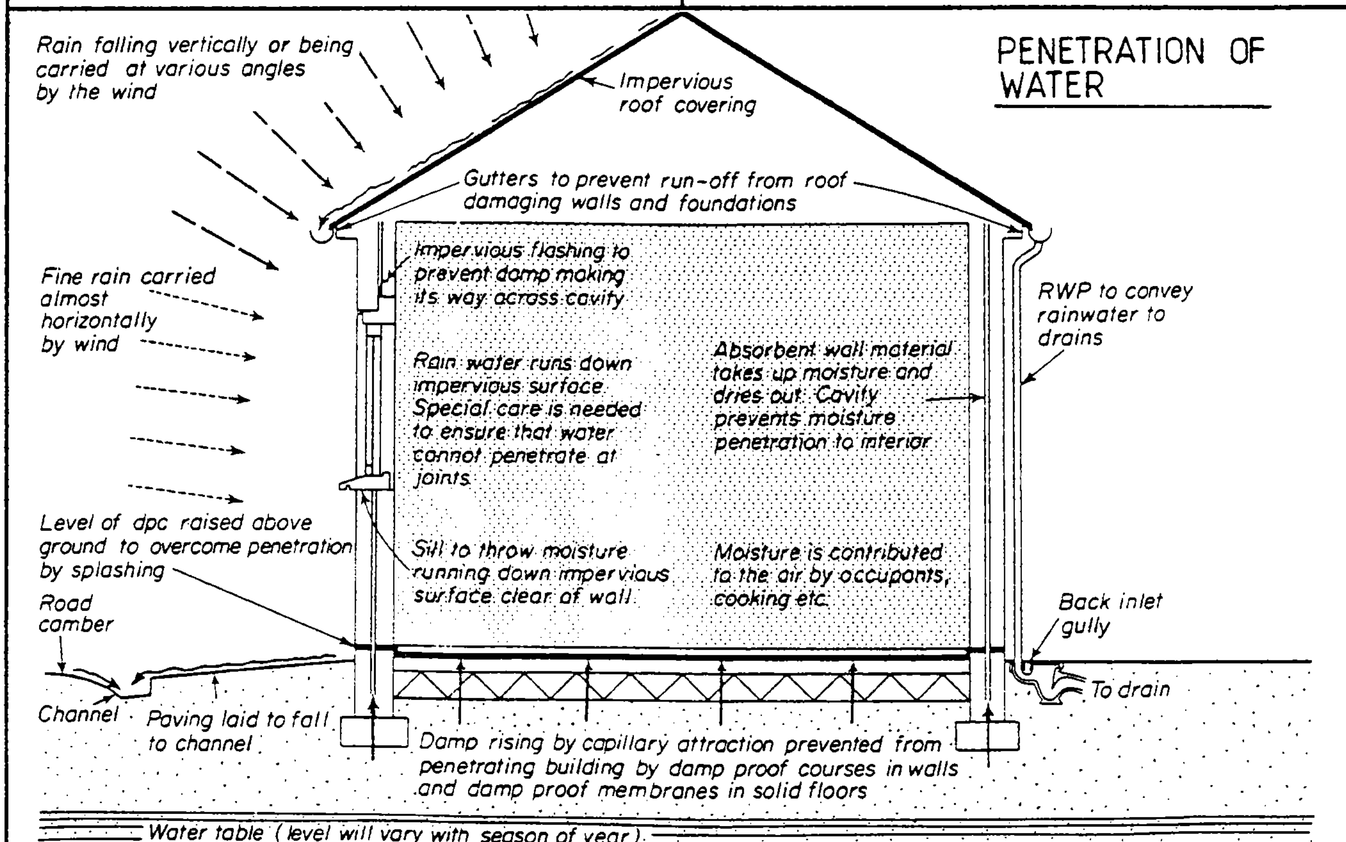
(use sketches for illustration!)

k) What are the ADVANTAGES of all timber portal frame types?

11. PROTECTION of BUILDINGS

CONTENTS:

PENETRATION OF WATER



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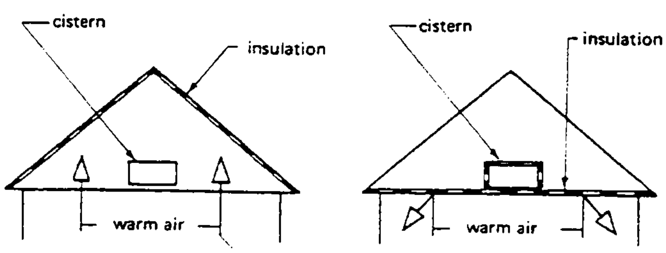


Insulation at rafter level

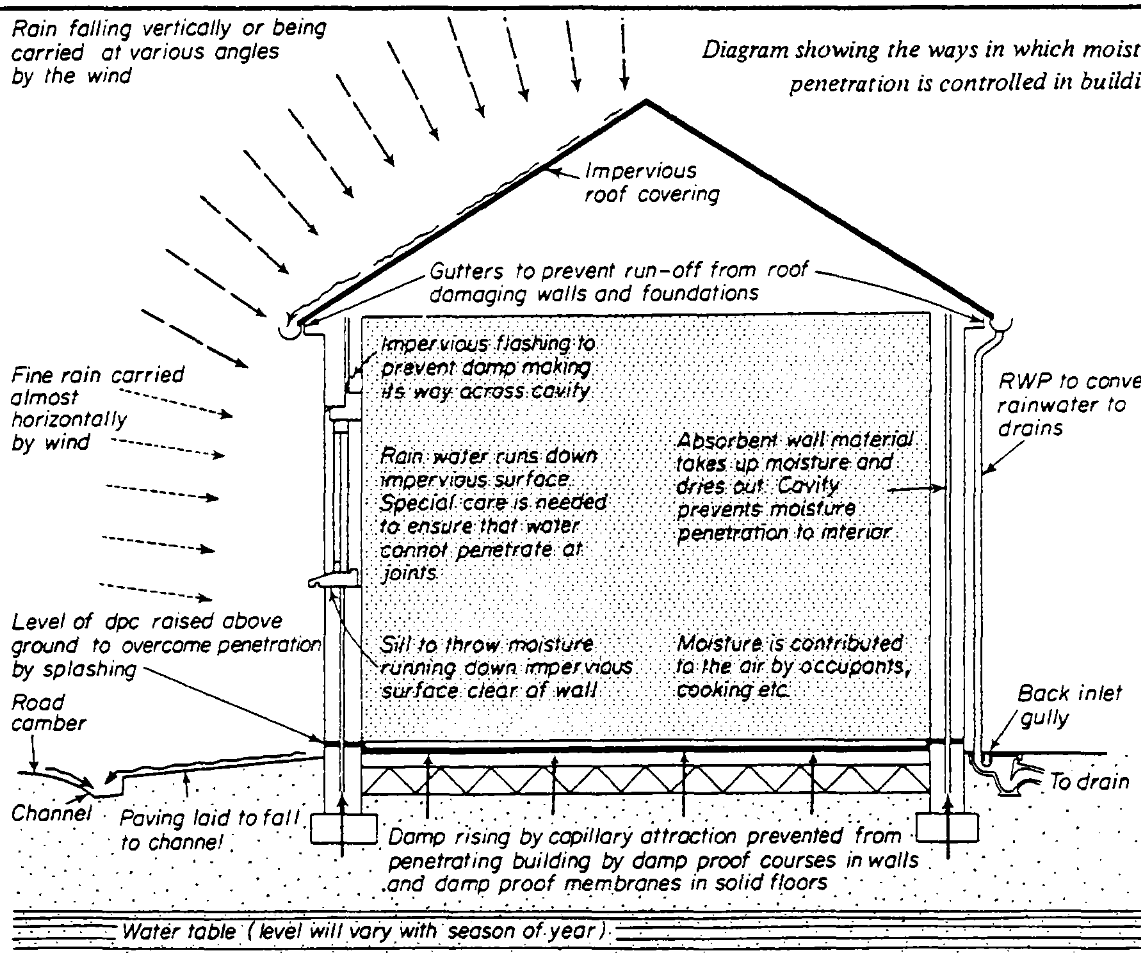
Insulation at ceiling level

1. R. L. Fullerton
" Building Construction in Warm Climates"
Vo. 2,3

2. Peter Burberry
MITCHELL,S BUILDING SERIES
"Enviroment and Services"

3. R. Chudley
"Construction Technology"
Vol. 2,3

11. PROTECTION of BUILDINGS



11. Protection of Buildings

11.1 Exclusion of Water

WATER in its free liquid form must be totally excluded from the interiors of buildings and its presence as VAPOUR in the air or as MOISTURE content of building materials must be controlled to within acceptable limits.

The shrinkage and swelling of soil, the effect of moisture on vegetation, and the water-retaining properties of soils all affect foundation design.

Combinations of soils and water are responsible for the settlement of buildings, cracking, shrinkage, decay, damp disease, chemical attack, subsidence, and landslips.

Moisture in buildings comes from three main sources:

I Precipitation as rain
II Damp rising from the ground through building materials by capillary attraction or as vapour.
III Condensation upon cold surfaces of humidity from the air.

In addition condensed droplets in the air (fog) can be carried by wind to wet the surfaces of the building and to penetrate joints and materials.

The relative humidity of air in buildings can be a critical factor in goverming thermal comfort since it influences the ability of the body to lose heat.

PRECIPITATION

11.1.1 Precipitation.

The frequency of rainfall is well recorded by weather stations every where, and, despite local variations, the designer usually knows what to allow for. In determining open channel and gutter sizes the annual rainfall is not so important as the actual period of the storm and its intensity.

Run-offs can also be hampered by insufficient fall, blockage, damage through traffic, or a sewage system which is simply too small. Soakaways should be large enough to accomodate sudden storms and should also have a seperate drainage system.
The construction of soakaways may be governed by local authorities, who sometimes have a standard layout.
Rainfall statistics in the tropics rarely give an adequate picture of the combined effects of rain, wind, and freak storms. Achieving a perfect match of weather and buildings is not often possible, owing to variations both in exposure and in the performance of the structure itself. These latter may be due to detailing, materials, the size of components, workmanship, and other such factors. And again, rain does not wet walls in the absence of wind. Storms, however, frequently drive rain horizontally and even upwards under balconies and ventilators.

ROOF DRAINAGE

11.1.1.1 Roof Drainage

The most likely source of trouble from water is the roof. Built-up felts, flat roof overflow, rainwater wall streaking, expansion, imperfect flashing, felt blistering inaccurate flow-load calculations incorrect size of large valley gutters, outlets, and r.w.p.s. are common causes of failure. Plastic pipes and gutters also need flexible joints to accomodate thermal movement. Areas subject to sudden storms should have adequate disposal capacity. Ground aprons which take roof discharge direct should have suitable collection channels with sufficient fall, and should be free of blockage and provide easy access to soakaways and drains.

FLOODING

11.1.1.2 Flooding

In coastal areas especially flooding is a common occurence. The extent of damage will depend on the nature of the foundations, the degree of buffeting by the elements, the degree of expansion of soils, erosion, settlement, and crakking. Services, including electricity, may be impaired, plasterboard ruined, timber and plywood split and warped.
After draining or pumping, it may be necessary to punch holes in the lowest areas and remove water trapped in underfloor ducts, pits or cavities. Ventilators and similar openings may have to be cleared of mud. Sea-water flooding can cause erosion of metals, concrete, and lime. Drains should be inspected before use; and one unpleasant effect could be due to backwash, particularly where cesspits and septic tanks are in use. Having cleaned up as well as possible, doors, windows, and vents should be opened and everythin should be done to create maximum air flow through the building.

DROUGHT

11.1.1.3 Drought

In hot dry climates where living conditions have been adapted to the environment low annual rainfall is not considered as drought. In such circumstances a building is made to combat excessive sunshine, heat, wind, and dust storms. Sanitary services are either designed to be able to cope using the water-supply available, or other means of disposal are used.

Drought in areas of reasonable rainfall and humidity can have serious effects. Shrinkage and settlement, with resulting crakking and bleaching of exposed finishes can occur. The building and its environment will deteriorate where maintanance depends on a supply of water, not to mention the unpleasantness and distress caused by the depletion of the supply. What is sometimes described as a drought is often a decrease in supply resulting from increased demand, particularly in growing towns.

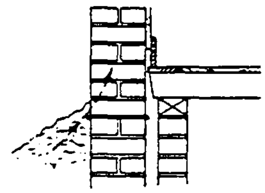
DAMP RISING & MOIST. MIGRATION

11.1.2 Damp Rising and Moisture Migration.

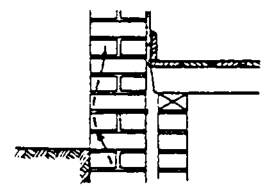
Movement of moisture through the materials of which the building is constructed can occur through capillary attraction or by diffusion of vapour through the pores of the material. The sources of moisture which must be considered in this context include not only precipitation on external surfaces but also damp from the ground floors are not often made in this way. Since, in the case of walls, the exposure to moisture is intermittent it is possible to use thick solid walls of porous materials which absorb moisture into their external faces and then allow it to evaporate without giving rise to serious internal penetration. This type of wall generally has to be very much thicker than is required for structural needs and in modern buildings, means other than thickness have to be used to limit moisture penetration.

Two methods of control are normally employed. Either a barrier of impervious material or an air gap is placed to intercept the movement. Flashings (capillary movement only), damp proof courses, damp proof membranes (capillary vapour diffusion) and vapour barriers (vapour only) are examples of impervious materials bein used as barriers. Cavities, provided that they are not bridged by moisture transmitting features, are a very effective means of arresting capillary movement. They are not necessarily effective against vapour diffusion since unless well ventilated it will be possible for the vapour to pass across. Suspended ground floors formed a good example of a cavity formed to prevent capillary and vapour movement which to be effective in preventing vapour reaching the other side had to be adequately ventilated. This type of construction has now largely gone out of use because of the high heat losses which resulted from the ventilation.

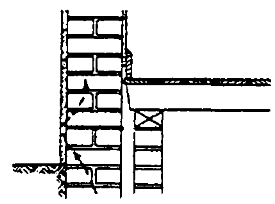
A floor resting solidly on the ground and having a continuous damp proof membrane gives a more satisfactory overall result.



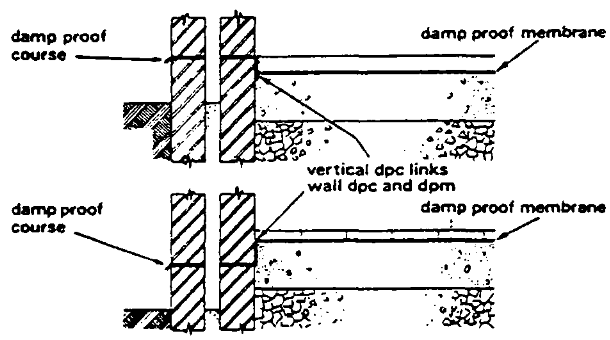
(a) Bridging by earth.



(b) Bridging by mortar pointing.



(c) Bridging by rendering.



CONDENSATION

11.1.3 Condensation. Condensation arises from the variation with temperature of the capacity of air to hold moisture in the form of water vapour. As temperatures increase the capacity increases. For each temperature, however, there is a saturation level of moisture. When air which has absorbed moisture is cooled to such a temperature that the moisture content exceeds the saturation point, the excess moisture will be deposited as water.

In buildings, the air from outside is taken in and warmed and moisture is addded from occupants and processes. If cold surfaces such as windows, badly insulated walls, or cold metal service pipes exist, they can cool the air immediately adjacent to them so that moisture is deposited on the surface in the form of CONDENSATION: This is both unsightly and likely to cause damage to the contents and finishes of rooms and also to the wall, ceiling and floor materials.

In equatorial coastal climates with little seasonal or diurnal variation in temperature there is not a great deal of heavy condensation. though humidity can be high. Hotels and public buildings are often equipped with air conditioning; if left on for long periods it reverses the process normal to temperate zones, causing heavy condensation to form on the outside of windows and thus spoiling visibility and speeding deterioration of the frames.

Table:Sources and approximate quantities of vapour input to buildings.

Source	Approximate quantity
People:Sedentary Active	0.05kg per person/ 0.2 kg per person/ / per hour
GAS:Cooking or any flueless heaters or appliances	0.81 per m3 of town gas
Paraffin:Flueless heaters	1 kg per litre appr. (1 litre represents approx.4MJ heat output)
Cooking, bathing and showers	0.03to0.06 kg per hour
Clothes washing and drying	Too variable for figure to be given but very substantial quantities of water can be put into the atmosphere and special precautions against general penetration of this moisture into buildings are required.

CONDENSATION

Drying out is mainly a matter of the time taken for water vapour from cellular pores to reach the surface of the material: the rate of evaporation reduces as the temperature falls. Buildings when drying out are thus cooler than the ambient air, and this isthe principle on which the traditional earthenware water cooler works. No rule of thumb on drying out is possible; but premature decoration can be disastrous, especially in damp regions. Dehumididfiers are sometimes used for thies purpose if circumstances warrant it.
The consequences of condensation are, in many modern constructions, more acute than was the case in the past. In masonry and brick constructions significant quantities of water can condense and subsequently evaporate without being apparent or causing serious deterioration.
Risk of condensation can be minimised by increased ventilation. The most effective method, however, is to keep the surface temperature of i.e. walls, windows, cold metal pipes etc. above dewpoint.

Table:
Excess moisture content of air (over outdoor content) for various building types

Building type	Excess content g moisture per kg of dry air
Shops, offices, classrooms, public buildings, dry industrial processes	1,7
Dwellings	3,4
Catering establishments or wet industrial processes	6,8

11.2 THERMAL INSULATION

11.2 Thermal Insulation

11.2.1 Definition

Thermal insulation may be defined as a barrier to the natural flow of heat from an area of high temperature to an area of low temperature. In buildings this flow is generally from the interior to the exterior. During hot seasons however the flow may occur from the exterior to the interior.
Heat is a from of energy consisting of the ceaseless movement of tiny particles of matter called molecules; if these particles are moving fast they collide frequently with one another and the substance becomes hot. Temperature is the measure of hotness and should not be confused with heat.
The transfer of heat can occur in three ways.
<u>Conduction:</u>
Vibrating molecules come into contact with adjoining molecules and set them vibrating faster and hence they become hotter; this process is carried on througout the substance without appreciable displacement of the particles.

<u>Convection:</u>
Transmission of heat within a gas or fluid caused by the movement of particles which become less dense when heated and rise thus setting up a current or circulation.

<u>Radiation:</u>
Heat is considered to be transmitted by radiation when it passes from one point to another without raising the temperature of the medium through which it travels.

In a building all three methods of heat transfer can take place since the heat will be conducted through the fabric of the building and dissipated on the external surface by convection and/or radiation.
The traditional thick and solid building materials used in the past had a natural resistance to the passage of heat in large quantities, whereas the lighter and thinner materials used today generally have a low resistance to the transfer of heat. Therefore to maintain a comfortable and healthy internal temperature the external fabric of a building must be constructed of a combination of materials which will provide an adequate barrier to the transfer of heat.
Thermal insulation of buildings will give the following advantages:
1. Reduction in the rate of heat loss
2. Lower fuel costs
3. Reduction in the risk of pattern staining.
4. Reduction of condensation and draughts thus improving the comfort of the occupants.

INSULATING MATERIALS

11.2.2 Insulating Materials

When selecting or specifying thermal insulation materials the following must be taken into consideration:

1. Resistance value of the materials.
2. Need for a vapour barrier since insulating materials which become damp or wet, generally due to condensation, rapidly loose their insulation properties; therefore if condensation is likely to occur a suitable vapour barrier should be included in the detail. Vapour barriers should always be located on the warm side of the construction.
3. Availability of material chosen.
4. Ease of fixing or including the material in the general construction
5. Appearance if visible.
6. Cost in relation to the end result and ultimate savings on fuel and/or heating installation.
7. Fire risk - all wall and ceiling surfaces must comply with the requirements of Building Regulation E 15 - restriction of spread of flame over surfaces of walls and ceilings.

Insulating materials are made from a wide variety of materials and are available in a number of forms.

INSULATING CONCRETE

Insulating concrete:
Basically a concrete of low density containing a large number of voids. This can be achieved by using lightweight aggregates such as clinker, foamed slag, expanded clay, sintered pulverised fuel ash, exfoliated vermiculite and expanded perlite, or alternatively an aerated concrete made by the introduction of air or gas into the mix. No fines concrete made by using lightweight or gravel aggregates between 20 and 10 mm size and omitting the fine aggregate is suitable for load bearing walls. Generally light - weight insulating concrete is used in the form of an in situ screed to a structural roof or as lightweight concrete blocks for walls.

LOOSE FILLS

Loose fills:
Materials which can be easily poured from a bag and levelled off between the joists with a shaped template. Materials include exfoliated vermiculite, fine glass fibrewool, mineral wool and cork granules. The depth required to give reasonable results is 25 - 35 mm; care should be taken to indicate, by paint or chalk marks on the sides of the joists, any electrical connections or junctions which have been covered over. Most loose fills are rot and vermin proof as well as being classed as noncombustible.

BOARDS

Boards;
Used mainly as dry linings to walls and ceilings either for self finish or direct decoration. Types include aluminium foil-backed plaster board, woodwool slabs, expanded polystyrene boards, asbestos insulating board and fibreboards. Insulating fibreboards should be conditioned on site before fixing to prevent buckling and distortion after fixing. A suitable method is to expose the boards on all sides so that the air has a free passage around the sheets for at least 24 hours before fixing. During this conditioning period the boards must not be allowed to become wet or damp.

QUILTS

Quilts:
Made from glass fibre or mineral wool bonded or stitched between outer paper coverings for easy handling. The quilts are supplied in rolls from 6.000-13.000 m long and cut to suit standard joist spacings. The are laid over the ceiling boards and can be obtained in two thicknesses, 25mm thick for general use and 50mm-thick for use where a central heating system is installed

REFLECTIVE INSULATION

Reflective insulation:
Used in both ceiling and wall insulation and consists of reinforced aluminium foil which should be used in conjunction with an unventilated cavity of at least 25 mm width.

INSULATING PLASTERS

Insulating plasters:
Factory produced pre-mixed plasters which have lightweight perlite and vermiculite expanded minerals as aggregat4e, and require only the addition of clean water before application. They are only onethird the weight of sanded plasters, have three times the thermal insulation value and are highly resistant to fire.

FOAMED CAVITY FILL

Foamed cavity fill:
A method of improving the thermal insulation properties of an external cavity wall by filling the cavity wall with urea-formaldehyde resin foamed on site. The foam is formed using special apparatus by combining urea-formaldehyde resin, a hardener, a foaming agent and warm water. Careful control with the mixing and application is of paramount importance if a successful result is to be achieved;specialist contractors are normally employed. The foam can be introduced into the cavity by means of 25 mm bore holes spaced 1.000m apart in all directions or by direct introduction into the open end of the cavity. The foam is a white cellular material containing approximately 99% by volume of air with open cells. The foam is considered to be impermeable and therefore unless fissures or cracks have ocurred during the application it will not constitute a bridge of the cavity, in the practical sense, but a relaxation of Building Regulation C9 (2) may be required. In most cases the foam, upon setting, shrinks away from the inner face of the outer leaf enabling any water penetrating the outer leaf to run down the inside face of the external skin.
The most effective method of improving thermal comfort conditions within a building is by fixing insulating materials at the outside position of the surface. Thermal insulation for buildings other than dwellings are covered by separate legislation.

11.3. Sound insulation

11.3.1 Definition

Anything that can be heard is a sound, whether it is made by conversation, machinery, or walking on a hard surface. All sounds are produced by a vibrating object which moves rapidly to and fro causing movement of the tiny particles of air surrounding the vibrating source. the displaced air particles collide with adjacent particles setting them in motion and in unison with the vibrating object. Air particles move only to and fro but the sound wave produced travels through the air until at some distance from the source the movement of the particles is so slight that the sound produced is inaudible.
For a sound to be transmitted over a distance a substance, called the sound medium, is required. It can be shown by experiments that sound cannot travel through a vacuum but it can be transmitted through solids and liquids.
Sounds can differ in two important ways, by loudness and by pitch. The loudness of a s ound depends on the distance through which the vibrating object moves to and fro as it vibrates; the greater the movement the louder the sound. The loudness with which a sound is heard depends upon how far away from the source the receiver or ear is. The unit of subjective loudness is a phon whilst the objective unit is called a decibel.

Although the loudness of a sound will vary with the frequency of the note for practical building purposes, the phon and the decibel are considered to be equal over the range of 0 phons, the threshold of hearing, to 130 phons the threshold of painful hearing.
The pitch of a sound depends on the rate at which the vibrating object oscillates. The number of vibrations in a second is called the frequency and the higher the frequency the higher the pitch. The lowest pitched note that the human ear can hear has a frequency of approximately 16 hertz whereas the heighest pitched note which can be heard by the human ear has a frequency of approximately 20.000 hertz or cycles per second.
When a sound is produced within a building three reactions can occur:
1. The pressure or sound waves can come into contact with the walls, floor and cailing and be reflected back into the building.
2. Some of the sound can be absorbed by these surfaces and/ or the furnishes. It mustbe noted that sound absorption normally only benefits the occupants of the room in which the sound is generated since its function is to reduce the amount of reflected sound.
3. The sound waves upon reaching the walls, floor and ceiling can set these members vibrating in unison and thus transmit the sound to adjacent rooms.
It must also be noted that sounds can enter a building from external sources such as traffic and low flying aircraft (see fig.)

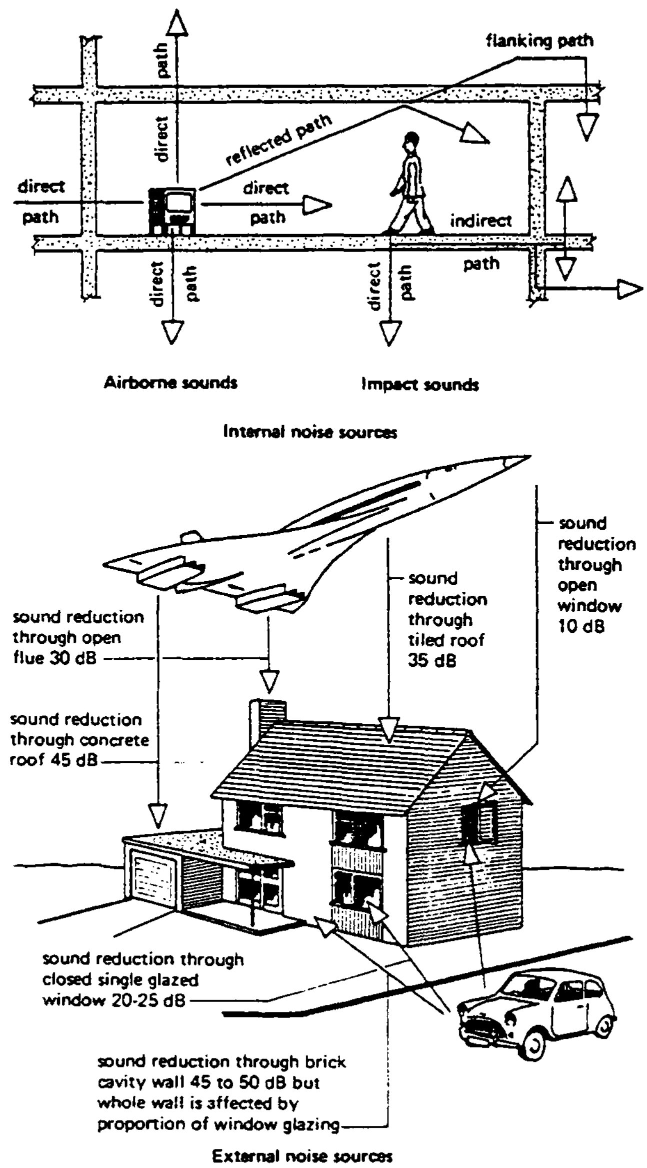
Sounds may be defined as either impact sounds, caused by direct contact with the structure such as footsteps and hammering on walls which will set that part of the structure vibrating, or they can be termed airborne sounds, such as the conversation or radio which sets the structure vibrating only when the sound waves emitted from the source reach the struc-

tural enclosure.
A noise can be defined as any undesired sound and may have any one of the following four effects on man:

1. Annoyance
2. Distrubance of sleep
3. Interfere with the ability to hold a normal conversation.
4. Damage his hearing.

It is difficult to measure annoyance since it is a subjective attitude and will depend upon the mental and physical well being of the listener, together with the experience of being subjected to such types of noise.
Damage to hearing can be caused by a sudden noise such as a loud explosion or by gradual damage resulting from continual noise over a period of years.
The solution to noise or sound problems can only therefore be reasonable to cater for the average person and conditions.
The approach to solving a noise problem can be three-fold:

1. Reduce the noise emitted at the source by such devices as mufflers and mounting machinery on resilient pads.
2. Provide a reasonable degree of sound insulation to reduce the amount of sound transmitted.
3. Isolate the source and the receiver.



Sources of noise within and around buildings

11.3.2 Sound Insulation

The most effective barrier to the passage of sound is a material of high mass. With modern materials and methods this form of construction is both impracticable and uneconomic. Unfortunately modern living with its methods of transportation and entertainment generates a considerable volume of noise and therefore some degree of sound insulation in most buildings is desirable.

EXTERNAL NOISE

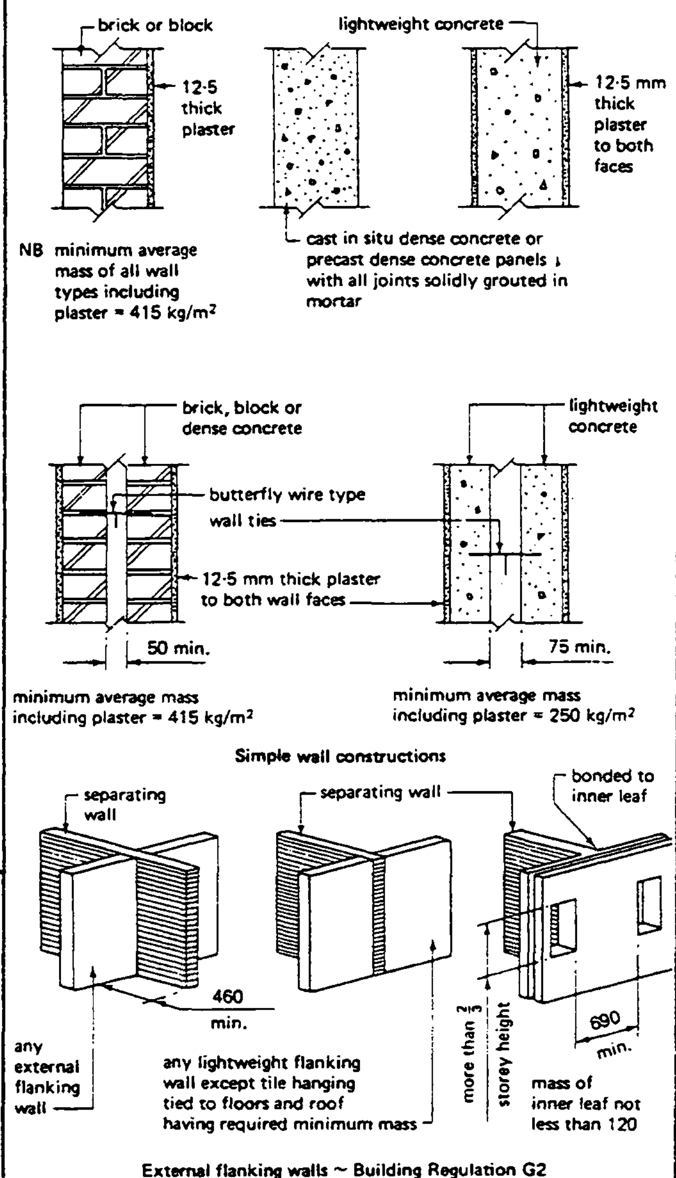
11.3.3 External noise

Another aspect of sound insulation which, although not covered by Building Regulations, requires consideration is insulation against external noise.

The main barrier to external noise is provided by the shell or envelope of the building, the three main factors being:

1. The mass of the enclosing structure.
2. The continuity of the structure.
3. Isolation by double leaf construction when using lightweight materials.

Generally the main problem for the insulation against external noise is the windows, particularly if these can be opened for ventilation purposes. Windows cannot provide the dual function of insulation against noise and ventilation, since the admission of air will also admit noise. Any type of window when opened will give a sound reduction of about 10 decibels as opposed to the 45 -50 decibel reduction of the traditional cavity wall. A closed window containing single glazing will give a reduction of about 20 decibels or approximately half that of the surrounding wall. It is obvious that the window to wall ratio will affect the overall sound reduction of the enclosing structure.



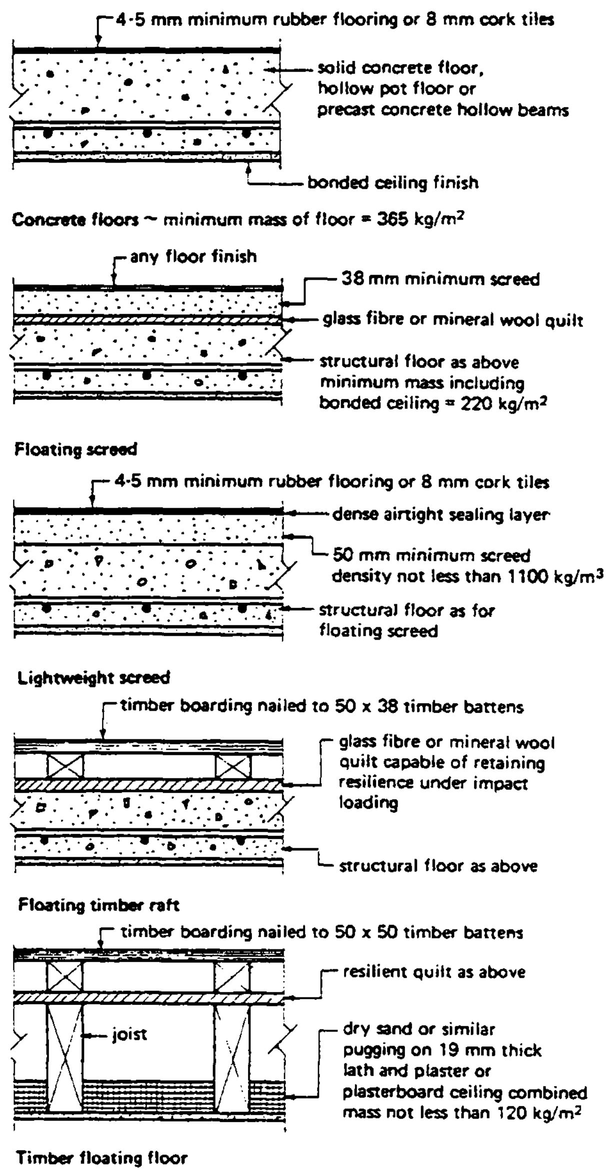
Sound insulation – walls

EXTERNAL NOISE

Double glazing can greatly improve the sound insulation properties of windows provided the following points are observed:

1. Sound insulation increases with the distance between the glazed units; for a reduction of 40 decibels the airspace should be 150-200 mm wide.
2. If the double windows are capable of being opened they should be weather-stripped.
3. Sound insulation increases with glass thickness particularly if the windows are fixed; this may mean the use of special ventilators having specific perfomances for ventilation and acoustics.
4. Double glazing designed to improve the thermal properties of a window have no real value for sound insulation.

Roofs of traditional construction and of reinforced concrete generally give an acceptable level of sound insulation, but the inclusion of rooflights can affect the resistance provided by the general roof structure. Lightweight roofing such as corrugated asbestos will provide only a 15-20 decibel reduction but is generally acceptable on industrial buildings where noise is generated internally by the manufacturing processes. The inclusion of rooflights in this type of roof generally has no adverse effects since the sound insulation values of the rooflight materials are similar to those of the coverings.
Modern buildings can be designed to give reasonable sound insulation and consequent comfort to the occupiers but the improvement to existing properties can present problems.



Sound insulation – floors

11.4 FIRE PROTECTION

11.4. Fire Protection

The precautions which can be taken within buildings to prevent a FIRE occuring, or, if it should occur, of containing it within the region of the outbreak, providing a means of escape for people in the immediate vicinity and fighting the fire can be summarized under three headings:

1. Structural fire protection
2. Means of escape in case of fire
3. Fire fighting

FIRE FIGHTING, which is generally integrated with the services of a building, is usually considered in that context and therefore NOT included in this text, as well as MEANS OF ESCAPE IN CASE OF FIRE, which is in the first instance a problem of designing and planning, rather than a problem of building construction.

11.4.1 Structural Fire Protection.

The purpose of structural fire protection is to ensure that during a fire the temperature of structural members or elements does not increase to a figure at which their strength would be adversely affected. It is not practicable or possible to give an element complete protection in terms of time, therefore elements are given a fire resistance for a certain period of time which it is anticipated will give sufficient delay to the spread of fire, ultimate collapse of the structure, time for persons in danger to escape and to enable fire fighting to be commenced.

Before a fire-resistance period can be determined it is necessary to consider certain factors:

1. Fire load of the building.
2. Behaviour of materials under fire conditions.
3. Behaviour of combinations of materials under fire conditions

11.4.1.1 Fire Load

Buildings can be graded as to the amount of overall fire resistance required by taking into account the following.

1. Size of building
2. Use of building
3. Fire load.

The fire load is an assessment of the severity of a fire due to the combustible materials within a building. This load is expressed as the amount of heat which would be generated per unit area by the complete combustion of its contents and combustible members and is given in Joules per square metre. It should be noted that the numerical grade is equivalent to the minimum number of hours fire resistance which should be given to the elements of the structure.

GRADE 1 Low fire load, not more than 1 150 MJ/m2. Typical buildings within this grade are flats, offices, restaurants, hotels hospitals, schools, museums and public libraries.

GRADE 2 Moderate fire load, 1 150to 2 300MJ/m2. Typical examples are retail shops, factories and workshops.

GRADE 4 High fire load, 2 300 to 4 600 MJ/m2. Typical exemples are certain types of workshops and warehouses.

When deciding the grade no account is taken of the effects of any permanent fire protection installations such as sprinkler systems.

11.4.1.2 Fire Resistance of Material

The materials used in buildings can be studied as separate entities as to their behaviour when subjected to the intense heat encountered during a fire and as to their ability to spread fire over their surfaces.

Structural steel is not considered to behave well under fire conditions although its ability to spred fire over its surface is negligible. As the fire progresses and the temperature of steel increases there is an actual gain in the ultimate strength of mild steel . This gain in strength decreases back to normal over the temperature range of 250to 400°C. The decrease in strength continues and by the time the steel temperature has reached 550oC it will have lost most of its useful strength. Since the rise in temperature during the initial stages of a fire is rapid this figure of 550oC can be reached very quickly. If the decrease in strength results in the collapse of a member the stresses it was designed to resist will be redistributed; this could cause other members to be overstressed and progressive collapse could occur.

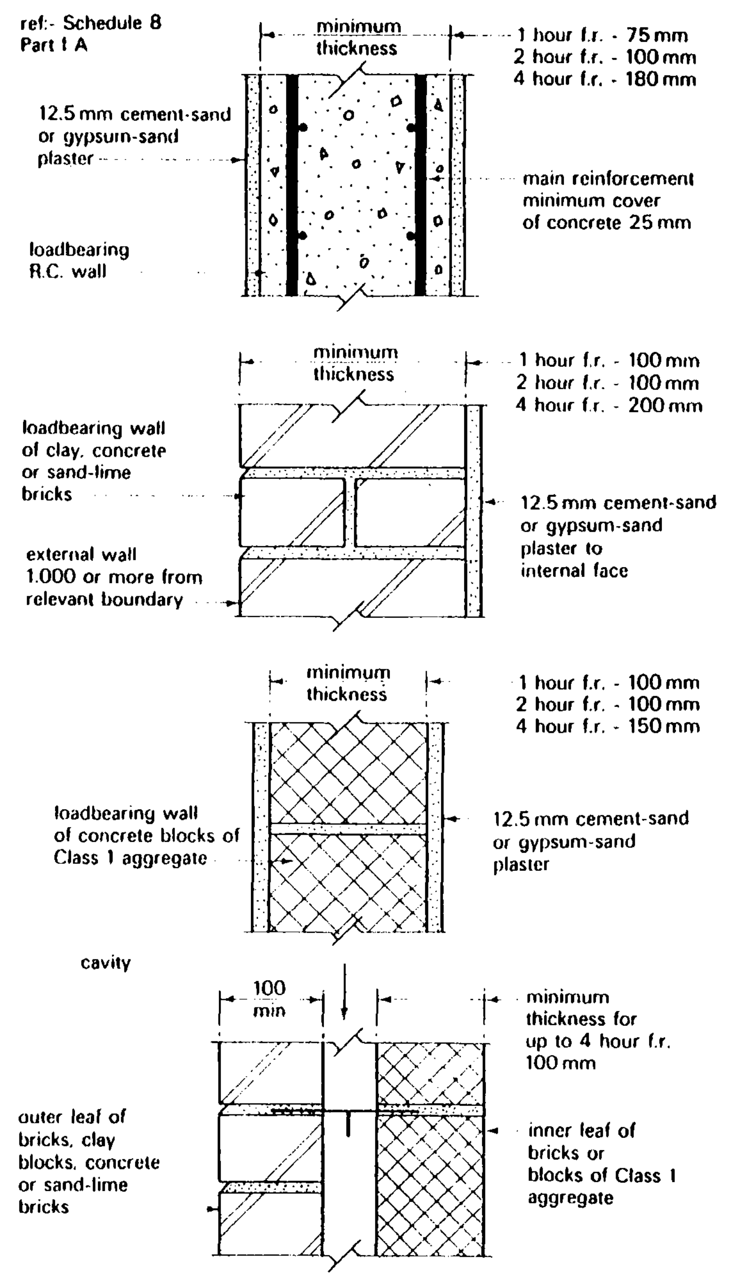
Reinforced concrete structural members have good fire resistance properties, and being non-combustible do not contribute to the spread of flame over their surfaces. It is possible however under the intense and prolonged heat of a fire that the bond between the steel reinforcement and the concrete will be broken. This generally results in spalling of the concrete which decreases both the protective cover of the concrete over the steel and the cross sectional area. Like structural steel members, this can result in a redistribution of stres ses leading to overloading of certain members, culminating in progressive collapse.

Timber, strange as at may seem, behaves very well structurally under the action of fire. This is due to its slow combustion rate, the strength of its core failure remaining fairly constant. The ignition temperature of timber is low (250-300oC) but during combustion the timber chars at an approximate rate of 0.5 mm per minute, the layer charcoal so formed slows down the combustion rate of the core. Although its structural properties during a fire are good, timber being an organic material and therefore combustible, will spread fire over its surface which makes it unsuitable in most structural situations without some form of treatment.

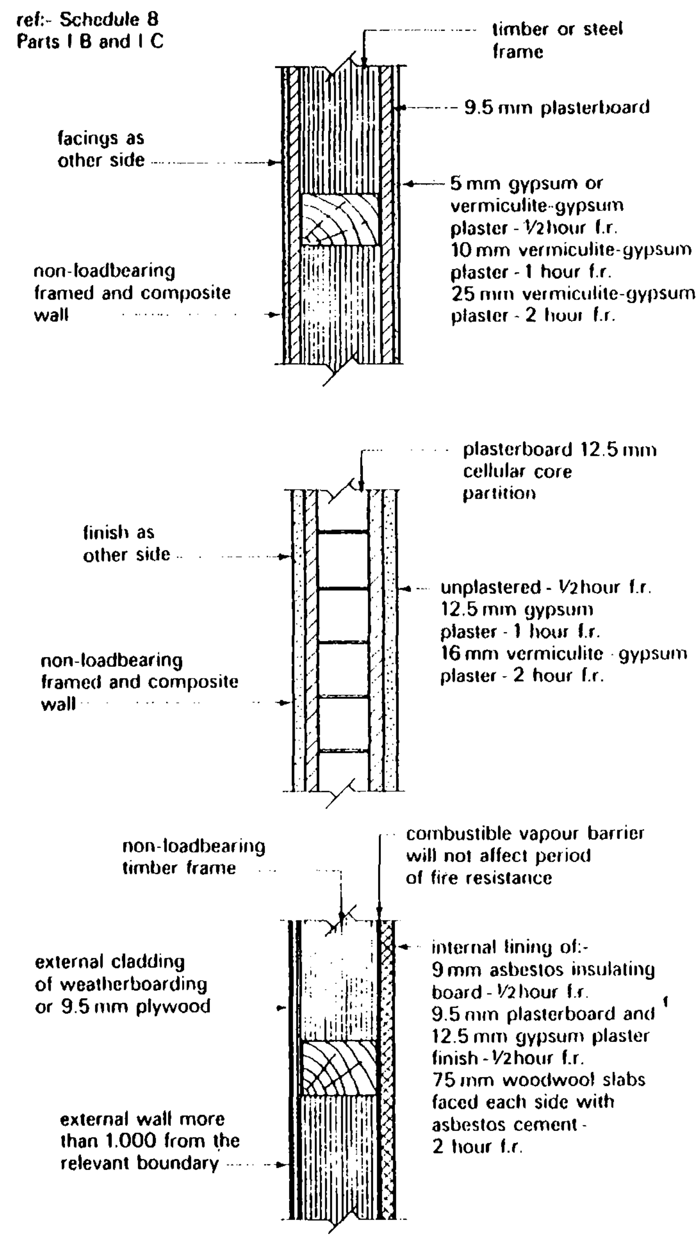
11.4.1.3 Appropriate Types of Construction.

BS 476, Part 8 and Schedule 8 give appropriate types of construction for various notional periods of fire resistance for WALLS, BEAMS, COLUMNS and FLOORS.

Schedule 8 of the Building Regulations gives in written and tabulated form various methods of providing the required protection which needs to be translated into working details. The following figures show typical examples taken from this schedules.

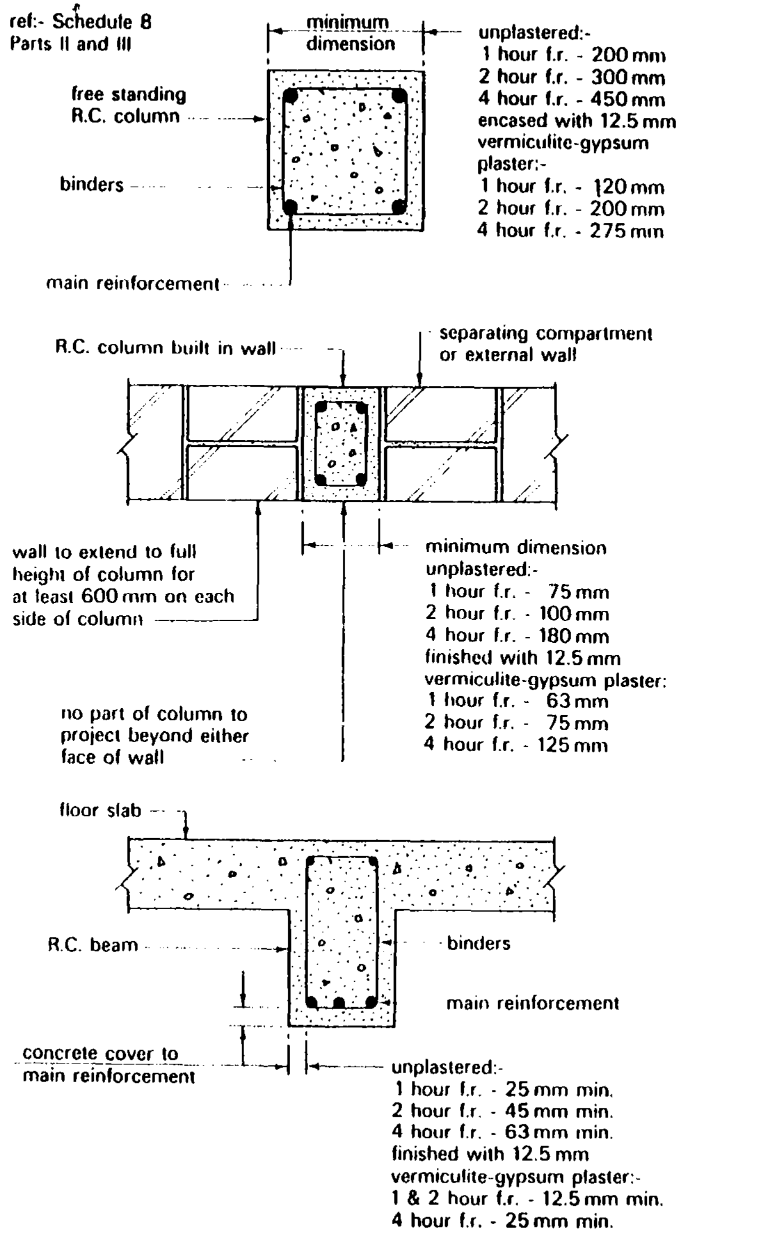


Fire Resistance—walls of masonry construction

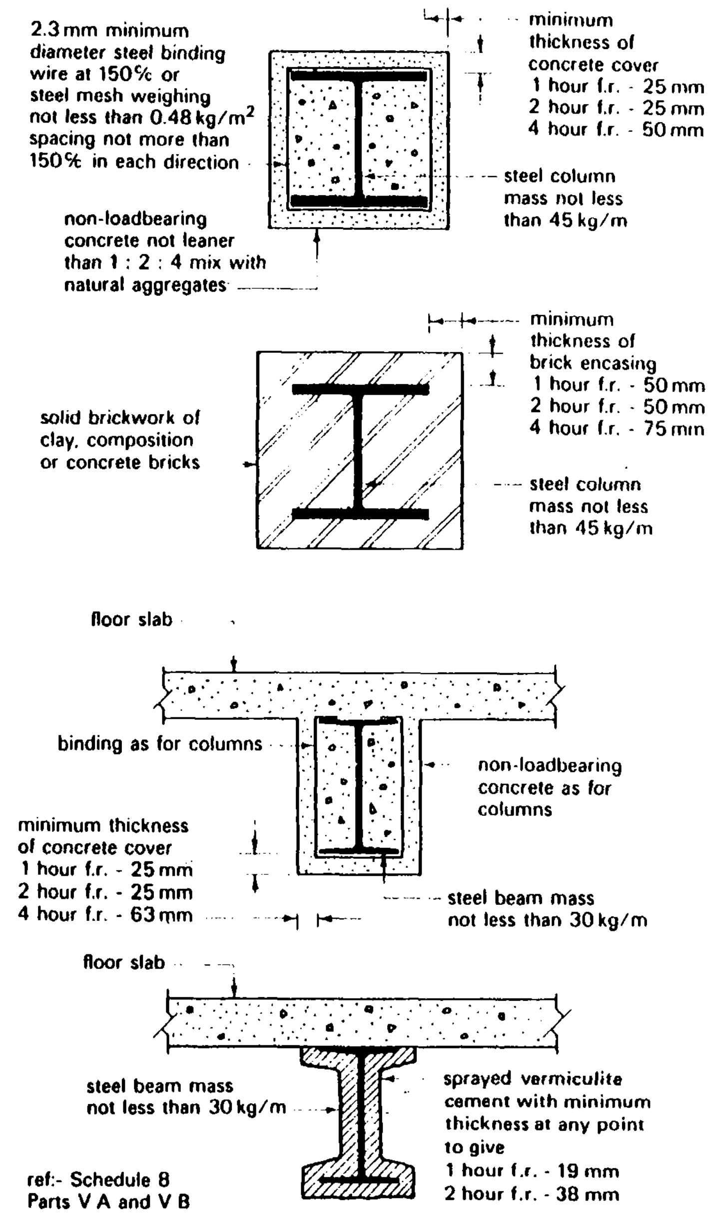


Fire resistance—framed and composite walls

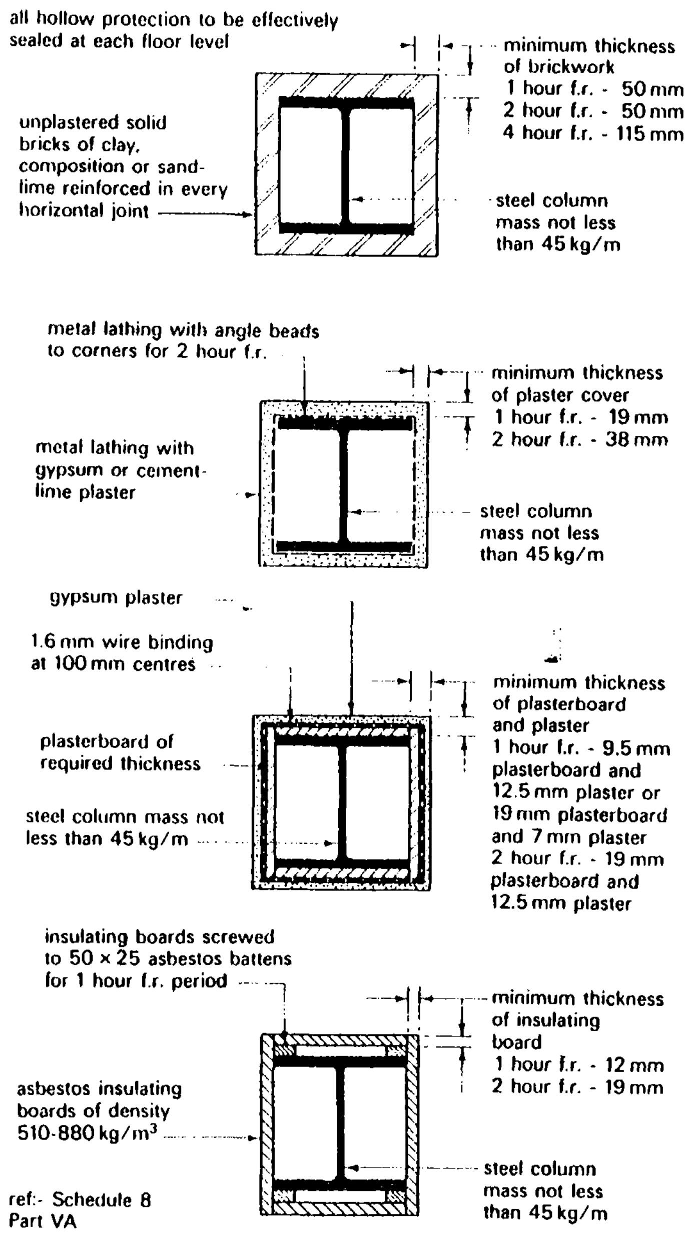
• COLUMNS & BEAMS



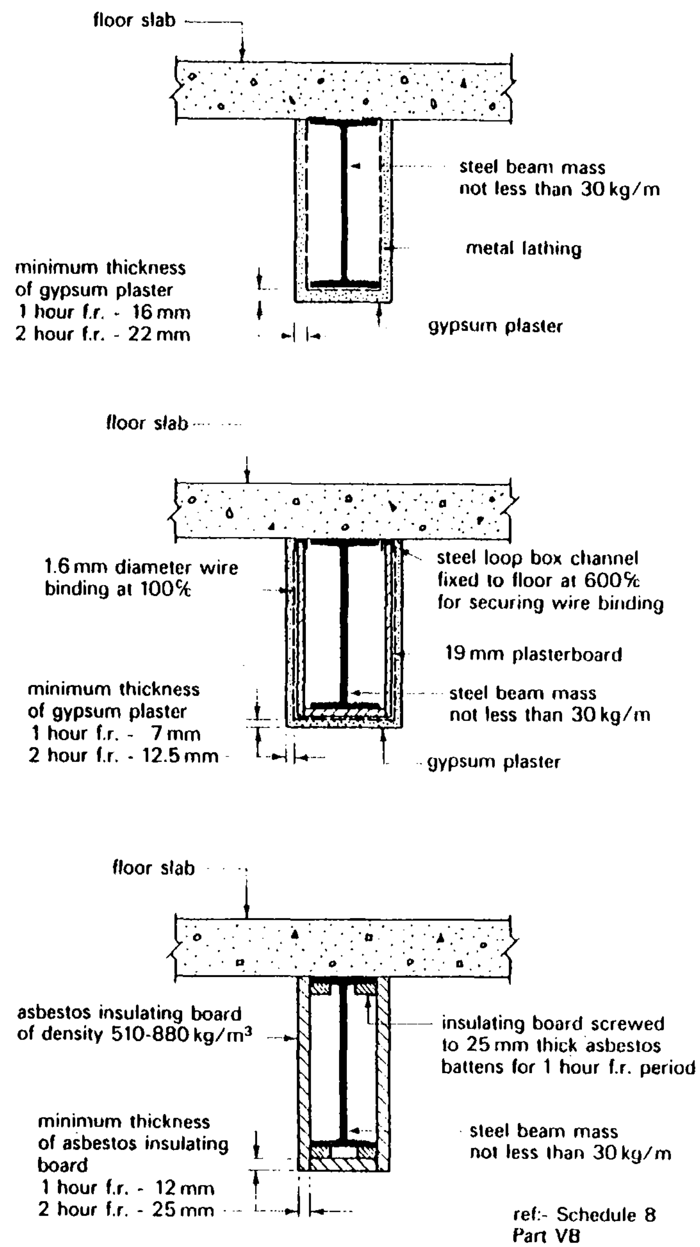
Fire resistance—R.C. columns and beams



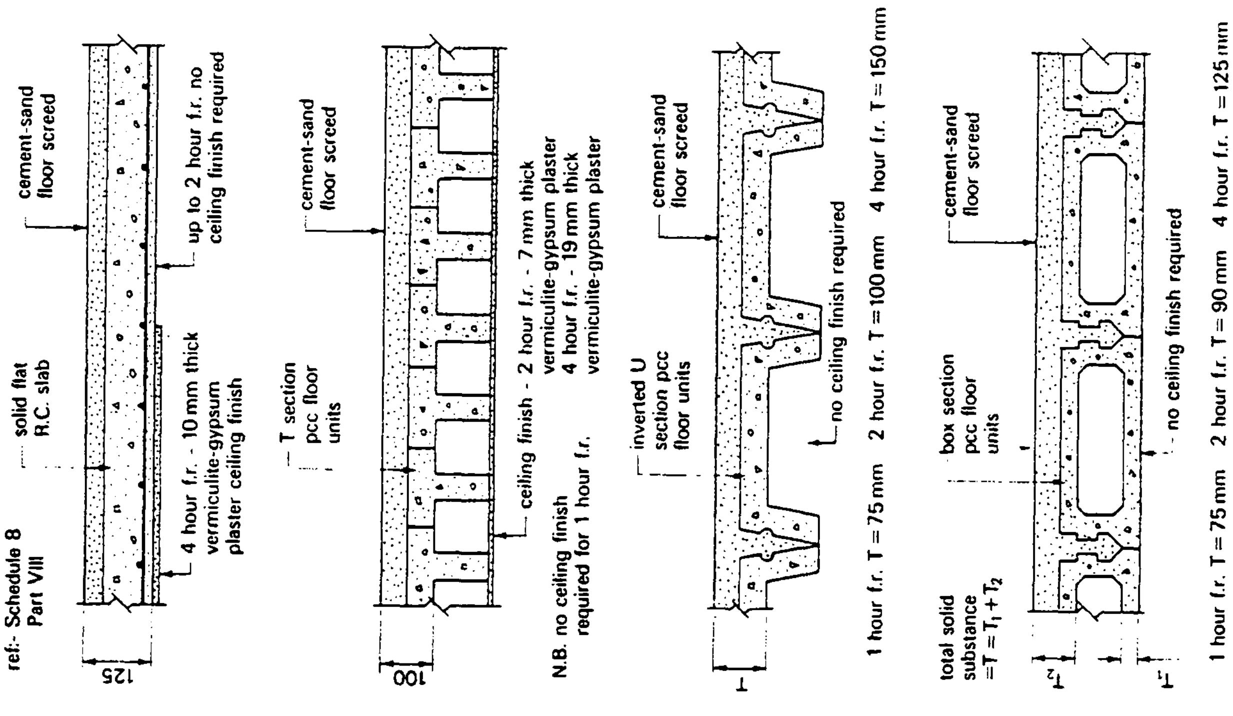
Fire resistance—steel columns and beams



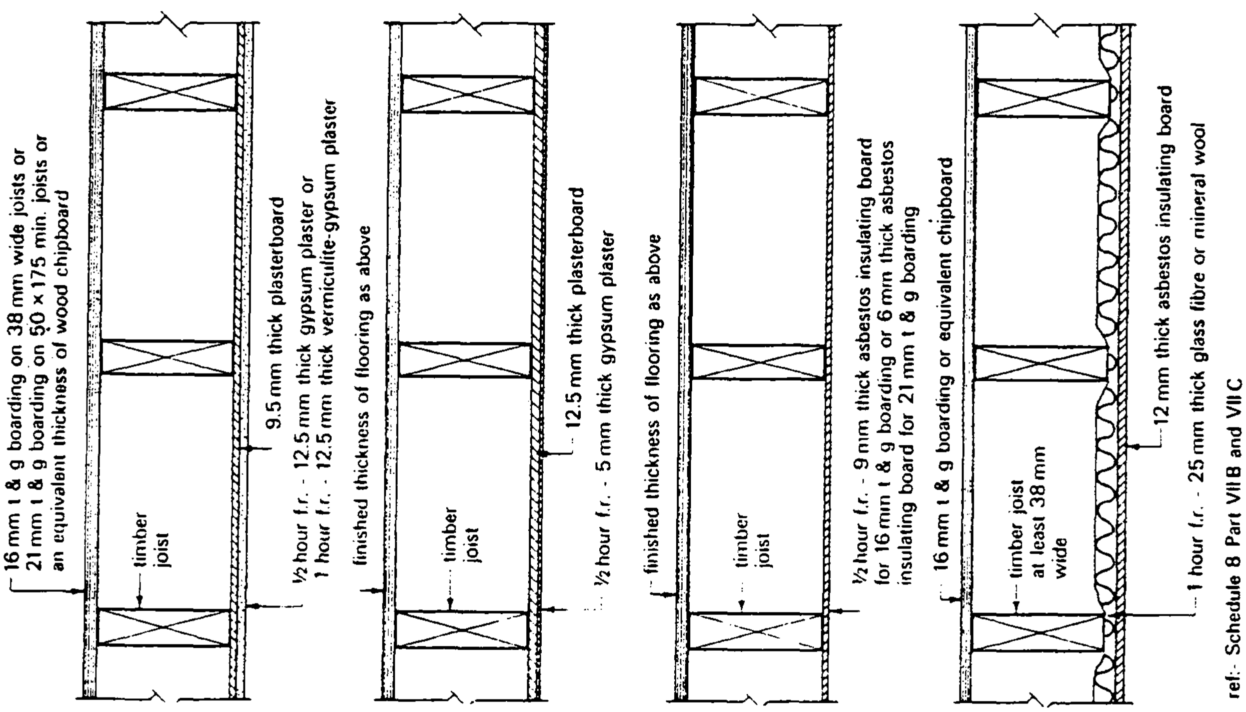
Fire resistance - hollow protection to steel columns



Fire resistance - hollow protection to steel beams



Fire resistance - concrete floors



Fire resistance - timber floors

REPETITION • exercises • REPETITION

Try to answer the following QUESTIONS and practice sketching where ever necessary and possible.

1. Exclusion of Water
   - Why must WATER be totally excluded from the interiors of buildings;
   - What are the three main sources of MOISTURE in buildings?
   - Write notes on PRECIPITATION!
   - Describe different ways of ROOF DRAINAGES!
   - Describe damages caused by FLOODING!
   - Where can DROUGHT occur and what does it cause;
   - Which two methods of MOISTURE CONTROL are normally employed?

2. Thermal Insulation
   - Define the term THERMAL INSULATION
   - In which three ways can the TRANSFER OF HEAT occur?
   - What are the ADVANTAGES OF thermal insulation of buildings?
   - Which factors are important in selecting or specifying thermal insulating materials?
   - List and describe different insulating materials

3. Sound Insulation
   - Define the following terms:

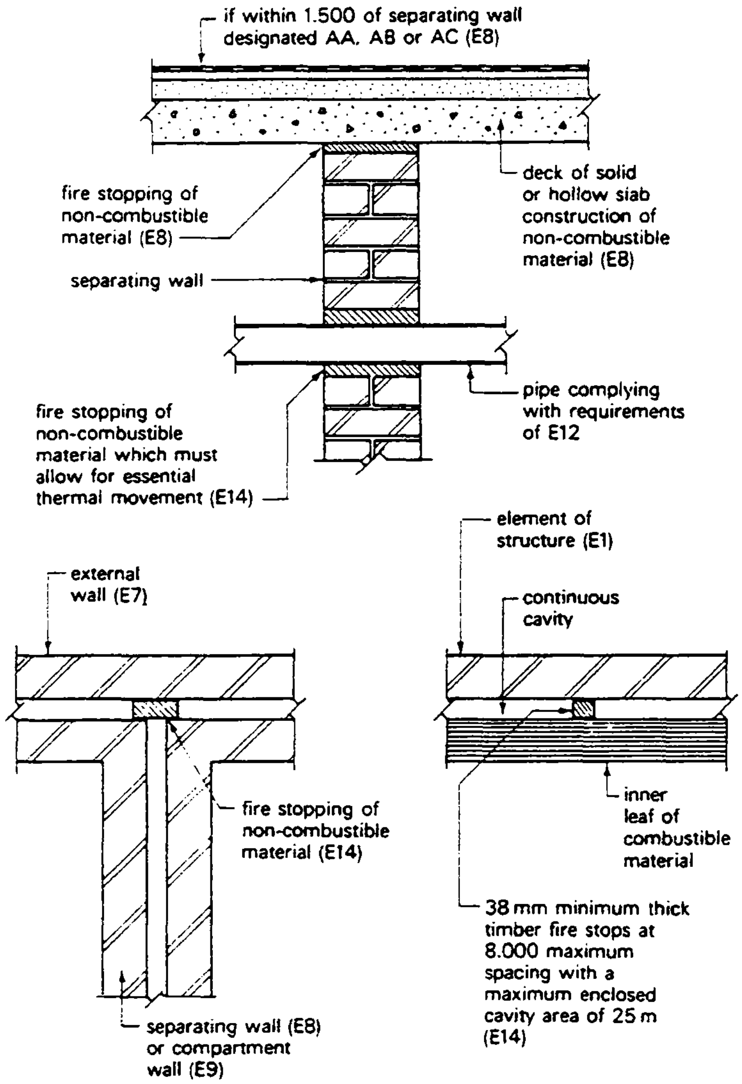
     . Sound
     . Pitch
     . Loudness
     . Frequency
     . internal noise sources
     . external noise sources
     . airborn sounds
     . impact sounds

   - What is the most effective barrier to the passage of sound through materials?
   - Explain in the form of neat sketches examples of Sound insulation in
     a WALLS
     b FLOORS
   - Write notes on EXTERNAL NOISE!

4. Fire Protection
   - What are the three main fields of FIRE PROTECTION?
   - Write notes on STRUCTURAL FIRE PROTECTION!
   - Define the term FIRE LOAD
   - List different building materials and describe their behaviour under intense heat or fire.

●●REPETITION ● exercises ● REPETITION●●

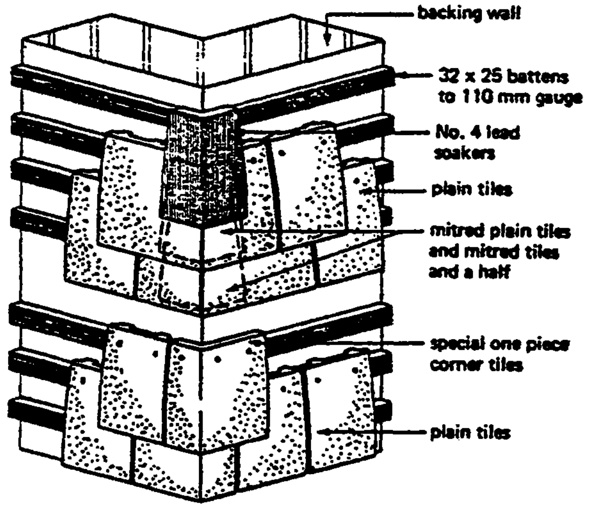
Building Reg. E1—fire stop means a barrier or seal which would prevent or retard the passage of smoke or flame within a cavity, around a pipe where it passes through a wall or floor or at junctions between elements of structure



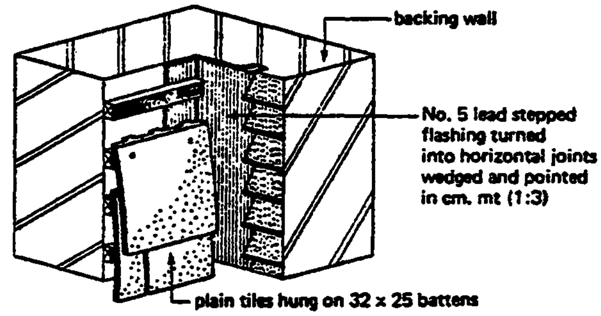
- Show in the form of neat sketches typical examples of working details for the fire protection of:
  - . Walls of masonry construction
  - . Framed and composite walls
  - . R. C. columns and beams
  - . Steel columns and beams
  - . Hollow protection to steel columns
  - . Hollow protection to steel beams
  - . Timber floors
  - . Concrete floors

12.FINISHING &. FINISHES

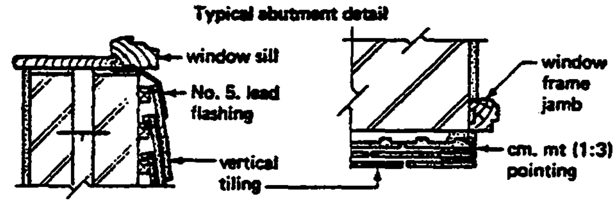
CONTENTS:

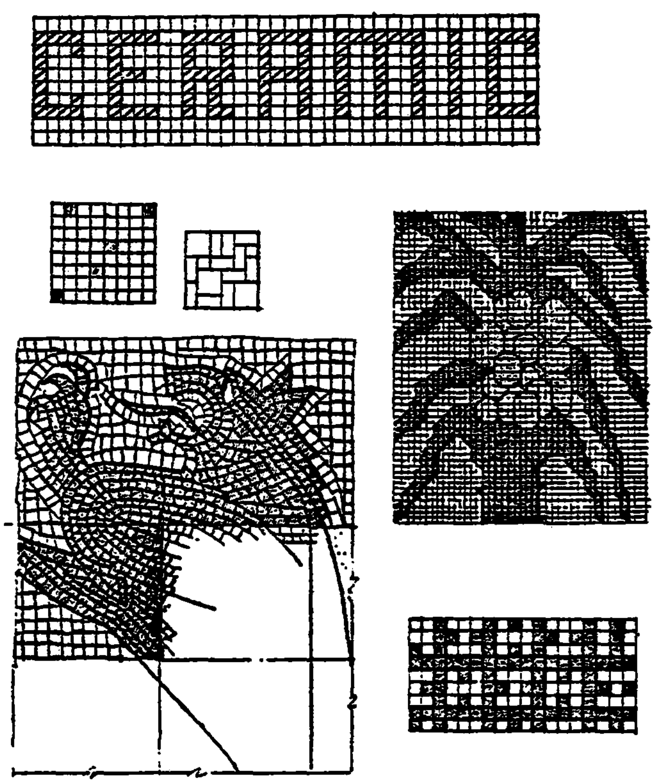


Alternative external angle treatments (internal angles treatments similar)



Typical abutment detail





REFERENCES:

1. R. Churley "CONSTRUCTION TECHNOLOGY" Volume 1,2,3,4

2. R.L. Fullerton "BUILDING CONSTRUCTION IN WARM CLIMATES" Volume 1,2,3

3. W.G. Nash "BRICKWORK 2"

12.1 EXTERNAL WALL FINISHES

12.1 EXTERNAL WALL FINISHES

External brickwork with an exposed face of facing bricks is a SELF FINISH and requires no further treatment.

External walls of common bricks or blocks can be treated to give an acceptable appearance by the application of PAINT, an application wall finish such as RENDERING or can be CLAD with boards or tiles.

EXTERNAL RENDERING

12.1.1 External Rendering

This is a form of plastering using a mixture of cement and sand, or cement, lime and sand, applied to the face of a building to give extra protection against the penetration of moisture or to provide a desired texture. It can also be used in the dual capacity of providing protection and appearance.

The rendering must have the properties of

- durability
- moisture resistance
- an acceptable appearance

The sucess of the rendering depends on

- the nature of the background
- the quality of the mix
- the location of the work
- the method of application.

• Good quality brick - or blockwork with raked joints and locked surface will give good results if the wall is wetted to reduce heat and suction.

• SPATTERDASH, i.e. cement and sand slurry 1:3 on concrete walling gives good results in bonding.

• The mix of materials is as important as their quality. Cement and sand mixes will produce a strong moisture resistant rendering but one which is subject to cracking due to high drying shrinkage.(These mixes are used mainly on members which may be vulnerable to impact damage such as columns.)

Cement, lime and sand mixes have a lower drying shrinkage but are more absorbent than cement and sand mixes; they will, however, dry out rapidly after periods of rain and are therefore the mix recommended for general use.

EXTERNAL RENDERING

Two common volume mix ratios are:

a) 1:1/2 : 4-4 1/2 cement:lime:sand, which is used for dense, strong backgrounds of moderate to severe exposure and for application to metal lathing or expanded metal backgrounds.

b) 1 : 1 : 6-8 cement : lime : sand which is for general use.

a) 1:1/2:4-4 1/2

b) 1 : 1 : 6-8

- The number of coats required will depend upon the surface condition of the background and the degree of exposure. Generally a TWO COAT application is acceptable, except where the background is very irregular or the building is in a position of severe exposure when a three coat application would be specified. The thickness of any one coat should not exceed 15 mm and each subsequent coat is about 5 mm thick.
- Finishes should be floated, not trowelled smooth.
- Various textured surfaces can be obtained on renderings by surface treatments such as scraping the surface with combs, saw blades or similar tools to remove a surface skin of mortar. These operations are carried out some three to four hours after the initial application of the rendering and before the final set takes place.

EXTERNAL RENDERING

- Alternative treatments are:

1. ROUGHCAST: a wet plaster mix of 1 part cement : 1/2 part lime : 1 1/2 parts shingle : 3 parts sand, which is thrown on to a porous coat of rendering to give an even distribution.
2. PEBBLEDASH: selected aggregate such as pea shingle is dashed or thrown on to a rendering background before it has set and is tamped into the surface with a wood float to obtain a good bond.
3. SPATTERED FINISHES: these are finishes applied by a machine (which can be hand operated), guns or sprays using special mixes prepared by the machine manufacturers.
4. TYROLEAN FINISH: it consists of 3 coats alltogether.
   1.coat: 1part waterproof cement
   2 parts of sand
   (applied as spatter dash)
   2.coat: 1part of cement
   1part of lime
   8parts of sand
   (15mm thick)
   3.coat: 1part cullamix or snowcrete Tyrolean grade,2 1/2 parts sand applied by a special hand machine, which flips the mix evenly over the wall

   It provides a pleasing and waterproof finish.

MATERIALS

- Quality of materials:
  - sand: should be washed, if dirty and thrown through a sieve.
  - lime: should be well burned and free from unslaked particles.
  - cement: can be a problem, because the quality of local factories is not always in conformity with B.S.
    Therefore the local cement should be tested and compared with B.S. Specifications.
    The most practical test, however, is to lay a sample panel of specified rendering on a wall as soon als the job begins and note the result some month later.

12.1.2 Concrete Finishes

There are a number of methods of finishing concrete walls apart from rendering or painting. The main treatments are to:

- leave it untouched after striking the shuttering
- use formwork other than timber
- use a retarding agent
- make a punched or tooled finish
- make patterns on the formwork.

- The texture of the finish created by the formwork depends on the boards used and the quality of the workmanship.
- Hardwood does not produce the grain effects of soft wood.
- Boards are more difficult to "true up" owing to poor seasoning and warping of timber.
- Tight joints in concrete should be ensured and boards levelled up to the same height.
- Day joints in concrete must be carefully constructed.

- Fins of concrete should be removed immediately the formwork is struck and the whole rubbed down with carborundum.
- Mortar to repair blemishes should be of lighter texture than the concrete it self otherwise it will dry darker. - It should be floated - not trowelled smooth.
- Corrugated metal shuttering is frequently used for effect and comes away easily.
- Plastic-moulded forms produce effects but are expensive.

- Retarding agents are normally brushed on to the formwork before concreting is started, and must be applied evenly. After striking, the concrete surface is brushed to expose the aggregate.
- A tooled finish is normally achieved by electric or pneumatic hammers with special heads. The can be varied to suit the texture required. Bush hammering is a favourite finish. Hand-tooling is done where labour is cheap, or where mechanical hammers could damage corners.
- Care should be taken that tooling does not expose the reinforcement.

CLADDING

12.1.3 Cladding

The term CLADDING is used when thin concrete, stone, granite, marble or slate is employed as a facing in addition to the normal structural requirements. It should not be fixed too tightly to the structure, for some measure of give must be allowed so that the cladding does not bear the strain of the finished construction.

ADVANTAGES

Cladding has several advantages over traditional types of construction.

1. The units can be prepared in a factory, where their production is not hampered by bad weather conditions, and where good quality control can be maintained.

2 They can be produced in readiness for fixing while the framework is being built.

3 The units do not carry any structural loads (other than their own weight) and therefore they may be comparatively thin.

4 A wide variety of surface finishes is available

5 The framework and internal lining can be erected comparatively quickly, so that the internal finishes and services can be put into operation very soon after fixing the external cladding.

Certain points, however, must be observed if failures are to be avoided with this type of construction. Some, of course, are the responsibility of the designer, but the cladding fixer must also play his part by making certain that the fixings are securely made and that all types of joints are constructed in accordance with approved practice.

CLADDING

Important points for the designer:
He should:

1 allow for the thermal movement of the structure
2 allow for movement due to drying shrinkage (The fixing of the slabs should not be started too soon after the main structure. Some time must be allowed for the shrinkage in the framework to take place)
3 allow for elastic deformation particularly with wind loading on tall slender buildings.
4 allow for creep, which is a gradual compression of the structure due to sustained stress. Great care must be, therefore, taken with the compression joints.
5 allow for uneven settlement of the structure
6 avoid the use of a cladding material which is too thin, thus preventing adequate and safe fixing methods from being used
7 provide well designed cramping details
8 ensure that bonder courses or other means of supporting the weight of the cladding are provided at each storey height
9 avoid using slabs of too large an area which would reduce the number of joints and probably absorb movement
10 specify the correct metal for the fixing cramps.

Important points for the cladding fixer:
He should:

1 point the joints thoroughly to prevent the percolation of water behind the slabs (This will have a particularly harmful effect in the winter if the water freezes)
2 use the correct type of fixing cramps as specified and not substitute different types or metals

3 make certain that the bonders or supporting nibs are well constructed

4 ensure accurate setting out of the fixing holes and slots

5 not use hard mortars for the joints

6 have sufficient thickness of the joints

7 construct expansion and compression joints in accordance with the designer's requirements

8 ensure that the correct gap is maintained at a maximum of 18 mm and a minimum of 6mm. (If these limits are exceeded then the cramps will be either too short or too long and liable to lead to makeshift adaptations)

9 Take precautions against rusting of the reinforcement, which might cause damage to the cladding, if for any reason the concrete structural wall has to be cut back.

for the designer

for the cladding fixer

CLADDING

<u>Cramps and other fixings</u>

These should be made from:

1 non-ferrous metal, for example copper, gun-metal, phosphor bronze

2 stainless steel alloys

3 sherardised steel.

It is preferable that all the fixings on each job are of the same metal to prevent the possibility of electrolytic action taking place between dissimilar metals. This is likely to cause deterioration in at least one of the metals. Iron or steel are not generally suitable for use as cramps or fixings even though they may be coated, as the coating may become damaged and allow the steel to rust and cause staining on the cladding surface, or expansion which is likely to damage the cladding at the joints, or by spalling of the surface.

<u>Cramp holes or mortices.</u>

These should be cut or drilled in the cladding without fracturing or spalling the material immediately surrounding the hole.
Claddings to buildings can be considered under two classifications

1 Claddings fixed to a structural backing

2 Claddings to framed structured.

CLADDINGS fixed to a STRUCTURAL BACKING

12.1.3.1 CLADDINGS FIXED TO A STRUCTURAL BACKING

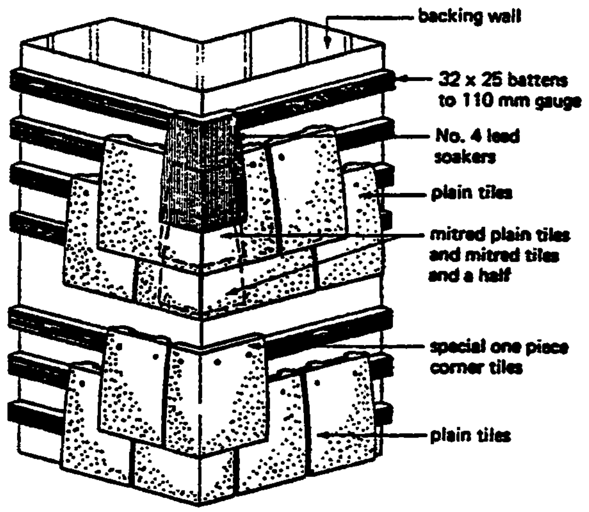
Materials used in this form of cladding are generally considered to be small unit claddings and are applied for one of two reasons. If the structural wall is unable to provide an adequate barrier to the elements a covering of small unit claddings will generally raise the wall's resistance to an acceptable level. Alternatively small unit claddings can be used solely as a decorative feature, possibly to break up the monotony of a large plain area composed of a single material.

The materials used are tiles, slates, shingles, timber boarding, plastic boards and stone facings. The general method of fixing these small units is to secure them to timber battens fixed to the structure backing.

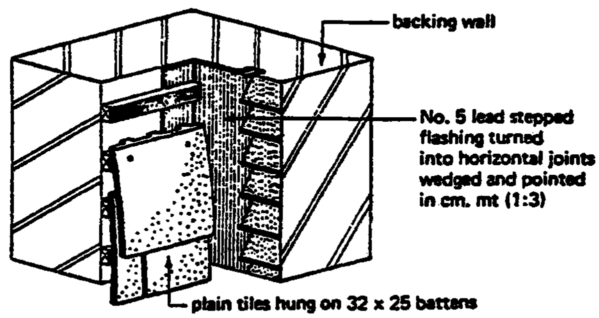
TILE HANGING

- TILE HANGING

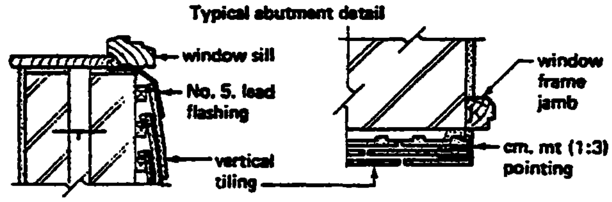
The tiles used in tile hanging can be ordinary plain roofing tiles or alternatively a tile of the same dimensions but having a patterned bottom edge solely for a decorative appearance. The tiles are hung and fixed to tiling battens although nibless tiles fixed directly to the backing wall are sometimes used (see Fig.) The battens should be impregnated to prevent fungi and isect attack so that their anticipated life is comparable to that of the tiles. Each tile should be twice nailed to its support batten with corrosion resistant nails of adequate length.



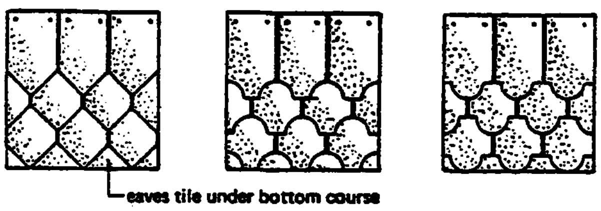
Alternative external angle treatments (internal angles treatments similar)



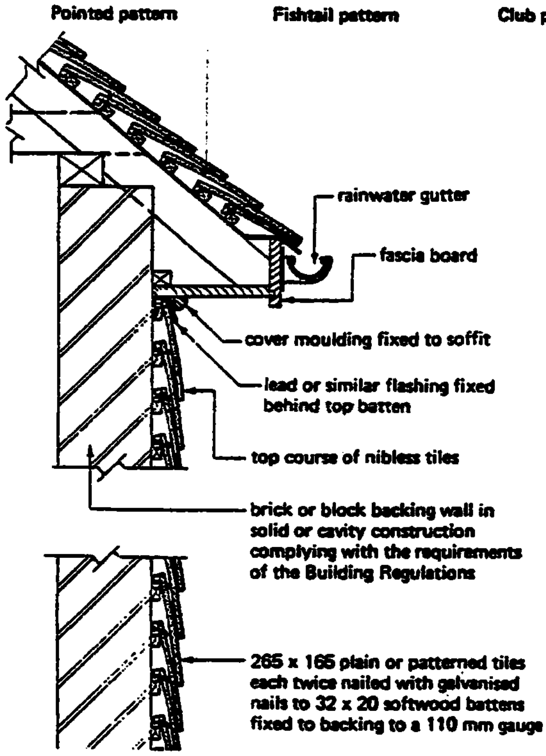
Typical abutment detail



Typical opening details



Pointed pattern   Fishtail pattern   Club pattern



The general principles of tile hanging are similar to those of double lap roof tiling and the gauge is calculated in the same manner. The minimum lap recommended is 40 mm which would give a gauge of 112.5 mm using a standard 265 long tile.

A gauge dimension of 112.5 mm is impracticable and therefore a gauge of 110 mmwould be usual.

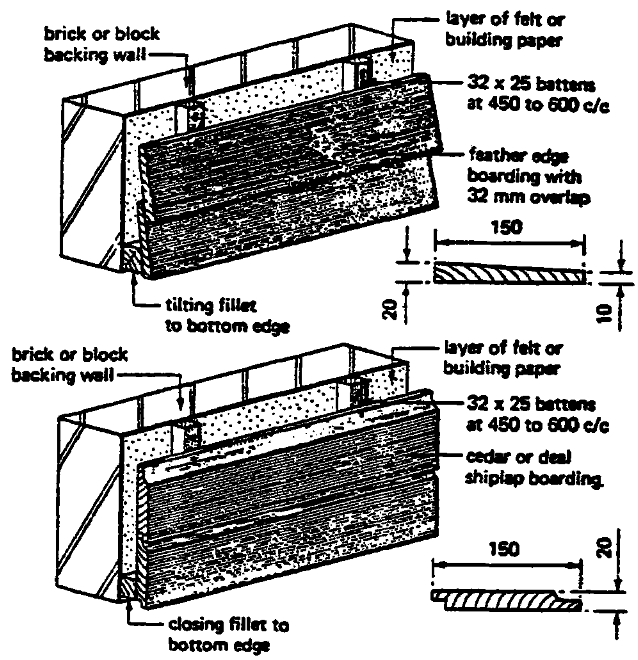
TILE HANGING

Typical details of top edge finishes, bottom edge finishes corners and finishes at windows are shown in the fig.
It should be noted that if the structural backing is of timber framing a layer of impervious felt should be placed over the framing immediately underneath the battens to prevent any moisture which is blown in between the tiles from having adverse effects upon the structure. In this situation building paper is not considered to be a suitable substitute. The application of slates as a small unit hung cladding follows the principles outlined above for tile hanging.

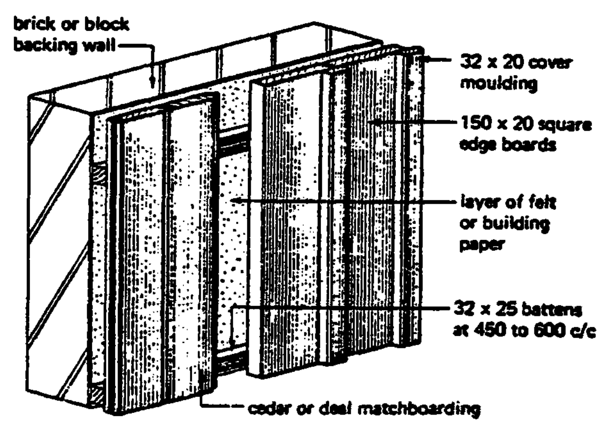
TIMBER CLADDINGS

- TIMBER CLADDINGS

Timber claddings are usually in the form of moulded or shaped boards fixed to battens as either a horizontal or vertical cladding. Timber claddings will require regular maintenance to preserve their resistance to the elements. Softwoods are generally painted and will need repainting at intervals of three to five years according to the exposure. Hardwoods are sometimes treated with a preservative and left to bleach naturally; the preservative treatment needs to be carried out at two-to five-year intervals. Western red cedar is a very popular wood for timber cladding since it has a natural immunity to insect and fungi attack under normal conditions. It also has a pleasing natural red/brown colour which can be maintained if the timber is coated with a clear sealer such as polyurethane, however, it will bleach to a grey/white colour if exposed to the atmosphere. Plastic boards are a substitute for timber and are fixed in a similar manner.



Typical horizontal claddings



Typical vertical cladding

CLADDINGS to FRAMED STRUCTURES

12.1.3.2 CLADDINGS TO FRAMED STRUCTURES

Claddings are a form of masking or infilling a structural frame and can be considered under the following headings:

1 Panel walls with or without attached facings

2 Concrete and similar cladding panels.

3 Light infill panels

4 Curtain walling which can be defined as a sheath cladding which encloses the entire structure

All forms of cladding must fulfil the following functions:

1 Be self supporting between the framing members

2 Provide the necessary resistance to rain penetration.

3 Be capable of resisting both positive and negative wind pressures.

4 Provide the necessary resistance to wind penetration

5 Give the required degree of thermal insulation

6 Provide the required degree of sound insulation to suit the building type.

7 Give the required degree of fire resistance

8 Provide sufficient openings for the admittance of natural daylight and ventilation

9 Be constructed to a suitable size.

BRICK PANEL WALLS

- BRICK PANEL WALLS

These are non-load bearing walls which must fulfil the following requirements:

1 Adequate resistance to the elements

2 Have sufficient strength to support their own self weight plus any attached finishes.

3 Strong enough to resist both positive and negative wind pressures

4 Provide the required thermal and sound insulation.

5 Provide the required fire resistance

6 Have adequate durability

BRICK PANEL WALLS

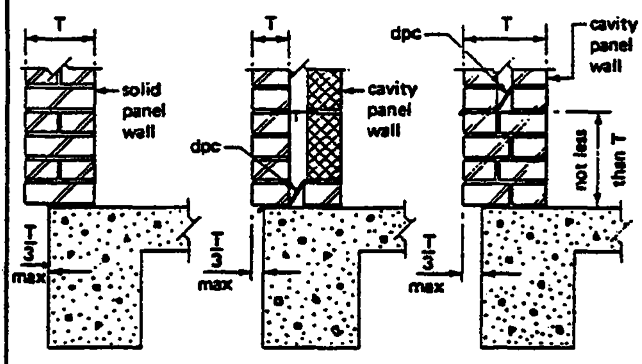
Brick panel walls are constructed in the same manner as ordinary solid or cavity walls and any openings for windows or doors are formed by traditional methods. The panels must be supported at each structural floor level and tied to the structure at the vertical edges. Projection of the panel in front of the structural members is permissible providing such overhangs do not impair the stability of the panel wall; acceptable limits are shown in the fig. The top edge of the panels should not be pinned rigidly to the frame since the effect of brick panel expansion together with frame shrinkage may cause cracking and failure of the brickwork. A compression joint should therefore be formed between the top edge of the panel and the underside of the framing member at each floor level (see fig.)

Two methods of tying the panel to the vertical structural members are in common use:

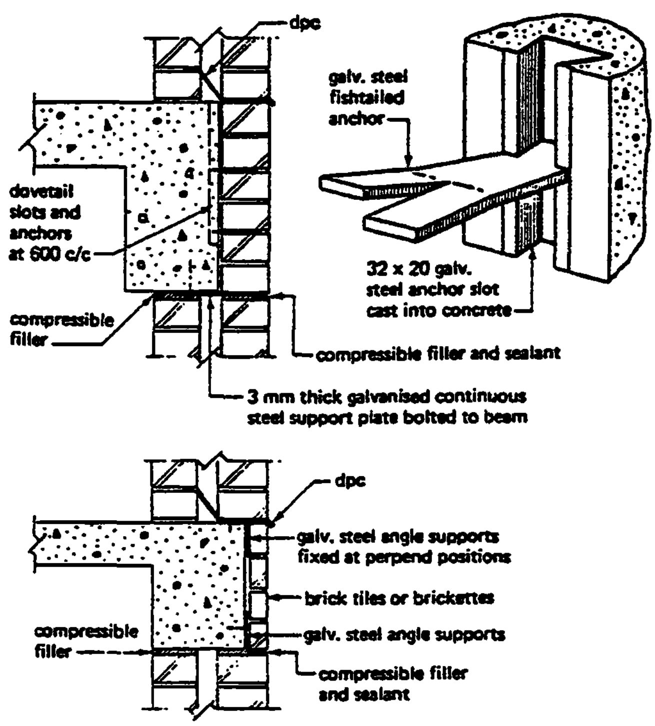
1 Butterfly wall tiles are cast into the column and built into the brick joints at four-course intervals.

2 Galvanised pressed steel dovetail slots are cast into the column and dovetail anchors are used to form the tie (see fig.)

The second method gives greater flexibility with the location and insertion of adequate ties but is higher in cost.



Maximum overhang for panel walls



Typical beam facing details

Brick panel walls

FACINGS

Facings to brick panel walls.

Any panel wall must have an acceptable and durable finish; this can be achieved by using facing bricks with a neat pointed joint or by attaching to the face of a panel of common bricks a stone or similar cladding. Suitable materials are natural stone, artificial stone, reconstructed stone and precast concrete of small units up to 1 m^2 and with a thickness related to the density of the material. Dense materials such as slate and marble need only be 40 mm thick, whereas the softer stones such as sandstone and limestone should be at least 75 mm thick.

Two major considerations must be taken into account when deciding on the method to be used to fix the facings to the brick backing:

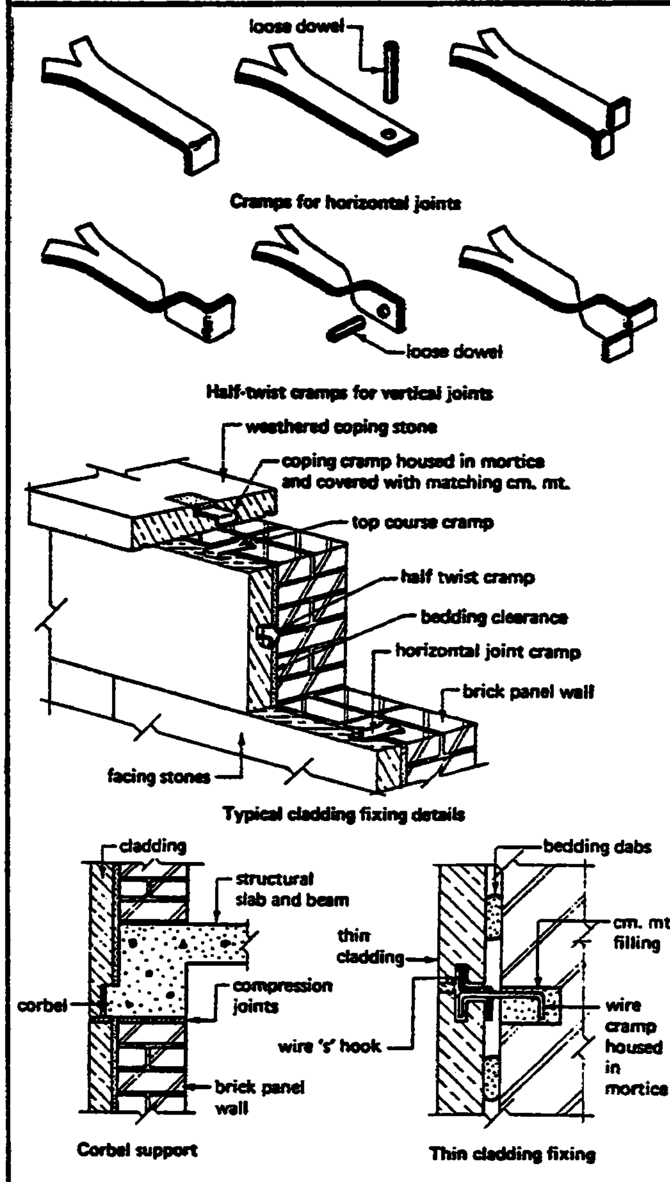
1 Transferring the load to the structure

2 Tying back the facing units.

The load of the facings can be transferred by using bonder stones or support corbels at each floor level, which should have a compression joint incorporated in the detail for the same reasons given above when considering brick panels (see fig.).

The tying back of the facings is carried out by various metal such as gunmetal, copper, phosphor bronze or stainless steel. To avoid the problem of corrosion caused by galvanic action between dissimilar metals a mixture of fixing materials should not be used. Typical examples of fixings and cramps for thick and thin facings are shown in fig.

To provide for plumbing and alignment a bedding space of 12 - 15 mm should be left between the face of the brick panel and the back of the facing. Dense facings such as marble are usually bedded on a series of cement mortar dabs, whereas the more porous facings are usually placed against a solid bed which ensures that any saturation which occurs will be uniform over the entire face.



Cladding fixings

CONCRETE CLADDING PANELS

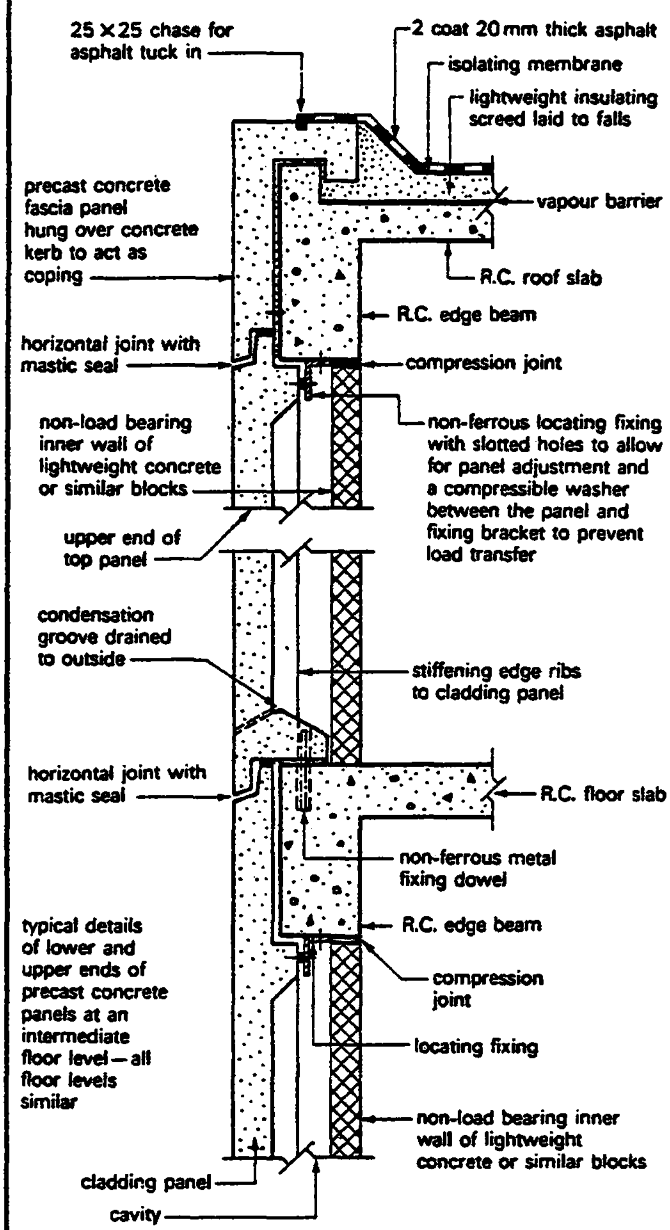
- CONCRETE CLADDING PANELS

These are usually made of precast concrete with a textured face in a storey height or undersill panel format. The storey height panel is designed to span vertically from beam to beam and if constructed to a narrow module will give the illusion of a tall building. Undersill panels span horizontally from column to column and are used where a high wall/window ratio is required. Combinations of both formats are also possible.

Concrete cladding panels should be constructed of a dense concrete mix and suitably reinforced with bar reinforcement or steel welded fabric. The reinforcement should provide the necessary tensile resistance to the stresses induced in the final position and for the stresses set up during transportation and hoisting into position. Lifting lugs, positions or holes should be incorporated into the design to ensure that the panels are hoisted in the correct manner so that unwanted stresses are not induced. The usual specification for cover of concrete over reinforcement is 25 mm minimum. If thin panels are being used the use of galvanised or stainless steel reinforcement should be considered to reduce the risk of corrosion.

When designing or selecting a panel the following must be taken into account:

1 Column or beam spacing
2 Lifting capacities of plant available
3 Jointing method
4 Exposure conditions
5 Any special planning requirements as to finish or texture.



Typical storey height concrete cladding panel

CONCRETE CLADDING PANELS

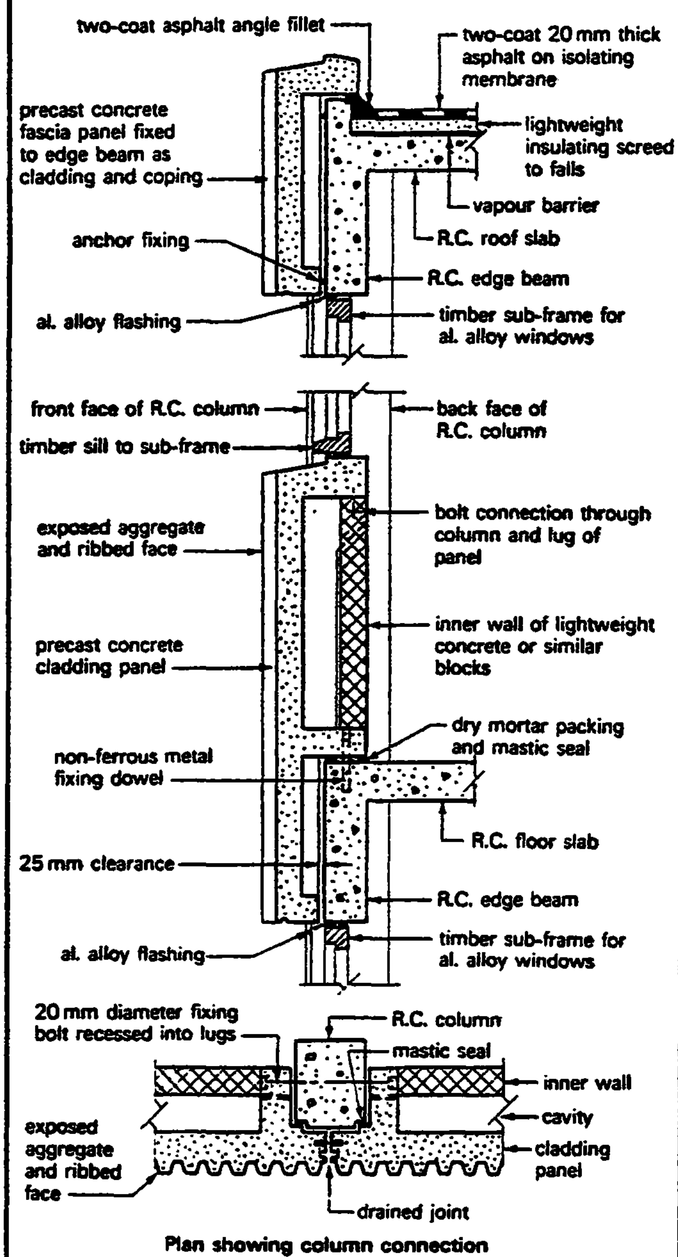
The greatest problem facing the designer and installer of concrete panels is one of jointing to allow for structural and thermal movements and at the same time provide an adequate long term joint - see fig.

Where a stone facing is required to a framed structure, possibly to comply with planning requirements, it may be advantageous to use a composite panel. These panels have the strength and reliability of precast concrete panel design and manufacture but the appearance of traditional stonework. This is achieved by casting a concrete backing to a suitably keyed natural or reconstructed stone facing and fixed to the frame by traditional masonry fixing cramps or by conventional fixings - see fig.

Thermal insulation can be achieved when using precast concrete panes by creating a cavity as shown in the fig.

Concrete cladding panels can be large and consequently heavy. To reduce the weight they are often designed to be relatively thin (50 to 75 mm) across the centre portion and stiffened around the edges with suitably reinforced ribs which usually occur on the back face but can be positioned on the front face as a feature which can also limit the amount of water which can enter the joint.

Another form of cladding material which is beginning to gain popularity and acceptance is glass fibre reinforced plastics (GRP) which consists of pigments and a suitable catalyst as a hardener.



Typical undersill concrete cladding panel

12. FINISHES	EXTERNAL WALL FINISHES	BUILDING CONSTR.
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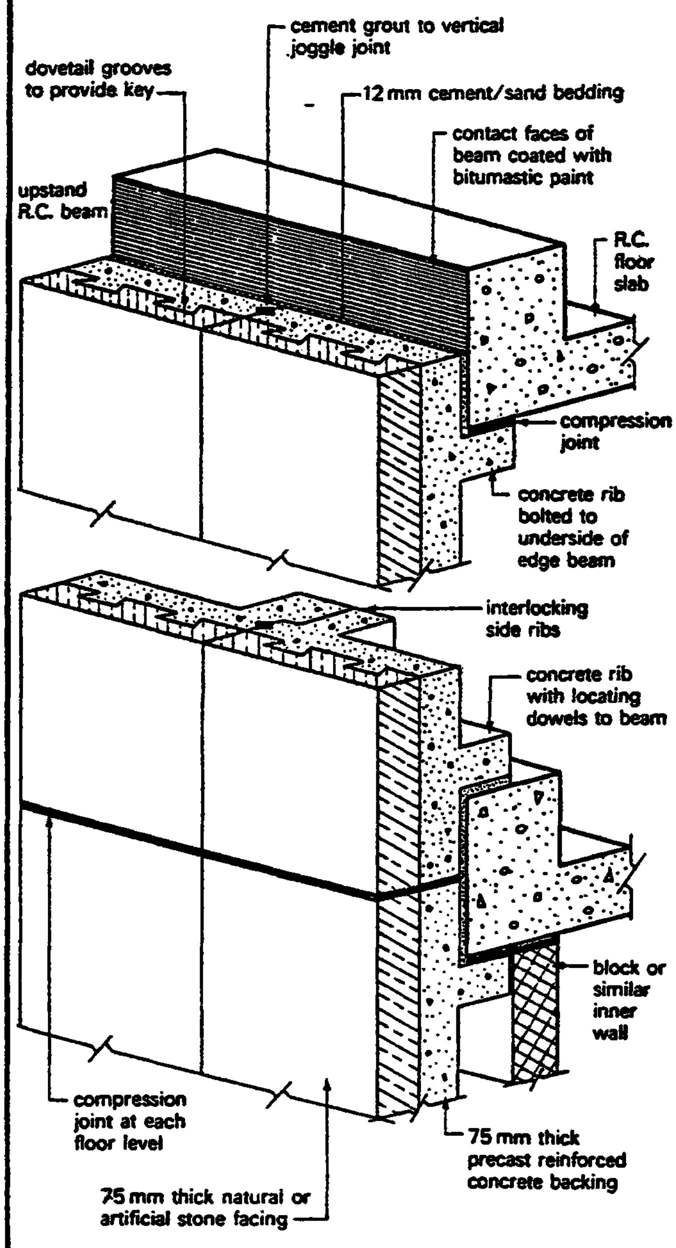
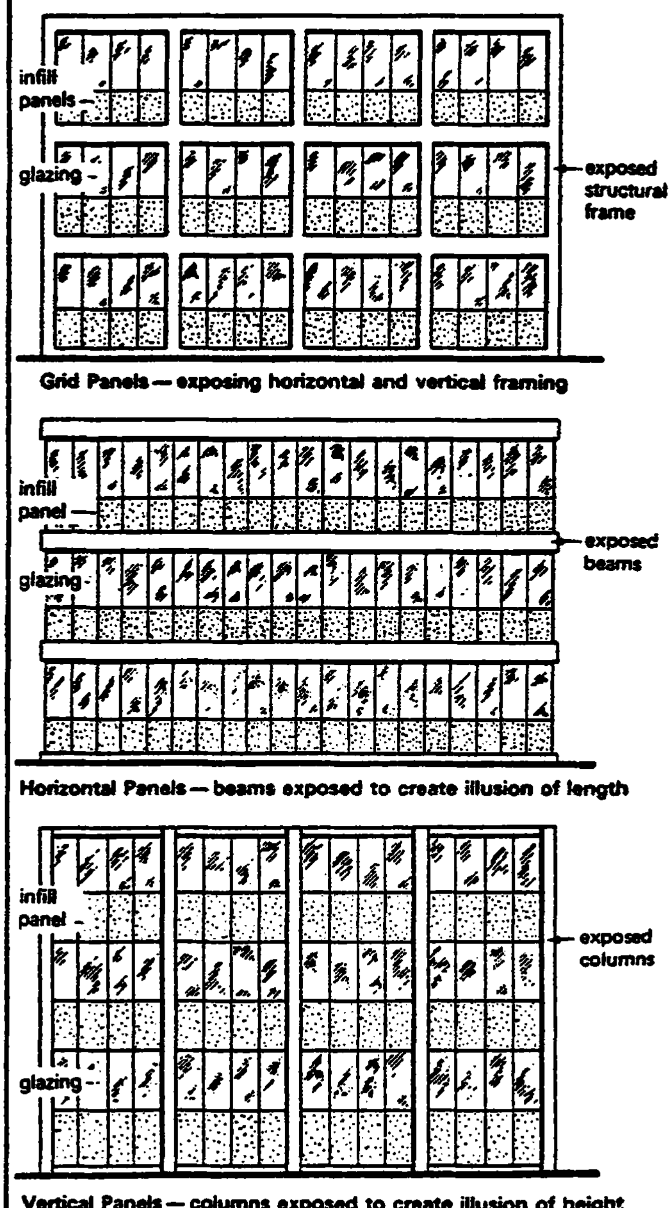
CONCRETE CLADDING PANELS

The resultant panels are lightweight, durable, non-corrosive, have good weather resistance, can be moulded to almost any profile and have good aestetic properties. Students seeking further information are recommended to study the Building Research Establishment Digest 161.

INFILL PANELS



Typical storey height composite panel



Typical infill panel arrangements

INFILL PANELS

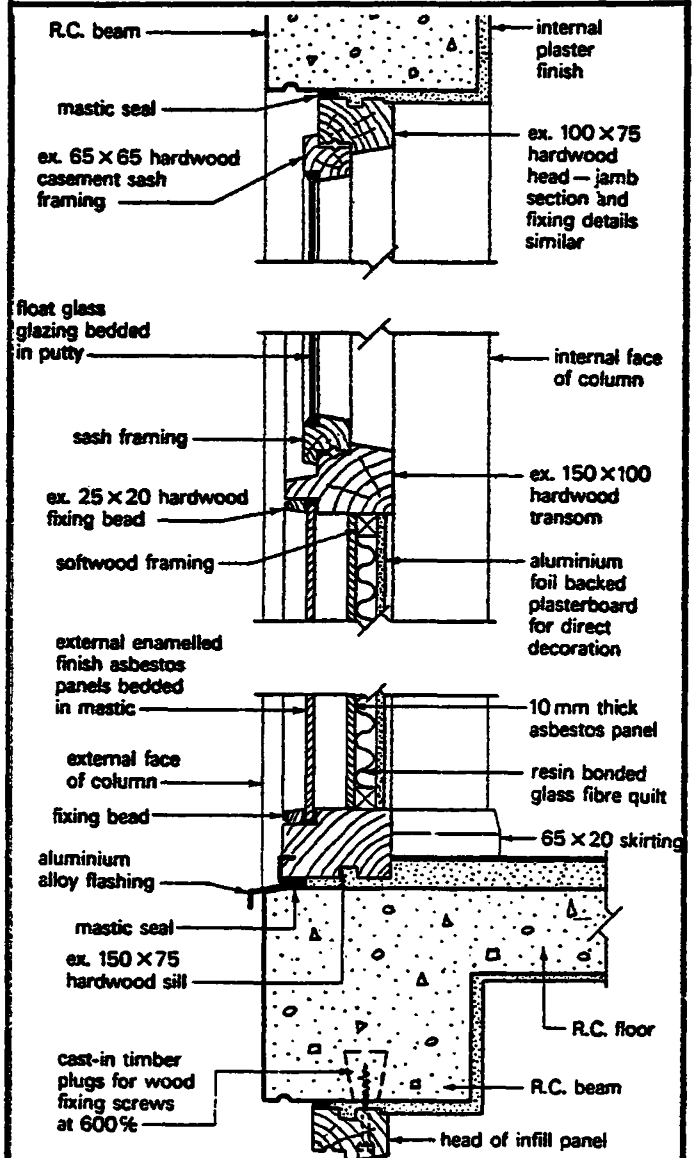
- INFILL PANELS

Infill panels are lightweight and usually glazed to give good internal natural daylighting conditions. The panel layout can be so arranged to expose some or all of the structural members creating various optical impressions. For example, if horizontal panels are used, leaving only the beams exposed, an illusion of extra length and/or reduced height can be created. - see fig.
A wide variety of materials or combinations of materials can be employed such as timber, steel aluminium and plastic. Single and double glazing techniques can be used to achieve the desired sound or thermal insulation. The glazing module should be such that a reasonable thickness of glass can be specified.

The design of the 'solid' panel is of great importance since this panel must provide the necessary resistance to fire, heat loss, sound penetration and interstitial condensation. Most of these panels are of composite or sandwich construction as shown in the fig.

The jointing problem with infill panels occurs mainly at its junction with the structural frame and allowance for moisture or thermal movement is usually achieved by using a suitable mastic or sealant.

Most infill panels are supplied as a manufacturer's system, since purpose-made panels can be uneconomic, but whichever method is chosen the design aims remain constant; that is, to provide a panel which fulfils all the required functions and has a low long term maintenance factor.
It should be noted that many of the essentially curtain walling systems are adaptable as infill panels which gives the designer a wide range of systems from which to select the most suitable.
One of the maintenance problems encountered with infill panels and probably to a lesser extent with the concrete claddings is the cleaning of the facade and in particular the glazing. All buildings collect dirt, the effects of which can vary with the material: concrete and masonry tend to accept dirt and weather naturally, whereas impervious materials such as glass do not accept dirt and can corrode or become less efficient.



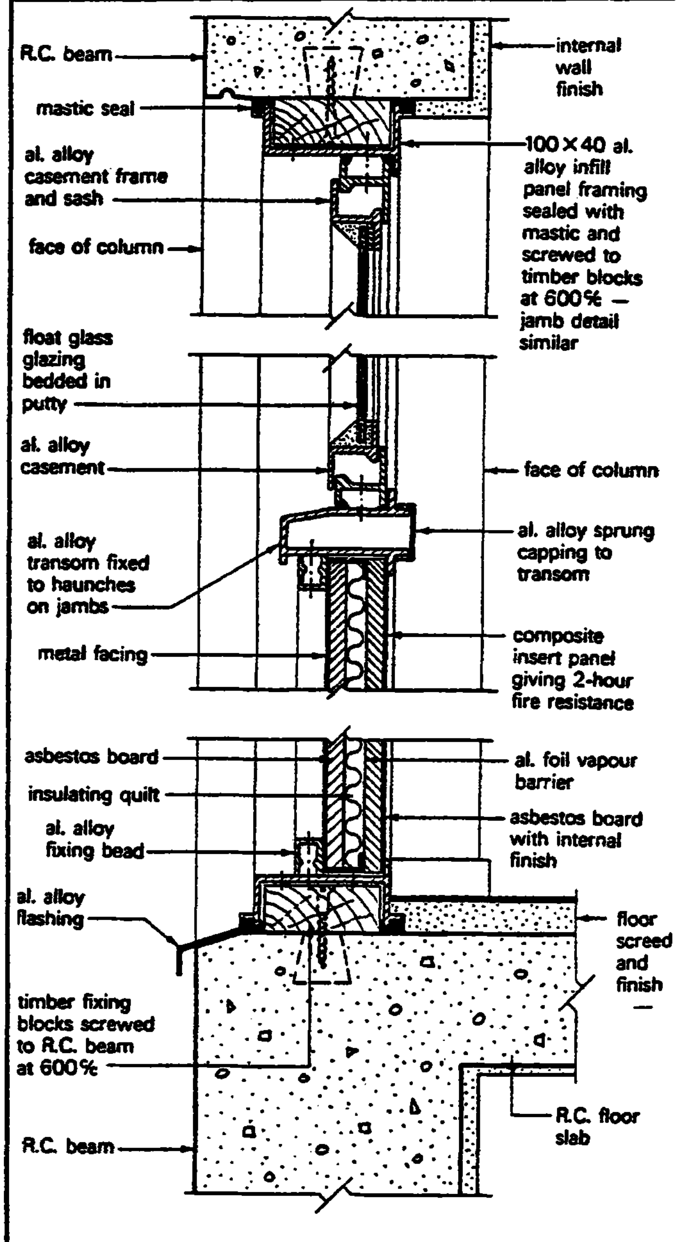
Typical timber infill panel details

INFILL PANELS

If glass is allowed to become coated with dirt its visual appearance is less acceptable, its optical performance lessens since clarity of vision is reduced and the useful penetration of natural daylight diminishes. The number of times that cleaning will be necessary depends largely upon the area, ranging from three-monthly intervals in non-industrial areas to six-weekly intervals in areas with a high pollution factor.

Access for cleaning glazed areas can be external or internal. Windows at ground level present no access problems and present only the question of choice of method such as hand cloth or telescopic poles with squeegee heads. Low and medium rise structures can be reached by ladders or a mobile scaffold tower and usually present very few problems. High rise structures need careful consideration. External access to windows is gained by using a cradle suspended from roof level; this can be in the form of a temporary system consisting of counterweighted cantilevered beams from which the cradle is suspended. Permanent systems, which are incorporated as part of the building design, are more efficient and consist of a track on which a mobile trolley is mounted and from which davit arms can be projected beyond the roof edge to support the cradle. A single track fixed in front of the roof edge could also be considered; these are simple and reasonably efficient but the rail is always visible and can therefore mar the building's appearance.

Internal access for cleaning the external glass face can be achieved by using windows such as reversible sashes, horizontal and vertical sliding sashes, but the designer is restricted in his choice to the reach possible by the average person.
It cannot be over emphasised that such windows can be a very dangerous hazard unless carefully designed so that all parts of the glazed area can be reached by the person cleaning the windows whilst he remains standing firmly on the floor.

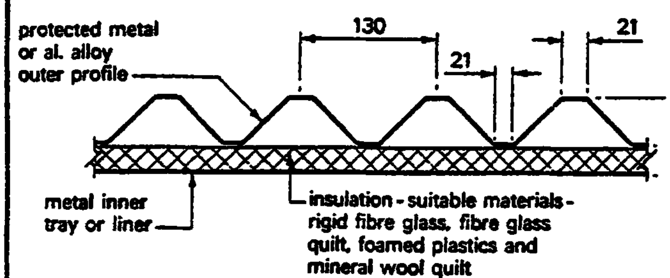


Typical metal infill panel details

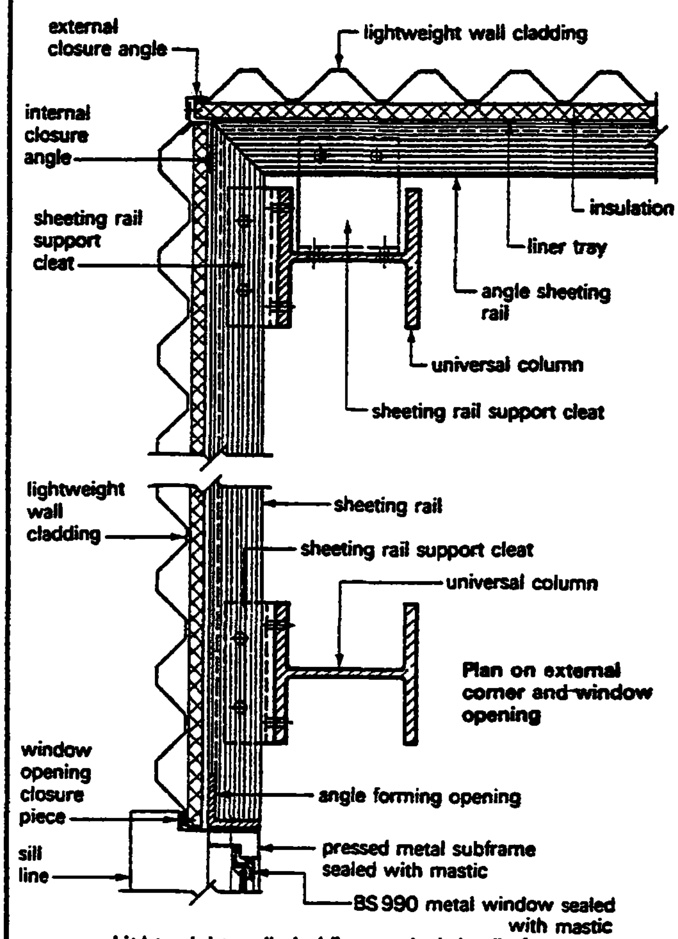
LIGHTWEIGHT WALL CLADDING

- LIGHTWEIGHT WALL CLADDINGS

In common with other cladding methods for framed buildings, lightweight wall claddings do not require high compressive strength since they only have to support their own dead load and any imposed wind loading, which will become more critical as the height and/or exposure increases. Lightweight claddings are usually manufactured from impervious materials which means that the run off of rain water can be high particularly under storm conditions when the discharge per minute could reach 2 litres per square metre of wall area exposed to the rain.
A wide variety of materials can be used as a cladding medium, most being profiled to a corrugated or trough form since the shaping will increase the strength of the material over its flat sheet form. Flat sheet materials are available but are rarely applied to large buildings because of the higher strength obtained from a profiled sheet of similar thickness. Special contoured sheets have been devised by many manufacturers to give the designer a wide range of choice in the context of aesthetic appeal. Claddings of various sandwich construction are also available to provide reasonable degrees of thermal insulation, sound insulation and to combat the condensation hazard which can occur with lightweight claddings of any nature.
The sheets are fixed in a similar manner to that for sheet roof coverings. The support purlins are replaced



Typical cladding profile



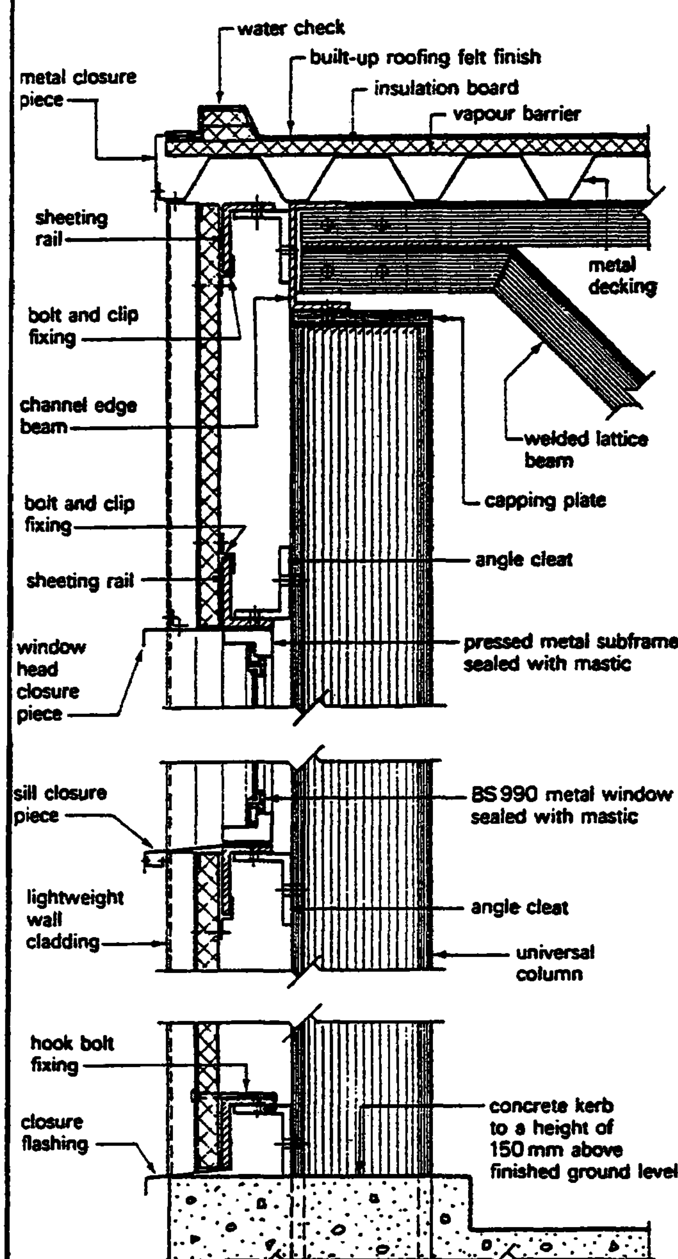
Lightweight wall cladding - typical details 1

LIGHTWEIGHT WALL CLADDING

in walls by a similar member called a sheeting rail which is fixed by cleats to the vertical structural frame members. The major difference occurs with the position of the fixings which in wall claddings are usually specified as being positioned in the trough of the profile as opposed to the crest when fixing roof coverings. This change in fixing detail is to ensure that the wall cladding is pulled tightly up to the sheeting rail or lining tray.

Plastic protective caps for the heads of fixings are available, generally of a colour and texture which will blend with the wall cladding. A full range of fittings and trims are usually obtainable for most materials and profiles to accommodate openings, returns, top edge and bottom edge closing. Typical cladding details are shown in the fig.
Common materials used for lightweight wall claddings are:

1 Asbestos cement
non-combustible material in corrugated and troughed sheets which are generally satisfactory when exposed to the weather but are susceptible to impact damage. Average life is about 20 years which can be increased considerably by paint protection. Unpainted sheets loose their surface finish at the exposed surface by carbonation and become ingrained with dirt. To achieve reasonable thermal insulation standards a lining material will be required, which is normally sandwiched between the cladding and an inner lining tray.



Lightweight wall cladding - typical details 2

LIGHTWEIGHT WALL CLADDING

2 Coated steel sheets non-combustible material with a wide range of profiles produced by various manufacturers. The steel sheet forms the core of the cladding providing its strength and this is covered with various forms of coatings to give weather protection, texture and colour. A typical specification would be a galvanised steel sheet core covered on both sides with a layer of asbestos felt to increase resistance to fire, a layer of bitumen-impregnated felt to act as a barrier to the passage of moisture to the core and on the face surface a coloured and textured coating of plastic. Fixing and the availability of fittings is as described above for asbestos cement.

3 Aluminium alloy sheets non-combustible material in corrugated and troughed profiles which are usually made to the recommendations of BS 2858 and BS 3428 respectively. Other profiles are also available as manufacturers' standards. Durability will depend upon the alloy used but this can be increased by paint applications; if unpainted, regular cleaning may be necessary if its natural bright appearance is to be maintained. Fixing, fittings and the availability of linings is as given for other cladding materials.

4 Polyvinyl chloride sheets generally supplied in a corrugated profile with an embedded wire reinforcement to provide a cladding with a surface spread of flame classification of class 1 in accordance with BS 476: Part7.

The durability of this form of cladding is somewhat lower than those previously considered and the colours available are limited. The usual range of fittings and trims are available.

The importance of adequate design, detail and fixing of all forms of lightweight cladding cannot be overstressed since the primary objective of these claddings is to provide a lightweight envelope to the building giving basic weather protection and internal comfort at a reasonable cost. Claddings which will fulfil these objectives are very susceptible to wind damage unless properly secured to the structural frame.

- CURTAIN WALLING

Curtain walls are a form of external lightweight cladding, attached to a framed structure or monolithic walls, forming a complete envelope or sheath around the structural frame.

They are non-load-bearing claddings, which have to support only their own deadweight and any imposed wind loadings which are transferred to the structural frame through connectors which are usually positioned at the floor level.

The basic conception of most curtain walls is a series of vertical MULLIONS spanning from floor to floor interconnected by horizontal TRANSOM S forming openings into which can be fixed panels of glass or infill panels of opaque materials like:

- metal faced insulation materials
- weatherproof blockboard
- plastic materials, etc.

of various thickness built in metal frames.

Most curtain walls are constructed by using a patent or proprietary system produced by metal window manufacturers.

The primary objectives of using curtain walling systems are:

1 Provide an enclosure to the structure which will give the necessary protection against the elements.

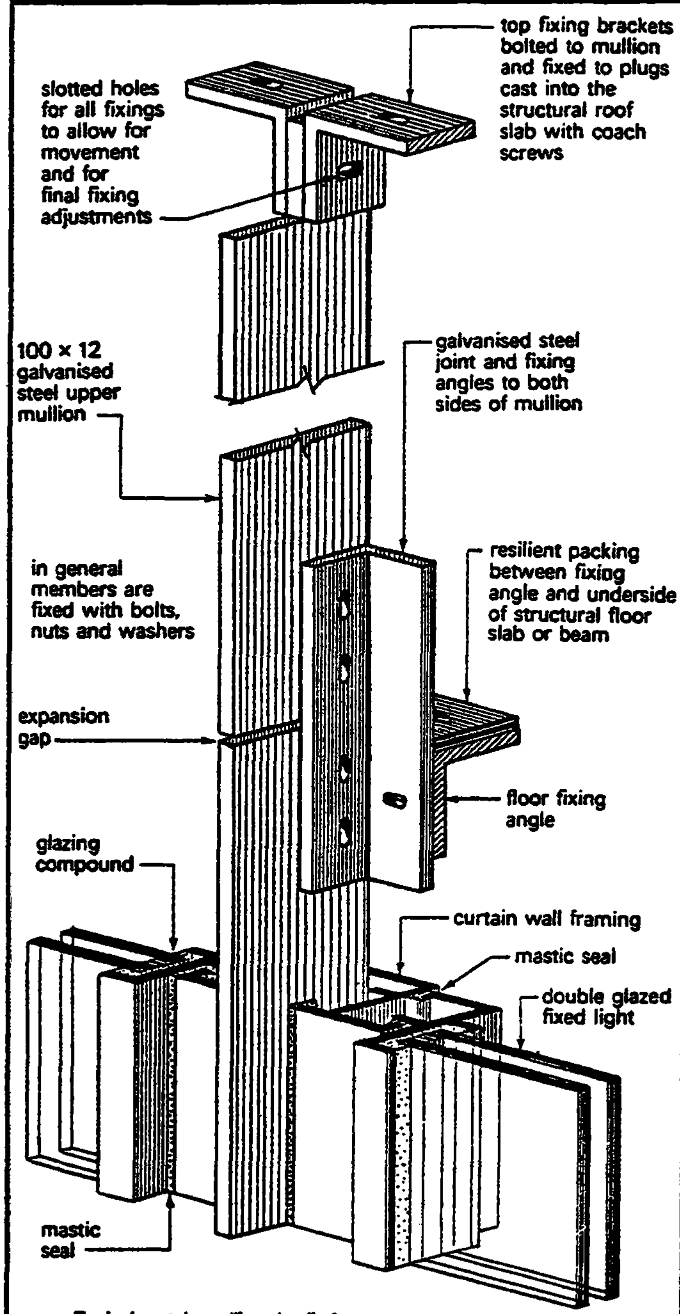
2 Make use of dry construction methods.

3 Impose onto the structural frame the minimum load in the form of claddings.

4 Exploit an architectural feature.

To fulfil its primary functions a curtain wall must meet the following requirements:

1 Resistance to the elements the materials used in curtain walls are usually impervious and in themselves present no problem but by virtue of the way in which they are fabricated a large number of joints occur. These joints must be made as impervious



Typical curtain walling details 1

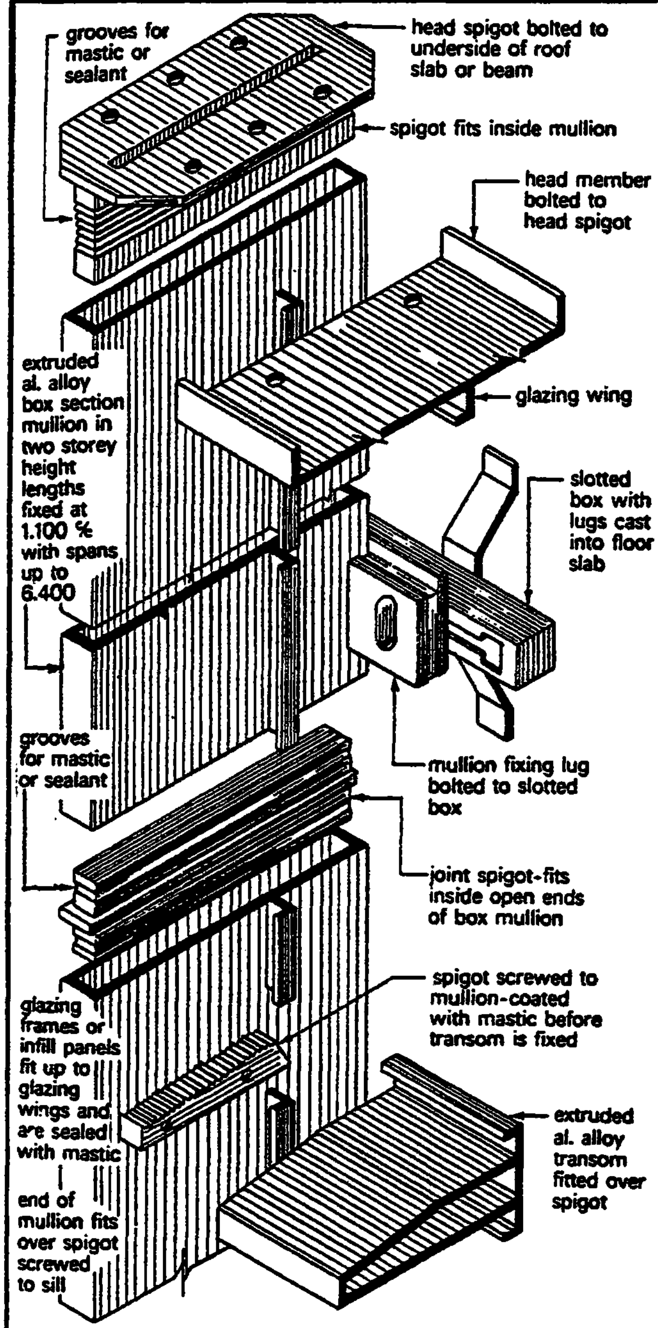
as the surrounding materials or designed as a drained joint. The jointing materials must also allow for any local thermal, structural or moisture movement and generally consist of mastics, sealants and/or preformed gaskets of synthetic rubber or PVC.

2 Assist in maintaining the designed internal temperatures - since curtain walls usually include a large percentage of glass the overall resistance to the transfer of heat is low and therefore preventive measures may have to be incorporated into the design. Another problem with large glazed areas is solar heat gain since glass will allow the short wave radiations from the sun to pass through and consequently warm up the surfaces of internal walls, equipment and furniture. These surfaces will in turn radiate this acquired heat in the form of long wave radiations which cannot pass back through the glazing thus creating an internal heat build-up. Louvres fixed within a curtain walling system will have little effect upon this heat build-up but they will reduce solar glare. A system of non-transparent external louvres will slightly reduce the heat gain by absorbing heat and radiating it back to the external air. The usual methods employed to solve the problem of internal heat gain are:

a Deep recessed windows which could be used in conjunction with external vertical fins.

b Balanced internal heating and ventilation systems

c Use of special solar control glass such as reflective glasses which during manufacture are modified by depositing on the surface of the glass a metallic or dielectric reflective layer. The efficiency of this form of glazing can be increased if the glass is tilted by 5° to 15° to increase the angle of incidence.



Typical curtain walling details 2

damage of the glazed and infill panel areas by enabling these units to move independently of the curtain wall framing.

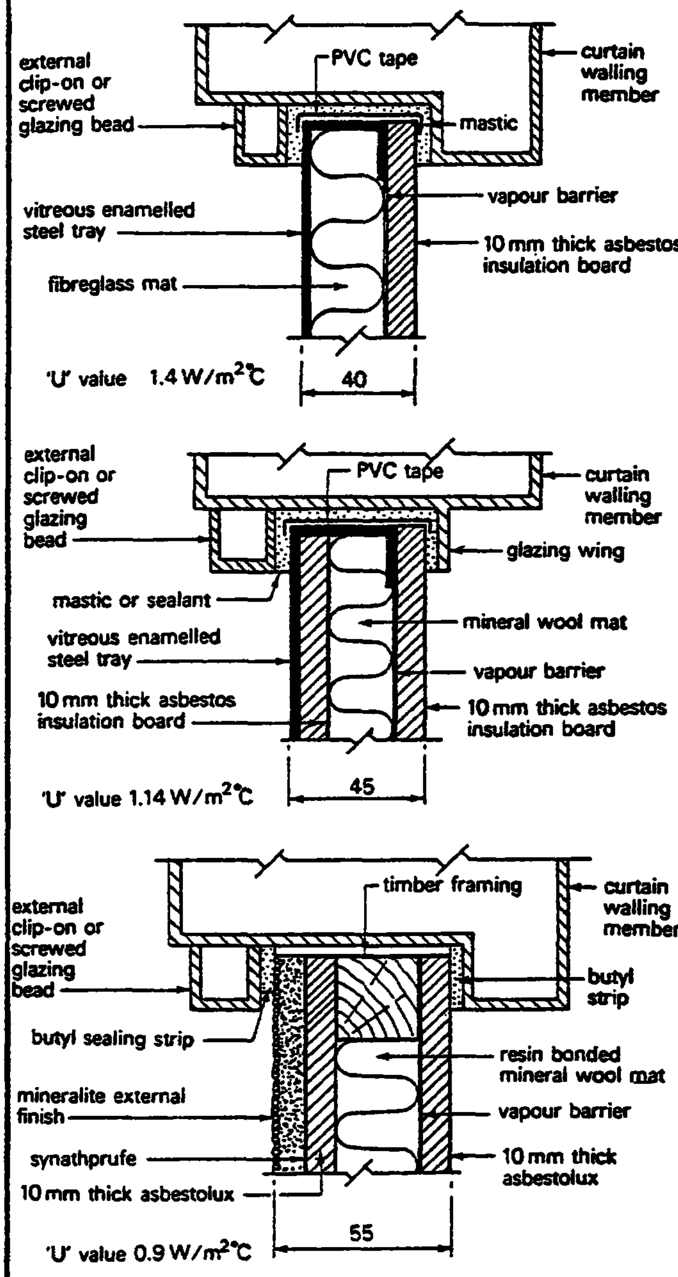
4 Provide required degree of fire resistance - this is probably one of the greatest restrictions encountered when using curtain walling techniques because of the large proportion of unprotected areas as defined in Building Regulation E 1 and by the conditions set out in Building Regulation E 7 and Schedule 9. By using suitable materials or combinations of materials the opaque infill panels can normally achieve the required fire resistance to enable them to be classified as protected areas.

5 Easy to assemble and fix - the principal member of a curtain walling system is usually the mullion which can be a solid or box section which is fixed to the structural frame at floor levels by means of adjustable anchorages or connectors.

3 Adequate strength - although curtain walls are classified as non-load-bearing they must be able to carry their own weight and resist both positive and negative wind loadings. The magnitude of this latter loading will depend upon three basic factors:

a Height of building
b Degree of exposure
c Location of building

The strength of curtain walling relies mainly upon the stiffness of the vertical component or mullion together with its anchorage or fixing to the structural frame. Glazing beads and the use of compressible materials also add to the resistance of possible wind



Typical curtain walling infill panel details

The infill framing and panels may be obtained as a series of individual components or as a single prefabricated unit. The main problems are ease of handling, amount of site assembly required and mode of access to the fixing position.

6 Provide required degree of sound insulation - sound originating from within the structure may be transmitted vertically through the curtain walling members. The chief source of this form of structure-borne sound is machinery and this may be reduced by isolating the offending machines by mounting them on resilient pads and/or using resilient connectors in the joints between mullion lengths.

Airborne sound can be troublesome with curtain walling systems since the lightweight cladding has little mass to offer in the form of a sound barrier, the weakest point being the glazed areas. A reduction in the amount of sound transmitted can be achieved by

a Reducing the areas of glazing
b Using sealed windows of increased glass thickness
c Double glazing in the form of inner and outer panes of glass with an air space of 150 to 200 mm between them.

7 Provide for thermal and structural movements - since curtain walling is situated on an external face of the structure it will be more exposed than the structural frame and will therefore be subject to greater amounts of temperature change resulting in high thermal movement. The main frame may also be subjected to greater settlement than the claddings attached to its outer face. These differential movements mean that the curtain walling systems should be so designed, fabricated and fixed that the attached cladding can move independently of the structure. The usual methods of providing for this required movement are to have slotted bolt connections and, to allow for movement within the curtain walling itself, to have spigot connections and/or mastic sealed joints.

EXTERNAL PAINTS and FINISHES

12.1.4 EXTERNAL PAINTS AND FINISHES

The usual colour renderings today are achieved either by use of cement paints, i.e. paints containing coloured cements supplied as powder and mixed with water, or by use of PVA emulsion paints. The former are very popular, especially with Tyrolean finish. The latter are supplied as a thick liquid to which water is added. They are easily applied, require no special skill and form a plastic skin which adheres well to cement rendering. Emulsion paint, however, does fail occasionally because of the alkaline nature of the background. The emulsion paint used must be of external quality.
Oil paints are not greatly used in the tropics on the grounds of their expense, and emulsion paint cannot be applied over them.
Water-bound distemper is still used, as it is cheap and easily applied. It needs frequent renewal.
An expensive but strong and durable surface can be obtained from the use of epoxy resin paint. It is waterproof and adheres well. It is very good for cement screeded floors

Bitumen paints are good, particularly in coastal areas or in damp atmospheres. They are used widely on corrugated iron sheeting and other metals in need of protection from rust. The surfaces must

be cleaned before paint is applied. No other kind of paint can be applied over bitumen paint.

Woodwork which is mainly from hardwood does not always receive the preparative treatment which is usual in the case of softwood. Frequently it is not primed. Hardwoods, however, are sometimes subject to rapid decay in external conditions and should be carefully primed before undercoat is applied.

Varnishing of wood used externally although still popular is not always successful on exposed faces. It is quite satisfactory in sheltered areas, under canopies, walkways, etc. but will not stand up to sunlight.

12.2 INTERNAL WALL FINISHES

12.2.1 PLASTERING

A number of factors causes a great variation in the art of plastering from one country to another:

- traditional customs
- religious influences
- the material available
- the tools used
- the background to which it is applied.

Therefore only the main plastering techniques will be dealt with here.

. MATERIALS

The chief materials used for plastering are:

- lime
- cement
- gypsum and
- sand.

LIME

LIME

Lime for plastering is produced by calcining (burning) limestone, mainly chalk, which removes the carbon dioxide. On cooling, the quicklime is stored in a dry place from where it is transported to its destination. Before it can be used, however, the lime must be 'slaked', i.e. water added a week or two before it is needed. Lime for plastering is usually 'fat' lime, i.e. easily slaked and workable as distinct from hydraulic lime which is not, but which has the property of setting under water. Locally burnt lime produced under primitive conditions is rarely of good quality and results in pitting or blowing of the rendering caused by uneven burning.

Modern lime production can be carried out on similar lines to the manufacture of Portland cement. Quicklime is exposed to steam which reduces the lime to a powder. This is bagged for transport in the same way as Portland cement although it is only about half its weight. The lime is usually soaked on site for a short while, say a day, after which it is ready for use.

CEMENT

PORTLAND CEMENT

Where a country has no supply of its own, cement may be imported in 1 cwt (50kg) bags or drums, as explained. There appears to be no reason, however, why the clinker produced by burning, when cooled off, should not be shipped to its destination where it sould then be ground into cement. This method would have a number of advantages: it would be cheaper to transport in bulk; it could be freshly ground as required and the clinker would be unaffected by moisture which is an important consideration in humid areas. The grinding process could be incorporated into the full production plant for manufacturing cement when or if it was eventually built.

BUILDING PLASTERS

BUILDING PLASTERS

The bulk of these have a gypsum base, gypsum being a naturally occurring material found in many parts of the world. There are many varieties which, under the BS system are divided into classes.

The main divisions are:

Class A plaster:
This is usually called plaster of Paris. To produce it, gypsum is burnt to a fairly low temperature (160°C) when it loses most of its water of hydration. When the finished plaster is mixed with water, it sets very quickly, within 5 minutes usually. Plaster of Paris is used extensively in plaster casting shops. Here prefabricated panels and mouldings are prepared, reinforced by wood laths and hessian scrim. These are transported to the site and nailed or screwed to wood grounds or bearers which are shaped if necessary. The joints are then neatly filled with gauged plaster. Much fine plaster work is carried out in this way.

Class B plasters.
These are plasters in which the 'set' has been retarded, or the setting time increased. This allows the plasterers time to lay on the material and bring it to a smooth finish. There are three grades of Class B plasters, usually, undercoat, finishing and 'dual purpose', the latter being most widely used, particularly when it has to be imported.

Class C plasters.
These are normally of better quality than those of Class B. They are made by heating gypsum to a higher temperature than 160°C. This causes the plaster to lose its quick-setting power. Accelerators are then added which cause the material to set in enough time to allow the plasterer to obtain a smooth finish.

Class D plasters.
The main plaster in this group is Keene's cement, a high-quality slow-setting plaster giving a smooth marble-like finish. Adhesion of decorative finish on Keene's or Parian cement is very poor unless a coat of sharp oil paint is applied as soon as it has set.

Other types.
Class B,C and D plasters should be applied to backgrounds as undercoats and/or finishes in accordance with the recommendation given in Mixes. Other types of plasters, however, are available which may be applied to any surface including concrete, blockwork or plasterboard. Lightweight plasters are also available with improved acoustical and insulating properties. For further information on these, the reader is referred to M.O.P. B.W. Advisory leaflets, B.R.S. publications, etc.

MIXES

Mixes.
For internal work Cement and Sand is only used, where lime is not available or where a building is designed on an open plan. In most areas in Tanzania all internal renderings are of Portland cement and sand, no other material is used even for the finish coat. This practice is costly in cement and does not provide for a smooth finish, particularly when application and finishing are done with only the aid of a mason's trowel and a straight - edge.

LIME may be added to either Portland cement or gypsum plaster, but Portland Cement must NOT be mixed with gypsum plaster.
Usually Portland cement/lime/sand is reserved for external work and gypsum plasters for internal, although there are many exceptions to this practice.
Gypsum plasters are also used externally in areas of low rainfall and humidity.
The most common mixes are given in the table below.

Background	*Undercoat*	*Finish*
Brickwork or blockwork	(1) Cement/lime/sand 1:2:6	Lime/gypsum Class B 1:¼ (*R*)
	(2) Cement/sand 1:4	Gypsum C neat (*S*)
	(3) Gypsum B/sand 1:3	Lime/gypsum B 1:¼ (*T*)
	(4) Gypsum C/lime/sand 2:1:6	*R*, *S*, or *T* above
Concrete cast *in situ*	As (2) above	As *S* above
	As (3) above	As *T* above
	If none needed	As *S* above
Metal lathing	As (1) above (two coats)	As *R* above
	As (3) above (two coats)	As *T* above
Expanded plastic sheets, plasterboard or fibreboard	None usual (except joints)	As *R* above
Wood-wool slabs	As (1) above	As *R* above
	As (3) above	As *T* above

KEY

Key.
Adhesion of plaster to the background is very important. Concrete should be cleaned free of grease of film and either 'hacked' or painted with an epoxide resin adhesive.
Each coat of plaster should be scratched or grooved the top undercoat only lightly so.

FINISHING COAT

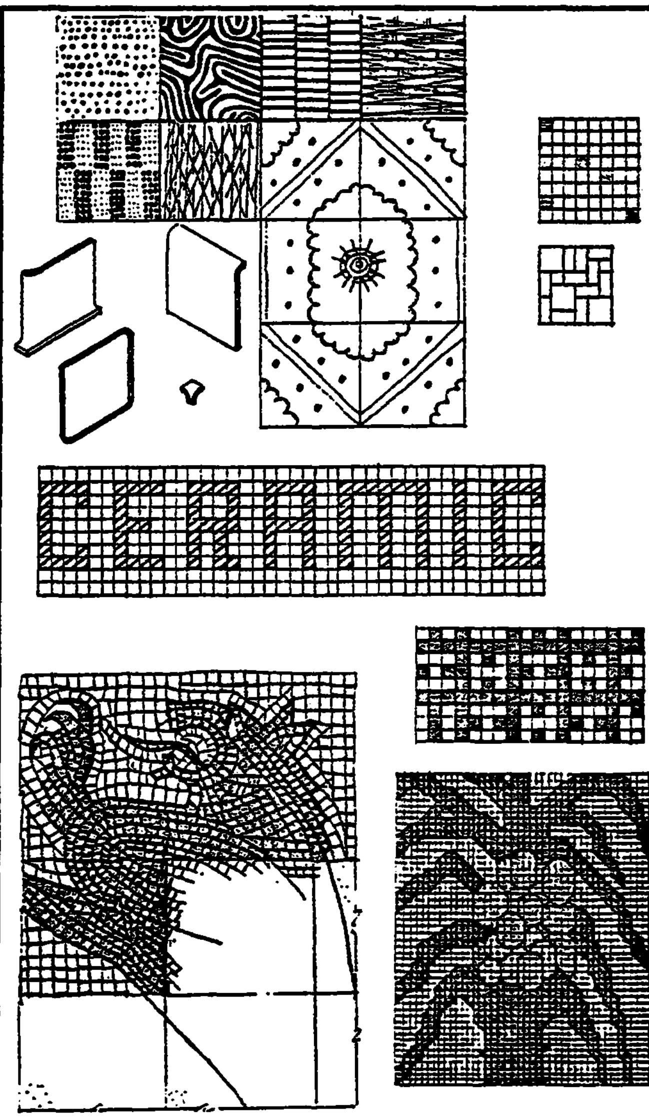
Finishing Coat.
This should not be applied too quickly. One coat 1,5mm to 3 mm is usually sufficient. Undercoat thicknesses vary but 10 to 15 mm is usual.

OTHER INTENAL WALL FINISHES

12.2.2 Other Internal Wall Finishes

There is a wide range of finishes available today and new materials are constantly being introduced. Fashion, ideas, prefabrication, cost and the economic state of the community all effect demand.
Only the basic finishes, therefore, may be listed up to give an idea about the variety of different materials used as internal wall finishes:

- Glazed Tiles
- Decorative Patterned Tiles
- Ceramic Mosaics
- Marble
- Terrazzo
- Mosaic
- PVC Tiles
- Glass,
  i.e. plate glass (coloured)
  glass panels
  patterned glass
  glass blocks
- Dry Lining Techniques etc.



PAINTING

12.2.3 Painting

Protection and decoration are the two important functions of painting.
On interior work, particularly walls and ceilings, the decorative function may be considered more important even though walls may have to withstand washing.

PAINT is a mixture of a liquid or medium and a colouring or pigment. Mediums used in paint manufacture range from thin liquids to stiff jellies and can be composed of linseed oil, drying oils, synthetic resins and water. The various combinations of these materials forms the tape of class of paint. The medium's function is to provide the means of spreading and binding the pigment over the surface to be painted. The pigment provides the body, colour and durability of the paint. White lead is a pigment which gives good durability and moisture resistance but it is poisonous, therefore its use is confined mainly to priming and undercoating paints. Paints containing a lead pigment are required by law to state this fact on the can. The general pigment used for finishing paint is titanium dioxide which gives good obliteration of the undercoating but is not poisonous.

OIL BASED PAINTS

Priming paints:
These are first coat paints used to seal the surface, protect the surface against damp air, act as a barrier to prevent any chemical action between the surface and the finishing coats and to give a smooth surface for the subsequent coats. Priming paints are produced for application to wood, metal and plastered surfaces.

Undercoating paints:
These are used to build up the protective coating and to provide the correct surface for the finishing coat(s). Undercoat paints contain a greater percentage of pigment than finishing paints and as a result have a matt or flat finish. To obtain a good finishing colour it is essential to use an undercoat of the type and colour recommended by the manufacturer.

Finishing paints:
A wide range of colours and finishes including matt, semi-matt, eggshell, satin, gloss and enamel are available. These paints usually contain a synthetic resin which enables them to be easily applied, quick drying and have good adhesive properties. Gloss paints have less pigment than the matt finishes and consequently less obliterating power.

POLYURETHANE PAINTS.
These are quick drying paints based on polyurethane resins giving a hard heat resisting surface. They can be used on timber surfaces as a primer and undercoat but metal surfaces will require a base coat of metal primer, the matt finish with its higher pigment content is best for this 'one paint for all coats' treatment. Other finishes available are gloss and eggshell.

PAINTING

WATER BASED PAINTS.
Most of the water based paints in general use come under a general classification of emulsion paints: they are quick drying and can be obtained in matt, eggshell, semi-gloss and gloss finishes. The water medium has additives such as polyvinyl acetate and alkyd resin to produce the various finishes. Except for application to iron work, which must be primed with a metal primer, emulsion paints can be used for priming, undercoating and as a finishing application. Their general use is for large flat areas such as ceilings and walls.

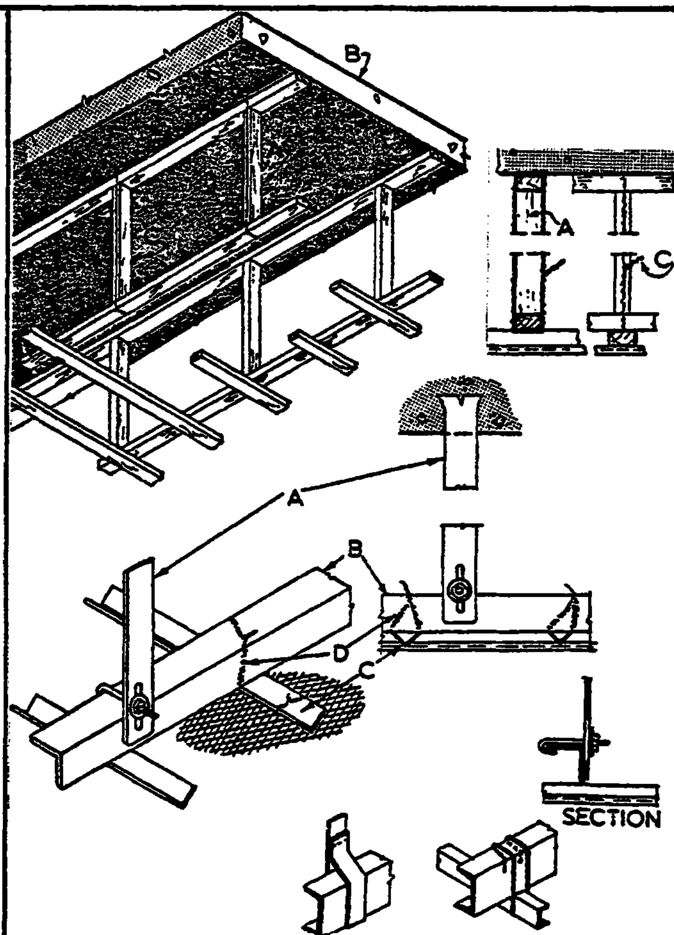
VARNISHES AND STAINS
Varnishes form a clear, glossy or matt, tough film over a surface and are a solution of resin and oil. their application being similar to oil based paints.

The type of resin used, together with the correct ratio of oil content, forms the various durabilities and finishes available. Stains can be used to colour or tone the surface of timber before applying a clear of varnish; they are basically a dye in a spirit and are therefore quick drying.

CEILING FINISHES 12.3

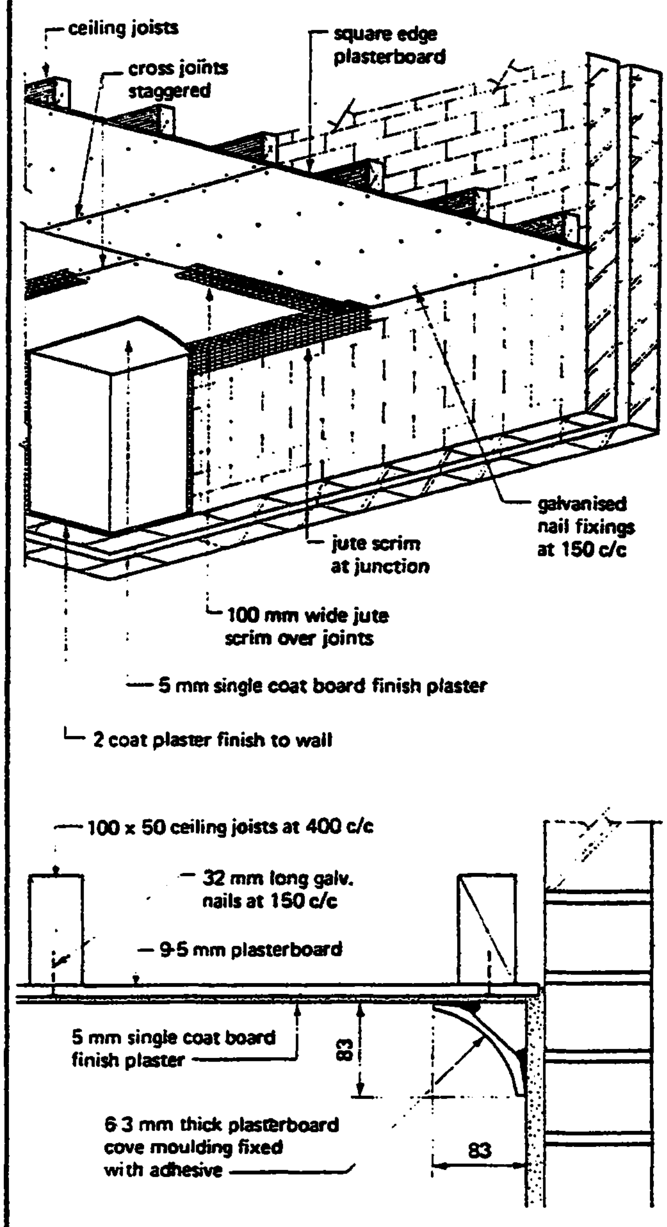
12.3 CEILING FINISHES

Ceilings can be finished by any of the dry lining techniques previously described for walls. The usual method is a plasterboard base with a skim coat of plaster. The plasterboards are secured to the underside of the floor or ceiling joists with galvanised plasterboard nails to reduce the risk of corrosion to the fixings. If square edged plasterboards are used as the base a jute scrim over the joints is essential. The most vulnerable point in a ceiling to cracking is at the junction between the ceiling and wall, this junction should be strengthened with a jute scrim around the internal angle (see fig.) or alternatively the junction can be masked with a decorative plasterboard or polystyrene cove moulding.



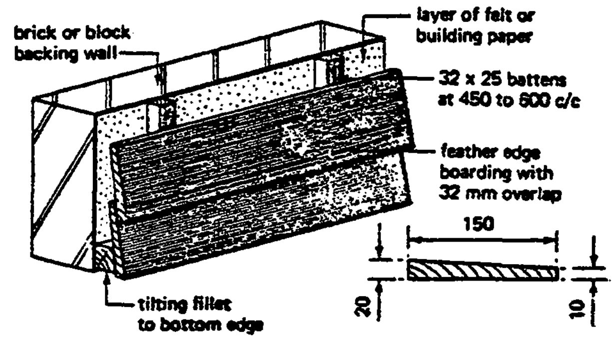
CEILING FINISHES

The cove moulding is made in a similar manner to plasterboard and is intended for direct decoration. Plasterboard cove moulding is jointed at internal and external angles with a mitred joint and with a butt joint in the running length. Any clean, dry and rigid background is suitable for the attachment of plasterboard cove which can be fixed in one of two ways. It can be secured by using a special water mixed adhesive applied to the contact edges of the moulding which is pressed into position; any surplus adhesive should be removed from the edges before it sets. Alternatively the cove moulding can be fixed with galvanised steel or brass screws to plugs or battens - fixings to the wall are spaced at 300 mm centres and to the ceiling at 600 mm centres. A typical plasterboard cove detail is shown in the fig.
Many forms of ceiling tiles are available for application to a joisted ceiling or solid ceiling with a sheet or solid background. Fixing to joists should be by concealed or secret nailing through the tongued and grooved joint. If the background is solid such as a concrete slab then dabs of a recommended adhesive are used to secure the tiles. Materials available include expanded polystyrene, mineral fibre, fibreboard and glass fibre with a rigid vinyl face.
Other forms of finish which may be applied to ceilings are sprayed plasters which can be of a thick or thin coat variety. Spray plasters are usually of a proprietary mixture applied by spraying apparatus directly on to the soffit giving a coarse texture which can be trowelled smooth if required. Various patterned ceiling papers are produced to give a textured finish. These papers are applied directly to the soffit or over a stout lining paper. Some ceiling papers are designed to be a self finish but others require one or more coats of emulsion paint.



Plasterboard ceilings

Try to answer the following questions and practice sketching where ever necessary and possible



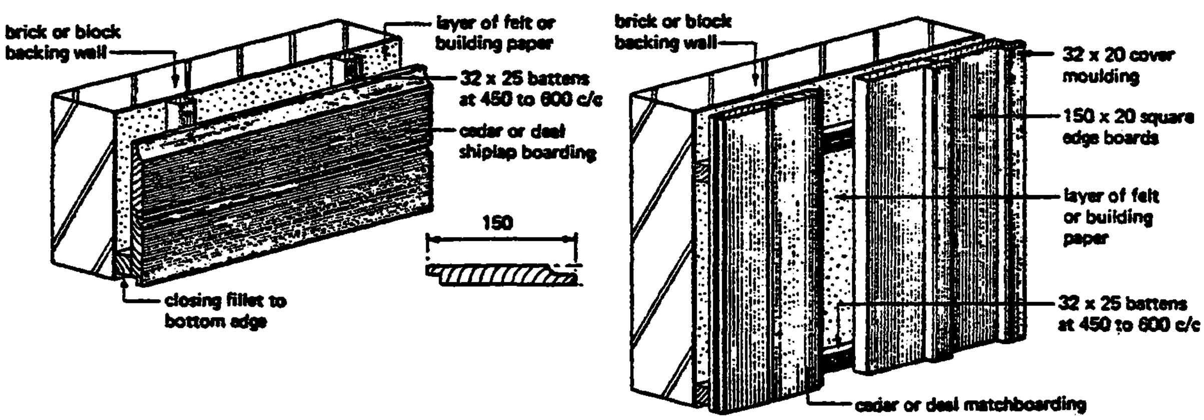
12.1. External Wall Finishes

- Define the terms: External Rendering
  Spatterdash
  Roughcast
  Pebbledash
  Tyrolean Finish
- What are the properties of the rendering and where does the success of the rendering depend on?
- Give the two common volume mix ratios!
- Write notes on the application of external rendering.
- List and describe methods of finishing concrete walls apart from rendering or painting.
- What are the advantages of cladding over traditional types of construction?
- Which points must a designer keep in mind to prevent failures?
- Which points must a cladding fixer keep in mind?
- Where should cramps and other fixings be made from?
- Write notes on claddings fixed to a structural backing, including Tile Hanging and Timber Claddings.
  Use sketches for illustration!
- Write notes on claddings to framed structures, including Brick Panel Walls, Concrete Cladding Panels, Infill Panels, Lightweight Wall Claddings and Curtain Walling.
  Use sketches for illustration.
- Compare the different types of external paints and finishes!

REPETITION •• exercises •• REPETITION

12.2 Internal Wall Finishes

- List and describe the different materials used for plastering!
- Write notes on Mixes for internal work and give the most common Mixes.
- Describe the important factors of a good key and the finishing coat for plaster
- List other Internal Wall Finishes
- What are the important functions of painting
- Define the terms: Priming Paints
  Undercoating Paints
  Finishing Paints
  Polyurethane Paints
  Water Based Paints
  Varnishes and Stains



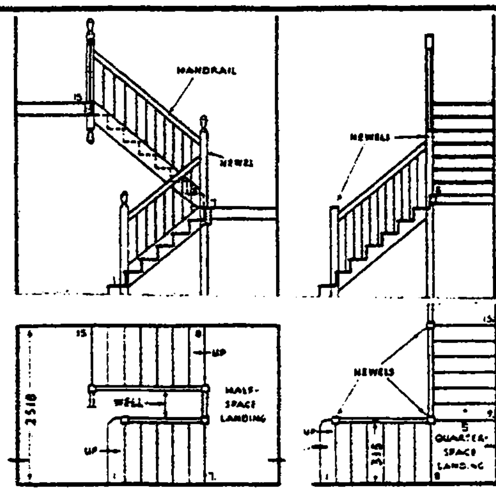
Typical horizontal claddings

Typical vertical cladding

12.3 Ceiling Finishes

- Write notes on ceiling finishes and use sketches for illustration.

13. STAIRS



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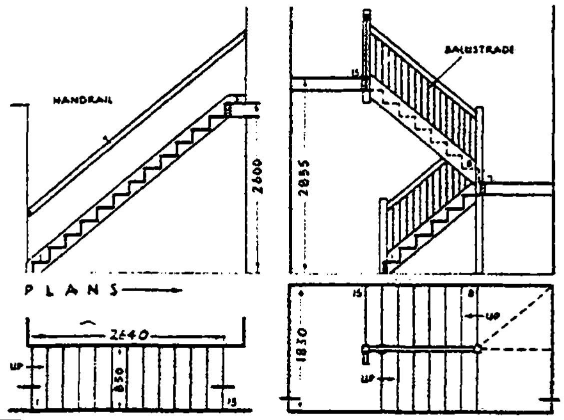

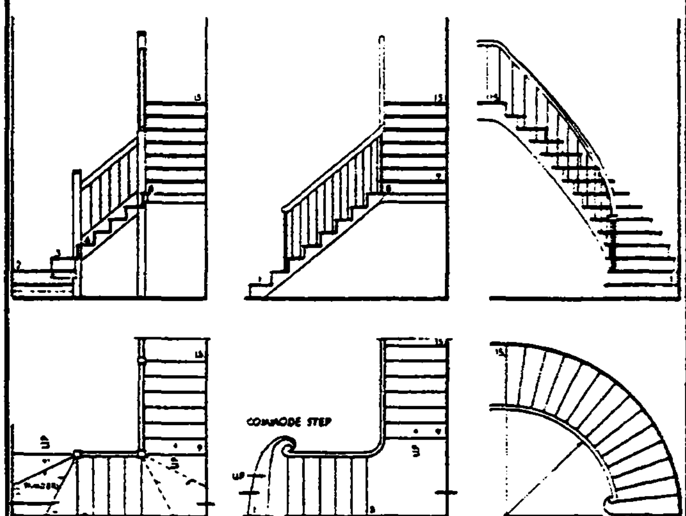

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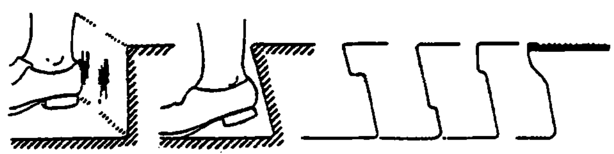
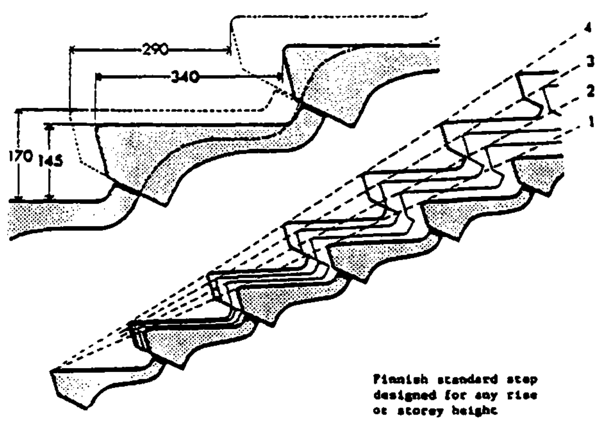
13. STAIRS

13.1 INTRODUCTION





Finnish standard step designed for any rise or storey height

For each 1 mm increase in height of step the tread is reduced by 2 mm as follows:

h	145	146	147	148	149	150	151	152	153	154	155	156	157
b	340	338	336	334	332	330	328	326	324	322	320	318	316
h	158	159	160	161	162	163	164	165	166	167	168	169	170
b	314	312	310	308	306	304	302	300	298	296	294	292	290

13. STAIRS

13.1 Introduction

- A STAIR is a number of at least 3 STEPS leading from one level to another, in order to provide means of movement between different levels in and attached to buildings and for predestrian walkways.
- To make STAIRS usable without danger, they have to be designed and constructed carefully:
  - The type of STAIRS has to be choosen
  - All measurements have to be calculated
  - \- if necessary - the tapering of the steps has to be designed. etc.
- For the construction of STAIRS different suitable materials can be used, such as
  - Stone (both natural and artificial)
  - Concrete
  - Timber
  - Steel
- Often you may find different materials combined at the same STAIR (i.e. Steel and Timber or reinforced concrete and Steel)
- The BALLUSTRADE is a part of the STAIR, which is installed for the purpose of SAFETY of the STAIR. Beside that, ballustrades may help to beautify the stair case.

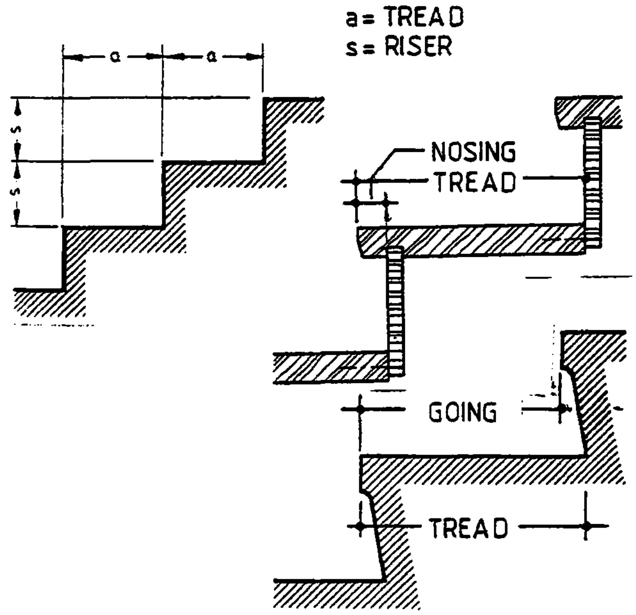
13.2. Definition of Terms

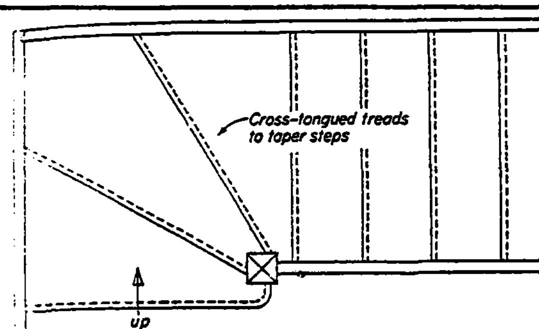
- STEP: is a short horizontal surface for the foot to ease ascent from one level to another.
  It consists of an horizontal element called TREAD and a vertical element called RISER.
  The external junction of the tread and riser, or the front edge of the tread (if projects beyond the face of the riser) is called NOSING.
  Special names are given to steps according to their shape on plan:
  - FLIERS are normal parallel steps, uniform in width and rectangular on plan.
  - TAPERED STEPS are steps of which the nosing is not parallel to that of the step above it. There are two forms of tapered steps:

  a) WINDERS - are tapered steps the back and the front edge of which radiate from the centre on a newel post.

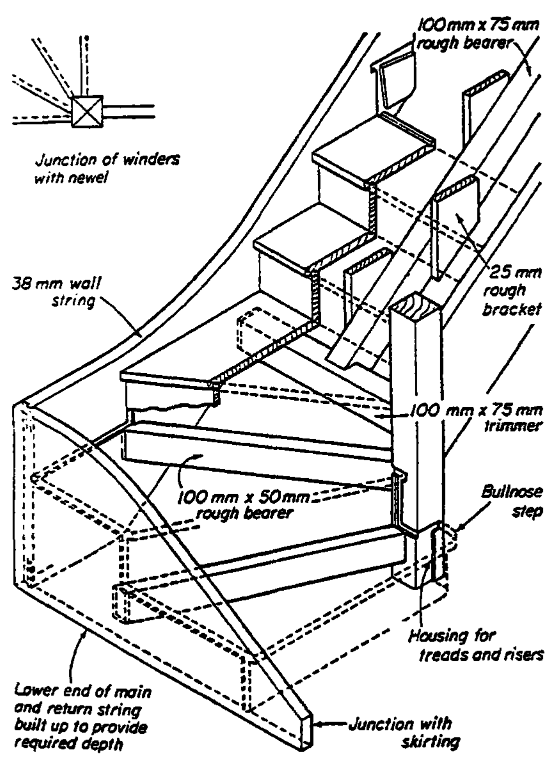
  b) DANCING STEPS (or BALANCED STEPS) - are tapered steps the edges of which do not radiate from a common centre. They are built in a way that their narrow end is little narrower than the parallel tread of the straight part of the STAIRS. They are therefore more comfortable to walk on, than a WINDER, in which the nosing radiate from a common centre.

13.2 DEFINITION OF TERMS



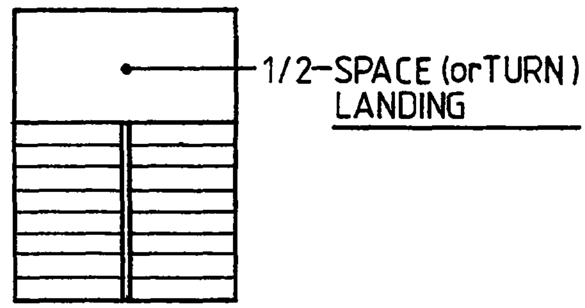


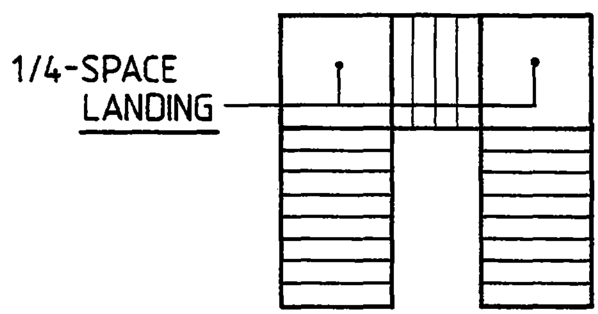
Plan of taper steps at foot of stair

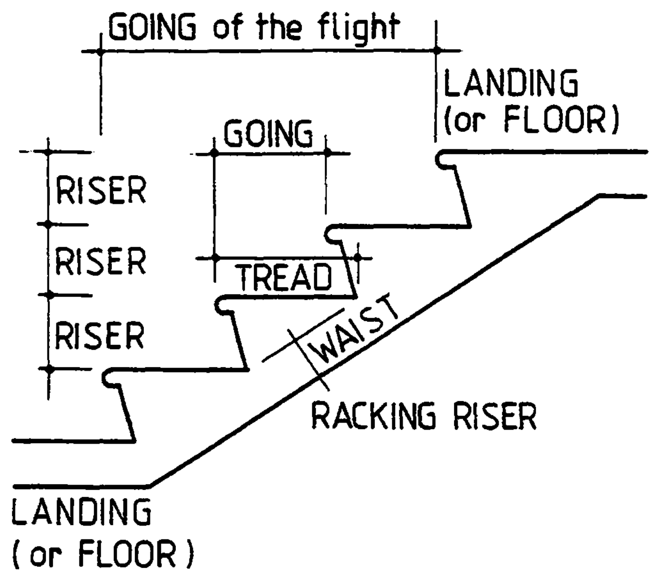


- FLIGHT : A series of steps between FLOORS and LANDINGS.
- LANDING : A platform between two flights. A landing serves as a <u>rest</u> between flights and also as a means to turn a STAIR.
  . A HALF - SPACE-LANDING extends across the width of two flights and on it a <u>complete half turn</u> is made.
  . A QUARTER-SPACE-LANDING is one on which a <u>quarter turn</u> only is made from the end of one flight to the beginning of the next.
- RISE of a STEP is the vertical distance between the upper surface of 2 consecutive treads and the RISE of a FLIGHT is the total height between the floors or landings i t connects.
- RACKING RISER: A riser which is not vertical and overhangs the tread below, to give more foothold. The tread is bigger than its going.
- GOING (or RUN) of a step is the horizontal distance between the nosings or risers of 2 consecutive steps, and of a flight, the horizontal distance between the top and bottom nosings.
- LINE OF NOSINGS: Is an imaginary inclined line touching the nosings of a flight.
- PITCH or slope: The angle made between the line of nosings and the line of the floor or landing.

DEFINITION OF TERMS





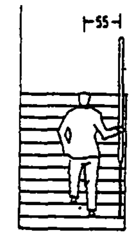


DEFINITION OF TERMS

- WALKING LINE: The average position taking up by a person ascending or descending the stair and generally taken to be 450 mm from the centre of the handrail.
- HEADROOM: The vertical distance between the line of nosings and any obstruction over the stair, usually the soffit of an upper flight or the lower edge of a floor or landing.
- BALUSTRADE: Provides protection on the open side or sides of a stair; it may be either solig or open. An open balustrade consists of vertical bars called BALUSTERS supporting and HANDRAIL.
- STRING or STRINGER: An inclined member which, if fixed to a wall, may act simply as a housing for the steps as in a timber steirs. If it is not feixed to a wall, it then acts as an inclined beam supporting the steps.
- STAIRCASE: This term is applied to a stair together with the part of the building, which encloses it, although it is also commonly used in reference only to the complete assembly of flights, landings and balustrades in a single stair.

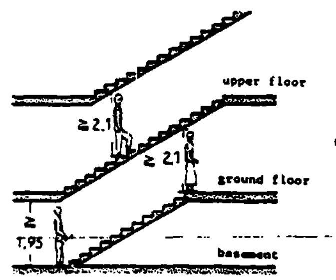
WALKING LINE

If stairs are narrow or curved, distance of walk line from outer string is 350-400 mm (14-16 in)

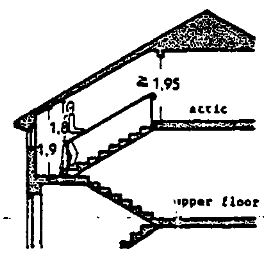


If stairs are wide and straight, distance of walk line from handrail is 550 mm (22 in)

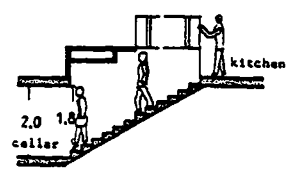
HEADROOM



Stairs correctly placed above each other save space

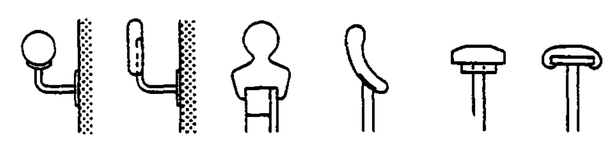


Rafters and joists running parallel to stair save space and costly trimmings

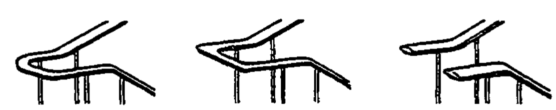


Avoid trap doors and necks to cellars, but combination shown is good and safe

HANDRAILS



HANDRAIL PROFILES



HANDRAILS AT LANDINGS

13.3 TYPES OF STAIRS

13,3 - TYPES OF STAIRS

- The form of a stair depends on the size of the STAIRCASE. Also practical or aesthetical reasons might be taken in to consideration for the choice of the stair.
- Stairs are classified according

  to: the number of flights,
  the plan form,
  the kind of landings,
  and whether they are
  RIGHT - HAND or
  LEFT - HAND - STAIRS.

. According to the number of flights, stairs may be classified as:

a one-flight stairs
b two-flight stairs
c multi-flight stairs

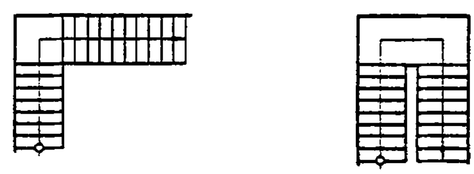
a: one-flight stairs lead without landing from one floor-level to the other

b: two-flight-stairs consist of two flights and a landing in between.

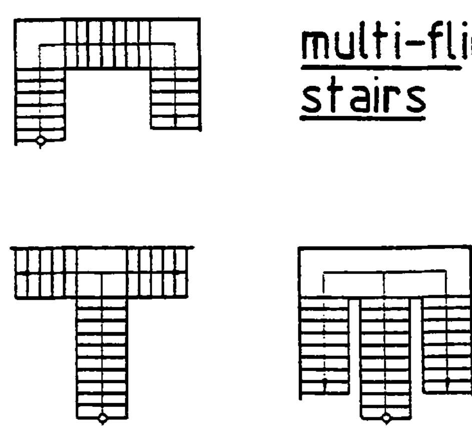
c: in case the difference in level between two floors increases, more than two flights with landings in between might become necessary.
In multi-story buildings, two-or multi-flight stairs are common, in order to make ascent and descent more comfortable.

one-flight stairs

two-flight stairs



multi-flight stairs

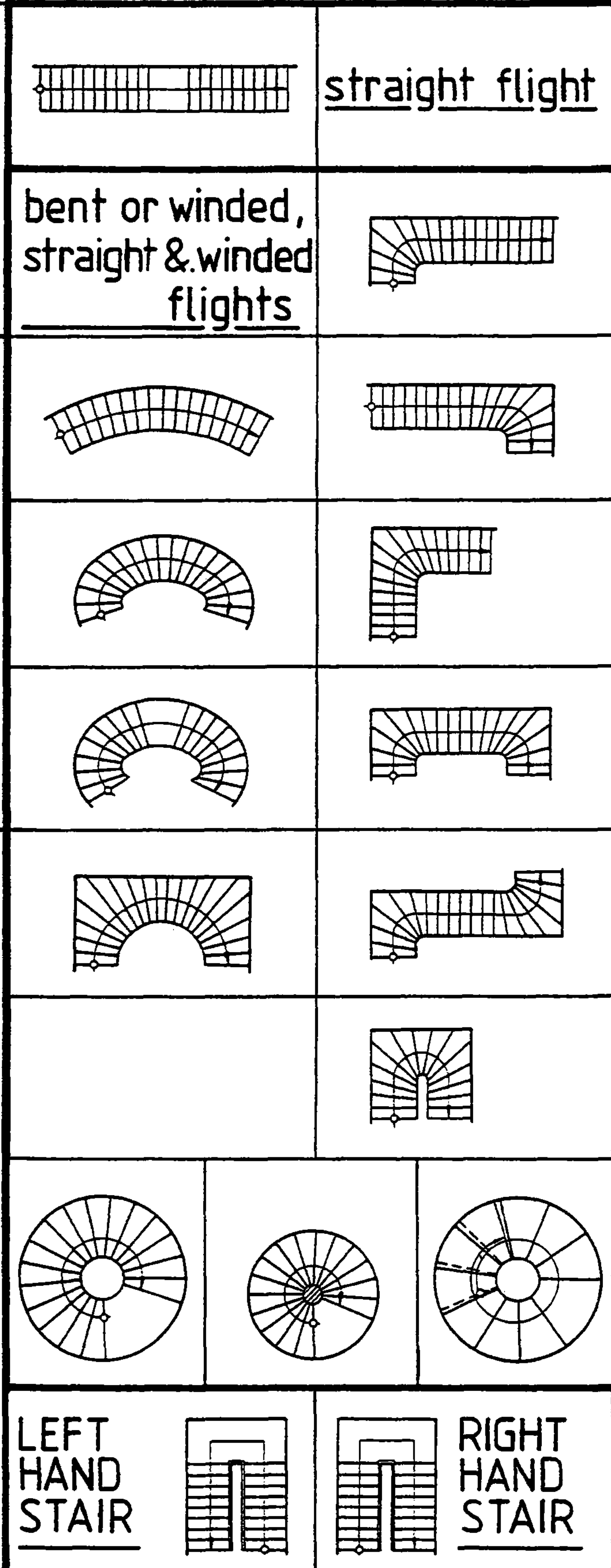


TYPES OF STAIRS

- According to the plan form stairs can be classified as:
  stairs with straight flights
  stairs with bent or circular (winding)flights
  stairs with straight <u>and</u> winding flights.

- According to the kind of landing stairs can be classified as:
  stairs with a half-space-landing and
  stairs with a quarter-space-landing (ref.13.2)

- The term RIGHT-Hand or LEFT-Hand-Stair depends on the open side of the stair:
  Ascending the stair, if you have to hold the handrail with your right hand, it is called a RIGHT HAND STAIR.
  In case of a LEFT HAND STAIR you will find the hand rail on your left hand side.
  Tapered or spiral Stairs are called RIGHT-HAND-STAIRS if the walking direction turns to the right (clockwise) from the straight. Left-hand-stairs turn to the left.

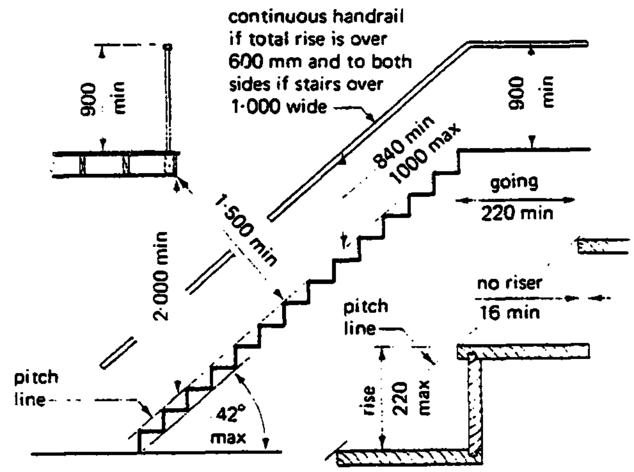


13.STAIRS compiled : D.VOLKE DEC. '82	TYPES OF STAIRS	BUILDING CONSTR. —LECTURE— CET 7031 / 1 13.3 o6

13.4 DESIGN OF STAIRS

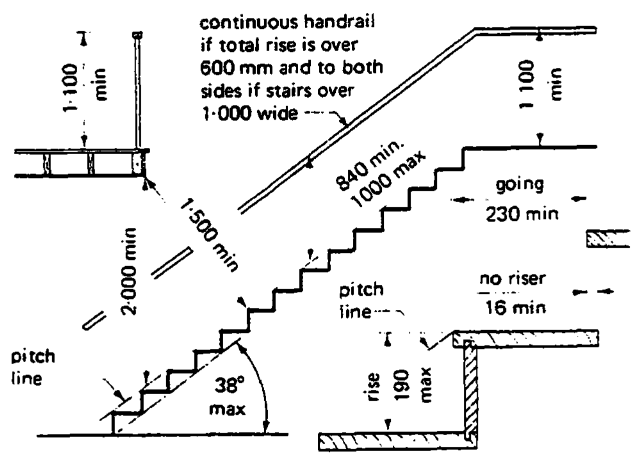
13.4 DESIGN OF STAIRS

- Apart from economic factors, a number of other related to COMFORT and SAFETY in use must be considered in the design of a STAIR. These are concerned with ease of ascent and decent and with protection and support at the sides.
- The dimensions of a STAIR will depend on the VOLUME of TRAFFIC it must carry and also on the NATURE of FURNITURE and EQUIPMENT, which is likely to be carried on it.
- The WIDTH of the flights and landings are important, particulary at the turns. The DIMENSIONS of the TREADS and RISERS should be proportioned to give easy ascent and decent.
- STAIRS to be placed correctly within the building.
- MEANS OF ESCAPE
- . Unobstructed egress facilities from big buildings to be provided by ESCAPE ROUTES (I.e.stairs, corridors, balconies and exits) These should be protected by FIRE-RESISTING ENCLOSURES with fire-resisting doors to prevent smoke and fire spread.
- . Tall residential blocks may be planned round a single fire-resistent staircase with access by a common cross ventilated lobby.
- . Office-shop-,factory- and public buildings have special regulations; number, width and position of stairways are related to area and height of these buildings, number of users, and fire risk caused by various activities carried out in them.



sum of going + twice rise = 550 min. to 700 max.
in any flight all risers of equal height and all goings of equal width

Private Stairways



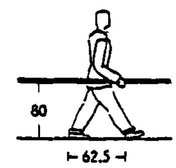
sum of going + twice rise = 550 min. to 700 max.
maximum number of risers in any flight = 16
in any flight all risers of equal height and all goings of equal width.

Common Stairways

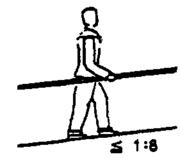
13.41 RISE-TREAD-PROPOR= TION

13.41 RISE - TREAD- PROPORTION

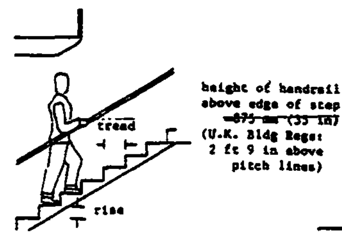
- Comfort in use of a stair depends largely upon the relative dimentions of the rise and going of the steps.
  Rules for determining the proportion are based to some extend upon the assumptions that about <u>twice as much effort is required to ascend than to walk horizontally.</u>
- The average pace of a person walking horizontally measures up to 70 cm. Ascending, the pace will be reduced to 61- up to 65 cm.
- Important for a comfortable and safe use of a stair is the <u>rise</u>.



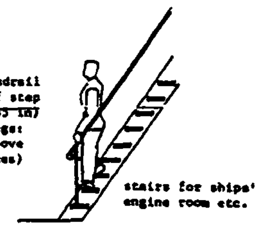
Standard pace of an adult on a horizontal plane



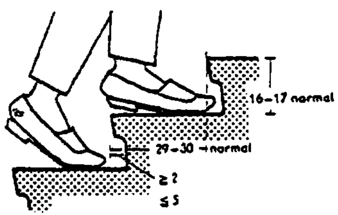
On a ramp the pace is reduced proportionately. Desirable slope 1:10-1:8



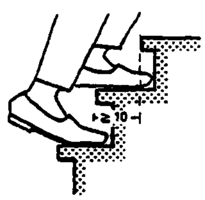
Optimum rise is 2a+1b =625 mm (approx. 23 in: U.K. Bldg Regs 1965)



Ladder stairs with handrails up to 210 x 150 mm (8.4 x 6 in), without handrails up to 250 x 100 mm (10 x 4 in)



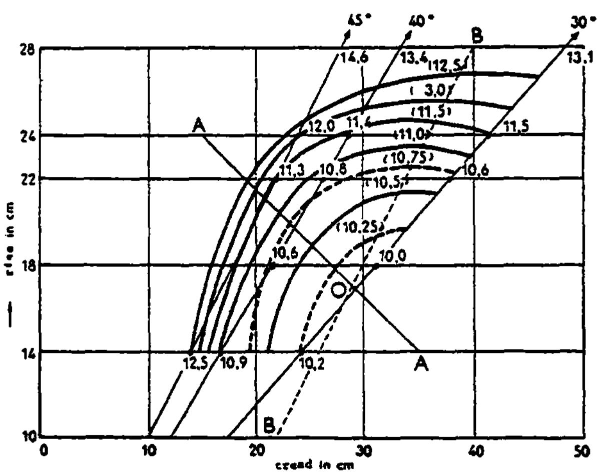
Standard rise of stairs in dwellings and office buildings



Minimum tread if stairs are curved;

- Ascending a stair, one has to step over one tread and two rises.
- All the above mentioned facts result in certain rules which are the base for a good <u>rise-tread proportion</u>.

Common rises for different types of stairs	
stair	rise
garden-and open air stairs	12 to 16 cm
stairs in Public Buildings	16 to 18 cm
stairs in flats and dwellings	17 to 19 cm
stair of minor importance	up to 21 cm



Relationship between energy required and form of stair (after Dr W.Doll & Dr G.Lehmann)

Figures at the left show the rises, those underneath the treads (both in cm). The figures in the curves show energy in calories per mkg climb-effort. The figures above indicate some pitch angles of stairways. The curves connect all points of equal energy consumption. Therefore all stairs with rise-tread proportions on one of these curves are of equal energy consumption.

Line A + A equals the formula .... 2a + 1b = 630 mm (23 in)
Line B - B equals the formula .... 1b - 1a = 120 mm (4.8 in)

RISE-TREAD-PROPORTION

RULES :

I PACE - RULE:

2 Rises (a) + 1 tread(b) =
61 cm to 65 cm (average 63cm)

- 2a + b = 63 cm

  b = 63 cm - 2a

Example:

The rise-tread-proportion for a stair in a flat has to be calculated:

- rise a - (ref.Table)=17-19cm
- difference of floor levels - h - =2,75 m
- Number of rises - h - = always an integer number.

$$n = \frac{h}{\text{average } a} = \frac{2,75}{18} = 18,33 \text{ cm}$$

Tread - b- to be expressed in round cm numbers:

I Pace-Rule:

b= 63 cm-2.18,33=26,34 cm
choosen: b=26 cm
proportion:15x18,33/26

II Safety-Rule:

b= 46cm-18,33=27,67cm
choosen: b = 28 cm
proportion 15x18,33/28

III Comfort-Rule:

b= 12 cm + 18,33 =30,33 cm
choosen : b = 30 cm
proportion 15x18,33/30

II SAFETY - RULE:

(For stairs with steep or small pitches)

1 rise (a) + 1 tread(b) = 46 cm

- a + b = 46 cm

  b = 46 cm - a

III COMFORT - RULE:

(relatively wide treads with normal rises of 16-19 cm)

Tread (b) - rise (a) =12cm

- b-a = 12 cm

  b = 12 cm + a

Decision:

either: medium proportion 15x18,33/28

or : according to the space available in the staircase.

- The number of rises is defined as - n- (15 in our case).

Upwards the stair begins with a rise followed by a tread. The last rise is followed by the next floor lavel. There is therefore no tread:

No. of treads = No. of rises - I
= n - I
(= 15 - I = 14)

According to the PLAN the LENGTH of the stair - l - is equal to the sum of the treads:

L = b= (n-I)xb

The length - l - for the example:

I L = (15-I)x26=3,64 m
II L = (15-I)x28=3,92 m
III L = (15-I)x30=4,20 m

13.42 SLOPE OR PITCH

13.42 Slope or Pitch

of a stair should not exceed 45° nor be less than 25°.
For stairs in regular use a maximum of 35° should be taken.
The slope is given for the walking line.

$$\text{Pitch} = \frac{\text{rise}}{\text{tread}} = \frac{a}{b}$$

Example for the proportion 18,33/28 cm:

$$\frac{a}{b} = \frac{18,33\ \text{cm}}{28\ \ \text{cm}}$$

(A) - Pitch as proportion

$a : b = 1 : x$

$x = \frac{1 \times b}{a}$

$a : b = 1 : \frac{b}{a}$

Example for proportion 18,33/ 28 cm

$a : b = 1 : \frac{b}{a}$

$a : b = 1 : \frac{28\ \text{cm}}{18,33\ \text{cm}}$

$a : b = 1 : 1,53$

(3) - Angle of the Pitch:

$\tan X = \frac{a}{b}$

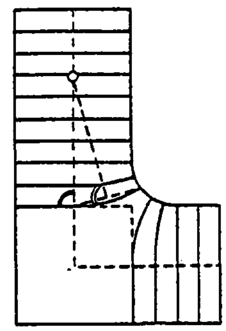
Example for proportion 18,33/28 cm

$\tan X = \frac{18,33\ \text{cm}}{28\ \text{cm}}$

$\tan X = 0,6546$

$X = 33,21°$

13.43 LANDINGS



Curved steps at landing on a narrow stair save landing space

13,43 - LANDINGS (already defined) ref.to 13.2

(a) Straight landings to be provided at least after 18 rises (as a REST)
Length of the landing:
in accordance with the pace

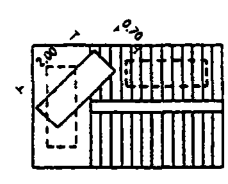
$L = N \times 63\ \text{cm} + 2\,\frac{b}{2}$

(No.of paces)

(b) Landings for turning the direction (half-space or quarter space)
Length of the landing:

$L = 1,1 \times \text{width (minimum 1m)}$

The important factor is the space required for the transportation of large pieces of goods.



Minimum space required to move furniture

13.STAIRS	DESIGN OF STAIRS	BUILDING CONSTR.
compiled : D.VOLKE		—— LECTURE ——
DEC. '82		CET 7031 / 1 13.4 1o

TCA TECHNICAL COLLEGE ARUSHA / CHUO CHA UFUNDI ARUSHA — CIVIL ENGINEER. DEPARTMENT

13.4.4. WIDTH

13.44 Width

The usable width of a stair has to be measured at the narrowest place of the staircase.

For main stairs the width depends on the use of the stair. (whereby the type of building the number of persons passing each other or the number of people staying in the building are of importance.)

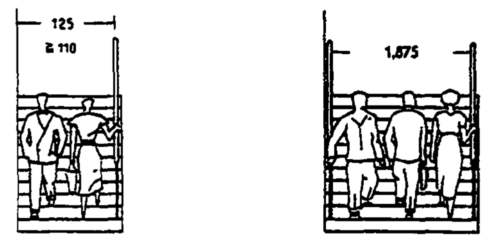
A Common usable width of STAIRS according to the type of building:

TYPE of BUILDING	WIDTH
1-,2-,3-,family flats/ dwelling houses	0.80 — 1.00 m
bigger flats	1.10 — 1.30 m
public buildings	1.30 — 1.90 m

B Usable width of STAIRS according to the number of persons passing each other

No. of PERSONS	WIDTH
2 PERSONS	1.10 — 1.30 m
3 PERSONS	1.80 — 1.90 m

For STAIRS of minor importance (i.e. emergency stairs, stairs in buildings with a lift, etc). the measurements may be reduced, but they have to be in accordance with the rules of the local authorities.



Width of stairs allowing two people to pass

⑧ width of stairs allowing three people to meet and pass

13.45 WALKING LINE

13.45 Walking line: (Definition ref. 13.2)

The representation of the walking line begins with a circle on the nosing of the lowest step and ends with an arrow on the nosing of the next floor level.

The walking line leads always upwards.

In case of all strenght and round flights up to a width of 0.95 m the walking line is always in the centre.

In case of a width exceeding 0.95m the walking line is taken to be generally 45 cm from the centre of the handrail.

On the walking line, the calculated measurements for the treads to be indicated.

	13.5 CONSTRUCTION OF STAIRS

13.5 Construction of Stairs

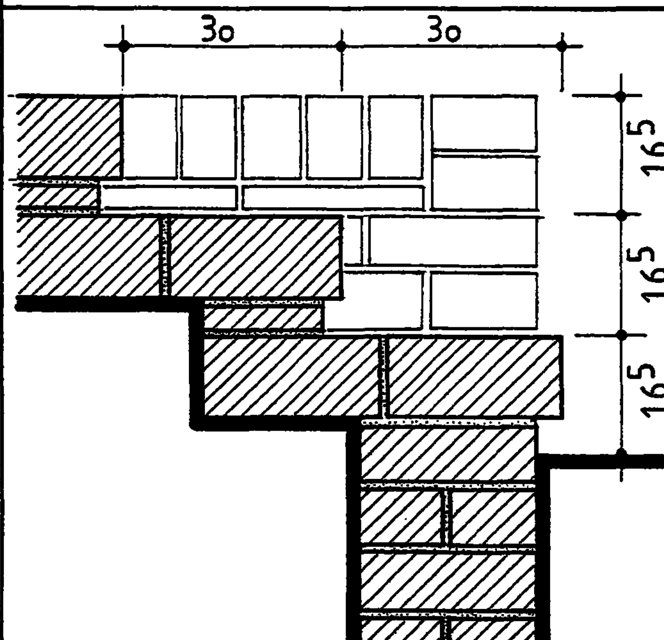
13.51 BRICK STAIRS

Bricks are used for simple external steps and stairs and occasionally for internal use.
The steps must be formed of good hard, square bricks and are bedded in cement mortar on concrete.

If the steps are not built on a natural slope of ground, the deep hardcore filling must be carefully and well consolidated to avoid settlement.

The bonding of the bricks will depend on the dimension of tread and riser and the bricks will normally be laid on edge to expose the face sides and the ends.

13.51 BRICK STAIRS



13.52 STONE STAIRS

13.52 STONE STAIRS
are used as external and internal stairs.
In case of external stairs the material has to resist the elements therefore GRANITE, BASALD and hard SANDSTONE are suitable materials.

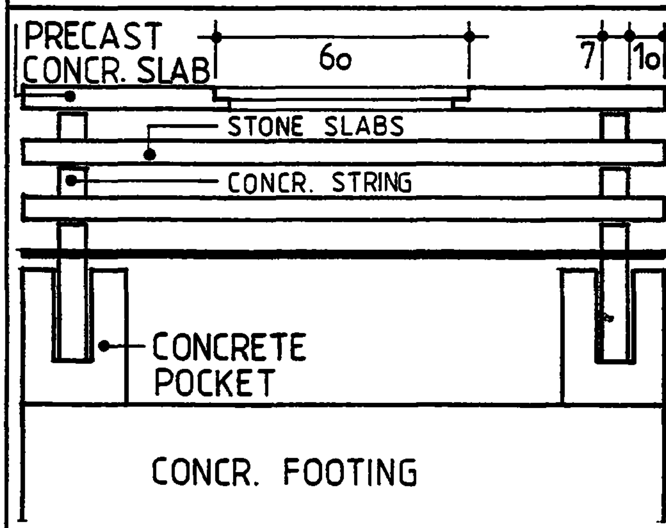
Stone stairs may be in the form steps simply supported on end walls or as cantilever flights and landings or in the form of a circular newel or turret stair.

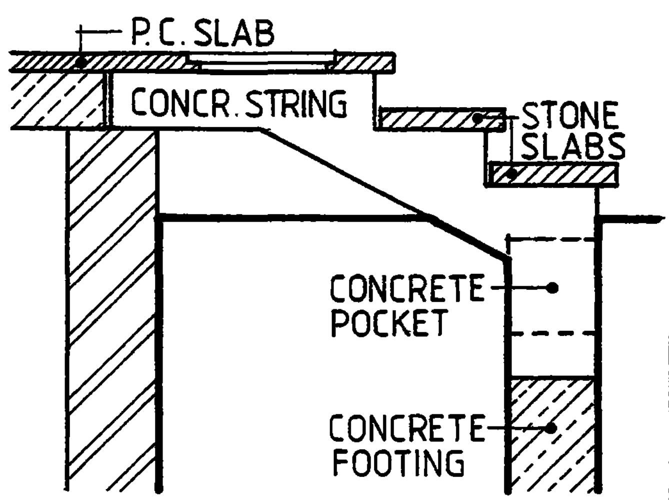
Simply supported or cantilevered steps can be either rectangular blocks giving a stepped soffit or spandrel steps, splayed on the underside to give a smooth soffit.

Cantilever stone steps should not usually exceed 1.50mto1.80m in projection, the safe max. depends upon the type of stone used.

If landings are large, these are made up of a number of slabs with joggeled joints.

The newel stair is similar to the spiral newel stair in precast concrete, but because of the transverse weakness of stone the steps are not to cantilever out from the central newel (where the stone is thinnest); the outer ends are built into the enclosing wall, so that each is a step simply supported on the wall and the newel.





13.53 Concrete Stairs

Concrete stairs are widely used in all types of buildings
- They have a high degree of fire resistance,
- are strong, and
- make possible a wide variety of forms.

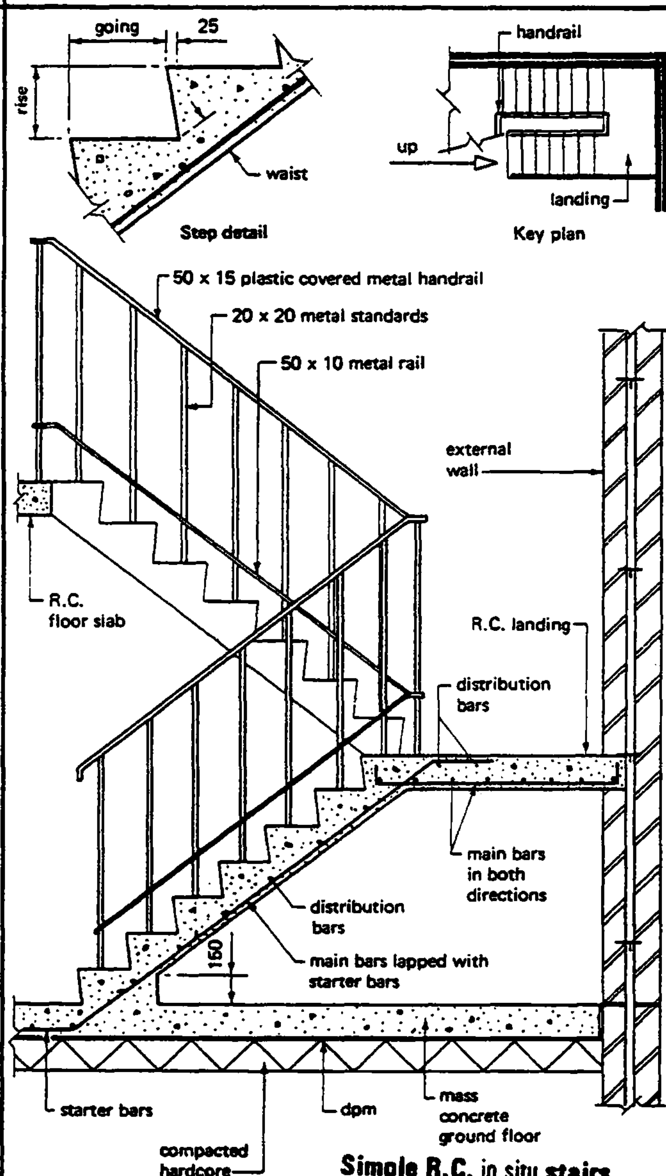
They may be cast in-situ or be precast as whole flights of in seperate parts.

13.531 In Situ Cast R.C.Stairs

- The concrete specification is usually
  - concrete mix 1 : 2 : 4
  - min. cover of concrete over reinforcement : 15 mm (or bar diameter whichever is greater)
  - waist thickness usually between 10 and 25 cm depending on stair type.
  - mild steel or yield steel bars can be used as reinforcement.

    The bars being lapped to starter bars at the ground floor and taken into the landing or floor support slab.

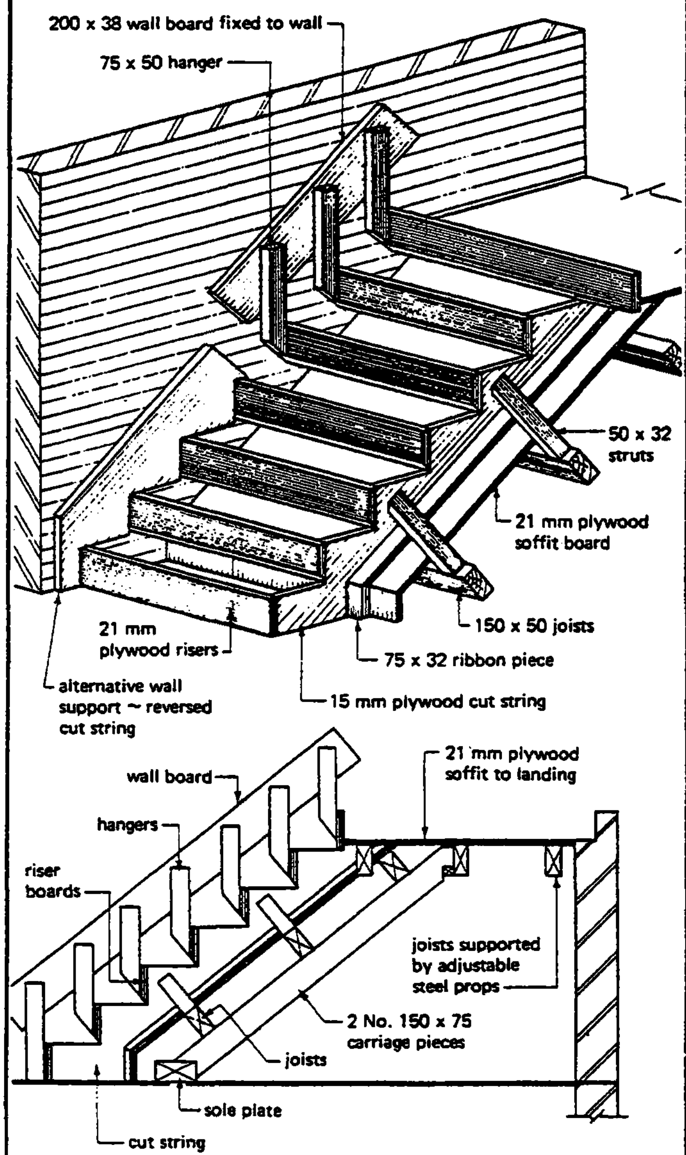
    Number, Diameter and Spacing of the main and distribution reinforcement must always been calculated for each stairway.



Simple R.C. in situ stairs

CONCRETE STAIRS

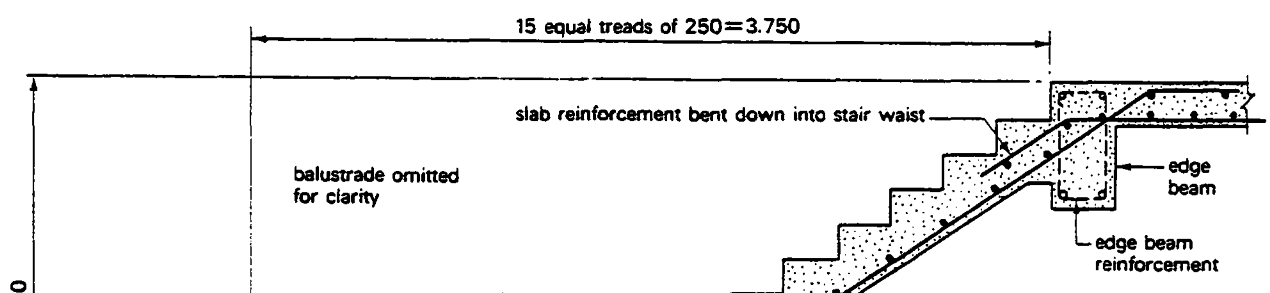
- A wide variety of finishes can be applied to the tread surface of the stairs.
- The soffits can be left as struck from the formwork and decorated or finished with a coat of spray plaster or a coat of finishing plaster
- The basic formwork requirements are the same as for formwork to a framed structure.
- . The stair profile is built of an adequately supported soffit of sheet material by using a cut string.
- . Riser boards are used to form the leading face of the steps (these should have a splayed bottom edge to enable complete trowelling of the tread surfaces and to ensure that air is not trapped under the bottom edge of the riser board thus causing voids.
- . If the stair abuts a vertical surface, two methods can be considered to provide the abutment support for the riser boards.
  a) a reversed cut string or
  b) a wall board with hangers.
- . wide stairs can have a reverse cut string as a central support to the riserboards to keep the thickness of these within an acceptable load limit.



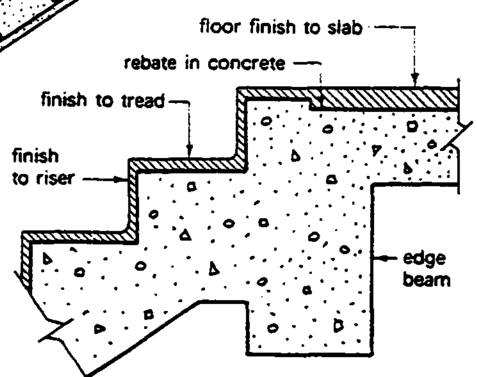
Typical formwork to R.C. in situ **stairs**

Single flight stairs
- Long and cross spans

- The structural behaviour of a stair flight is very similar to that of a simply supported slab,
  - its effective thickness being its waist. -
- When considering single flights between floors, it should be realised that it is uneconomic to span the flight between landings, since an extra distance of about 1 m at either and of the flight would result in a long span of up to 6 m.
- If downstand beams are provided at the edges of the landings, the effective span may be reduced to 4 m for the same flight which would result in a bending moment reduction of over 50 %.
- The arrangement of reinforcement is shown in figure



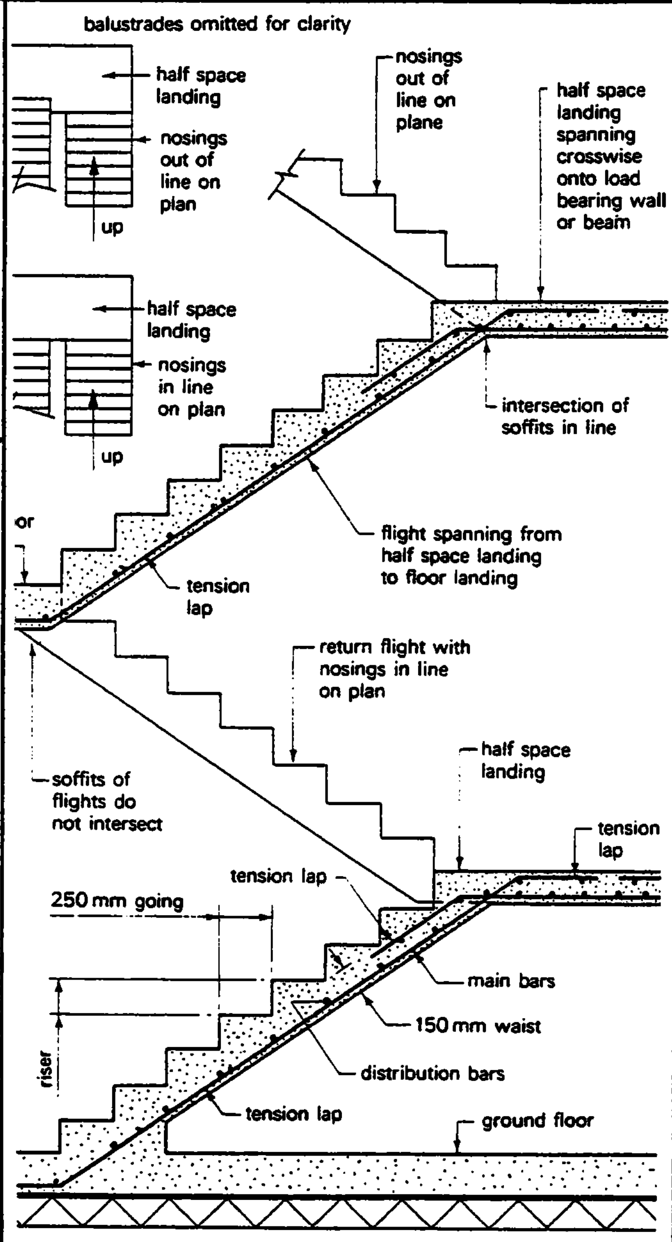
Straight flight concrete stairs



Method of accommodating different floor finish depths

Half flights with landings
(inclined slab concr.stair)

- Where half landings are incorporated it is normal for stairs to span on to the landings with the landings spanning cross ways.
- The arrangement of reinf.bars are shown in the figure. It should be noticed again, that the tension lab is required at the top and bottom of each flight, this is to overcome the tension inducted by the tendency of the external angles of the junctions between stair flights and landings to open out.

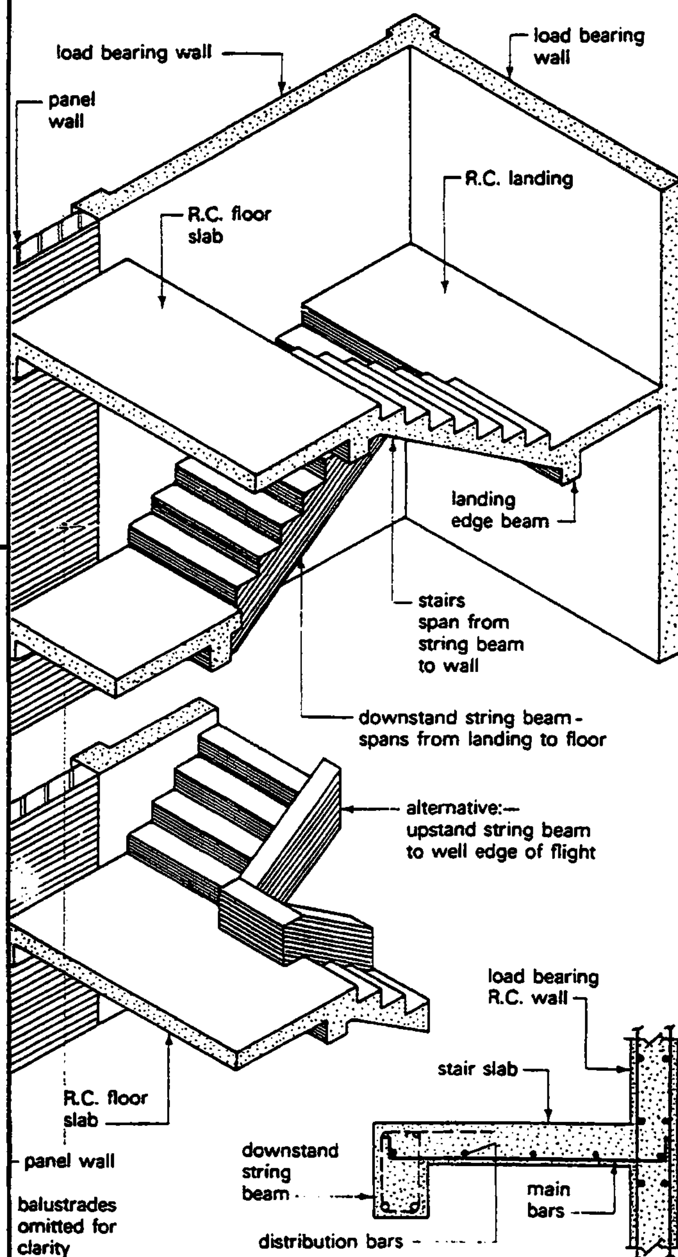


Inclined slab concrete stair with half space landings

STRING BEAM STAIRS

String beam stairs

- are an alternative design for the stairs described above. A string or edge beam is used to span from landing to landing to resist the bending moment with the steps spanning crosswise between them;
- this usually results in a thinner waist dimension and an overall saving in the concr. volume required. But this saving in material is usually offset by the extra formwork costs.
- The string beams can be either upstand or downstand in format and to both sides if the stairs are free standing.



String beam concrete stairs

CRANKED SLAB STAIRS

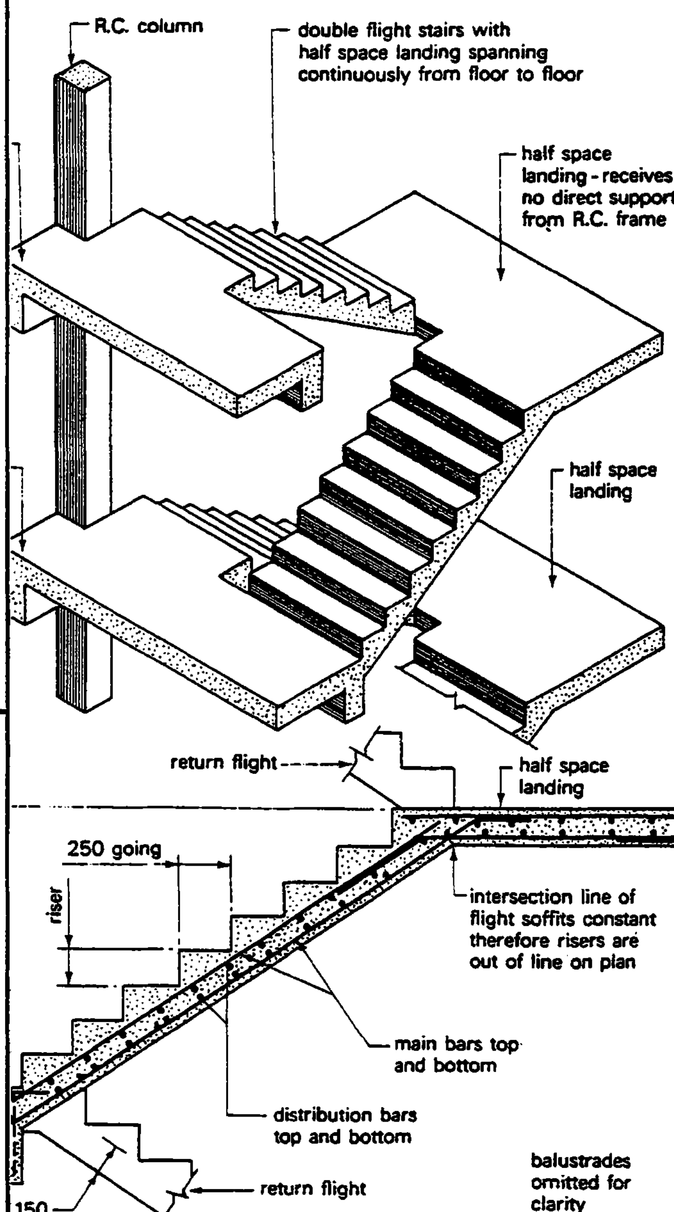
Cranked slab stairs

- are very often used as a special feature, since the half space landing has no visible support being designed as a cantilever slab.
- . Bending, buckling and torsions stresses are induced with this form of design.

Creating the need for reinforcement to both, faces of the landing and slab or waist of the flights.

- . The amount of reinforcement required can sometimes create site problems with regard to placing and compacting the concrete.

Typical details of a cranked slab stair (which is also known as a continous stair, scissor stair or jack knife stair) are shown in the figure.



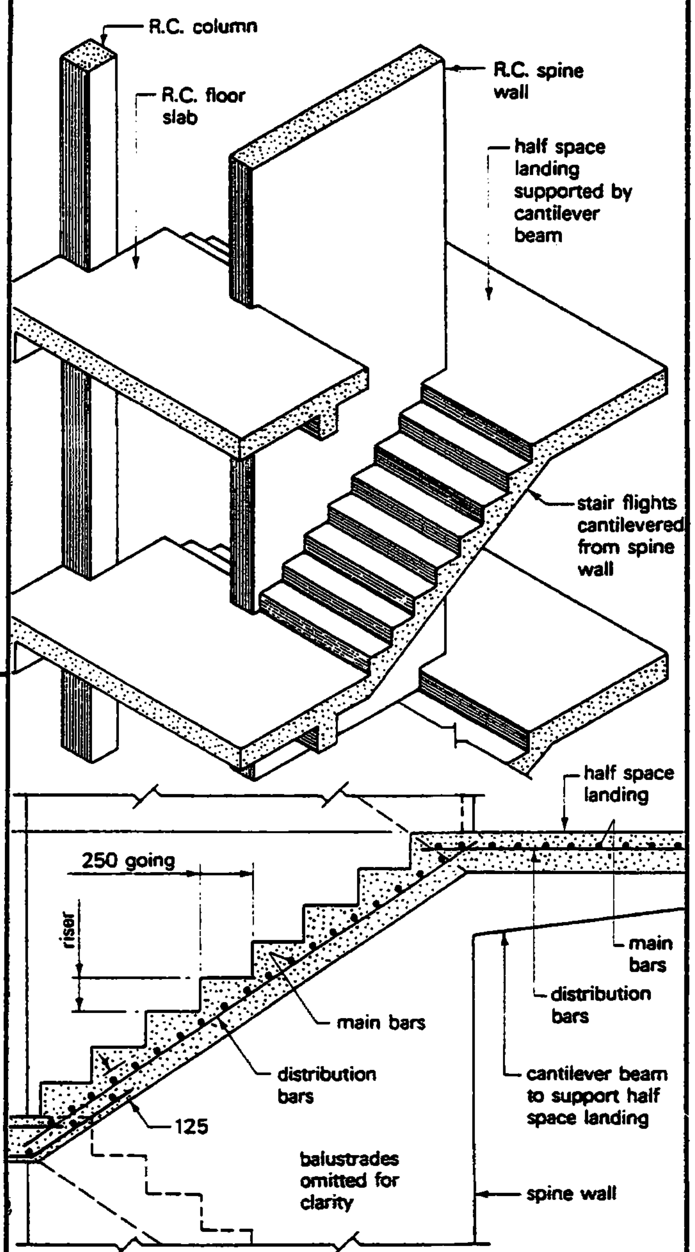
Cranked or continuous slab concrete stairs

CANTILEVER STAIRS

Cantilever stairs:
(sometimes called spine wall stairs) consist of a central vertical wall from which the flights and half space landings are cantilevered.

- The wall provides a degree of fire resistance between the flights and are therefore mainly used for escape stairs.

Since both flights and landings are cantilevers the reineforcement is placed in the top of the flight slab and in the upper surface of the landing to counteract the induced negative bending moments.
The plan arrangement can be single straight flight or - as is usual - two equal flights with an intermediate half space landing between consecutive stair flights.



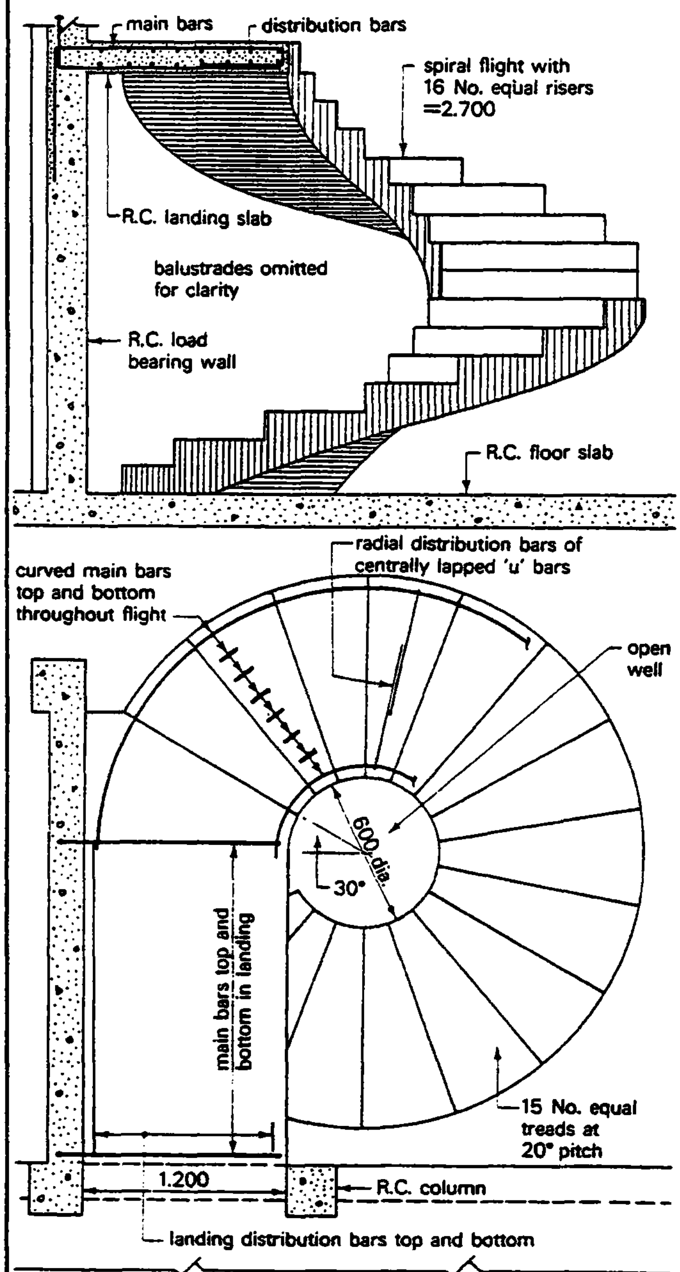
Cantilever concrete stairs

SPIRAL STAIRS

Spiral stairs
are used mainly as accomodation stairs in the foyers of prestige buildings such as theatres and banks.
They can be expensive to construct, being normally at least seven times the cost of conventional stairs.

- The plan is generally based on a circle althogh it is possible to design an open spiral stair with an elliptical core.
  The stair can be formed around a central large diameter circular column in a similar manner to that described for cantilivered stairs or - as it is an usual design with a circular open stair well.
  Torsion, Tension and compressive stresses are induced in this form of stair which will require reinforcement to both faces of the slab in the form of radial main bars, bent to the curve of the slab with distribution bares across the width of the flight.

Formwork for spiral stairs consists of a central vertical core or barrel to form the open stair well to which the soffit and riser boards are set out and fixed, the whole arrangement being propped and strutted as required from the floor level in a conventional manner.



Open spiral concrete stairs

13.532 Precast Concrete Stairs

- Most of the concrete stair arrangements previously described can be produced as PRECAST CONCRETE COMPONENTS which can have the following advantages:
  - better quality control of the finished product
  - saving in site space, since formwork storage and fabrication space is no longer necessary
  - stairway enclosing shaft can be utilised as a space for lifting materials dureing the major construction period
  - saving in time
  - can usually be positioned and fixed by semi-skilled labour.
- Like all precast components the stairs must be
  --repetitive and
  --in sufficient quantity
  to justify their use and to be an economic proposition.
- Simple precast concr. stairs spanning between landings can have a simple bearing or, by leaving projecting reinforcement to be grouted into preformed slots in the landings, they can be given a degree of structural continuity.
- Precast concrete stairs, constructed from a series of precast steps are either
  - built into or
  - cantilevered from

  a structural wall.

13.532 PRECAST CONCRETE STAIRS

- The use of precaste concr. steps to form a stair way is limited to situations such as
  - short flights between changes in level
  - external stairs to basements

  etc.

  They rely on the load bearing wall for support and if contilevered on the downward load of the wall to provide the necessary reaction.
- The support wall has to provide the necessary load and strength and at the same time it has to be bonded or cut around the stooled and of the steps.
- The steps are usually fabricated in factoris. They consist of a concrete core covered with a facing material (artificial stone).

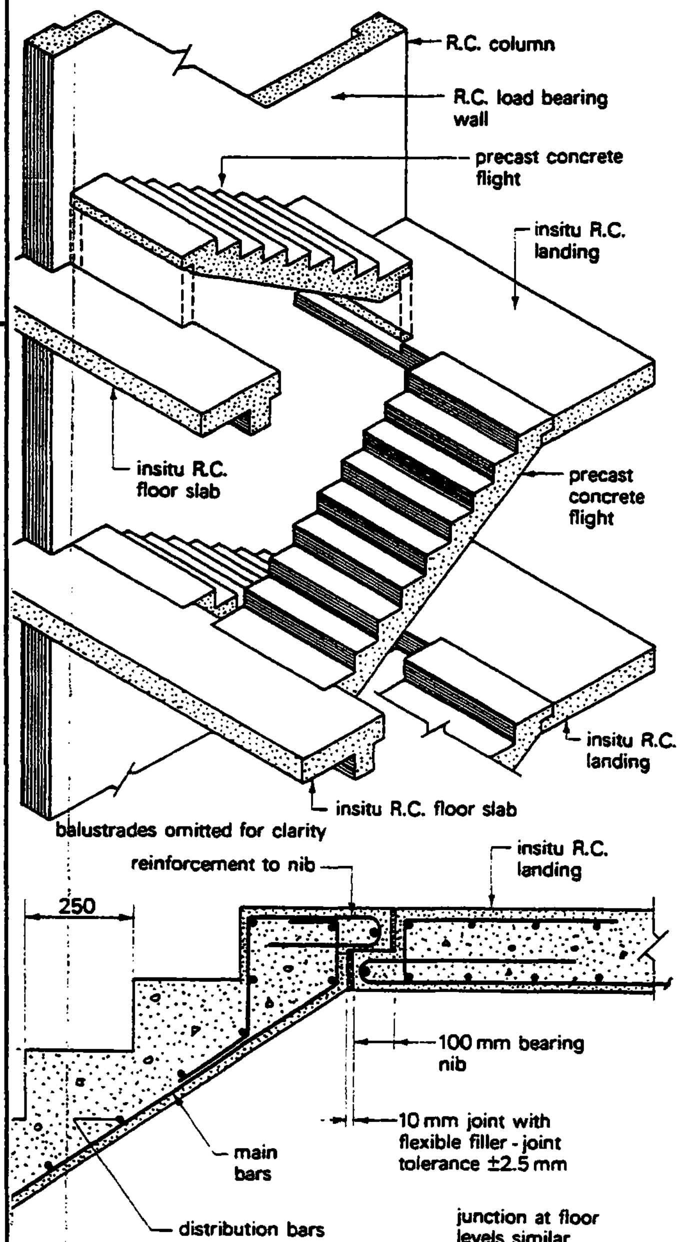
  To reduce the weight, the steps are often produced as hollow steps.

  It is advisable to protect the edges of the steps.

STRAIGHT FLIGHT PRECAST CONCRETE STAIRS

- Straight flight precast concrete stairs with a simple bearing require only Bottom Reinforcement to the slab and Extra Reinforcement to strengthen the bearing rebate or nib.

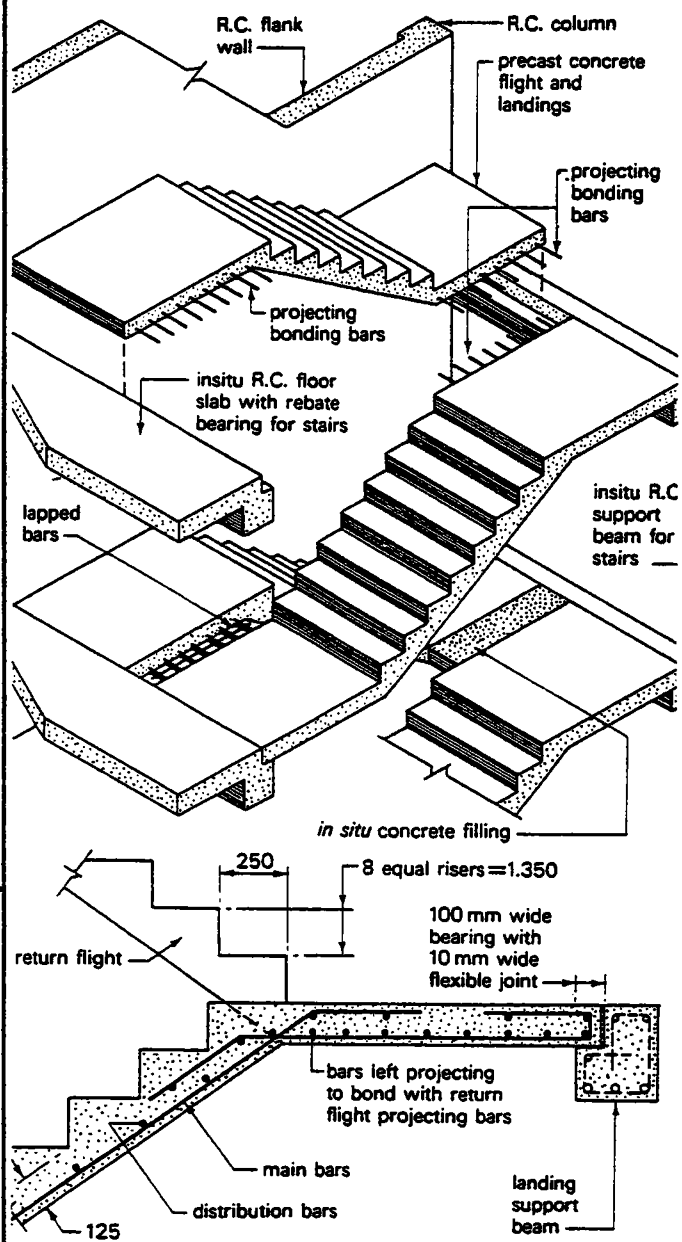
  The bearing location is a rabate cost in the in-situ floor slab or landing, leaving a tolerance gap of 8 to 12 mm which is filled with a compressible material to form a flexible joint.



Precast concrete straight flight stairs

CRANKED SLAB PRECAST CONCRETE STAIRS

- Cranked slab precast concrete stairs
  are usually formed as an OPEN WELL stair. The bearing for the precast landings to the in situ floor or to the structural frame is usually in the form of a simple bearing.
  The infill can be of in-situ concrete with structural continuity (provided by leaving reinforcement projecting from the inside edge of the landings)
  N.B. when p.c.c. stair flights are hoisted into position,
  different stresses may be inducted from those which will be encountered in the fixed position.
  To overcome this problem the designer can either reinforce the units for both conditions OR - as is more usual - provide definite lifting points in the form of projecting lugs or by utilising any holes cast in to receive the balustrade.

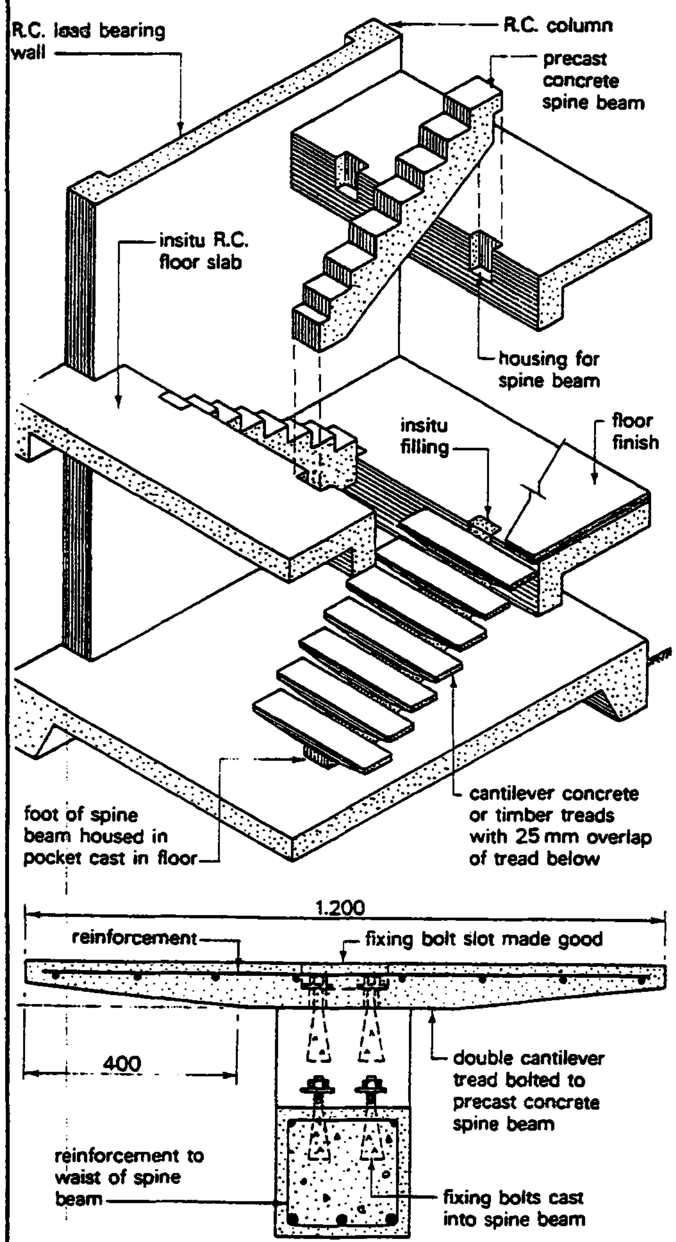


Precast concrete cranked slab stairs

OPEN RISER PRECAST CONCRETE STAIRS

- Precast open riser stairs
can be both:
economic and attractive - consisting of a central spine beam in the form of a cut string supporting double cantilever treads of timber or precast concrete.
The foot of the lowest spine beam is located and grounted into a preformed pocket cast in the floor whereas the support at landing and floor levels is a simple bearing located in a housing cast into the slab edge (ref. Fig.)
Provisions for fixings of steps to the beam are given in the figure.

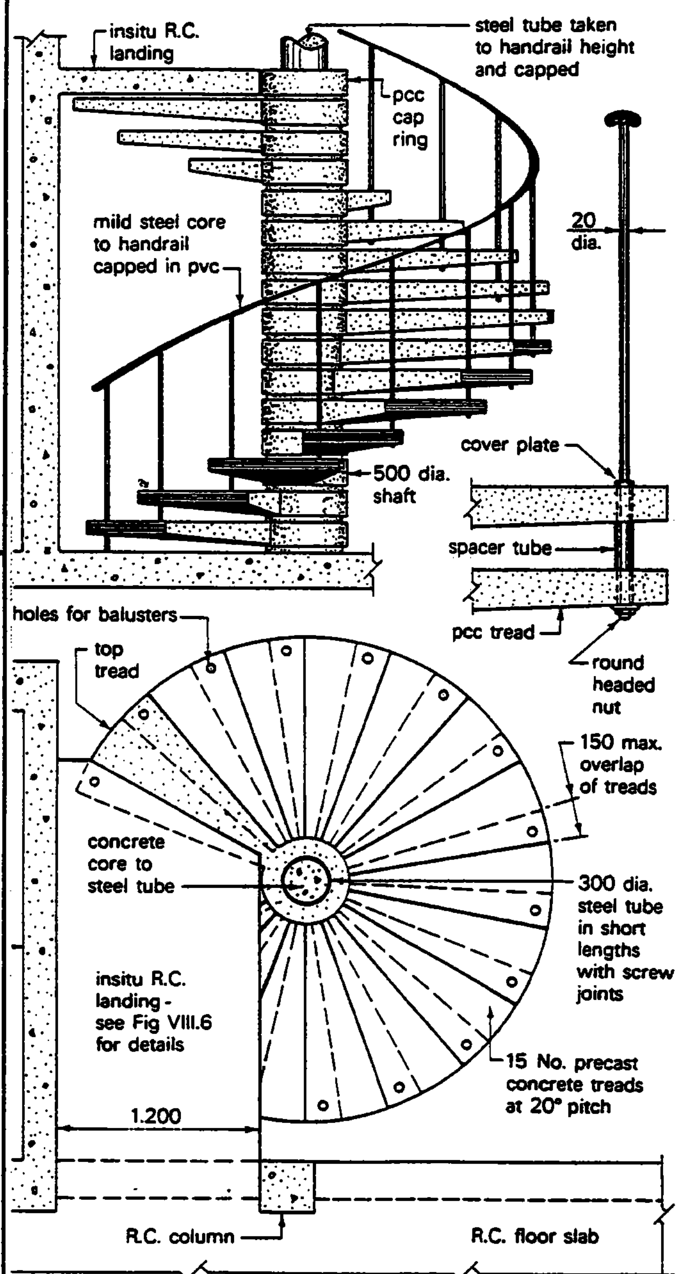
- Reinforcement to the treads is simply a meshwork of straight bars.
  Spine beam reinforcement to be similar to that of a normal beam.
- the anchor bolts to be placed sideways rather than lengthways to avoid possible rocking.
- the finishes are applied after the fixing slots have been grouted up so that no fixings show through.
- balusters are bolted directly to the treads and holes can be left to provide for these in casting.



Precast concrete open riser stairs

SPIRAL PRECAST CONCRETE STAIRS

- Spiral Stairs
in precast concrete work are based upon the stone stairs found in many historie buildings.
. They are usually open riser stairs with a r.c. core or (alternatively) a concrete - filled steel tube core.
. Holes are formed at the extreme ends of the treads, to receive the handrail supports in such a manner that the standard passes through a tread and is fixed to the underside of the tread immediately below. A hollow spacer or distance piece is usually incorporated between the two consecutive treads.



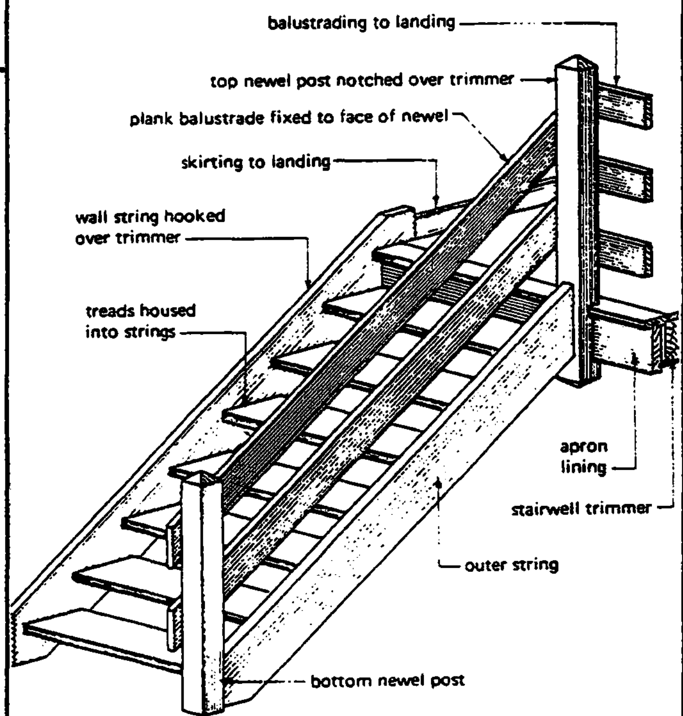
Precast concrete spiral stairs

13.54 TIMBER STAIRS

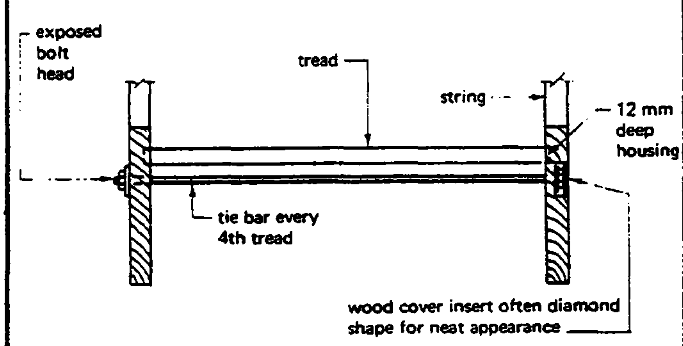
13.54 Timber Stairs

- timber stairs are commonly used in domestic buildings with either
  - . closed or
  - . open rises.
- Due to the position of their supports four basic types of timber stairs may be produced:

CLOSED STRING STAIRS



Typical arrangement



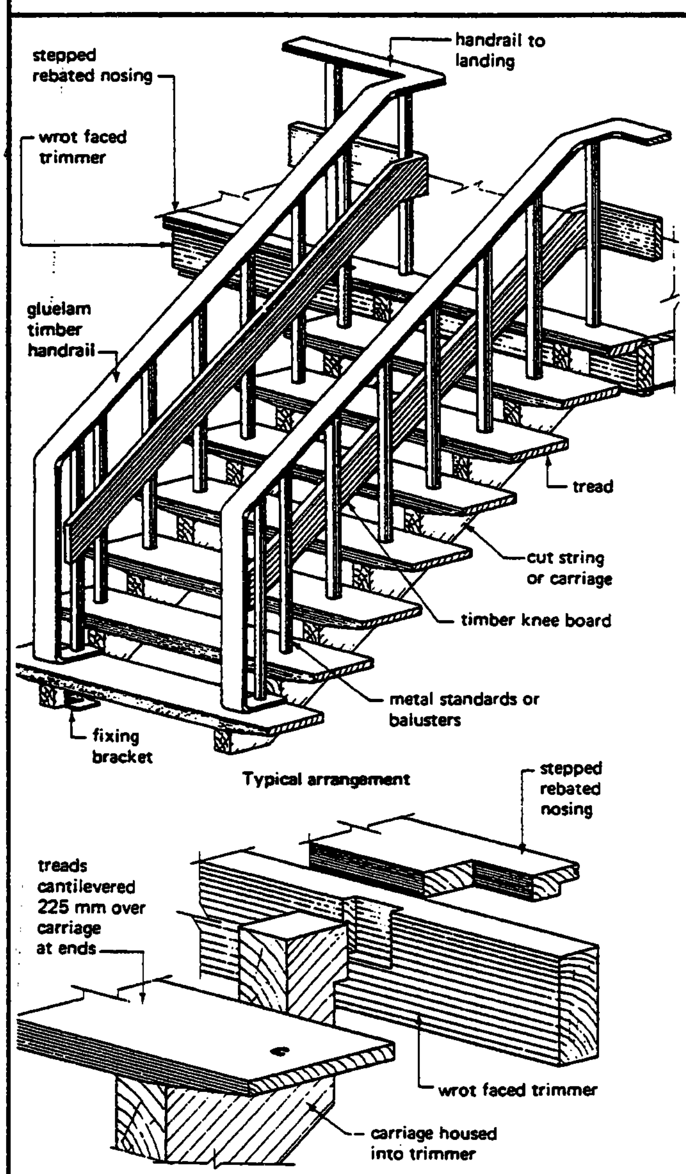
Alternative tie bar arrangements

Closed string open tread stairs

I. Closed string stairs

The treads are tightly housed into the strings which are tied together with long steel tie bars under the first, last and every fourth tread. The nuts and washers can be housed into the strings and covered with timber inserts.

CUT STRINGS or CARRIAGES

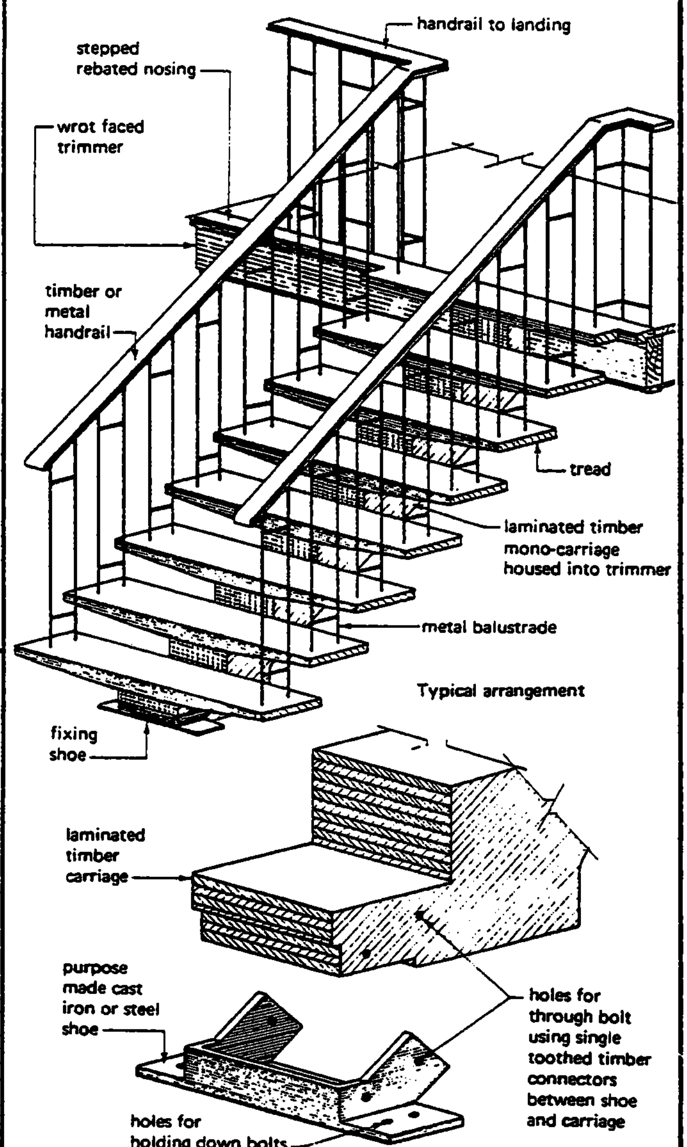


II Cut strings or Carriages

These are used to support cantilever treads and can be worked from the solid or of laminated construction. The upper end of the carrage can be housed into the stairwell trimming-member with possible additional support from metal brackets. The foot of the carriage is housed in a purpose made metal shoe or fixed with metal angle brackets.

III Mono-carriage (or spine beam)

employs a single central carriage with double cantilever treads. The carriage is of laminated construction and very often of a tapered section to reduce the apparent bulky appearence. The foot of the carriage is secured with a purpose made metal shoe in conjunction with timber connectors.



MONO CARRIAGE

IV Hanging stairs

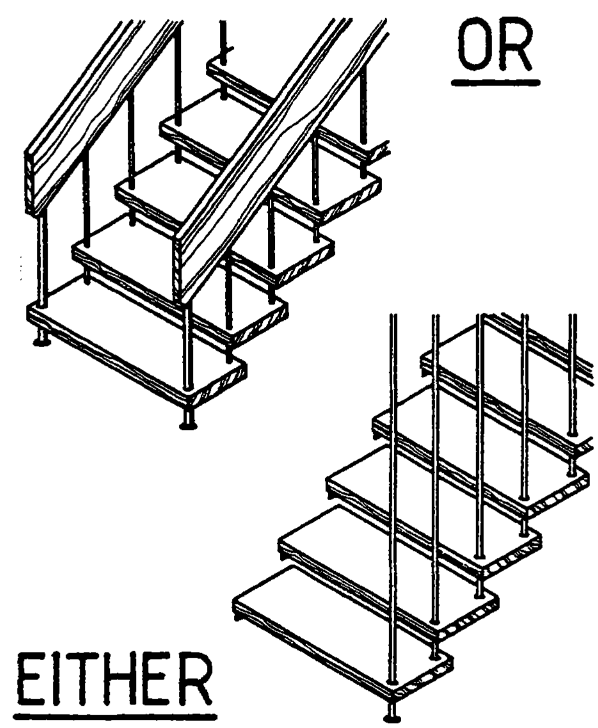
consist of treads which are kept in position by tension bars

- There are two methods of hanging the treads:

  Either tubular metal balusters, fixed at the ceiling, or a solid hardwood handrail are used as means of support for the treads.

- Cut of the number of different types of staircases, only the construction of newel and ladder type stairs suitable for domestic buildings will be considered

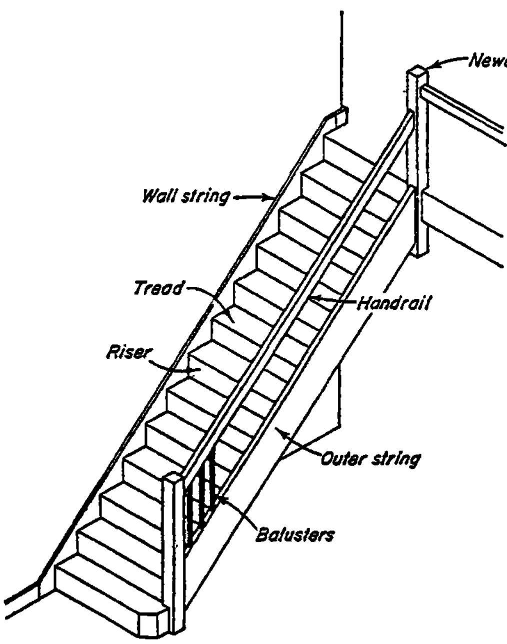
HANGING STAIRS



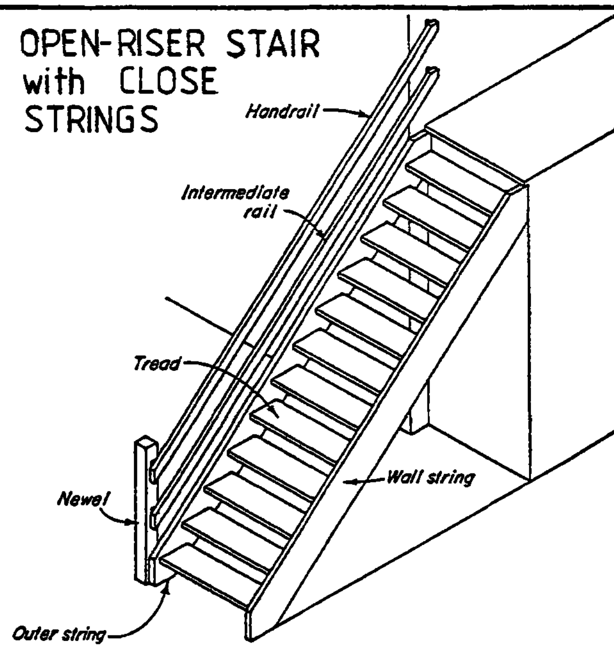
STRAIGHT FLIGHT STAIRS

Straight flight stairs

may be constructed between walls which give it continous support or it may be open on one or both sides.



CLOSED-RISER STAIRS with CLOSE STRINGS



13. STAIRS compiled : D.VOLKE DEC. '82	TIMBER STAIRS	BUILDING CONSTR. LECTURE CET 7031/1 13.5 29

- The sizes of members are not usually calculated, they are determined out of experiance.

  - Treads: 32 mm thick (27 mm plained)
  - Risers 25 mm thick (21 mm plained)
  - Method of fixing
    The top edge of the riser may be simply butted against the underside of the tread, but the joints should then be covered by a small mould fixed to the tread (to conceal any gap formed by shrinkage)
  - Projection of nosin g: not more then 25 mm. The nosing profile may be square, slightly splayed with rounded top edge or halfround.
  - an alternative 13 mm plywood may be used for the risers (ref. fig.)
  - The ends of the treads and risers are housed into grooves or housings - about 12 mm deep - formed in the strings. The housings are wider than thickness of tread and riser. They are tapered so that hardwood wedges, after covering with glue, may be driven behind the treads and risers forcing them tight against the outer faces of the housings.

STRAIGHT FLIGHT STAIRS

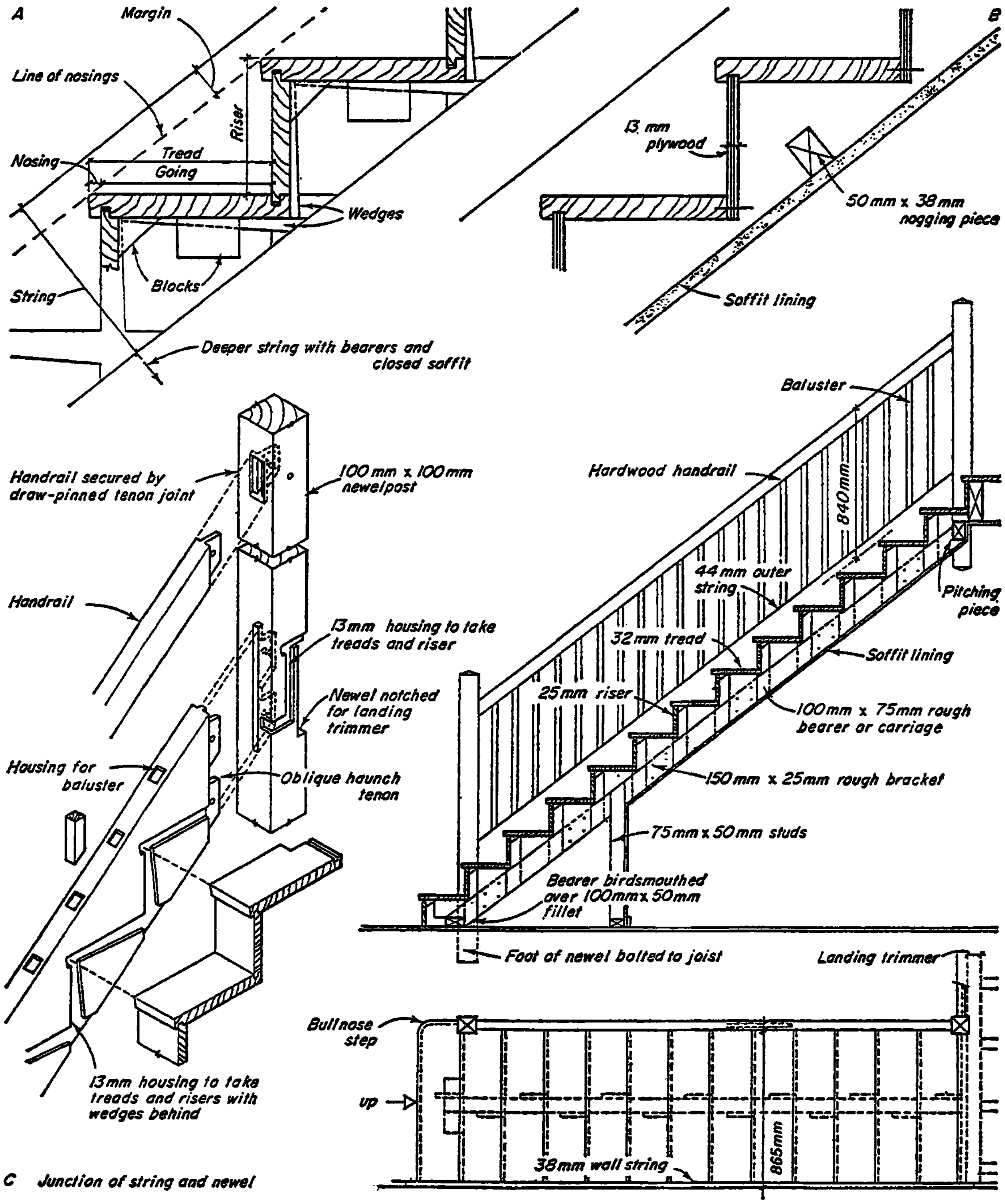
Triangular blocks of wood are glued at the junctions of the treads with the risers and strings to give increased rigidity to the whole staircase.

- Wall string: about 38 mm thick securely plugged to the wall.
- Outer string 45-50 mm thick
  It must be thicker than the wallstring as it acts
  as an inclined beam. (Whereas the former serves as a plate, supported by the wall).

- For stairs wider than 90 cm it is desirable to introduce intermediate support in the form of
  100 x 75 mm or
  100 x 50 mm rough bearers or carriages under the steps.

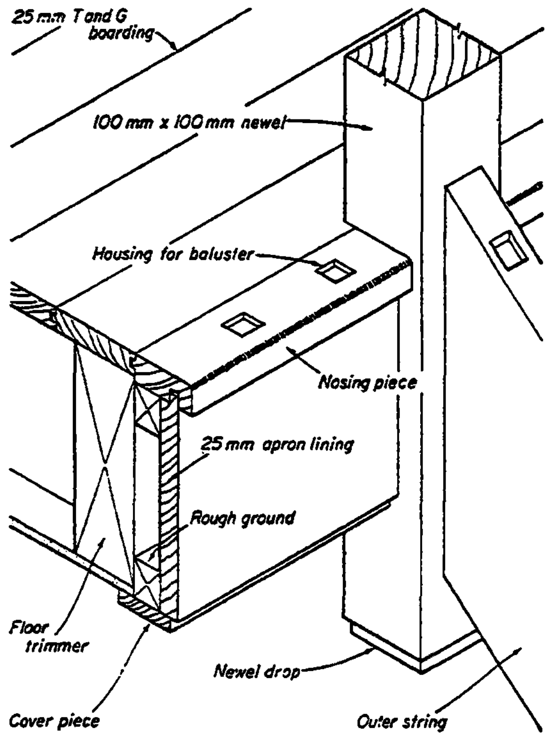
- The outer string is framed in to 100 x 100 mm newels at top and bottom of the flight.
  The strength of newel stairs depends largely on the rigidity of the joint between the string and newelpost. The normal method of joints the two is shown in the figure. This consists of a draw-pinned joint consisting of two obtique haunch tenons on the end of the string fitted into

STRAIGHT FLIGHT STAIRS



mortices formed by the newe
The whole is secured by a slightly tapering hardwood dowel at each tenon.
The newel post - like the strings - is housed to take the treads and risers and is (in addition) notched to fit over the landing trimmer to which it is nailed or - preferably - bolted.
The junction with the lower newel is similar, but the joint is reversed as shown.

STRAIGHT FLIGHT STAIRS



Apron lining to landing

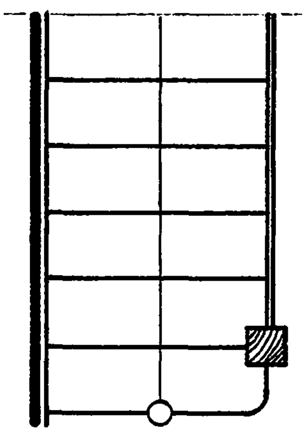
For architectural reasons the newel at the bottom of a stair case is usually set back one (or sometimes two) risers.

- The entry to the stair is less aprupt and may be made slightly from the side as mounting commences.

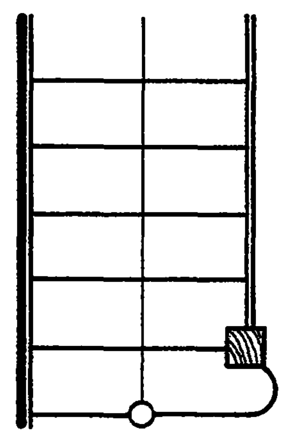
A specially shaped end to the bottom step (or steps) must be formed as shown in the examples illustrated.

The foot of the lower newel should be taken through the floor and bolted to a convenient joist, to sive a fire and secure connection.
The upper newel extends a short way below the string.
This is termed a <u>newel drop</u>.

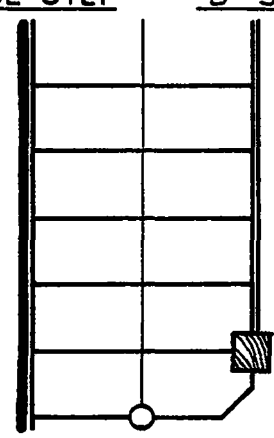
- Ends of handrails should be housed slightly into the newels and fixed by draw-pinned tenon joints.
- The trimmer to the upper floor landing is faced with an APRON LINING, toungued and grooved at the top to a nosing piece (preferably the same thickness as the stair treads, into which any landing balusters are housed and the floor boards tongued and grooved.



BULLNOSE STEP

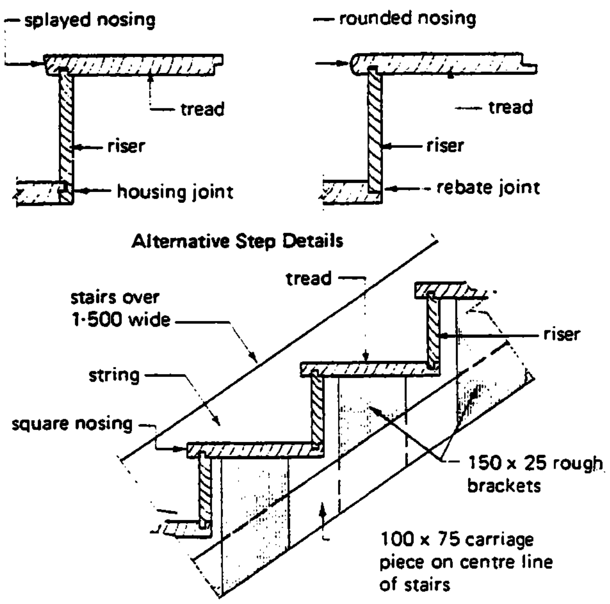


'D'-STEP

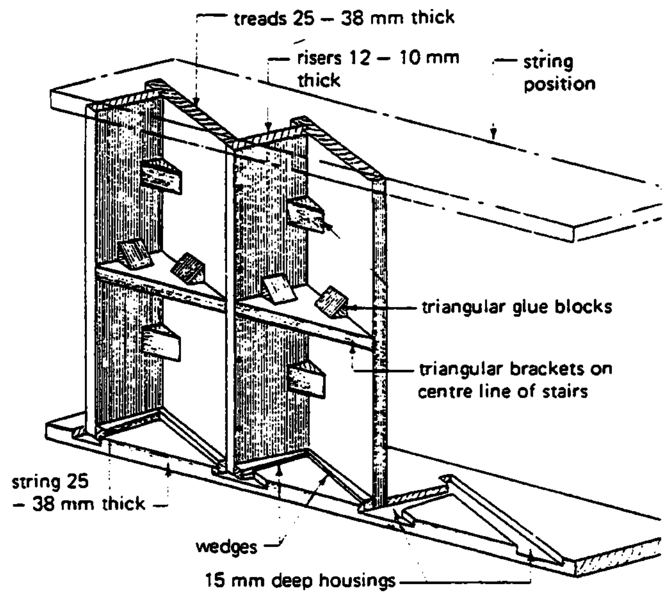


SPLAYED STEP

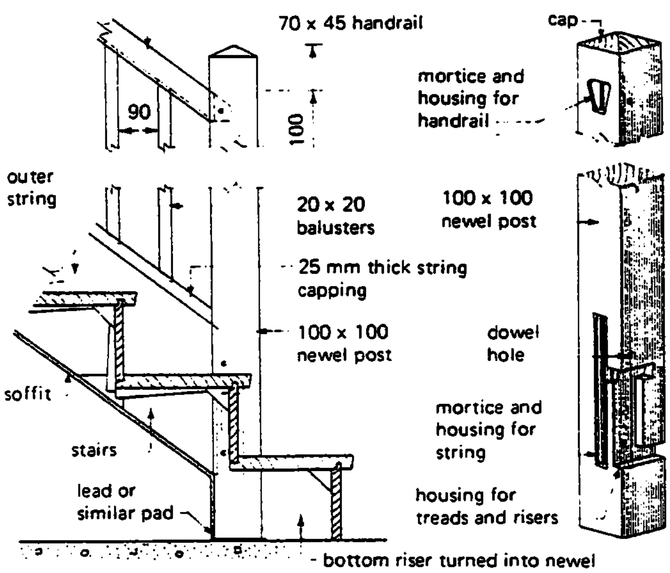
STAIR CONSTRUCTION DETAILS



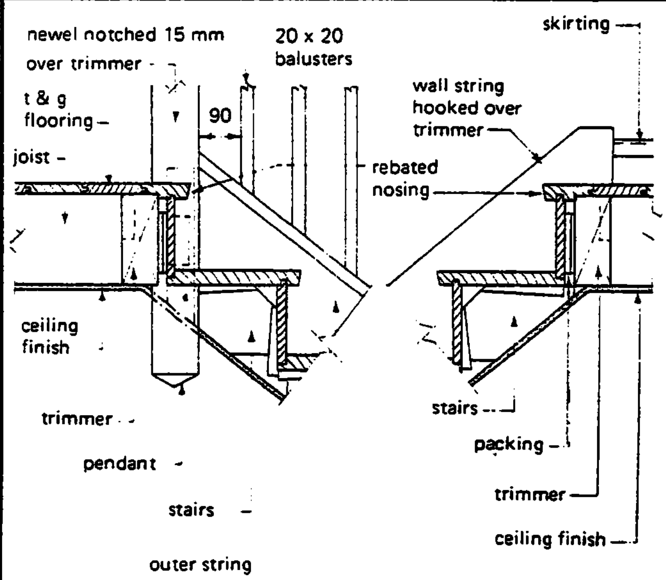
alternative STEP DETAILS



triangular GLUE BLOCKS & BRACKETS



detail at : BOTTOM NEWEL



details at : LANDING

13. STAIRS	TIMBER STAIRS	BUILDING CONSTR.
compiled : D. VOLKE		LECTURE
DEC. '82		CET 7031 / 113.5 33

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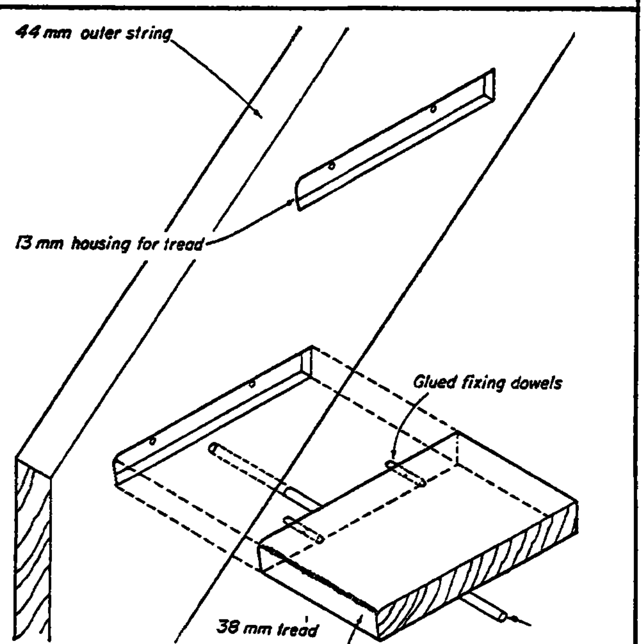
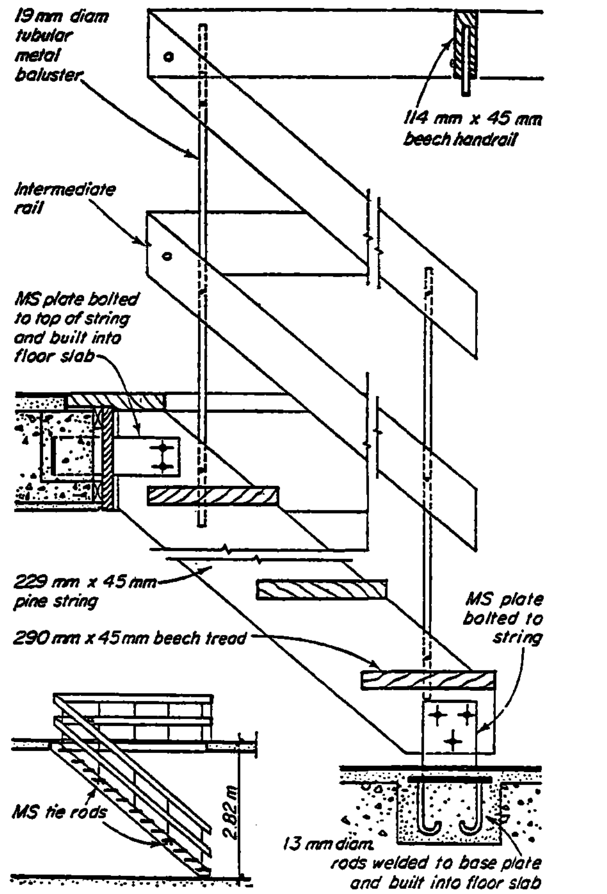
CIVIL ENGINEER.
DEPARTMENT

OPEN RISER STAIRS

<u>Open-riser or ladder stairs</u> may be constructed with close or cut strings.

- When close strings the connection between the ends of the treads and the strings is not as good as in a closed-riser stair, since there are no wedges or side blocks connecting the two.
  <u>Therefore</u>: The strings should be tied together by 10 mm or 12 mm Ø metal rods with sun and pelleted ends placed under every 4th tread.
- Screw fising: is not very strong as the screws enter the <u>end grain</u> of the tread.
- Glued dowels are better than screws.
- Cut strings are tied together by the treads which rest upon the string and are screwed to it.





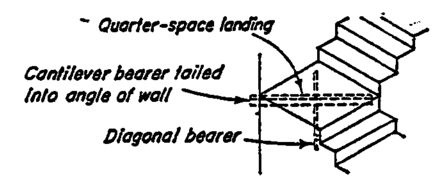
- With open-riser stairs no support is given to the tread by a riser. So the treads should be at least <u>38to44mm thick.</u>
  The treads are generally of hardwood.
- In case no newels are seen in the stair, this necessiates a direct fixing of the strings to the floors (for example: M.S. plates to which the strings are bolted are cast in the concrete floors.
- Alternative methods of securing the top of an open-riser stair are by fixing the strings directly to the wall face or by fixing to the upper floor by means of a head piece dowelled to the tops of the strings.

DOG LEG STAIR

DOG-LEG STAIR

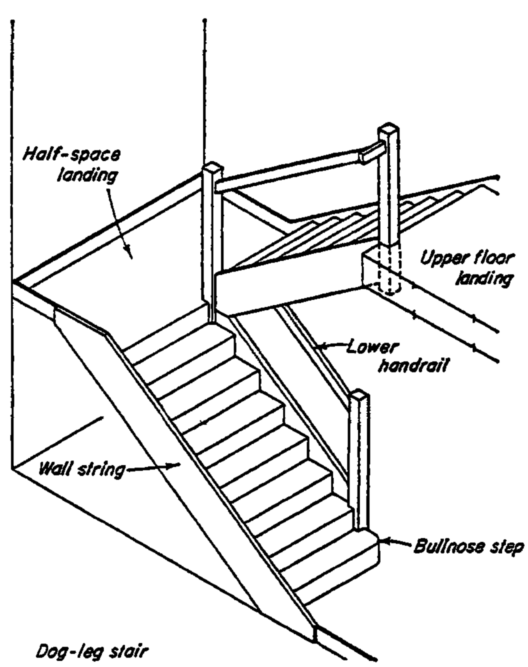
- The use of a single newel at the landing into which both outer strings are framed produces an elevation (the V-junction of strin gs) which gives rise to the name of the stair.
- Constructional details of the flights are identical with those already described for the straight flight stair - exept at certain points at the half - space landing and its newel.

  The latter is usually continued down to the lower floor for the sake of rigidity and fixed at the foot to the floor joist.

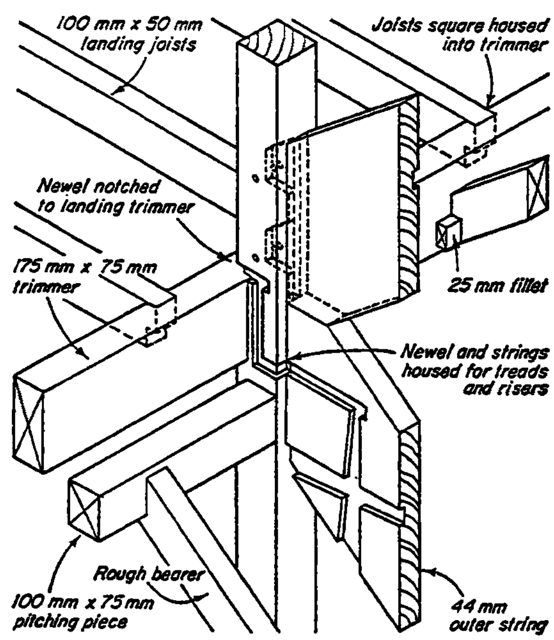


The strings bult against each other on an horizontal line, about 50 mm wide, outside the face of the newel.

The half-space landing, is formed of 100 mm x 50 mm joists supported by the trimmer at one end and by the stair case wall at the other.



Dog-leg stair



<u>OPEN WELL STAIR</u>
gives a better appearance than a dog-leg-stair and a continous handrail up to the landing newel.

All relevant details are similar to those described for the previous stairs.

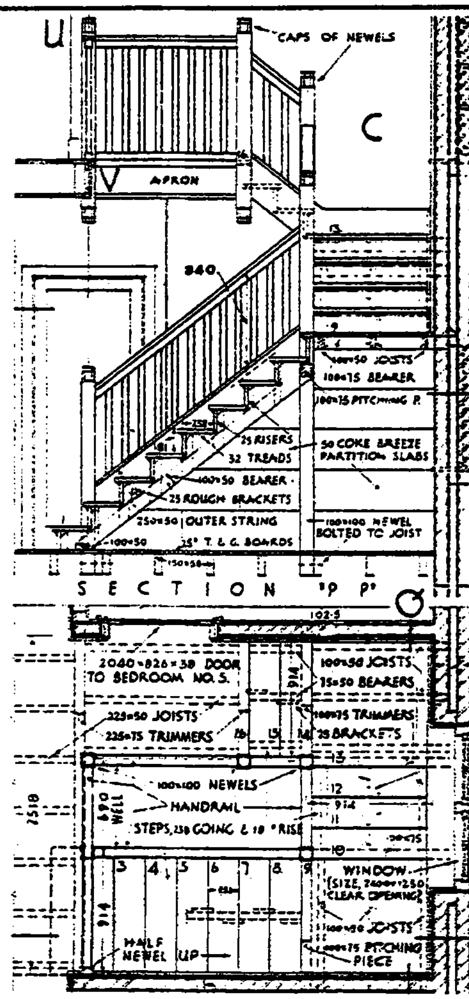
If the landing is half-space, the landing newels may terminate just below the landing as on the upper floor. The section of landing exposed between the newels is finished with an apron lining.

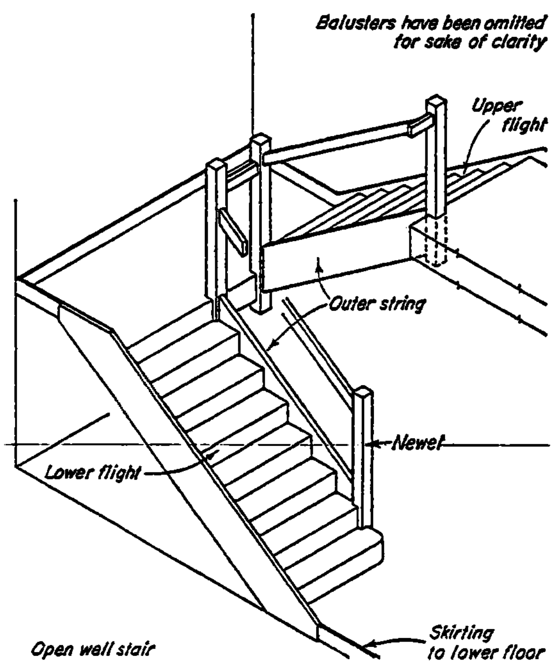
If a very narrow well is adopted (say 75 to 100 mm), a single newel about 250 mm wide is preferable to avoid an extremly small space between a pair of newels and its accompanying problems at handrail and landing level.

If an intermediate flight is incorporated, quarter-space landings will be formed; in small domestic stairs then landing will support itself (provided the surrounding walls are capable).
In larger stairs it is necessary to provide support to the trimmers of the landings: most simply

by carring the landing newels down to the floor below
or:
the landing and the newel may be supported on cantilever construction.

OPEN WELL STAIR





Open well stair

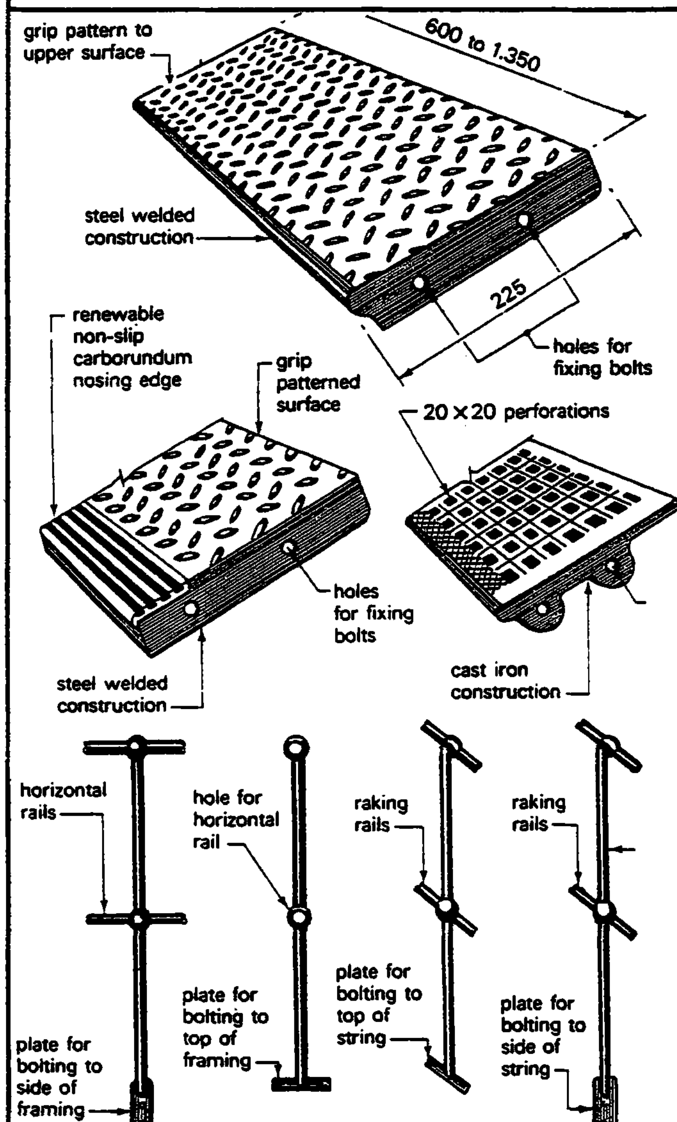
13.55 METAL STAIRS

13.55 Metal Stairs
are used as
- escape stairs
- internal accomodation stairs
- external accomodation stairs.

- Most metal stairs are manufactured from mild steel and in straight flights with intermediate half space landings. Spiral stairs in steel are also produced but their use as an escape stair is limited by size and the number of persons likely to use the stairway in the event of a fire. Aluminium alloy stairs are also made and are used almost exclusively as internal accomodation stairs.
- All steel stairs have the common disadvantage of requiring regular maintenance in the form of painting as a protection against corrosion.
- Most metal stairs are supplied in a form which requires some site fabrication and this is usually carried out by the suppliers site erection staff. The main contractor having been supplied with the necessary data as to foundation pads, holding-down bolts, any special cast-in fixings and any pockets to be left in the structural members or floor slabs to enable this preparatory work to be completed before the stairs are ready to be fixed.

- STEEL ESCAPE STAIRS

The treads of this type of stair are bolted to the strings and can be of a variety of types ranging from perforated cast iron to patterned steel treads with renewable non slip nosings.
Handrail balustrades or standards can be of steel square or tubular sections bolted to the upper surface of a channel string or to the side of a channel or steel plate string.



STEEL SPIRAL STAIRS

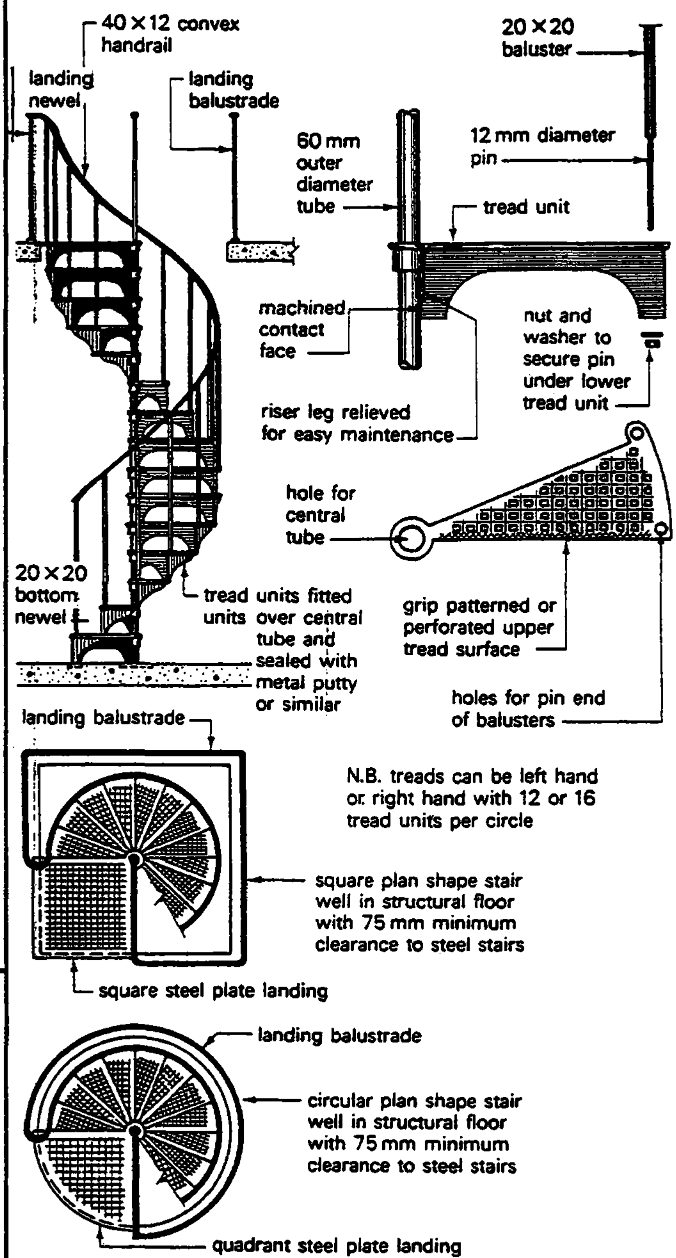
- Steel spiral stairs
are allowed as an internal or external means of escape stairs if they are not for more than 50 persons. The maximum total rise is 9,00 m and the minimum overall diameter is 1,50 m.

- Two basic forms are encountered:
  a) with treads, which project from the central pole or tube and
  b) those which have riser legs.

The usual plan format is to have 12 or 16 treads to complete one turn around the central core and terminating at floor level with a quarter circle landing or square landing.

The standards (like those used for precast concrete spiral stairs, pass through one tread and are secured on the underside of the tread below.

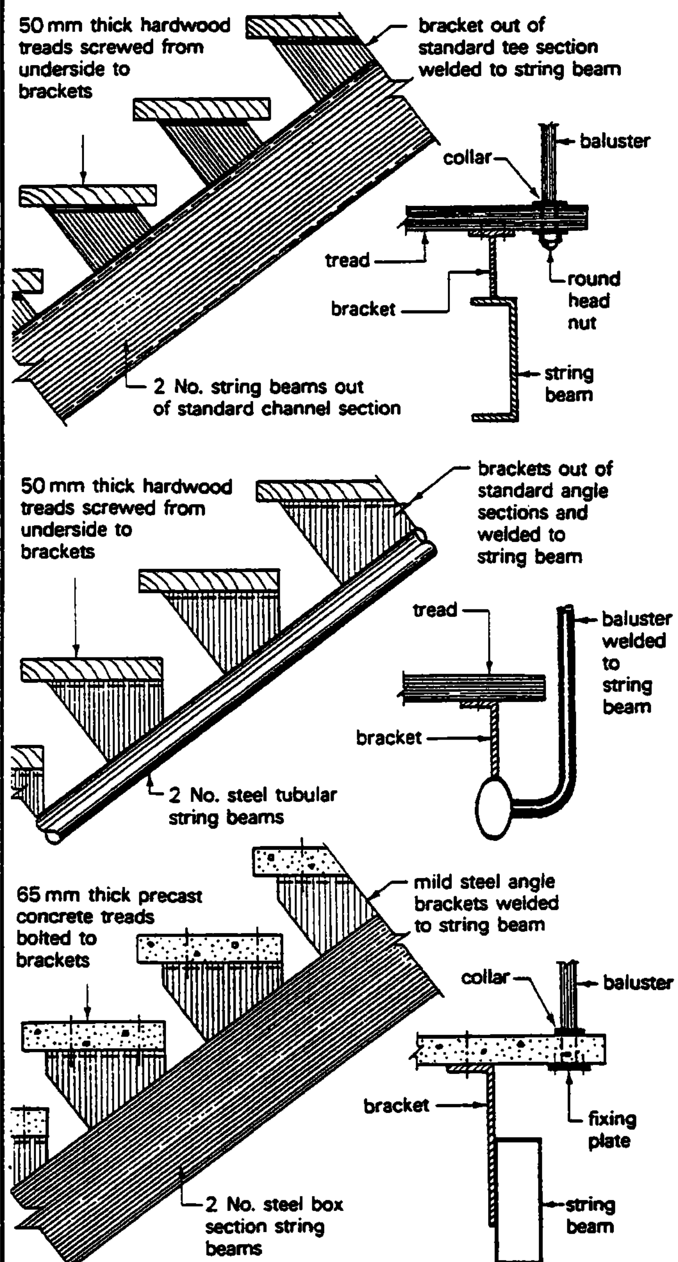
Handrails are continously and usually convex in cross section of polished metal painted metal or plastic covered.



STRING BEAM STEEL STAIRS

- String beam steel stairs

used mainly to form accomodation stairs which need to be light and elegant in appearance. The strings can be of mild steel tubes, steel channels steel boxes or small universal beam sections fixed by brackets to the upper floor surfaces or landing edges to act as inclined beams. The treads, which can be hardwood timber, precast concrete or steel are supported by plate, angle or tube brackets welded to the tup of the string beam. Balustrading can be fixed through the ends of the treads or (alternatively) supported by brackets attached to the outer face of the string beam.

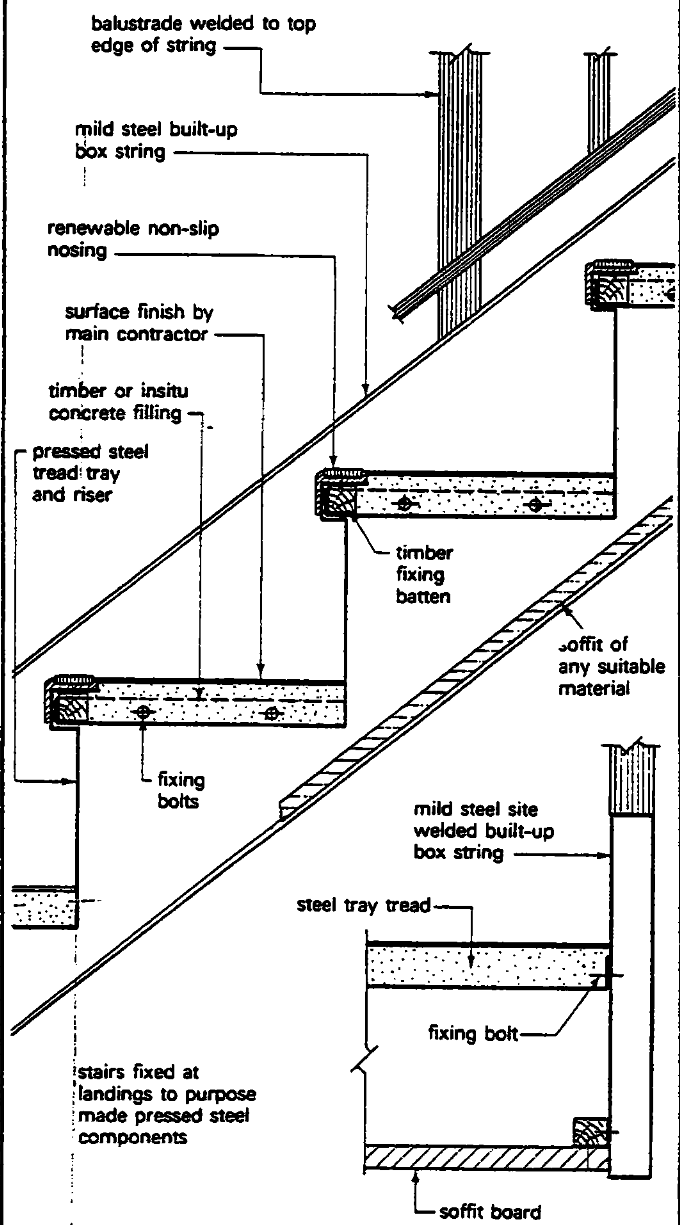


PRESSED STEEL STAIRS

- <u>Pressed steel stairs</u>
accomodation stairs made from light pressed metal such as mild steel.
Each step is usually pressed as one unit with the tread component recessed to receive a filling of concrete, granolithic, terrazzo, timber or any other suitable material.

The strings are very often in two pieces, consisting of a back plate to which the steps are fixed and a cover plate to form a <u>box - section</u> string.

The coverplate to be site-welded.
The complete strings are secured by brackets or built in to the floors or landings and provide the support for the balustrade. Stairs of this nature are generally purpose-made to the required layout and site assembled and fixed by a specialist sub-contructor.

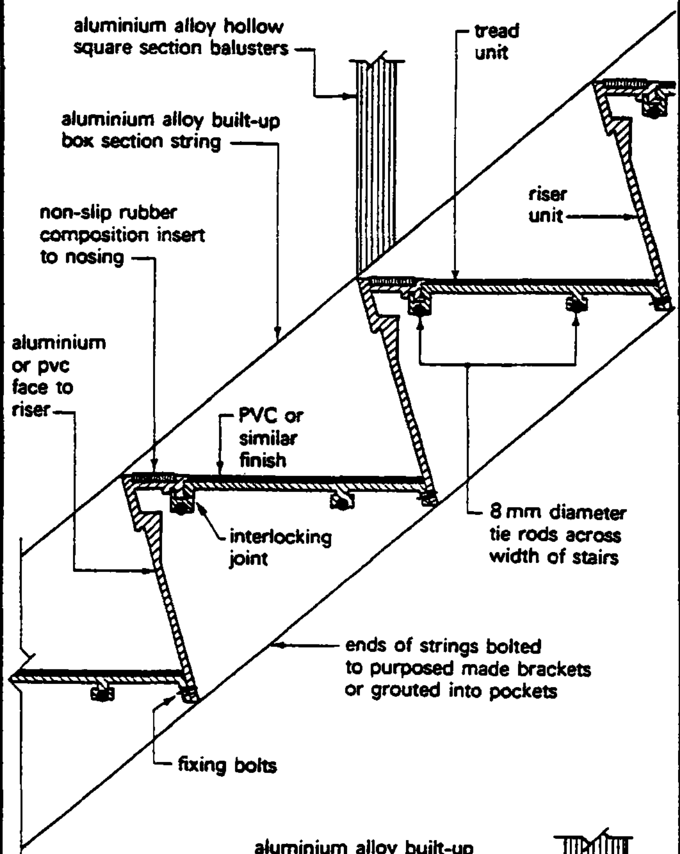


ALUMINIUM ALLOY STAIRS

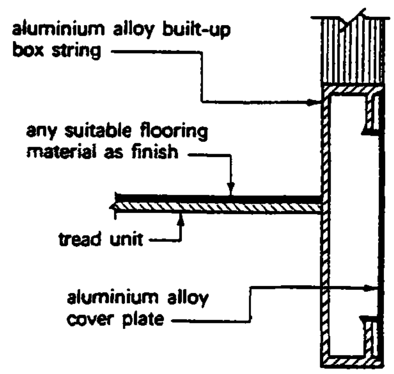
- Aluminium alloy stairs
are suitable for accomodation stairs in public buildings, offices and shops.
The treads have a non-slip nosing with a general tread covering of any suitable floor-finish-material. Format can be open or closed riser.
The two-part box strings support the balustrade and are connected to one another by small diameter tie rods which - in turn - support the tread units.

The flights are secured by screwing to purpose made base plates or brackets fixed to floors and landings or alternatively located in preformed pockets and grou ted in.

When the stairs are assembled they are very light and can usually be lifted and positioned by two men without the need for lifting gear. No decoration or maintenance is required.



open riser stairs also available

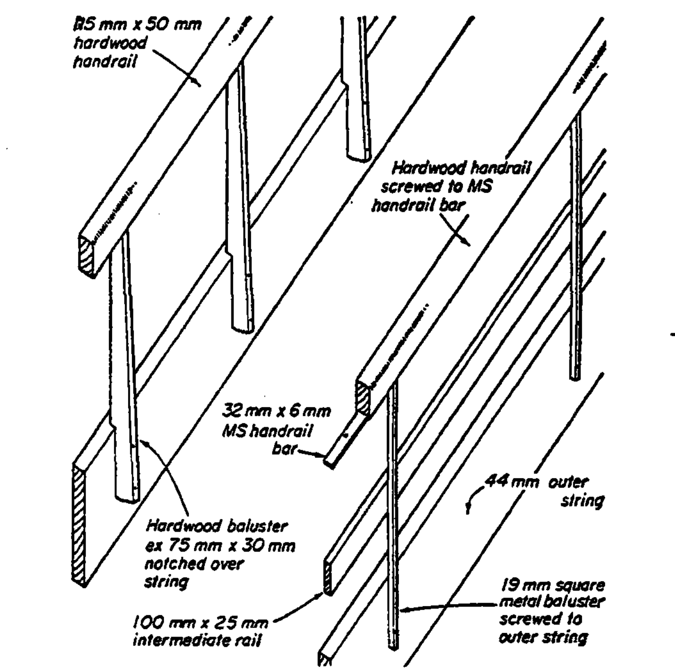


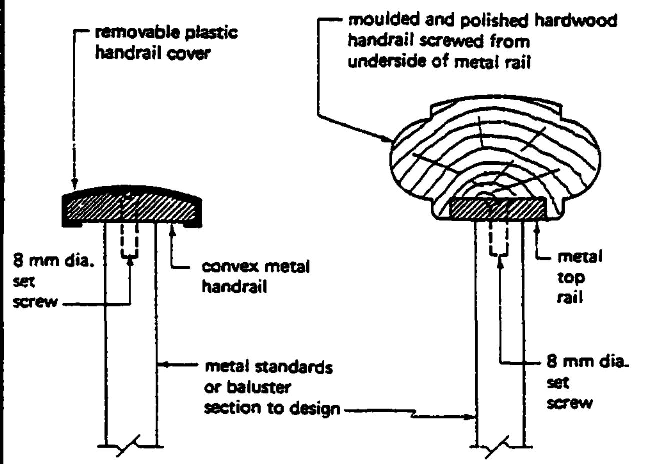
13.61 BALUSTRADES/HANDRAILS

Handrails

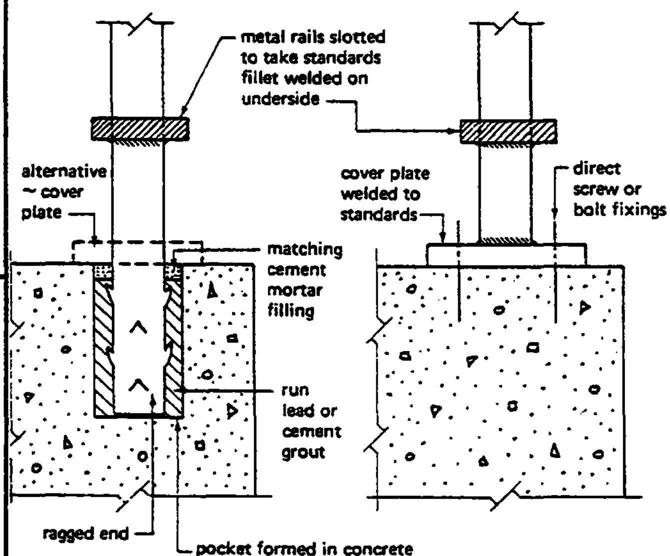
Continous handrails of non-combustible materials at a height of between 840 and 915mm above the pitch line (line of nosings) are required to all stairs and to both sides if the stairs width exceeds 1.06 m. The height above the floor to be between 1.07 and 1.09 m.

The capping can be of a combustable material such as plastic or timber provided that it is fixed to or over a non-combustible core.



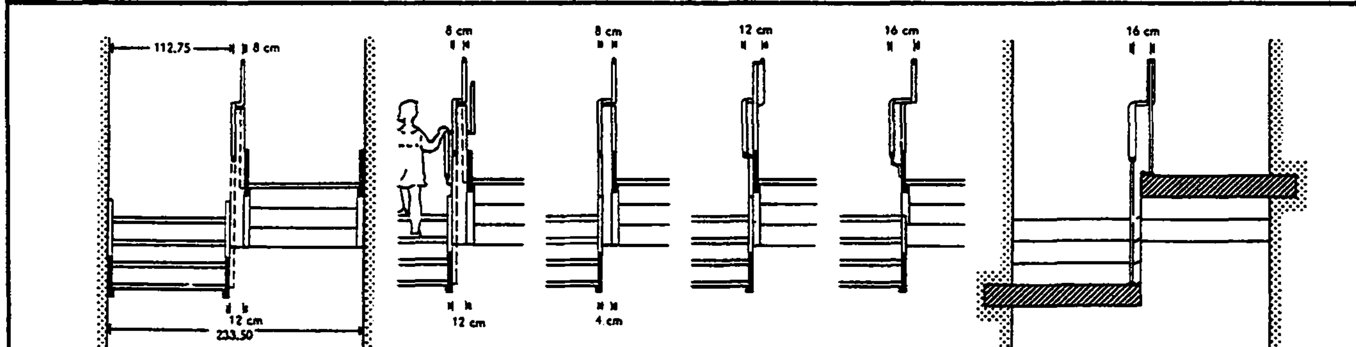


Typical handrails

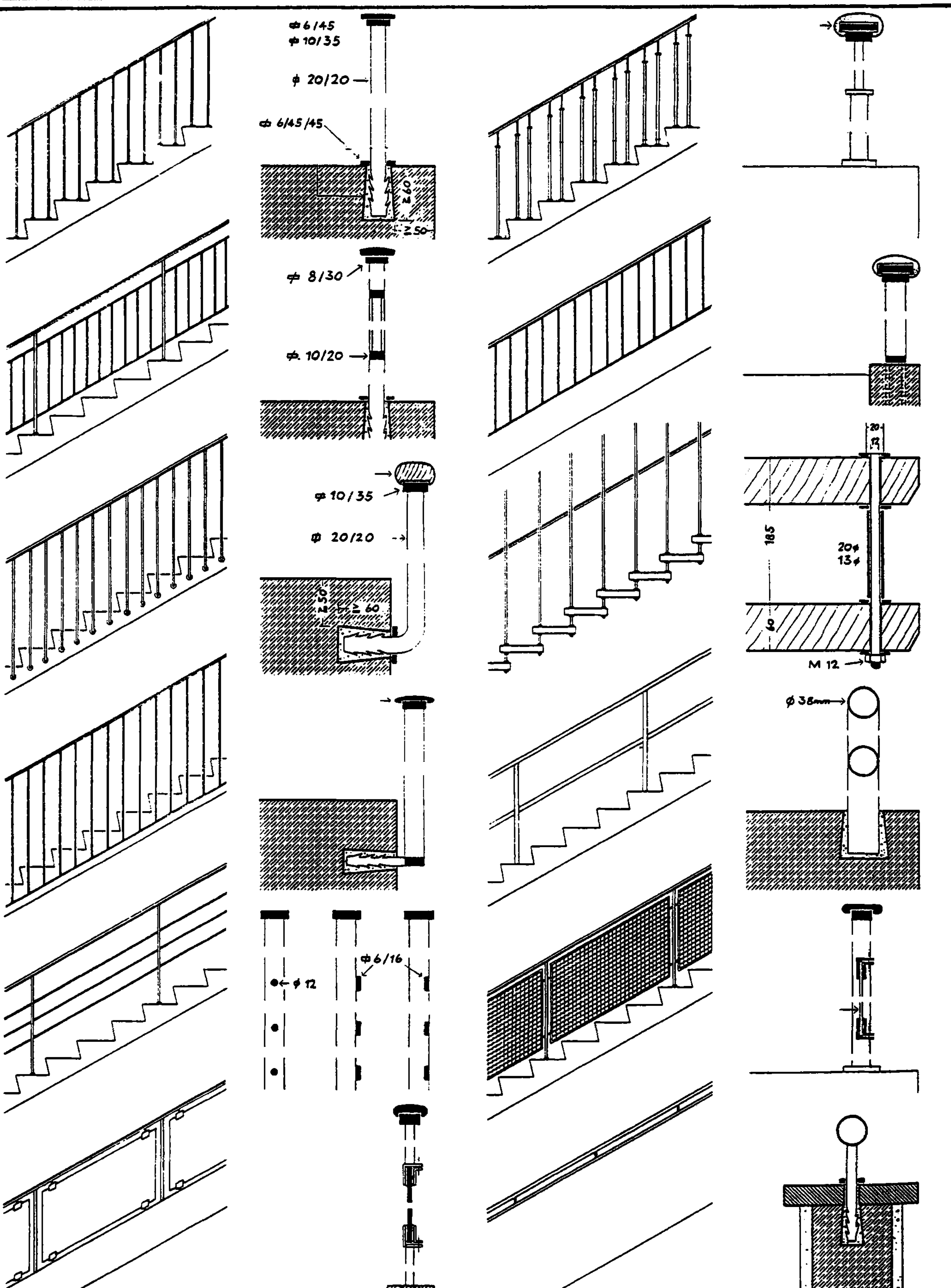


Typical fixing methods

Handrail and string details. Max space is required at hip (handrail) level, but considerably less at foot level. Width at string level therefore reduced to allow more space for stairwell. Staggering of handrail and string also offers better structural fixing of standards to strings, best with handrails 80 mm (3.2 in) apart and space between strings 120 mm (4.7 in), Additional handrail for children, height approx 600 mm (2 ft), Less favourable string and handrail positions, with no space between strings , string above string and stringless r.c. stair without any space between flights



BALUSTRADES and HANDRAIL DETAILS :



13.STAIRS	MISCELLANEOUS	BUILDING CONSTR.
compiled : D.VOLKE		LECTURE
DEC. '82		CET 7031/1 13.6 43

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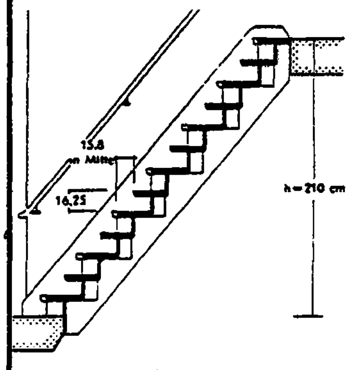
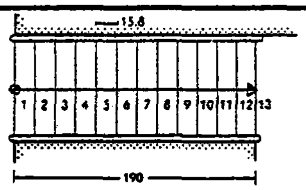
'SAMBA' STAIR; LADDERS; DISAPPEAR. STAIRS; RAMPS

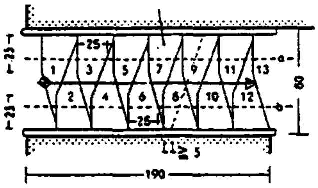


'Samba' stair from timber, section through centre



Normal stair (treads too short)

shape of treads if constructed in timber

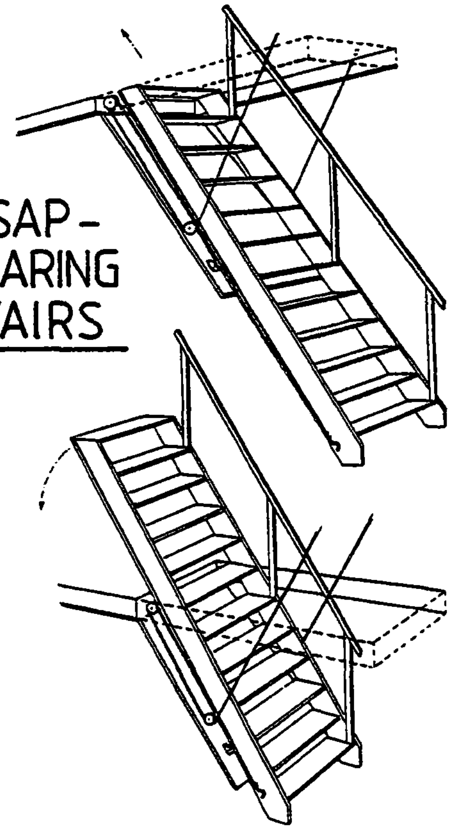


Plan. Tread width at line a and b ≧ 200 mm (8 in)

'Samba' stair

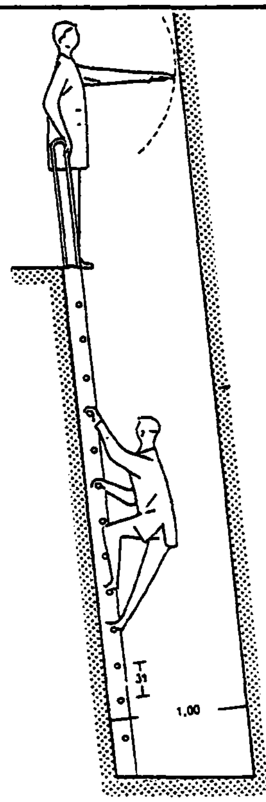
Example, Storey height 2.25 m (7 ft 6 in) = 12 risers = 187.5 mm (7.5 in) per rise; if constructed as a normal stair, a tread of 136 mm (5.4 in) is too small. Therefore steps are curved in such a way that on line a and b tread becomes 250 mm (10 in), fulfilling above requirement: 2 x 187.5 mm (7.5 in) + 1 x 250 mm (10 in) = 625 mm (25 in).

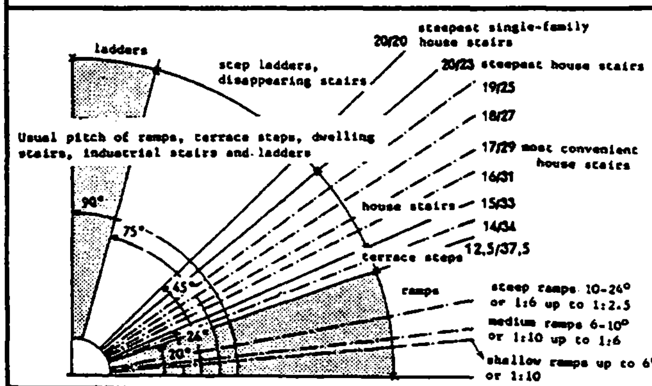
DISAPPEARING STAIRS



CONCEALED CATLADDER

Storey height from F.F.L. to underside of ceiling	Length of opening (width accord -ingly)	Required swivel radius in attic
3,00	1,45	2,30
3,00	1,30	2,45
3,00	1,15	2,60
3,00	1,00	2,75
3,00	0,85	2,90
2,70	1,45	1,95
2,70	1,30	2,10
2,70	1,15	2,25
2,70	1,00	2,40
2,70	0,85	2,55
2,40	1,45	1,65
2,40	1,30	1,80
2,40	1,15	1,95
2,40	1,00	2,10
2,40	0,85	2,25
2,10	1,45	1,30
2,10	1,30	1,45
2,10	1,15	1,60
2,10	1,00	1,75
2,10	0,85	1,90





ramps are divided according to gradient into:

1. **Shallow ramps** which do not require special non-slip treatment
2. **Medium gradient** with battens or low rise steps, or at least a rugged non-slip surface
3. **Steep ramps** requiring battens or low rise steps. Batten distances should be uniform and should conform to normal stride.

Steep stairs at an angle of 38–45° should be used only for short flights and little traffic. The sum of the going + twice its rise should be ⩾ 571 mm (22.5 in), ⩽ 630 mm (25 in).

Loft ladders, etc, have angle of 45–55°.

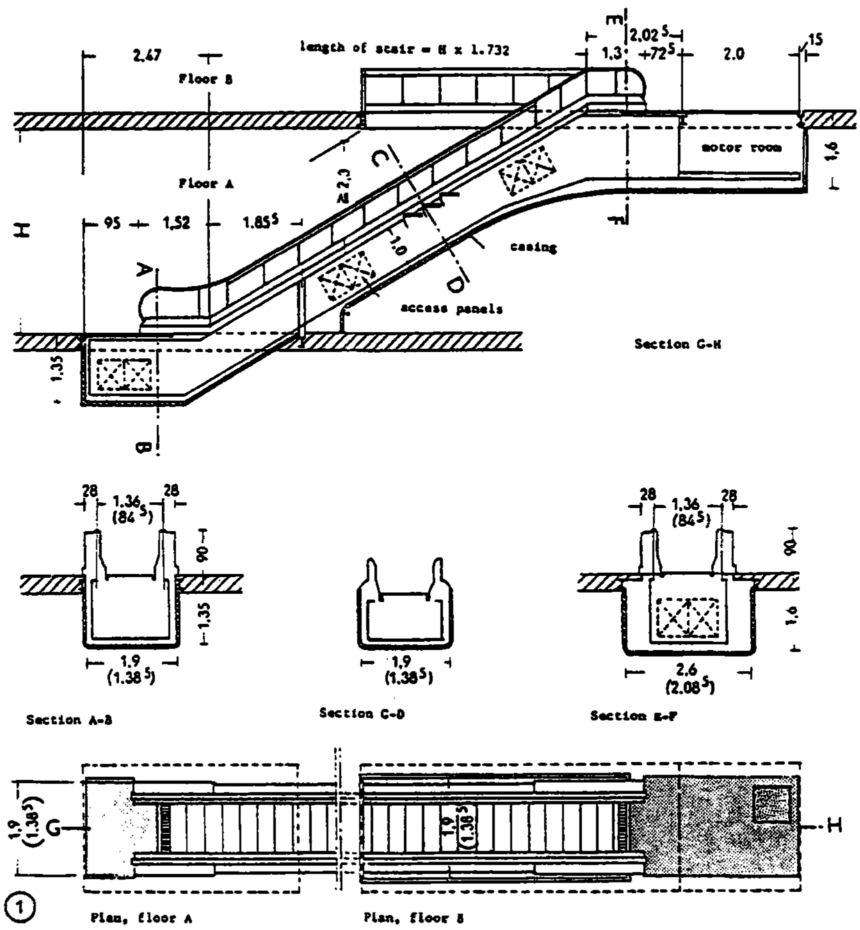
However, if user requirements stipulate a stair-like access (e.g. where loads are carried and available length is too short for flight of normal stairs), then stair with staggered steps, so-called Samba stair, may be designed. Risers for this type of stair should be as few as possible; riser ⩽ 200 mm (8 in). Here 'the sum of the going + twice its rise = 630 mm (25 in)' is achieved by shaping the treads; going is measured (staggered) at axes a and b, of right and left foot.

Movable ladders have angles of 65–80°. There are various types including extension ladders.

Fixed ladders have angles of 80°+ and should extend ⩾ 750 mm (2 ft 6 in) over platform to be reached if no other precautionary measure against accident is taken. Rung-distance for fixed ladders, 295–315 mm (11.5–12.5 in).

Escalators (1) are required for continuous transport of crowds (requirements of width and distance for means of escape do not take escalators into account). Automatic control by push buttons at top and bottom or through photo-electric cells reduces running times by 40—50%.

Escalators should be evenly distributed throughout all floors, where necessary varying width or speed. To cope with peak traffic a smaller number of escalators at speed of 1 m/sec (3 ft/sec) which move at off-peak times at 0.65 m/sec (2 ft/sec) more economical than larger number of slow moving escalators. However, in UK, max speed 0.75 m/sec (→ BS 2655).



Stringent requirements (function and security); 30° angle best, going 0.40 m (1 ft 4 in), width of stairs 0.60 m (2 ft) to ≤ 1.00 m (3 ft 4 in), usual 0.80 m (2 ft 8 in). Escalators of 30° angle and 1.00 m stair width permit easy overtaking.

Conveyor belt speed: international about 0.50 m/sec (1 ft 8 in/sec). At change-over from fixed floor to escalator a handrail projection ≥ 0.80 m (2 ft 8 in) is required.

Access and exit with min. 2 horizontal goings, but escalators with larger height dimensions or greater speed ≥ 0.50 m/sec (1 ft 8 in/sec) min 3 horizontal exit goings necessary.

Max capacity/h from steps area and speed

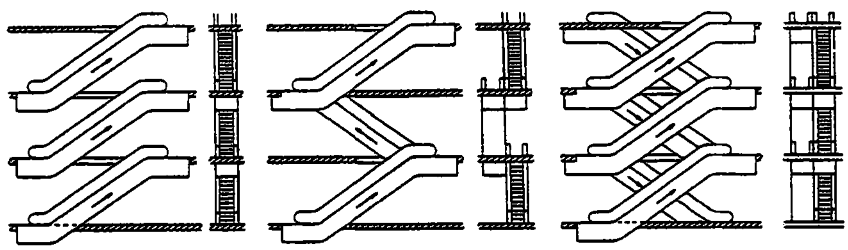
$$\text{Capacity } M = \frac{Q_1 \times V}{T} \times 3600$$

Q_1 = persons/step
T = going depth (m)
v = conveyor speed (m/sec)

Output only 75—80% of M, as steps not used to capacity.

Control: fully automatic through time clock and programme, or intermittent through photo-electric cells, or contact mats.

With working height of ≥ 6.0 m (20 ft) a centre support is normally necessary.



Types of escalators

(2) Superimposed (3) Crossover (4) Double crossover

Length in plan
With 30° escalator: 1.732 x storey height.
With 35° escalator: 1.428 x storey height.
Example: storey height 4.5 m (15 ft), angle 30°. Length in plan = 1.732 x 4.5 = 7.794 m (1.732 x 15 = 26 ft); adding for landings top and bottom, total length approx 9 m (30 ft), allowing about 20 persons to stand in a row.

speed	Time per person	Person/hr transported: 1 person width	2 person width
0,5 m/sec	18 sec	4000	8000
0,9 m/sec	10 sec	7200	14400

Energy consumption: 4 000 person/h: 8 hp AC
8 000 person/h: 15 AC

REPETITION ●● exercises ●● REPETITION

Try to answer the following questions and practice sketching where ever necessary and possible.

1) Introduction

   a) Explain the term STAIR and list suitable materials, which can be used for the construction of stairs.

2) Definition of Terms

   a) Define the following Terms:

- Step	- Going	- Width
- Tread	- Fliers	- Pitch or Slope
- Rise of a step	- Tapered Steps	- Walking line
- Riser	- Winders	- Headroom
- Racking Riser	- Dancing Steps	- Balustrade
- Nosing	- Flight	- String or Stringer
- Line of Nosings	- Landing	- Staircase

3) Types of Stairs

   a) How are Stairs classified?
      Use sketches for illustration!

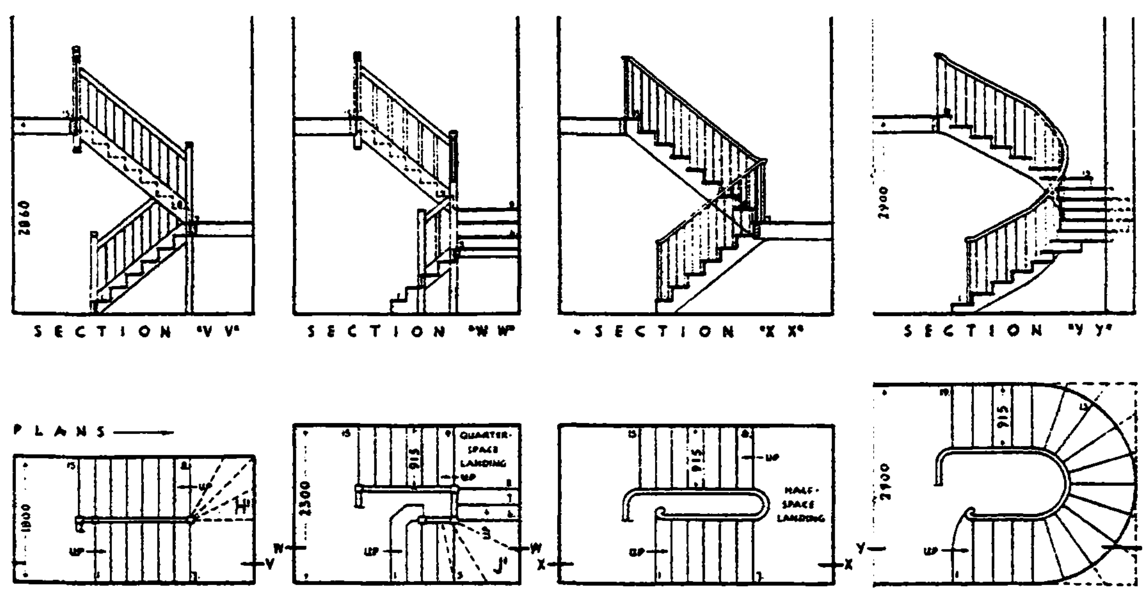
4) Design of Stairs

   a) What are the main factors in the design of Stairs?
   b) Write notes on the RISE-TREAD-PROPORTION.
   c) Calculate a Stair with a rise of 17-19 cm and defference of floor levels - h = 3.00 m,
      using the I. PACE-RULE
      II. SAFETY - RULE
      III. COMF ORT-RULE

5) Construction of Stairs

   a) Explain briefly the construction of BRICK STAIRS.
      Use sketches for illustration!

   b) Explain briefly the construction of STONE STAIRS.
      Use sketches for illustration!



●REPETITION●●exercises●OOO

c) Explain briefly the construction of 'IN-SITU' CAST R.C. STAIRS and give structural details of:
- single flight concrete stairs
- two-flight concrete stairs with half-space landings
- string beam concrete stairs
- cranked slab concrete stairs
- cantilever concrete stairs
- spiral concrete stairs

Use sketches for illustration!

d) Explain briefly the construction of PRECAST CONCRETE STAIRS and give structural details of
- straight flight p.c. stairs
- cranked slab p.c. stairs
- p.c. open riser stairs
- p.c. spiral stairs

Use sketches for illustration!

e) Explain briefly the construction of TIMBER STAIRS and give structural details of
- straight flight timber stairs
- open-riser or ladder timber stairs
- dog-leg timber stairs
- open well timber stairs

Use sketches for illustration!

f) Explain briefly the construction of METAL STAIRS and give structural details of
- steel escape stairs
- steel spiral stairs
- string beam steel stairs
- pressed steel stairs

Use sketches for illustration!

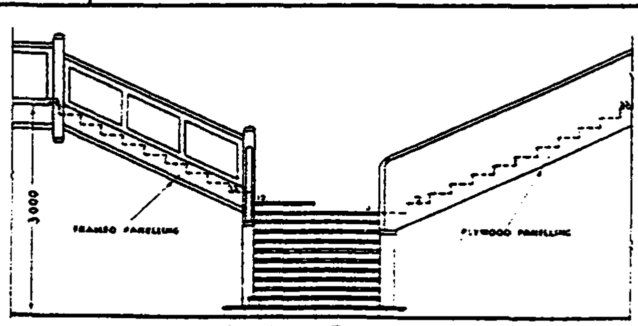
6) <u>Miscellaneous</u>

a) Describe - by using sketches - different types of balustrades and handrail details.

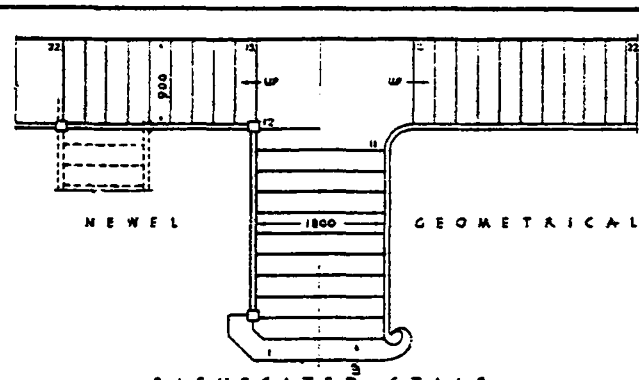
b) Explain the terms:
- 'samba' stair
- disappearing stair
- ladder
- ramp

by using sketches for illustration!

c) What do you know about ESCALATORS?



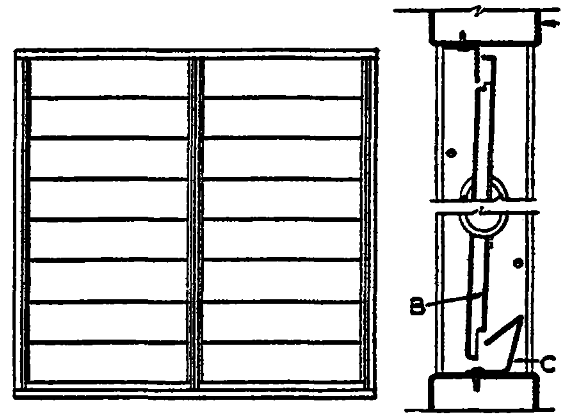
ELEVATION

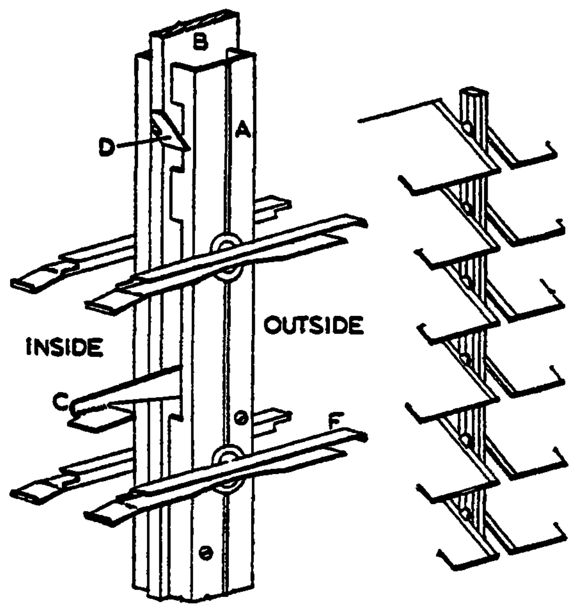


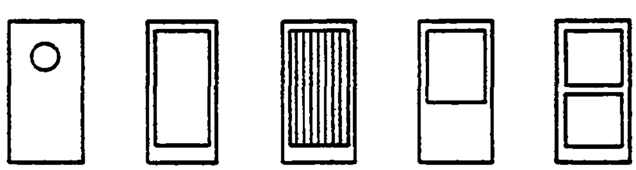
BIFURCATED STAIR

14. DOORS & WINDOWS

CONTENTS:







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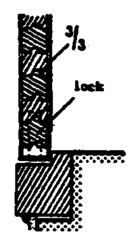
2. R. Chudley "CONSTRUCTION TECHNOLOGY" Volume 1,2,4
3. E. Neufert "Architect's Data" Edition 1978
4. R. Barry "The Construction of Buildings" Vol. I + II

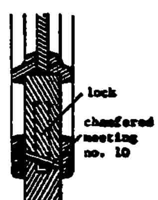
14.1 DOORS

14.1 DOORS

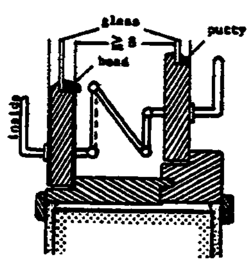
- A door is a screen used to seal an opening into a building or between rooms within a building.
- Doors can be made from
  - wood
  - glass
  - metal
  - plastic
  - felexible rubber
  - or any combination of the above
- They can be designed to
  - swing (side-hung)
  - slide
  - fold (slide and fold)
  - roll
  - shutter
  - or pivot
- They can range in size from tiny cupboard doors to the huge sliding-folding doors of aircraft hangers.
- All doors may be classified by their
  - Position in a building
  - Function
  - or method of Construction.



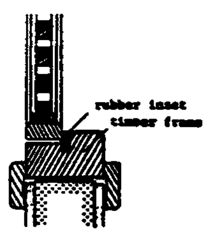
American solid-core door with metal channel profile



Two-leaved framed door with beaded panels



Two coupled doors



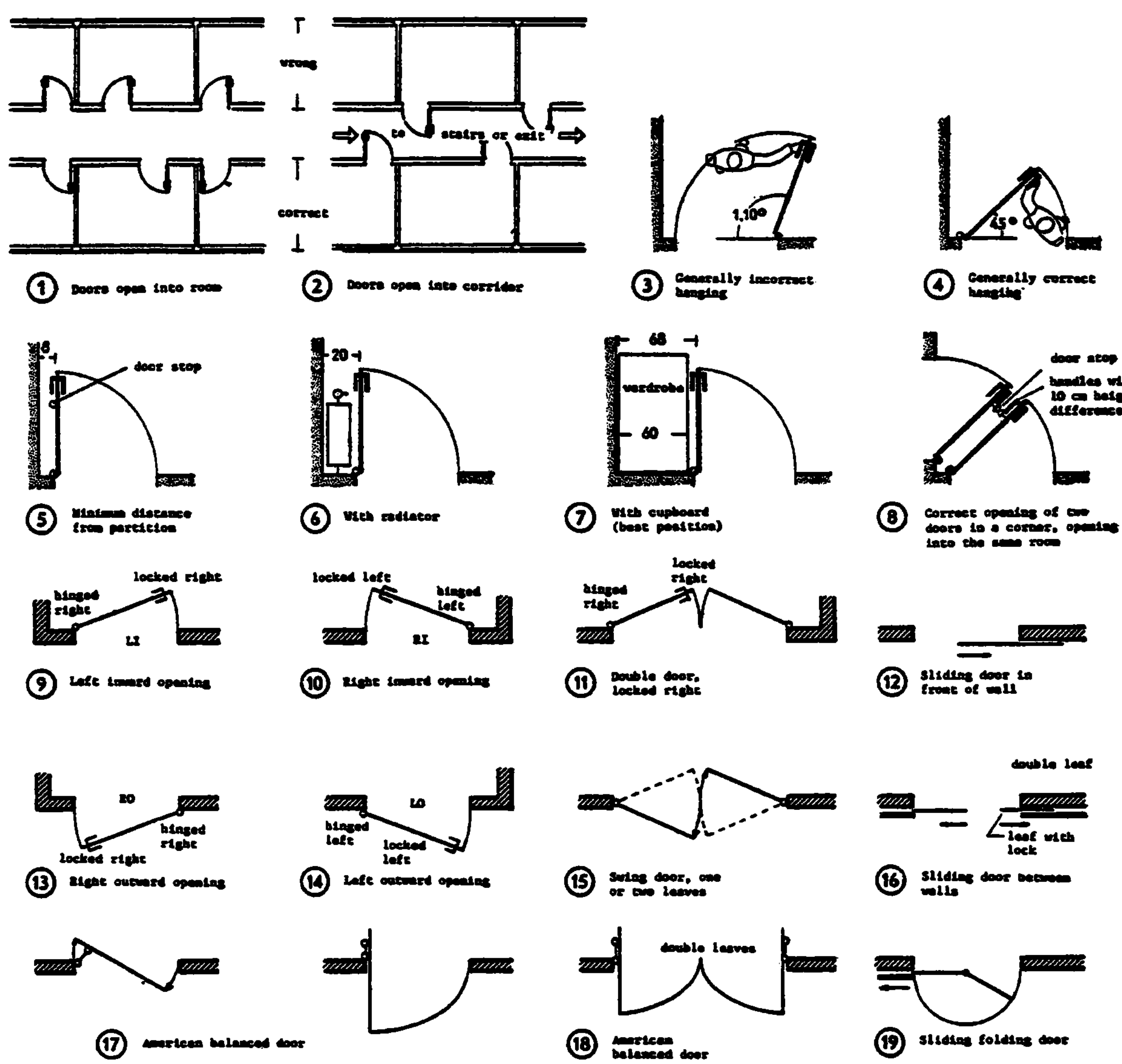
Skeleton-core plywood door

DOORS

Positioning

Correct positioning of doors important for convenient use of rooms, → (1)-(8). For common descriptions of doors in plan, → (9)-(16).

American balanced door, → (17)-(19), requires minimum effort to open and is suitable for passage doors in corridors, draught lobbies, etc.



EXTERNAL DOORS

14.1.1 External doors

are built
- to close the access
- to provide security

- They need to be weather resistant, provided by:
  - thickness
  - stability and durability of the construction
  - materials used together with protective coatings of paint or polish
- They should be constructed to maintain the insulation properties of the external walls.
- Standard sizes for external timber doors:
  1981 mm x 762 or 838 mm
  (high) (wide)
  and 45 mm thick
  (which is a metric conversion of the old Imperial door size)

Metric doors are produced so that, together with the door frames, they fit into a modular coordinated opening size and are usually supplied as door sets with the door already attached or hung to/in the frame.

INTERNAL DOORS

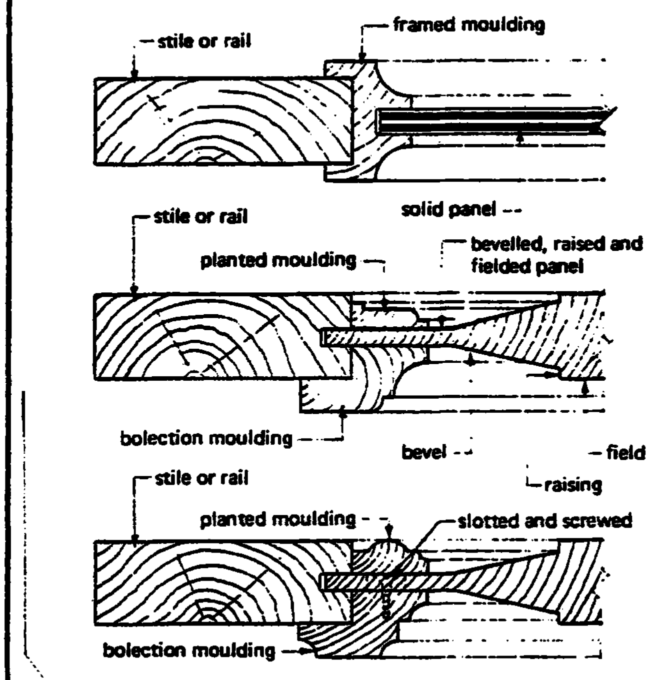
14.1.2 Internal doors

- As with external doors the aim of the design should be to maintain the properties of the wall in which they are housed.
- Generally: internal doors are thinner, standard sizes are similar to external doors, but with a wider range of width to cater for narrow cupboard openings.

PURPOSE MADE DOORS

14.1.3 Purpose made doors.

- The design and construction of these doors is usually based on B.S. 459 for standard doors, but are made to non-standard sizes, shapes ar designs.
- They are used mainly for
  - front elevation doors
  - in buildings such as
    banks
    civil buildings
    shops
    theatres
    hotels
    to beautify the external facade or internal decore.



Purpose made doors and mouldings

METHODS OF CONSTRUCTION

14.1.4 Methods of Construction.

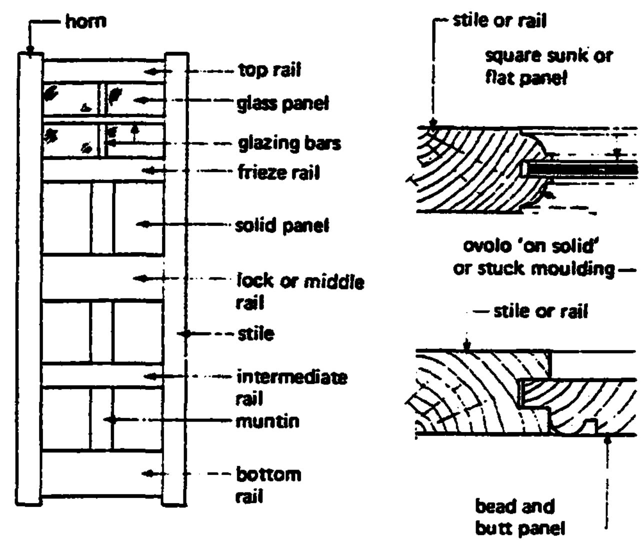
The B.S. for wood doors is divided into four parts, each being a different method of construction:

B.S. 459 Part 1:
Panelled and glazed wood doors
Part 2:
Flush doors
Part 3:
Fire-check doors
Part 4:
Match bearded doors.

Standard doors are used extensively since they are
- mass produced to known requirements
- readily available from stock
- and cheaper than purpose made doors.

DOOR TERMINOLOGY

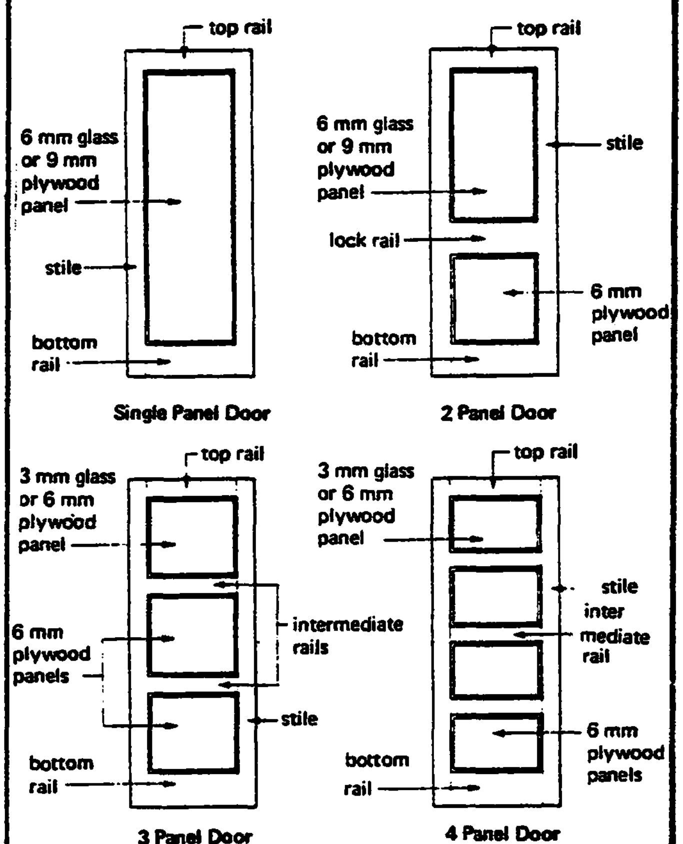
14.1.4.1 Door terminology



PANELLED &. GLAZED DOORS

14.1.4.2 Panelled and glazed wood doors

- The wide variety of types is based upon the one/two/three/ or four panel formate.
- They are constructed of timber which should be in accordance with BS 1186 with plywood or class panels.
- The joints used in framing the doors can be a dowelled joint or a mortice and tenon joint. (or double tenon joint)
  - The dowelled joint is considered superior to the mortice and tenon joint, and is cheaper when used in the mass production of standard doors. Bottom and lock rails have 3 dowels, top rails have two. Intermediate rails have a single one.
  - The plywood panels are framed into grooves with closely fitting sides, with a movement allowance within the depth of the groove of 2 mm.

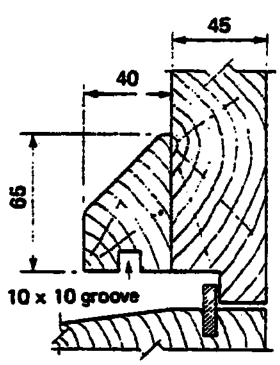


PANELLED&.GLAZED DOORS

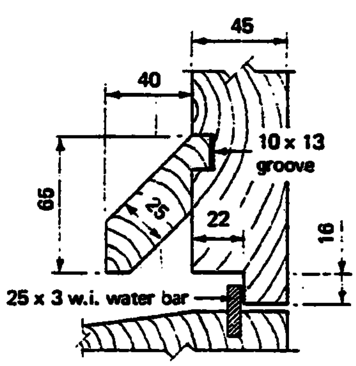
- The mouldings at the rail intersections are scribed, where as the loose glazing beads are mitred.
- Weatherboards for use on external doors can be supplied to fit onto the bottom rail of the door which can also be rebated to close over a water bar.

Terms :(Mortice and tenon)joints:

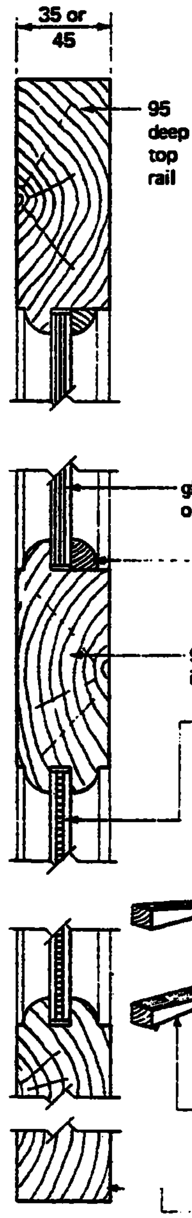
- Haunch
- Mortice: The top and bottom of the mortices are tapered in towards the rails, in order to give space to drive in small wood wedges when tenons are fitted.

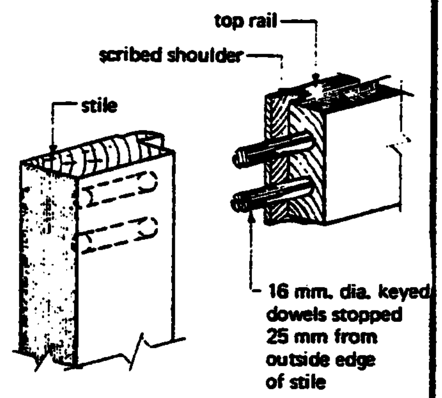


Standard Weatherboard

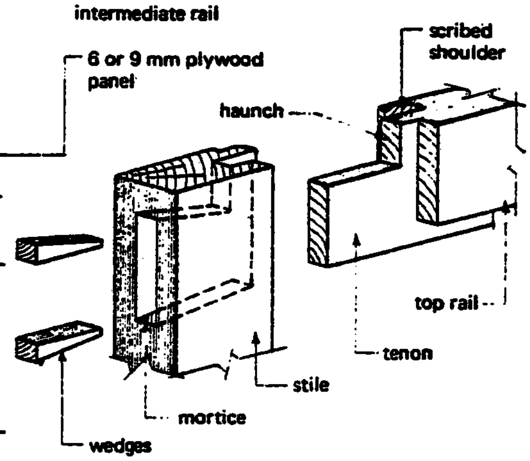


Non-standard Weatherboard





Typical Dowelled Joint



Typical Mortice and Tenon Joint

FLUSH DOORS

14.1.4.3 Flush doors

- Is very popular (with both the designer and the occupier)- it has a plain face which is easy to clean and to paint and is also free of the mouldings which collect dust.
- Flush doors can be faced with
  - hardboard
  - plywood or a
  - plastic laminate

FLUSH DOORS

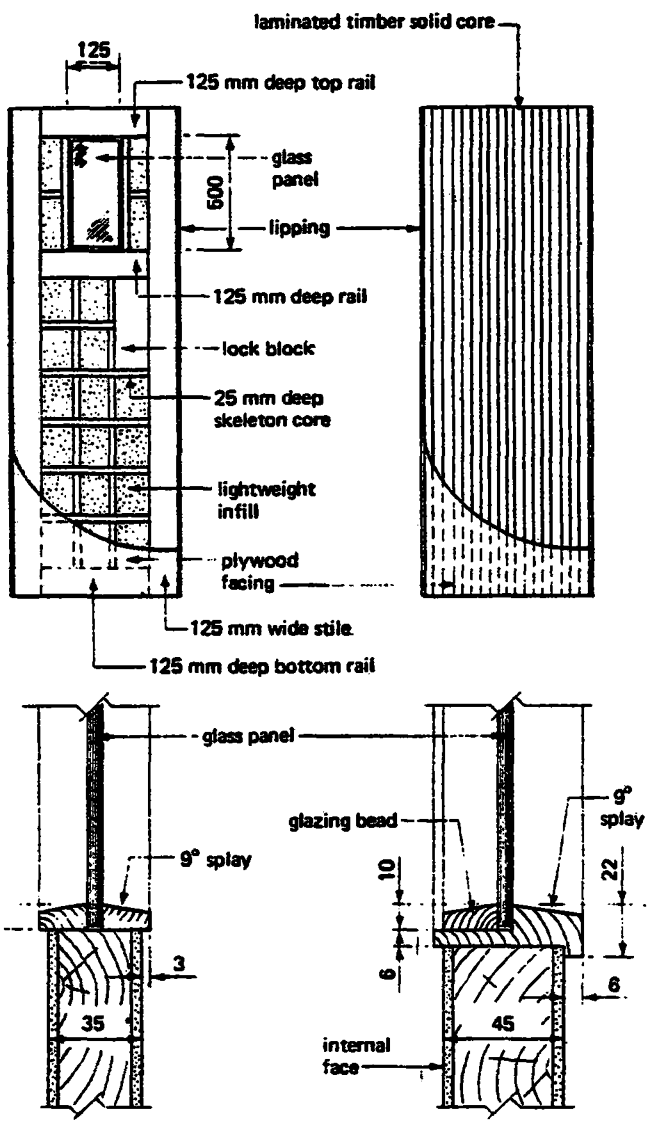
and by using a thin sheet veneer of good quality timber the appearance of high class joinery can be created.

- B.S. specifies the requirements for flush doors but leaves the method of construction to the manufacturer.

<u>therefore</u>: the forms of construction are many and vary, but <u>basically</u>: they can be considered as

-a- skeleton core doors or
-b- solid core doors.

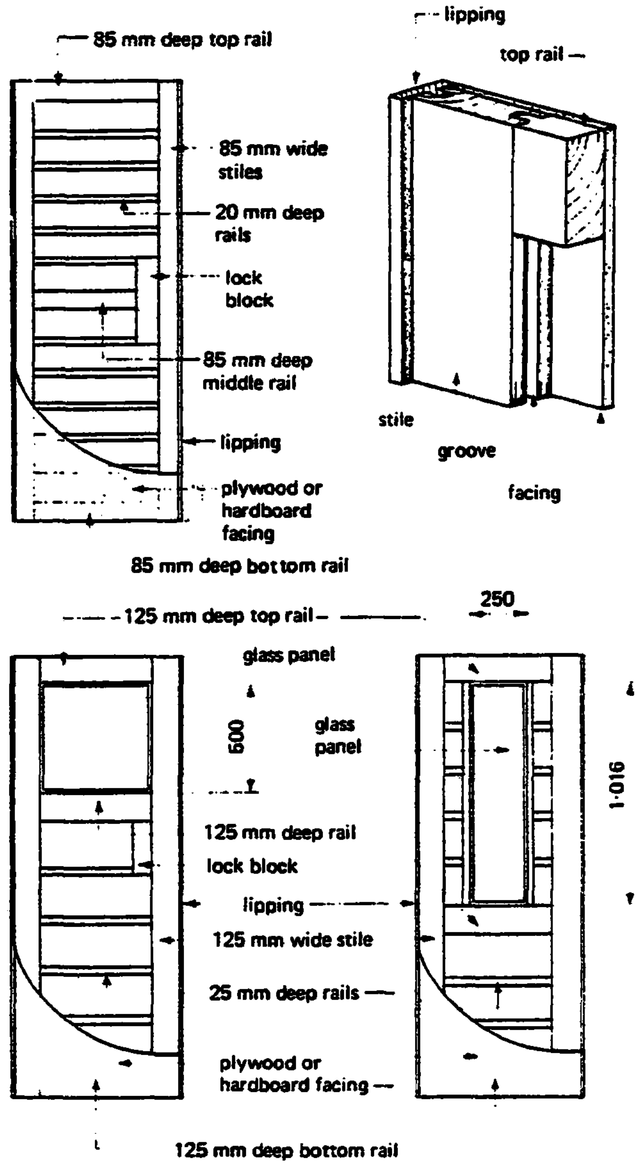
-a- consists of an outer frame with small section intermediate members over which is fixed the facing material. The facing has a tendency to deflect between the core members and this can be very noticeable on the surface especially if the facing is coated with gloss paint.



Internal Flush Door Glazing

External Flush Door Glazing

Solid core doors



Skeleton core flush doors

-b- solid doors of faced block or laminated board are available for
- internal and
- external

use.
Another method of construction is to infill the voids (created by a skeleton core) with a light weight material such as foamed plastic which will give support to the facings but will not add much to the weight at the door.

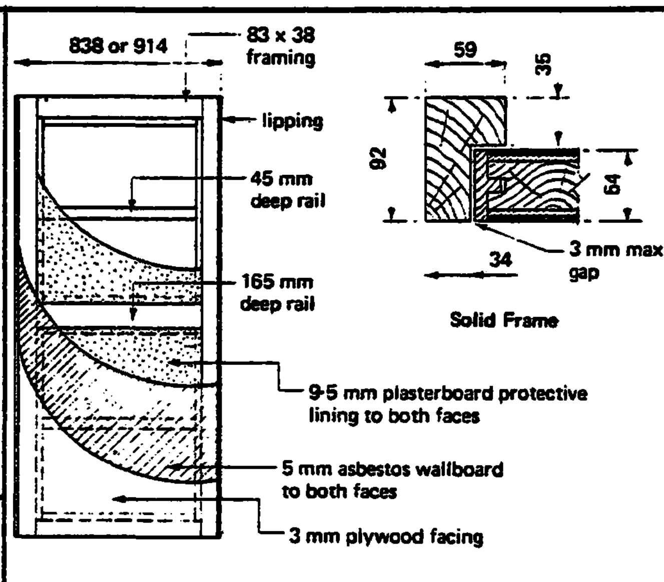
FLUSH DOORS

- The facings can be damaged easyly at the edges, therefore a lipping of solid material should be fixed to at least the vertical edges (good class doors have lippings on all four edges).
- Small glased observation panels can be incorporated in flush doors when the glass panel is secured by loose fixing beads.

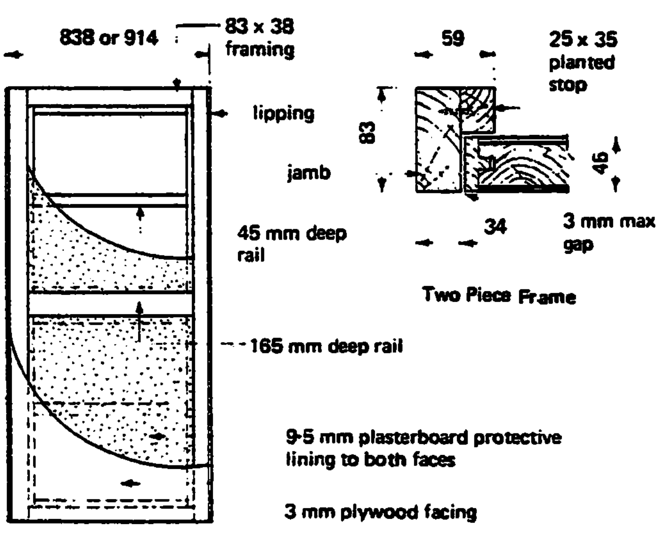
FIRE-CHECK FLUSH DOORS

14.1.4.4 Fire-check flush doors

- Provide an effective barrier to the passage of fire for the time designated by their type - but, to achieve this they must be used in conjunction with the correct frame.



One Hour Type Fire-check Door and Frame



Half-hour Type Fire-check Door and Frame

- Two types are mentioned in BS 459:
  - half-hour resistance
  - one -hour resistance
- This resistance is obtained by placing beneath the ply wood facing a suitably protective lining material (or materials).

Half-hour types are hung using one pair of hinges

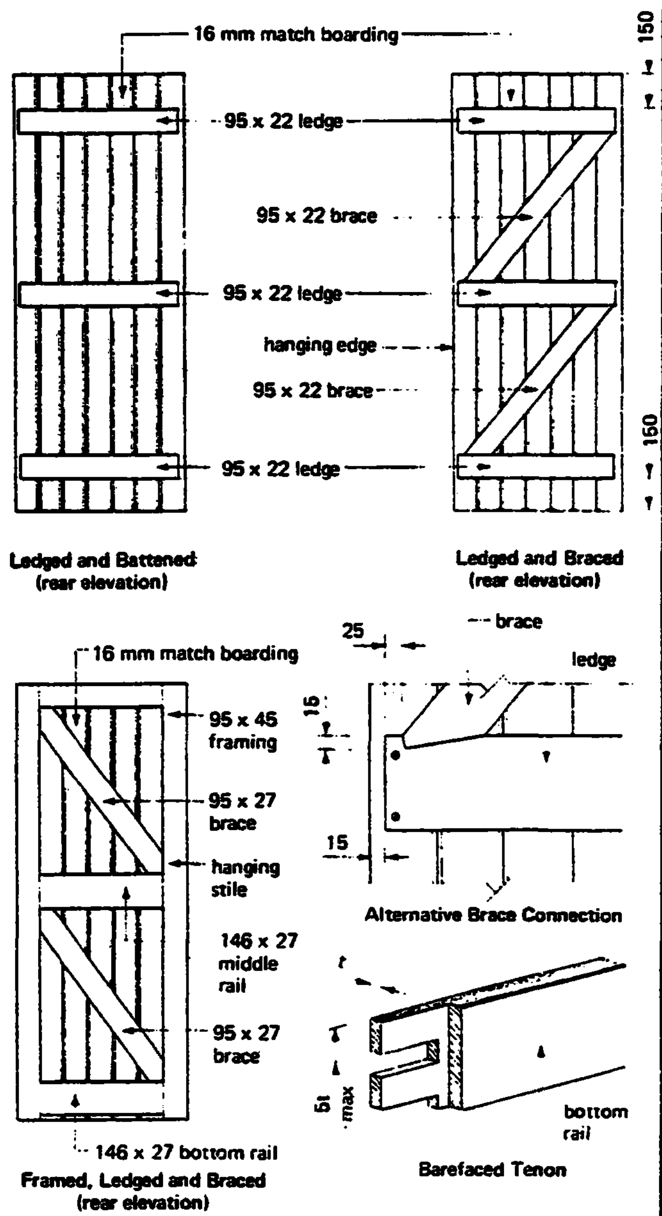
One-Hour types require 1 1/2 pairs of hinges.

MATCHBOARDED DOORS

14.1.4.5 Matchboarded doors

- These doors can be used as
  - . external and
  - . internal doors.
- There are 2 formes of standard doors:
  - . ledged and braced or
  - . framed, ledged and braced doors.

  (The latter is the stronger and more attractive version)
- The face is made from tongue and grooved boarding which has edge chamfers on one or both faces. - these form a Vee-joint between the boards.
- 3 horizontal members ('ledges') clamp the boards together - and in this form a non-standard door has been made, called: ledged and battened.
- . It is simple and cheap to construct, but it can be easily pulled out of square - the only resistance is that of nails, holding the boards to the ledges.
- . The use of that type is limited to buildings such as
  - sheds
  - outhouses etc.
  - In the standard door:
    - . Braces are added to resist the tendency to drop out of square.
    - . The braces are fixed between the ledges so that they are parallel to one another and slope downwards towards the hanging edge.
  - In the second standard type a mortice and tenoned frame surrounds the match boarded panel giving the door added strength.
  - If wide doors of this form are required the angle of the braces becomes too low to be value as an effective restraint and the brace must therefore be framed as a diagonal between the top and bottom rails. Wide doors of this design are not covered by B.S. but are often used in pairs as garage doors or as wide entrance doors to workshops or similar buildings.

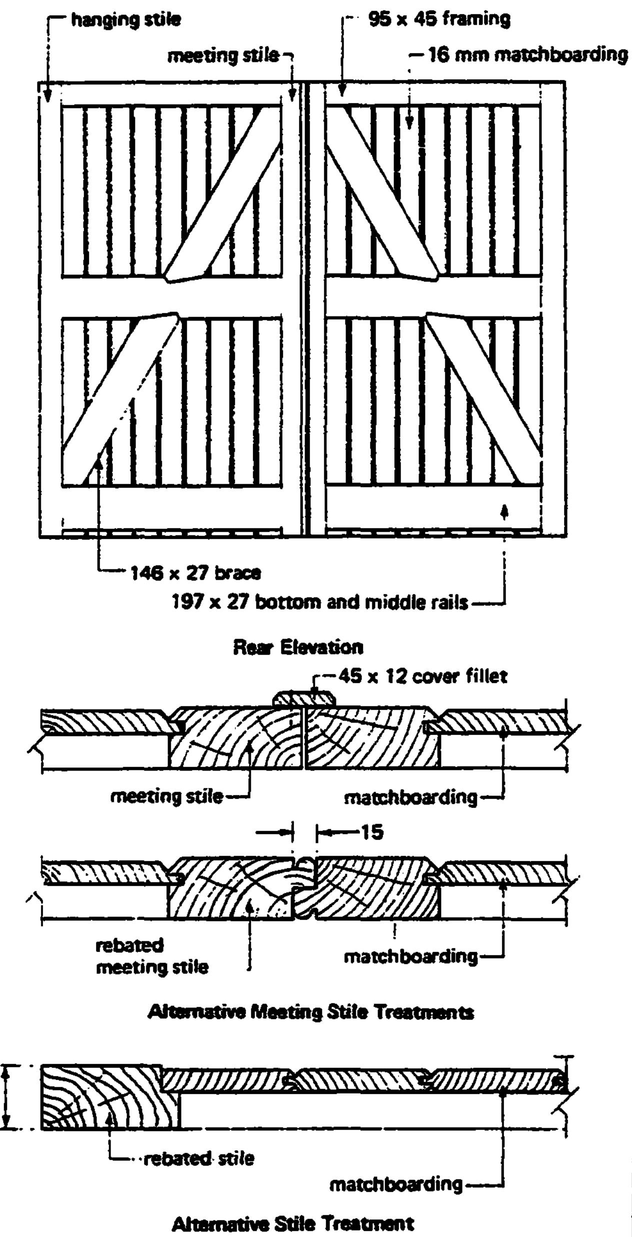


Matchboarded doors

MATCHBOARDED DOORS

- The operation of fixing a door to its frame or lining is termed hanging and entailes.
  - removing the protective horns from the top and bottom of the stiles
  - planing the stiles to reduce the door to a suitable width.
  - cutting and planing the top and bottom to the desired height.
  - marking out and fitting the butts or hinges which attach the door to the frame.
  - fitting any locks and door furniture which is required.
  - The hinges should be positioned 225 mm from the top and bottom of the door and where 1 1/2 pairs are specified for heavy doors the third hinge is positioned midway between the bottom and top hinge.
- A door has to be treated properly during
  - transportation
  - storage
  - after hanging.

+ It should receive a wood priming coat of paint before or immediately after delivery,
+ be stored in the dry and in a flat position (so that it does not twist)
+ receive the finishing coats of paint as soon as practicable after hanging.



Matchboarded double doors

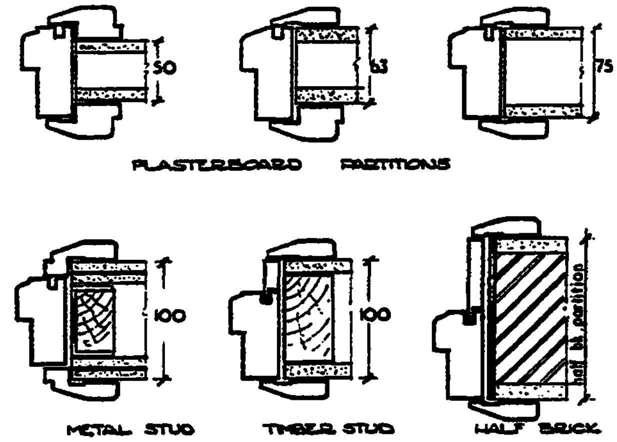
FRAMES and LININGS

14.1.5 Frames and Linings

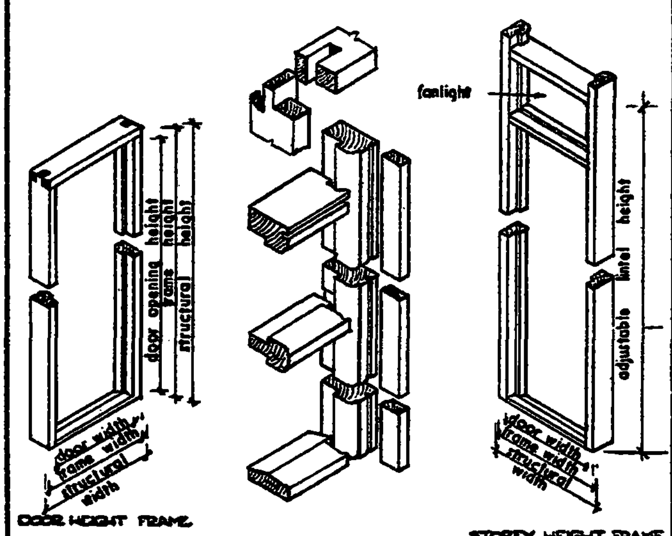
- A door frame or lining is attached to the opening in which a door is to be fitted, it provides a surround for the door and is the member to which a door is fixed or hung.
- Door sets are consisting of a story height frame with a solid or glazed panel over the door head.

14.1.5.1 Timber Door Frames

- Are made from rectangular section timber in which a rebate is formed or to which a planted door stop is fixed to provide the housing for the door.
- Generally a door frame is approximately twice as wide its thickness plus the stop.
- A timber door frame consists of three or four members:
  - . one head
  - . two posts or jambs
  - . one sill or threshold.
- The members can be joined together by
  - . wedged mortice and tenon joints,
  - . combed joints or
  - . mortice and tenon joints pinned with a metal star shaped dowel or a round timber dowel.
- All joints should have either a coating of adhesive or a coating of a lead based paint.
- Door frames which do not have a sill are fitted with mild steel dowels driven into the base of the jambs and cast into the floor slab or alternatively grouted into pre-formed pockets as a means of securing the feet of the frame to the floor.



DOOR FRAME COMPONENTS

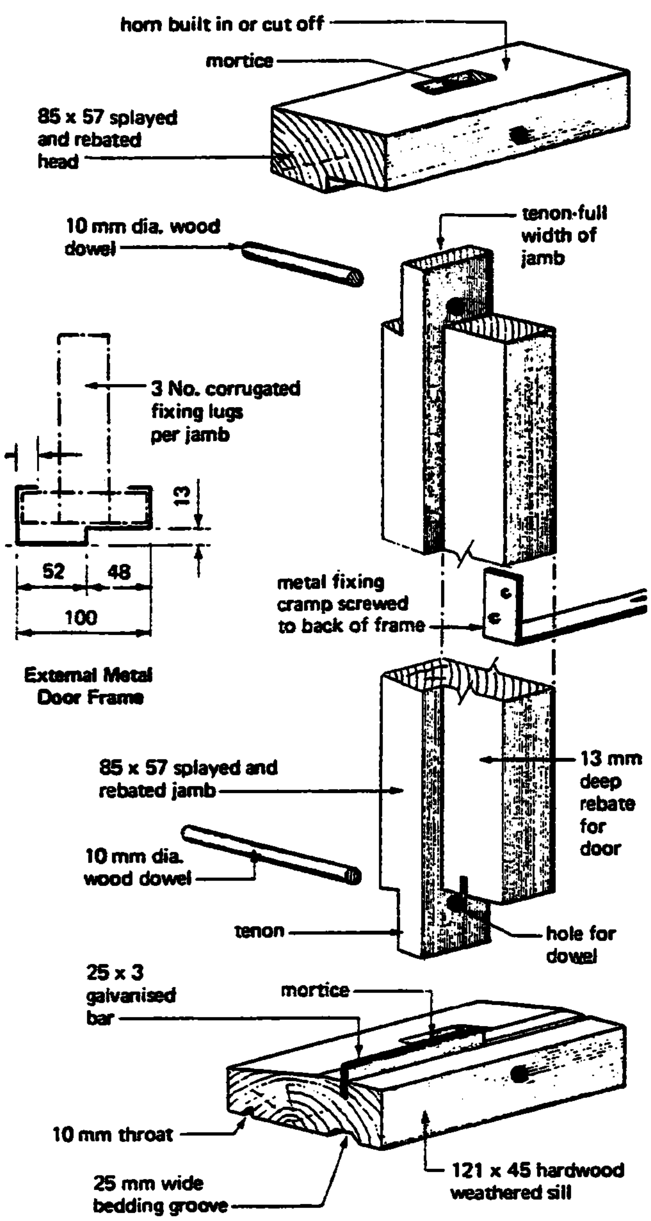


TIMBER DOOR FRAMES

- If the frame is in an exposed position it is advisable to site the feet of the jambs on a damp-proof pad, such as lead or bituminous felt, to prevent moisture soaking into the frame and creating the conditions for fungi attack.
- Door frames fitted with a sill are designed for one of two conditions:
  1. Doors opening out
  2. Doors opening in .

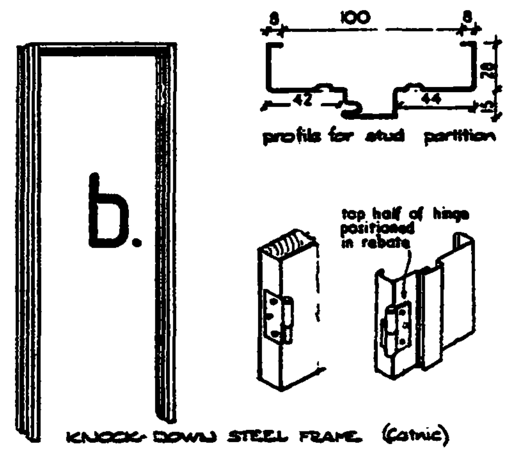
  In both cases the sill must be designed to prevent the entry of rain and wind under the bottom edge of the door.
  - Doors opening out close onto a rebate in the sill
  - Doors opening in have a rebated bottom rail and close over a water bar set into the sill.
- Timberdoor frames can be fixed to a wall by the following methods:
  a) Built into the brick or block wall as the work proceeds by using 'L'shaped ties or cramps.
  The ties are made from galvanised wrought steel with one end turned up 50mm, with 2 holes for wood screws, on the other end being 125 or 225 mm long and fishtailed for building into brick or block bed joints. The ties are fixed to the back of the frame for building in at 450 mm centres.
  b) Fixed into a brick opening at a late stage in the contract to prevent damage to the frame during the construction period.
  This metod is more expensive, but results in a better quality of joinery work.
- The frames are fixed to timber plugs inserted into the reveals with wood screws, whose heads are sunk below the upper surface of the frame.

DOOR FAMES



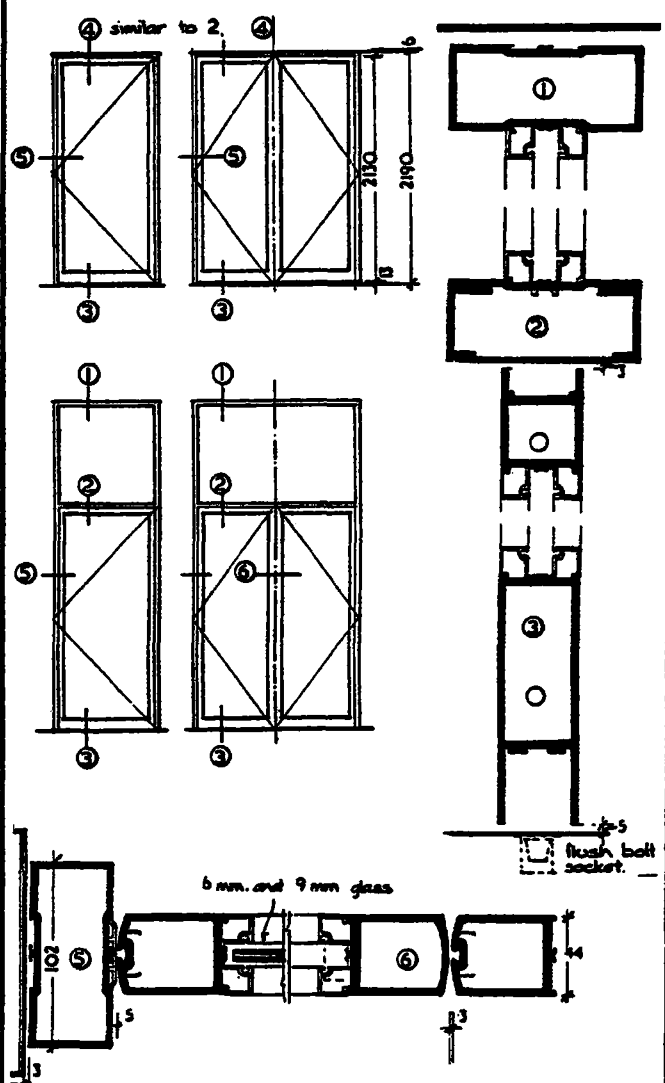
METAL DOOR FRAMES

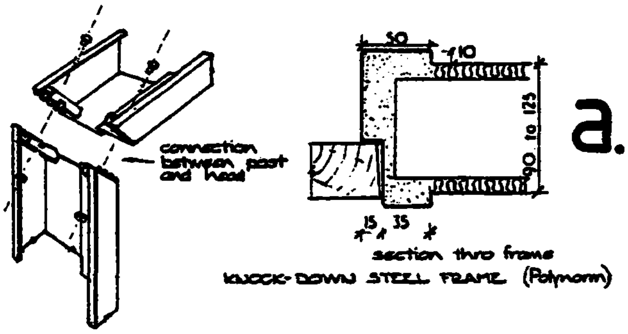
a.) STEEL FRAME 'PolyNORM'
b) STEEL FRAME 'CATNIC'
c.) STAINLESS STEEL FRAME



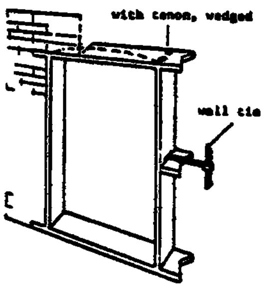
14.1.5.2 Metal door frames

- These are made from mild steel pressed into one of three standard profiles.
- They are suitable for both internal and external positions.
- The hings and striking plates are welded on during manufacture and the whole frame receives a rust-proof treatment before delivery.
- The frames are fixed in a similar manner to timber frames using a tie or lug, which fits into the back of the frame profile and is built into the bed joints of the wall.
- The advantage of this type of frame is that they will not shrink or warp, but they are more expensive than timber ones.

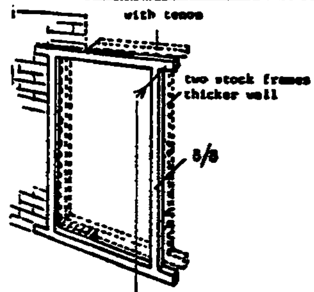




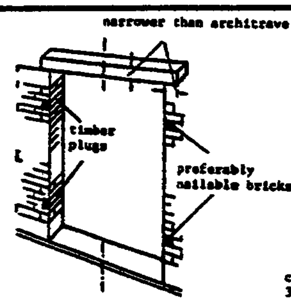
DOOR FRAMES



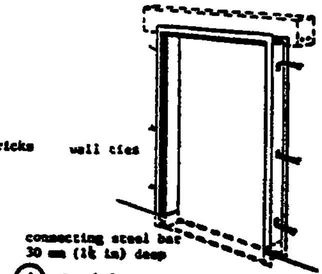
① Plank subframe



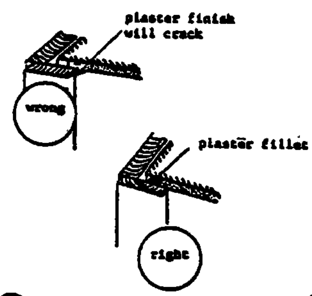
② Stock subframe



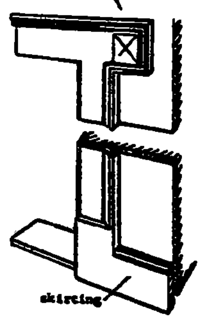
③ Timber plugs and timber lintel



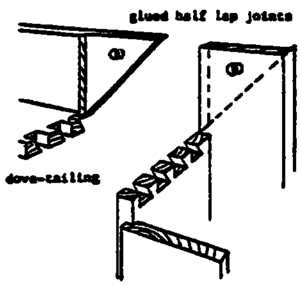
④ Steel frame



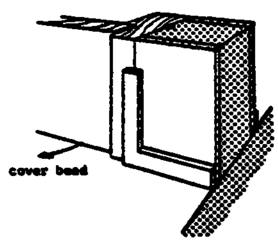
⑤ Connection to plaster



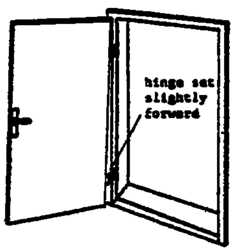
⑥ Traditional architrave for timber subframe



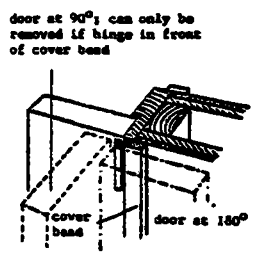
⑦ Skilfully executed corner detail



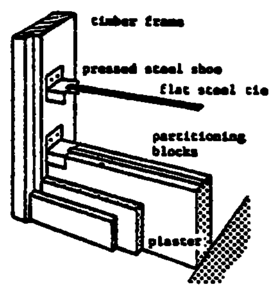
⑧ Modern stock frame for thin partitions



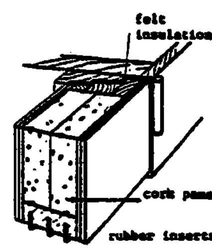
⑨ Correct fixing of door, with door slightly open



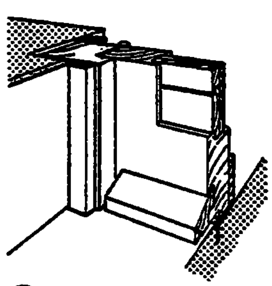
⑩ Easy removal of door at 90° or 180° (Continental type hinge)



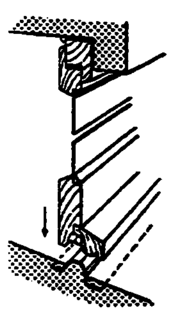
⑪ Frame fixed in light partition



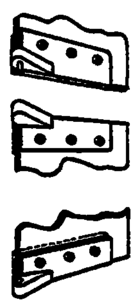
⑫ Sound-proof door with insulated threshold



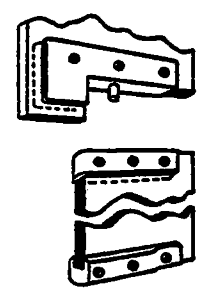
⑬ Entrance door



⑭ Rising French door

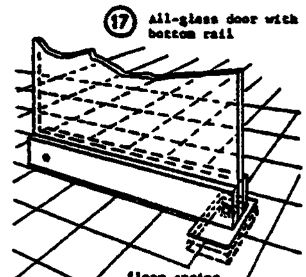


⑮ One sided hinge for all-glass doors with fan light



⑯ Swing door hinges for all-glass doors with fan light

⑰ All-glass door with bottom rail



Timber subframes and plugs require lining and architrave, which must cover up the plaster.

For the best finish the lining must be dovetailed and the architrave half-mitred, → (7). Planed stock frames for light partitions are also a guide for the plaster finish and are erected before putting up partition blocks, → (8); to avoid damage, doors should be easily removable, → (10).

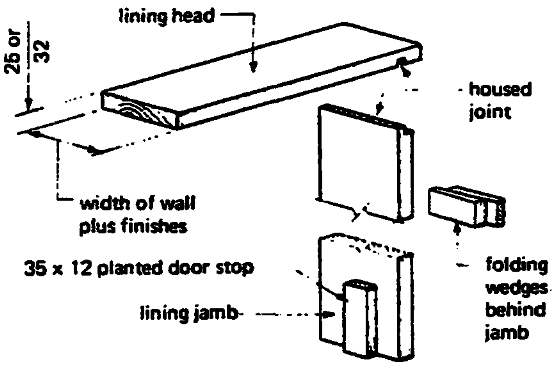
Doors in thin partitions are fixed in steel, → (8), or timber frames with wall tie, → (11). For outside doors plywood must be of external quality; timber doors (weather boarding), steel doors or steel-framed doors with glass panels are preferable. Panels in external doors must overlap, → (13). For French doors on balconies, doors should have rising gear, → (14).

In modern office blocks etc. frameless all-glass doors (armour-plate glass) are used, → (15)-(16), often with automatic electrically-operated opener and floor springs, → (17)

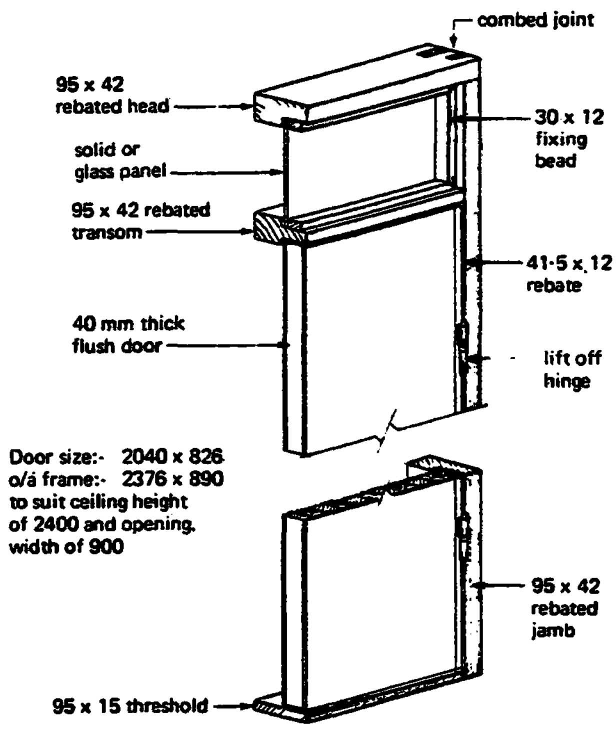
DOOR LININGS

14.1.5.3 Door linings

- These are made from timber board 25 or 35 mm thick and as wide as the wall and any wall finishes.
- They are usually only specified for internal doors.
- Door linings are not built in but are fixed into an opening by nailing or screwing directly into block walls or into plugs in the case of brick walls.
- Timber packing pieces or folding wedges are used to straighten and plumb up the sides or jambs of the linings.



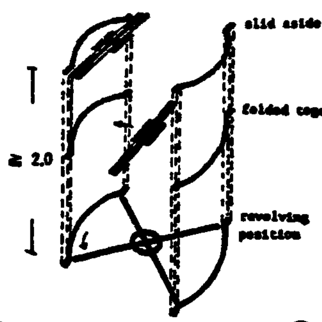
Typical Door Lining



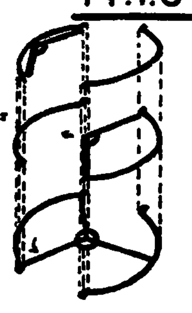
Typical Door Set

Door linings and door sets

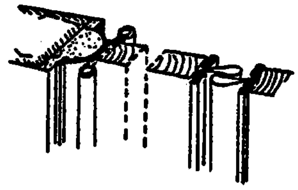
14.1.6 SPECIAL DOORS



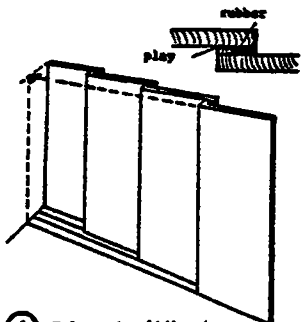
① Revolving door, compartments 1.8 m (5 ft 9 in)



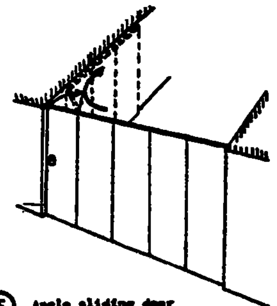
② Revolving door, compartments 1.5 m (4 ft 9 in)



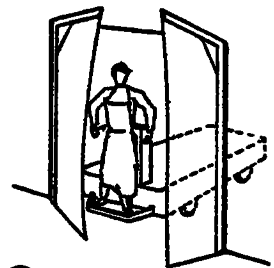
③ Swing door with rubber draught seal and steel frame



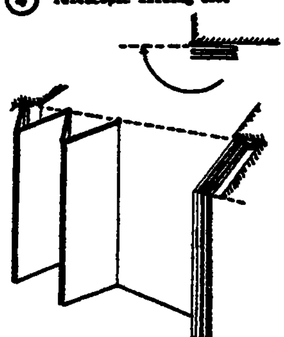
④ Telescopic sliding door



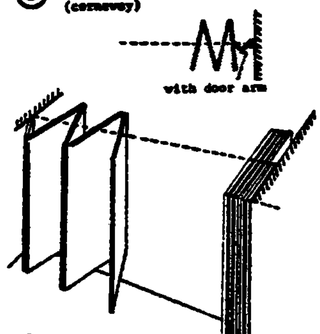
⑤ Angle sliding door (cornaway)



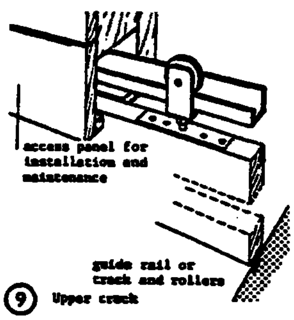
⑥ Rubber swing door



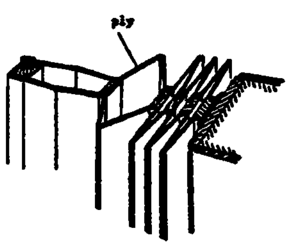
⑦ Folding doors (foldaway)



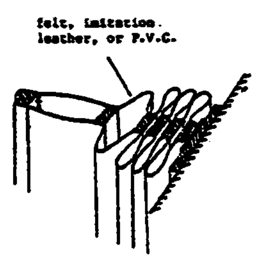
⑧ Folding doors (centafold)



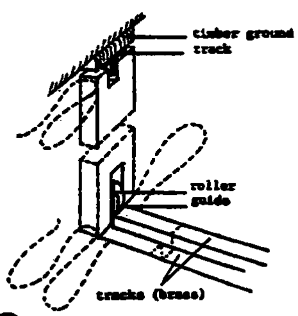
⑨ Upper track



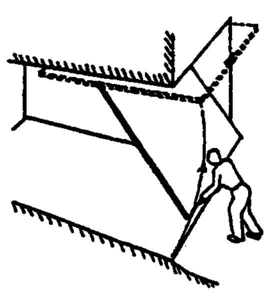
⑩ Concertina folding door (plywood)



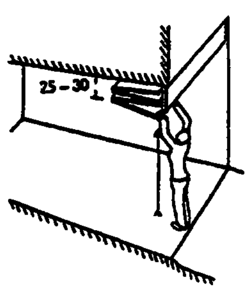
⑪ Concertina folding door (fabrics)



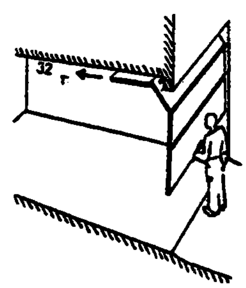
⑫ Upper and lower track



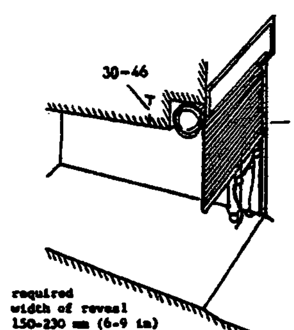
⑬ Overhead door (flyover)



⑭ Overhead door (foldaway)



⑮ Overhead door, sectional (flyover trader)



⑯ Roller shutter

Revolving doors have wings which may be folded back during peak traffic, especially in summer. Wings are folded away completely if traffic is in one direction only (e.g. at closing time).

Swing doors have spring, check and helical hinges, or shoes and top centres and floor springs. To stop swing and achieve air-tightness, interchangeable draught seals are inserted at meeting styles, → (3).

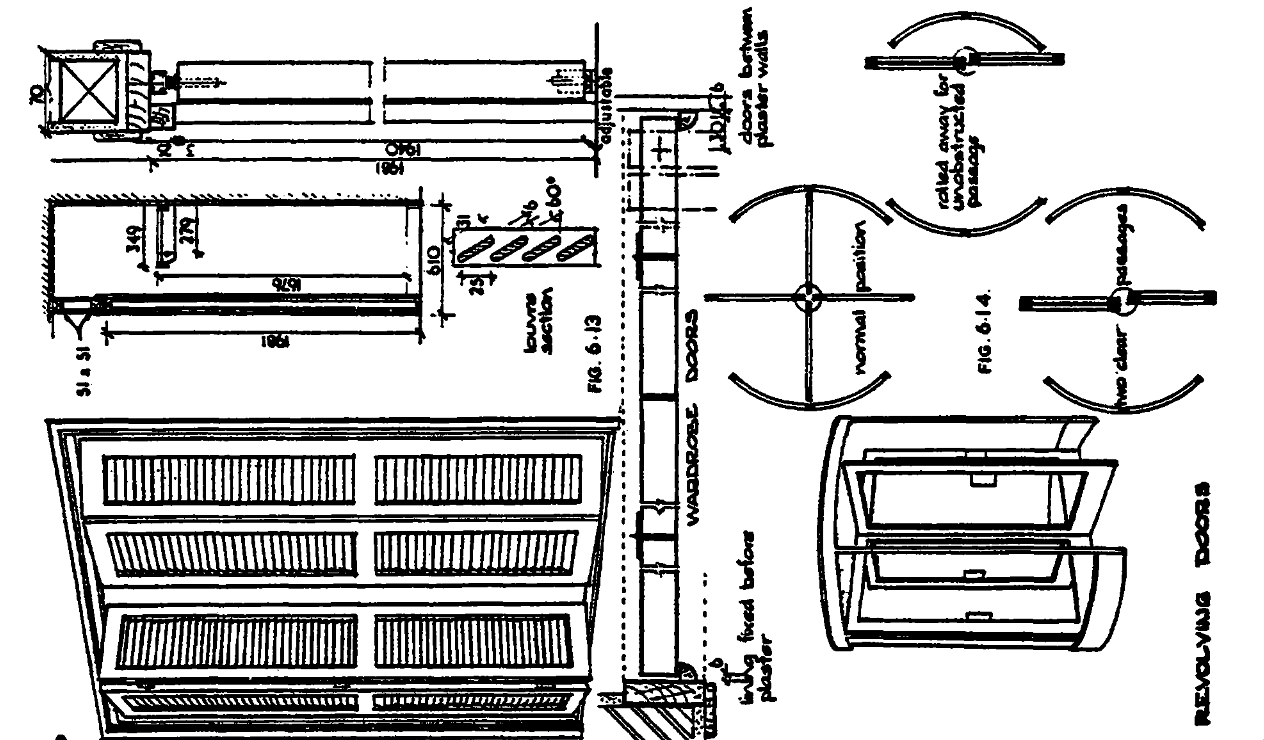
Large openings (partitions), etc, which cannot be closed by normal swing doors are fitted with special sliding doors, sliding-folding doors, or concertina-folding doors, → (4)-(8). Such doors have hangers (top hung) or rollers (bottom rolling), → (9); rollers, as in lightweight concertina doors, → (12), are infrequently used.

Narrow rooms which provide no space for sliding doors may be closed by overhead doors sliding beneath ceiling, → (13)-(16).

All these doors can be electrically operated and this is especially suitable for large openings with heavy door structures (garages, hangars, etc).

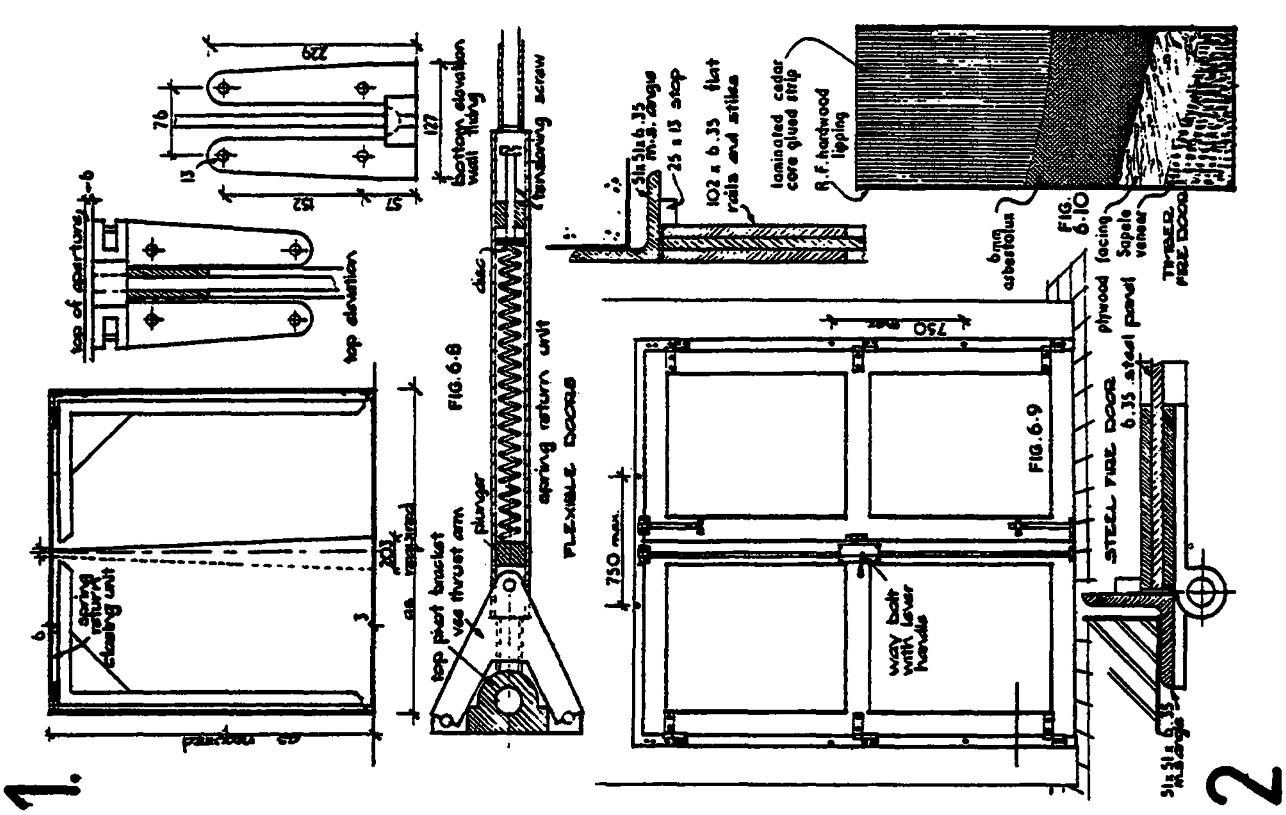
Adjustable fillet rails are necessary at the meeting styles of large doors to cope with temperature fluctuations in steel doors and shrinkage in large timber doors.

1.FLEXIBLE DOOR 2.STEEL FIRE DOOR
3.WARDROBE DOOR 4.REVOLVING DOOR



3.

4.

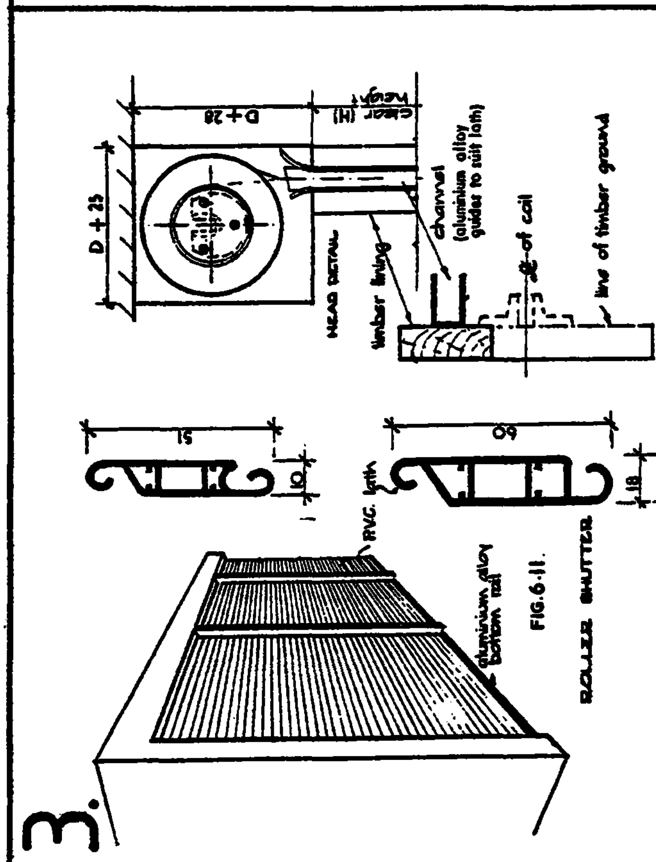


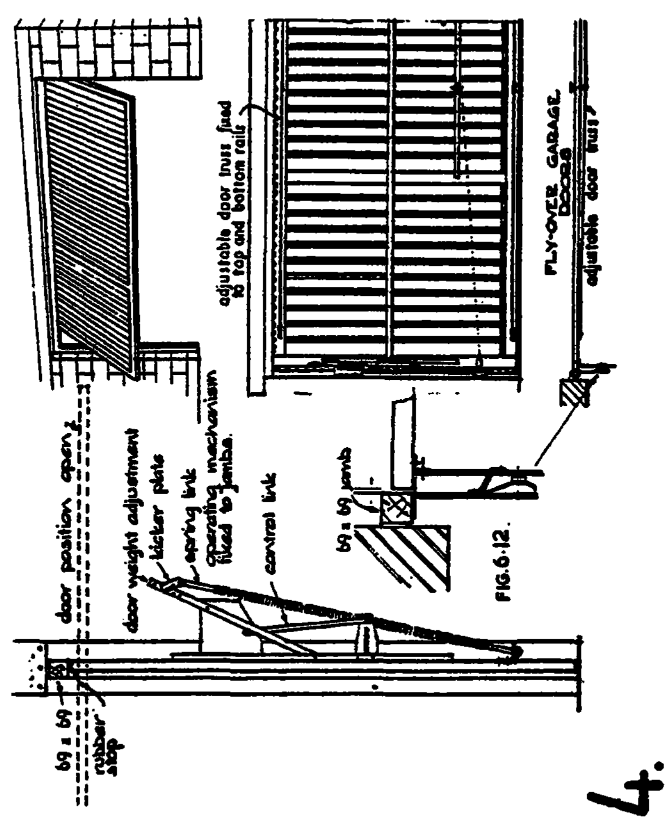
1.

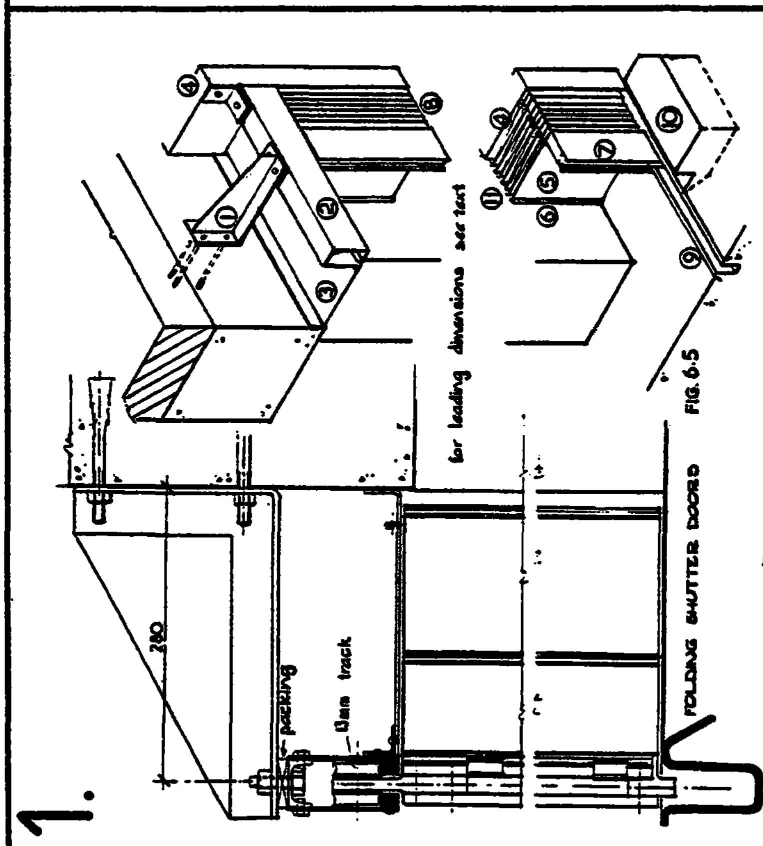
2

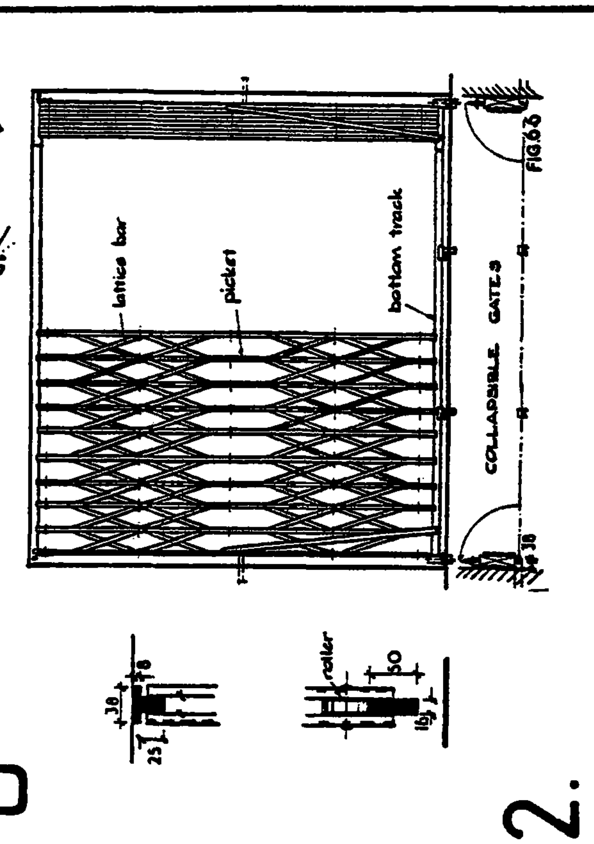
14.DOORS & WINDOWS	DOORS	BUILDING CONSTR.
compiled : D.VOLKE		LECTURE
JAN. '83		CET 8031/1 14.1 17

1.FOLD. SHUTT. DOOR 2.COLLAPS.GATE
3.ROLLER SHUTTER 4.FLY-OVER DOOR



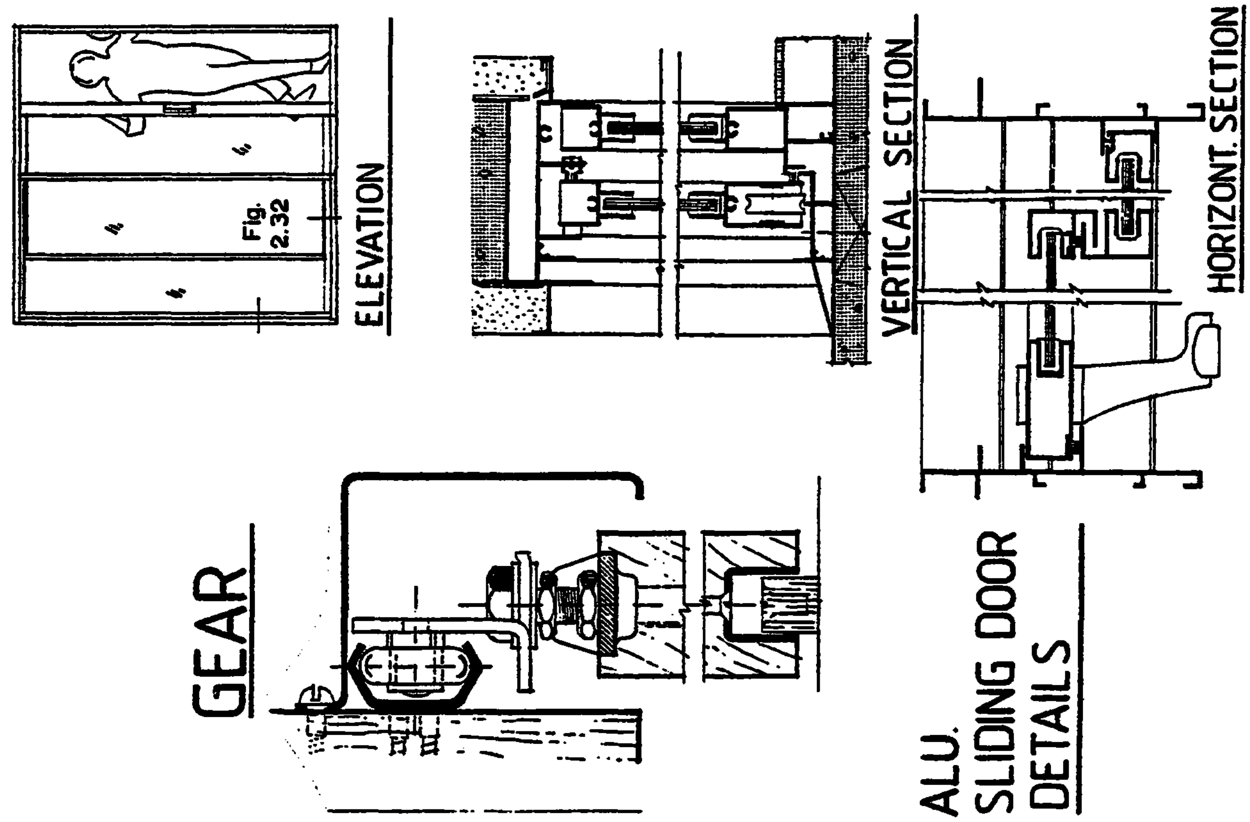


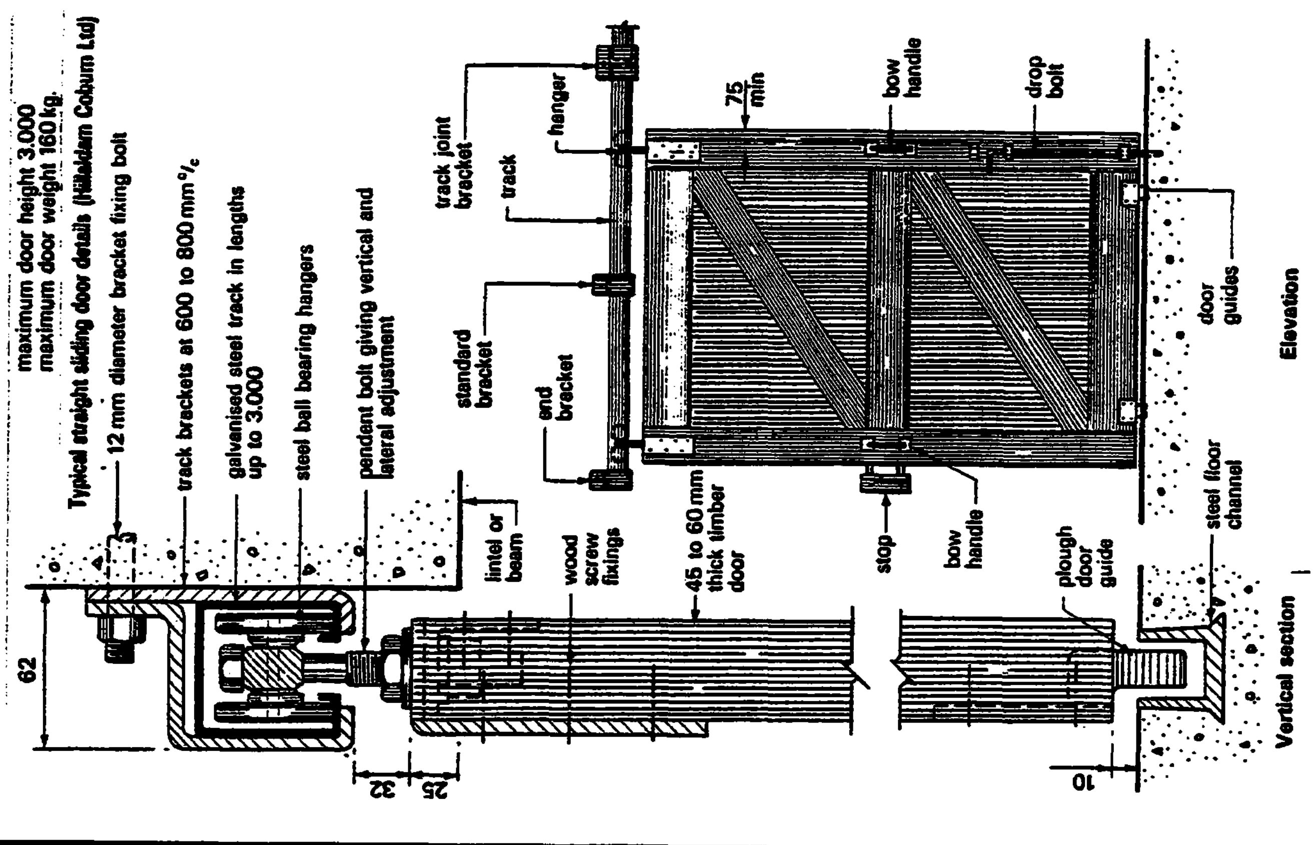




14. DOORS & WINDOWS compiled : D. VOLKE JAN. /83	DOORS	BUILDING CONSTR. —LECTURE— CET 8031/1 14.1 18

SLIDING DOORS

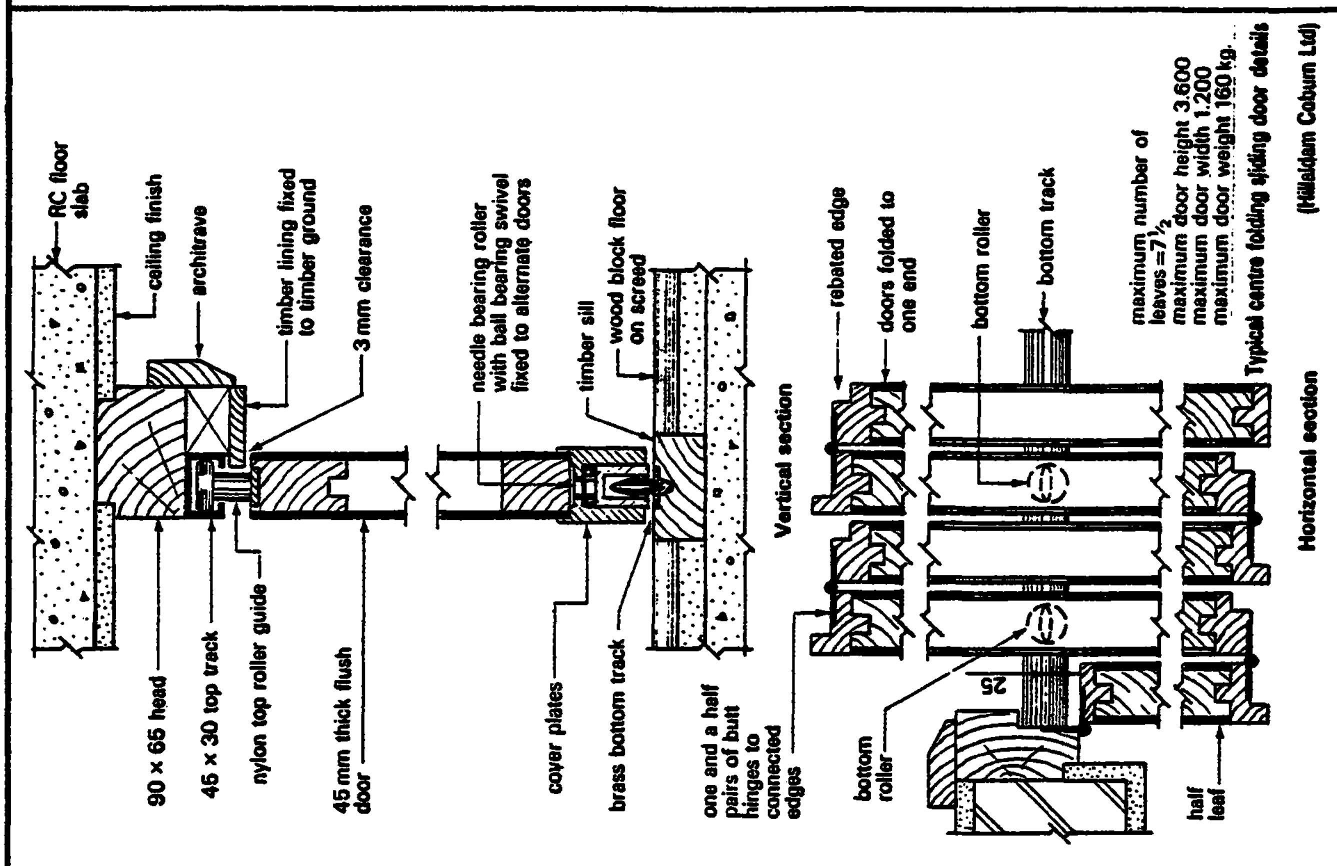


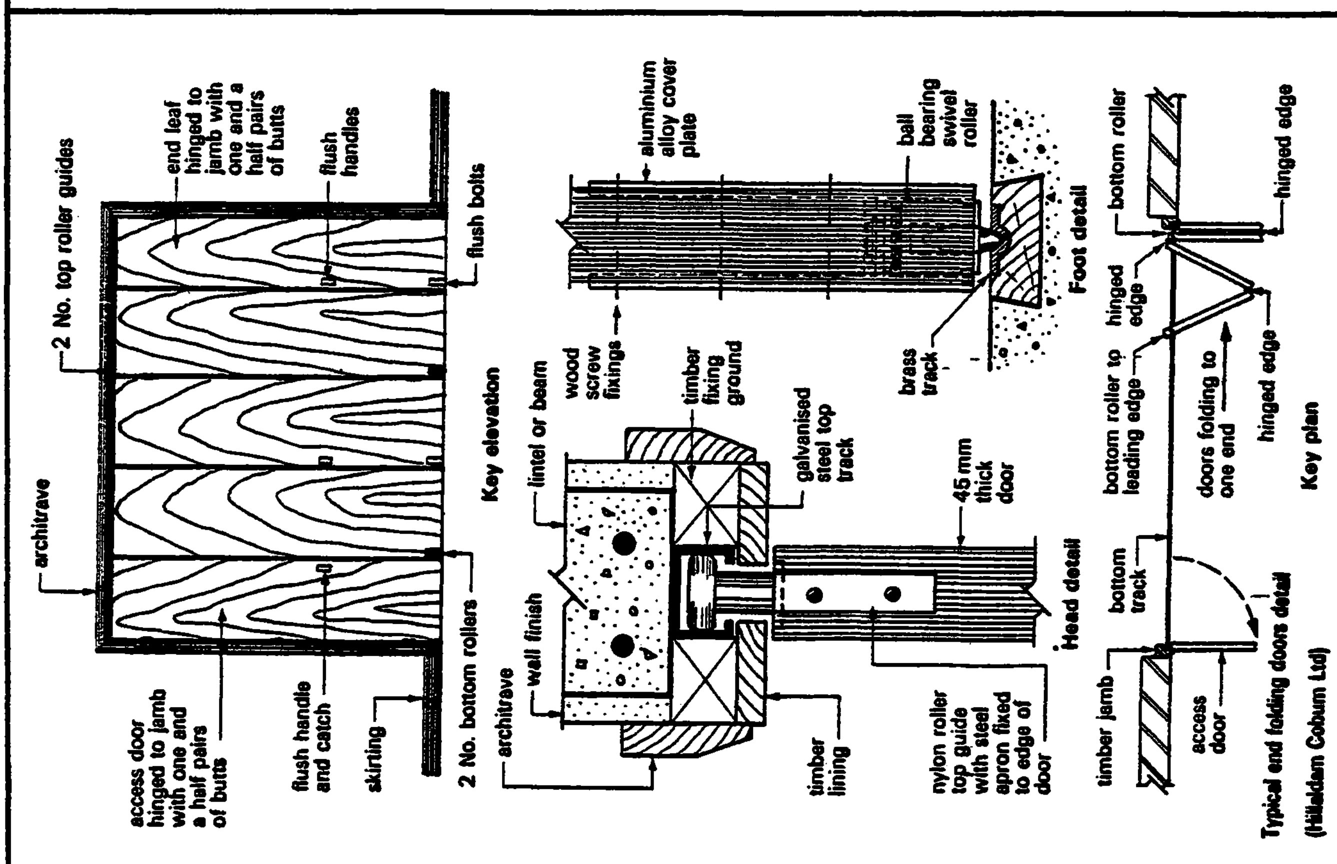


14. DOORS & WINDOWS	DOORS	BUILDING CONSTR.
compiled : D. VOLKE		LECTURE
JAN. 83		CET 8031/1 14.119

TCA	TECHNICAL COLLEGE ARUSHA CHUO CHA UFUNDI ARUSHA	CIVIL ENGINEER. DEPARTMENT	19

FOLDING DOORS





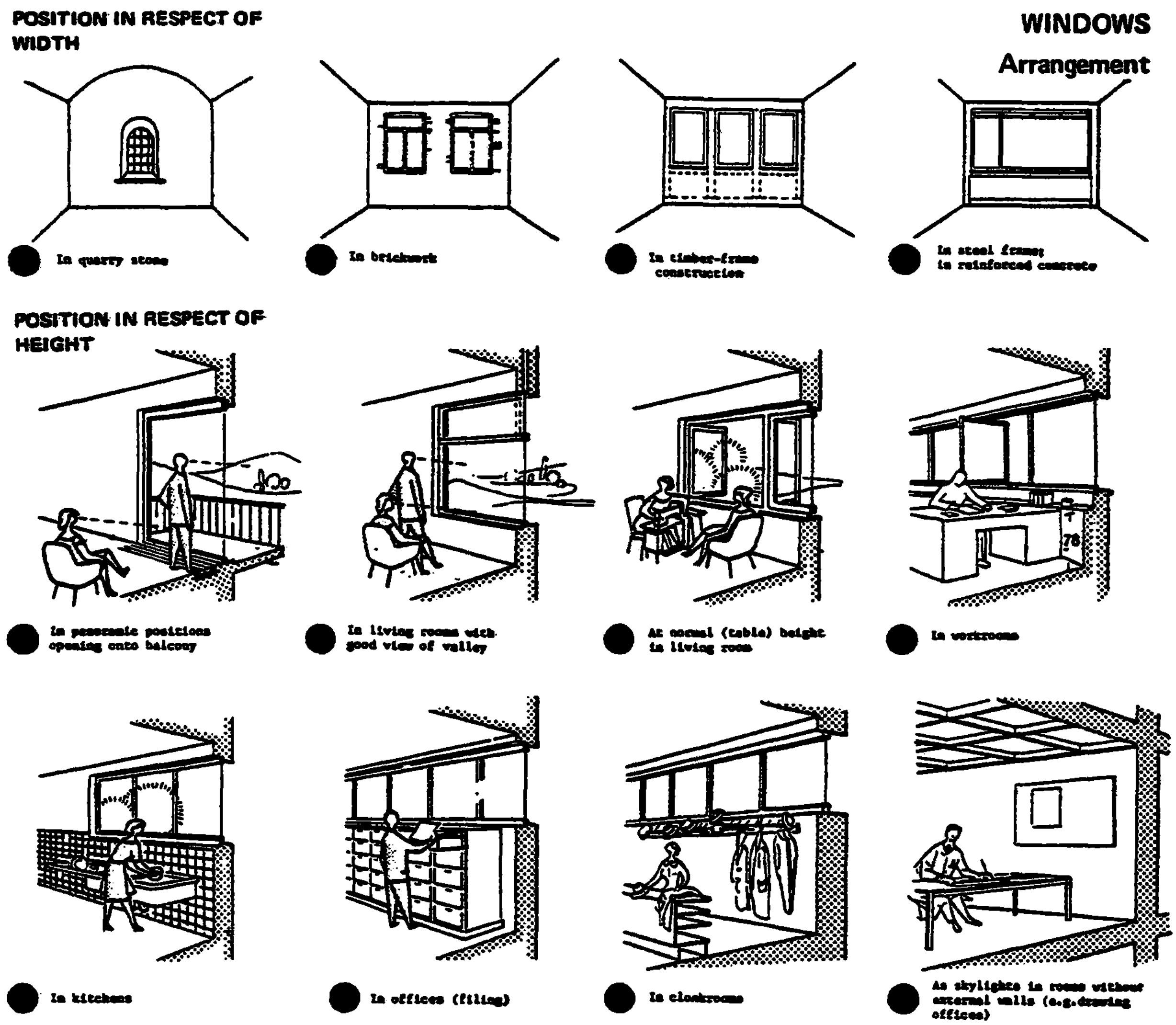
14. DOORS & WINDOWS compiled : D.VOLKE JAN. '83	DOORS	BUILDING CONSTR. LECTURE CET 8031/114.12o
TCA TECHNICAL COLLEGE ARUSHA CHUO CHA UFUNDI ARUSHA	CIVIL ENGINEER. DEPARTMENT	20

14.2 WINDOWS,GLASS &.GLAZING

PRIMARY FUNCTIONS OF WINDOWS

14.2.0 Primary Functions of Windows:

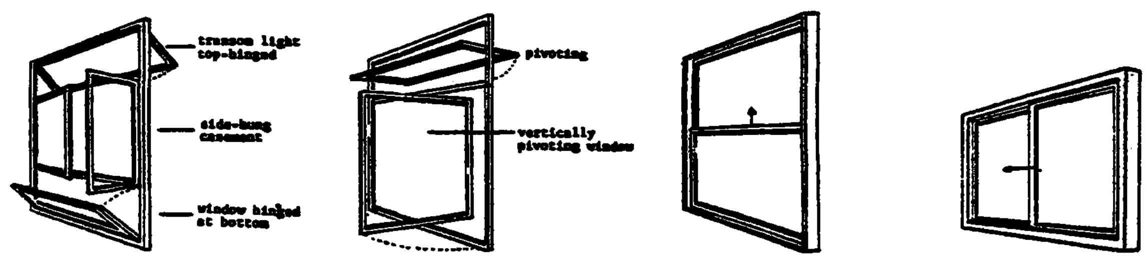
- to provide a means for admission of natural daylight to the interior of a building.
- to provide a means of the necessary ventilation of buildings by including opening lights into the windows.
- A window not only provides daylight and ventilation, also a view at the external surroundings, which is vital for the occupants.



- Windows, like doors, can be made from different materials (or a combination of these such as:
  - timber
  - metal and
  - plastic
- They can also be designed to operate in different ways by arranging for the sashes
  - to slide (vertically or horizontally
  - to pivote (vertically hung, horizontally hung)
  - to swing, by being hung to one of the frame members. This is known as a CASEMENT WINDOW and it is the most widely used type of windows.

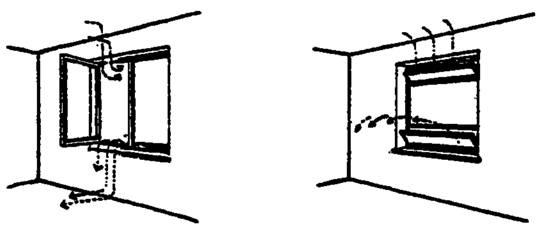
PRIMARY FUNCTIONS

TYPES OF OPENING



- Hinged casements (inwards and outwards)
- Pivoting window
- Vertical sash
- Horizontal sliding sash

VENTILATION

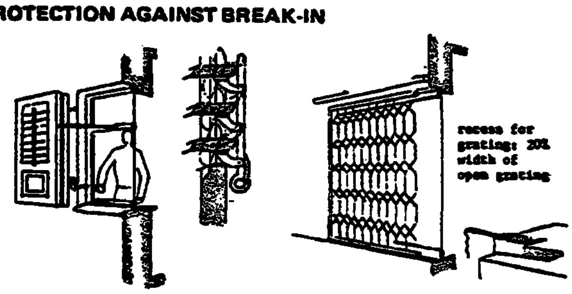


- Cold air falls into room, hot air escapes: draughts.
- Flaps improve ventilation

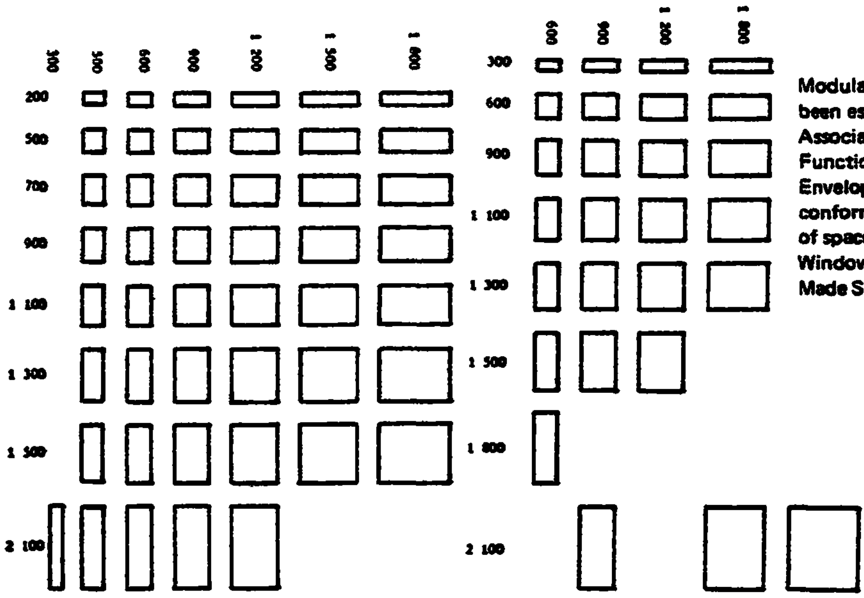
VENTILATION

PROTECTION

PROTECTION AGAINST BREAK-IN



- Shutters controlled by handle from inside
- Telescopic grating sliding in recesses



Basic spaces in mm for standard steel windows as issued by the Steel Window Association: (left) Housing (right) Other Building Types (purpose made steel windows).

Window spaces

Modular basic spaces for steel windows have been established for UK by the Steel Window Association from matrices produced by BSI Functional Group Panel B/94/4/2 (External Envelope), with lengths of basic spaces conforming to BS 4011. There are two ranges of space sizes: 1 Housing (Standard Steel Windows): 2 Other Building Types (Purpose Made Steel Windows).

BUILDING REGULATIONS

14.2.1 Building Regulations

K1 K2 K3

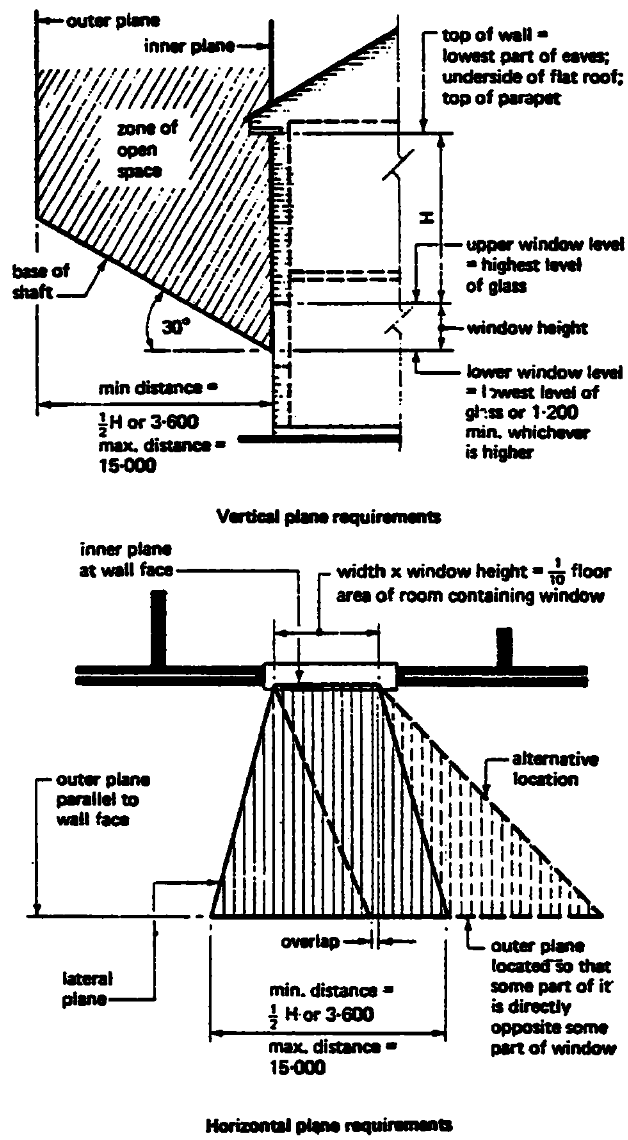
- Regulations K1, K2 and K3 deal with the daylight aspect of the windows.
  - These regulations require for an OPEN SPACE outside windows of habitable rooms (open to the sky and free from obstructions.
  - The minimum size of the open space is related to the height of the wall containing the window.
  - The height is measured from the lower window level (= actual or a min. of 1.20m above the floor to the top of the wall (1. Soffit of a flat roof; 2. lowest part of the eaves for a pitched roof; 3. the top of a parapet, wether the roof is flat or pitched).

K4

- BR K4 deals with the VENTILATION OF HABITABLE ROOMS. (For the purpose of this regulation, a room used i.e. for a kitchen is classified as a habitable room) A HABITABLE ROOM must have ventilation openings (unless it is adequately ventilated by mechanical means.

BUILDING REGULATIONS

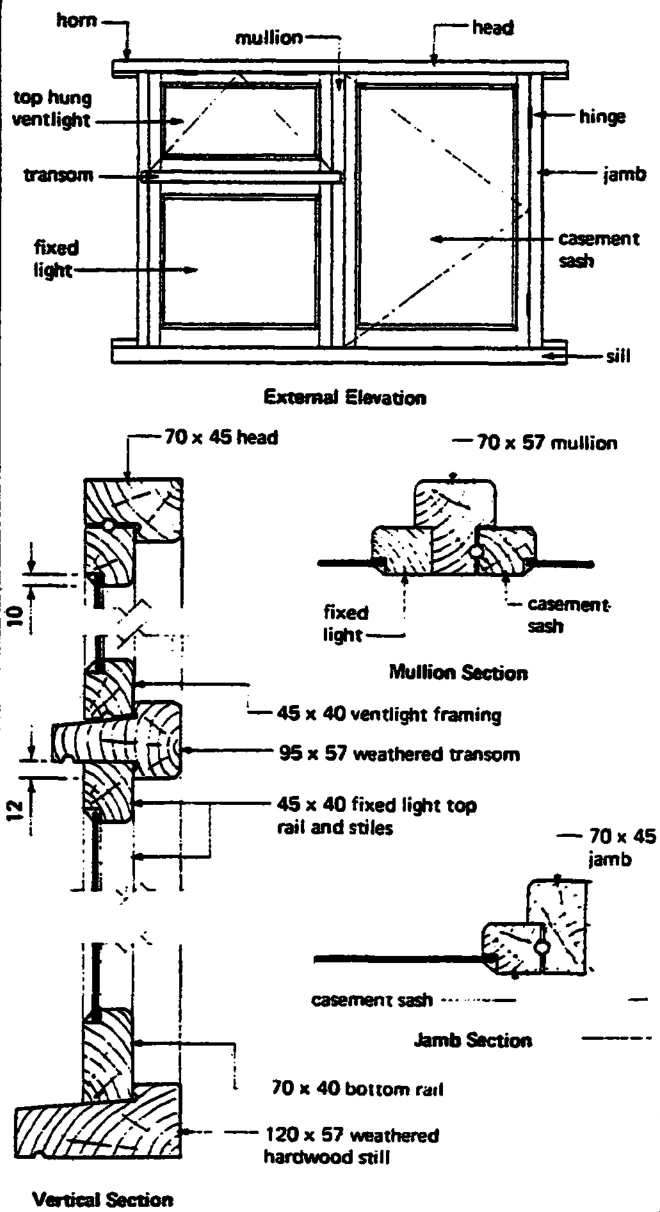
- Constructional by - laws require windows equal to at least 1/10th of the area of the floor of the room.
- There is no definition in the B.R. of adequate mechanical means, but it is generally recommended:
  - Three of four air changes per hour would be a reasonable ventilation standard.
- Ventilation opening = any part of a window or hinged panel, adjustable louvre etc. which opens directly to the open air. (excluded are openings assosiated with a mechanically operated system.
  = a door (if it opens directly to the external air) can be defined as a ventilation opening if it has an opening ventilator with an area of not less than 10 000 mm^2 or if it is situated in a room which contains one or more ventilation openings whose total area is not less than 10 000 mm^2.
- The basic requirements for ventilation openings are:
  1. Total area of the ventilation opening (or openings) must exeed 1/20th of the floor area of the room it serves.
  2. Some part of the ventilation opening must be not less than 1,75 m above the floor level.
  3. Rooms with an enclosed veranda must have vent. openings whose total area is not less than 1/20th of the combined floor areas.
  4. Any larder must be ventilated to the external air and if this is achieved by using windows they must have ventilation openings whose total area is not less than 85 000 mm^2 and must be fitted with a durable fly-proof-screen.



Windows and zones of open space – B. Reg. K1

14.2.2 Traditional casement windows.

- A wide range of designes can be produced by using various combinations of the members. A limiting factor is the size of glass pane relevant to its thickness.
- The general arrangement of the framing is important:
  - heads and sills always extend across the full width of the frame (and in many cases have projecting horns for building into the wall)
  - jambs and mullions span between the head and sill; these are joined to than by a wedged or pinned mortise and tenon joint.
- This arrangement gives maximum strength since the vertical members will act as struts. It will also give a simple assembly process.
- The traditional casement window frame has deep rebates to accomodate the full thickness of the sash (= term for the framing of the ventilator). If fixed glazing or lights are required it is necessary to have a sash frame surround to the glass since the depth of rebate in the window frames is too great for direct glazing to the frame.



Traditional timber casement window

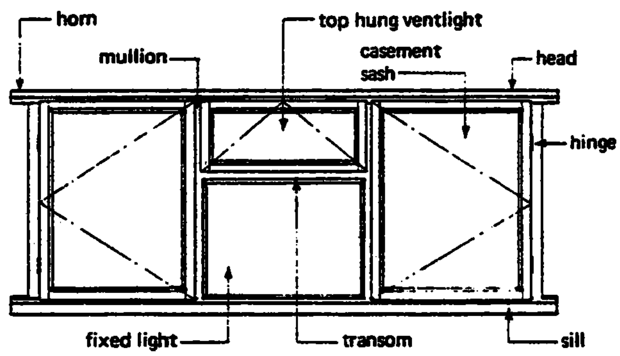
STAND. WOOD CASEM. WINDOWS

14.2.3 Standard Wood Casement Windows.

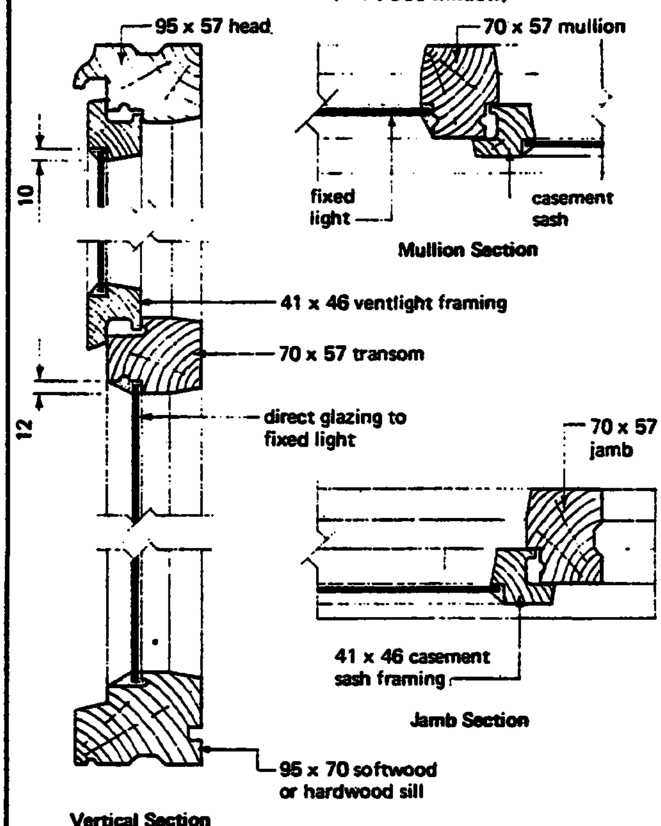
- B.S. 644, Part I, gives details of the
  - quality
  - construction and
  - design

  of a wide range of wood casement windows.
- Frames, sashes and ventlights are made from standard sections of soft wood timbers arranged to give a variety in design and size.
- Sashes and ventlights are designed so that their edges rebate over the external vace of the frame to form a double barrier to the entry of wind and rain.

  The general construction is similar to that described for traditional casement windows and the fixing of the frame into the walls follows that described for door frame.
- Most joinery manufacturers produce a range of modified standard casement windows following the basic priciples set out in BS 644 but with improved head, sill and sash sections.
- The range produced is based on a module for basic spaces of 300 mm giving the following lengths (in mm):
  600; 900; 1200; 1800; 2400
- Frame heights follow the same pattern with the exeption of one half module (in mm):
  600; 900; 1050; 1200; 1500.
- Window types are identified by a notation of figures and letters, i.e.: 4 C V 30 where
  4 = four width modules
  = 4 x 300 mm = 1200 mm
  C = casement
  V = ventlight
  30= three height modules
  = 3 x 300 mm = 900 mm



External Elevation (8 CVC35 window)

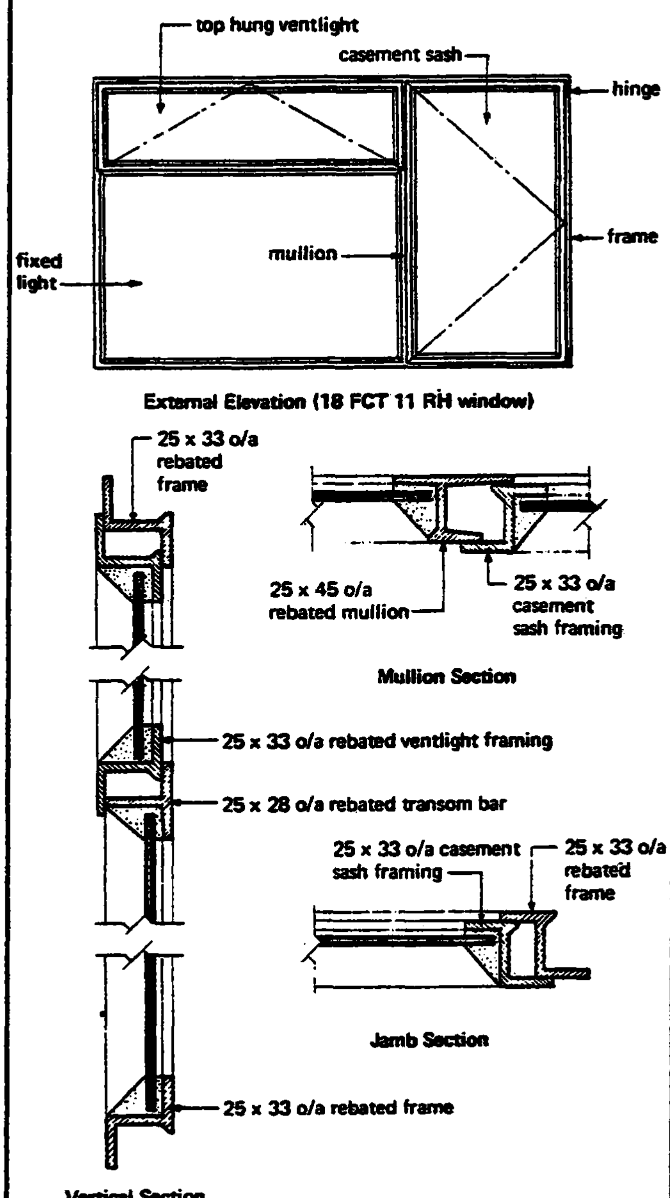


Typical modified BS casement window

STEEL CASEMENT WINDOWS

14.2.4 Steel Casement Windows

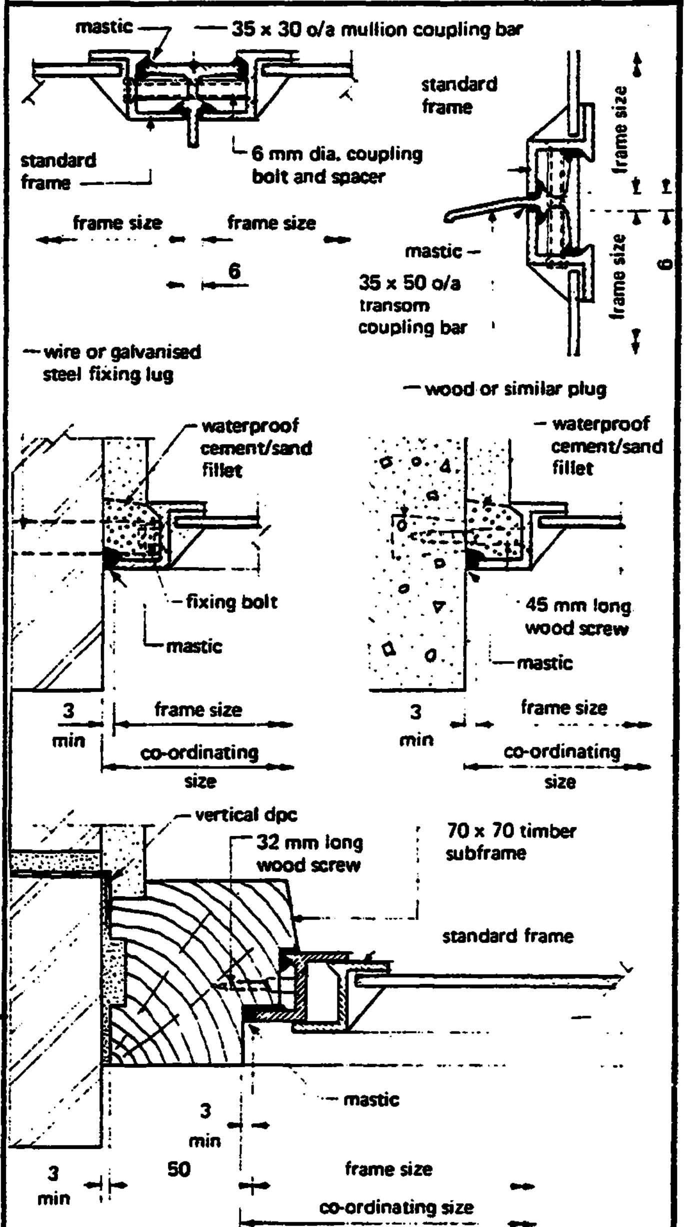
- B.S. 990 gives details of construction, sections, sizes, composites and hardware.
- The standard range coveres
  - fixed lights
  - hung casements
  - pivot casements and
  - doors.
- The lengths, in the main, conform to the basic space first preference of 300 mm giving the following range (in mm) 500; 600; 800; 900; 1200; 1500; 1800.
- Frame heights are based upon basic spaces for the preferred head and sill heights for public sector housing giving the following sizes (in mm): 200; 500; 700; 900; 1100; 1300; 1500.
- Steel windows (like wood windows) are identified by a notation of numbers and letters:
  - Prefix number x 100 = basic space length
  - code letters:
    F = fixed light
    C = side hung casement opening out
    V = top hung casement opening out and extending full width of frame
    T = top hung casement opening out and extending less than full width of frame.
    B = bottom casement opening inwards
    S = fixed sublight
- suffix number: x 100 = basic space height
- suffix code: R.H = right - hand casement as viewed from outside
  L.H = left-hand casement as viewed from outside.



Typical BS 990 steel window

STEEL CASEMENT WINDOWS

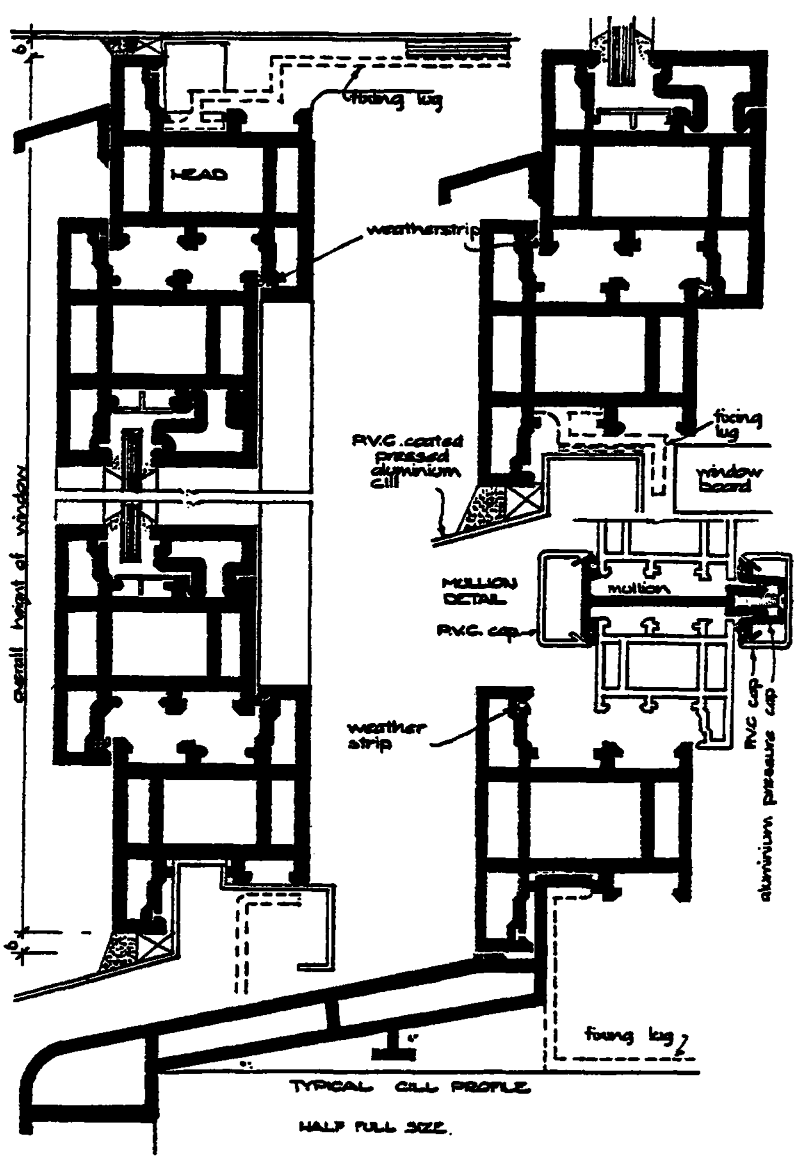
- The basic range of steel windows can be coupled together to form composite frames by using TRANSOM and MULLION coupling sections without increasing the basic space module of 100 mm - The actual size of a steel frame can be obtained by deducting the margin-allowance of 6mm from the basic space size.
- All the frames are made from basic rolled steel sections which are mitred and welded at the corners to form right- angles;
  - internal bars are tenoned and rivetted to the outer frame and to each other.
  - the completed frame receives a hot dip galvanised protective finish after manufacture and before delivery.
- Steel windows can be fixed into an opening by a number of methods such as:
  - using a wood surround which is built into reveals and secured with fixing ties or cramps. The wood surround will add 100 or 50 mm to the basic space size in each direction using either a nominal 75 x 75 mm or 50 x 75 mm timber section.
- Advantage of steel windows
  - larges glass area (due to smaller frame sections)
- Disadvantage of steel windows:
  - condensation, which can form on the frames because of the hight conductivity of the metal members.



Steel window couplings and fixings

14. DOORS & WINDOWS	WINDOWS	BUILDING CONSTR.
compiled : D. VOLKE		LECTURE
JAN. '83		CET 8031/1 14.2 28

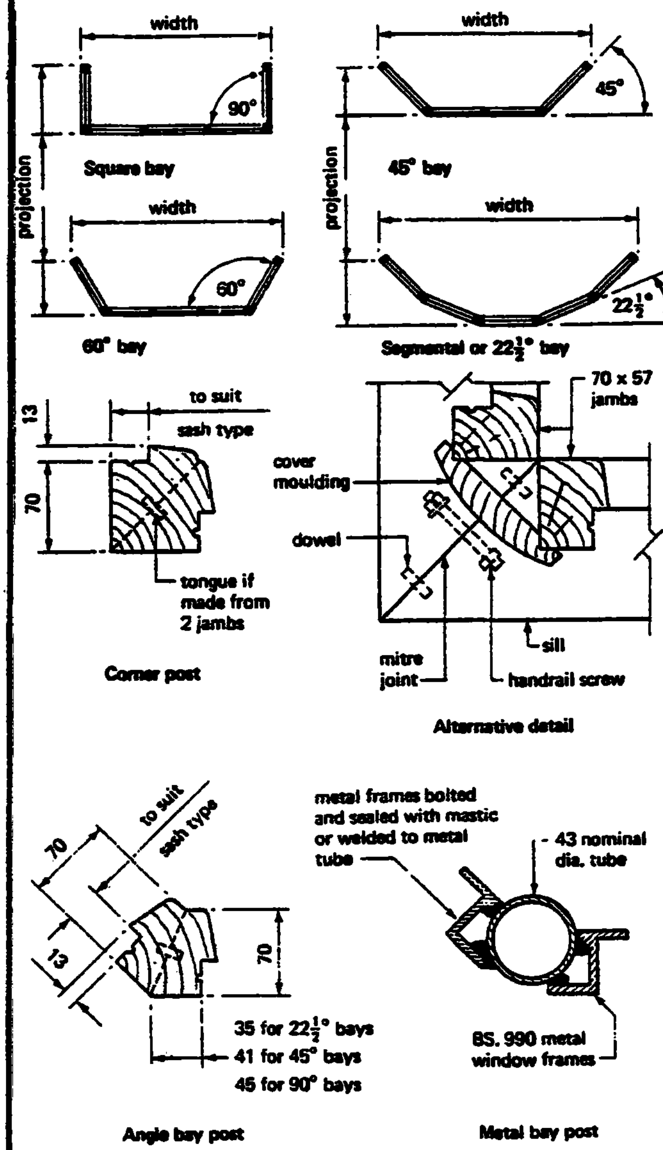
PLASTIC CASEMENT WINDOWS



Plastic windows. Unplasticized polyvinyl chloride (U.P.V.C.) is now in demand for all types, including horizontal and vertical sliders, particularly in modern housing development. Glass is secured in position with rigid P.V.C. slip-on beads. Double-glazing units, up to 24 mm thick, can also be accommodated. Single units can be coupled together using mullions and transoms, as with other types. The profiles are normally supplied in light grey or white, Fig.

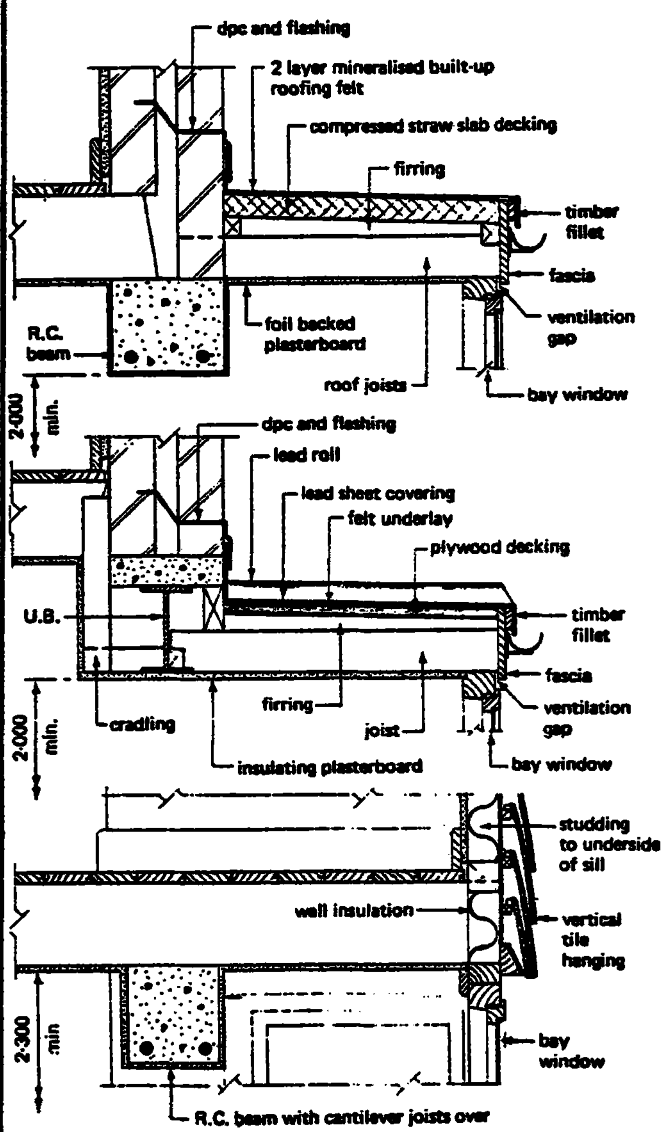
Glass-reinforced polyester resin (G.R.P.) is also used in window manufacture. It has excellent weathering properties and is impervious to insect and fungal attack.

BAY WINDOWS



Bay window types and corner posts

- the main difference in detail is the CORNER POST, which can be made from the solid, jointed or masked in the case of timber and tubular for metal windows.
- Any roof treatment can be used to cover in the projection and weather seal it to the main wall



Bay window roofs and 2-storey bays

14.2.5 Bay Windows

= any window which prejects in front of the main wall line.
- various names are given to various plain lay layouts (ref. to fig.)
- Bay windows can be constructed of timber, and/or metal and designed with
  - casement or
  - sliding sashes:

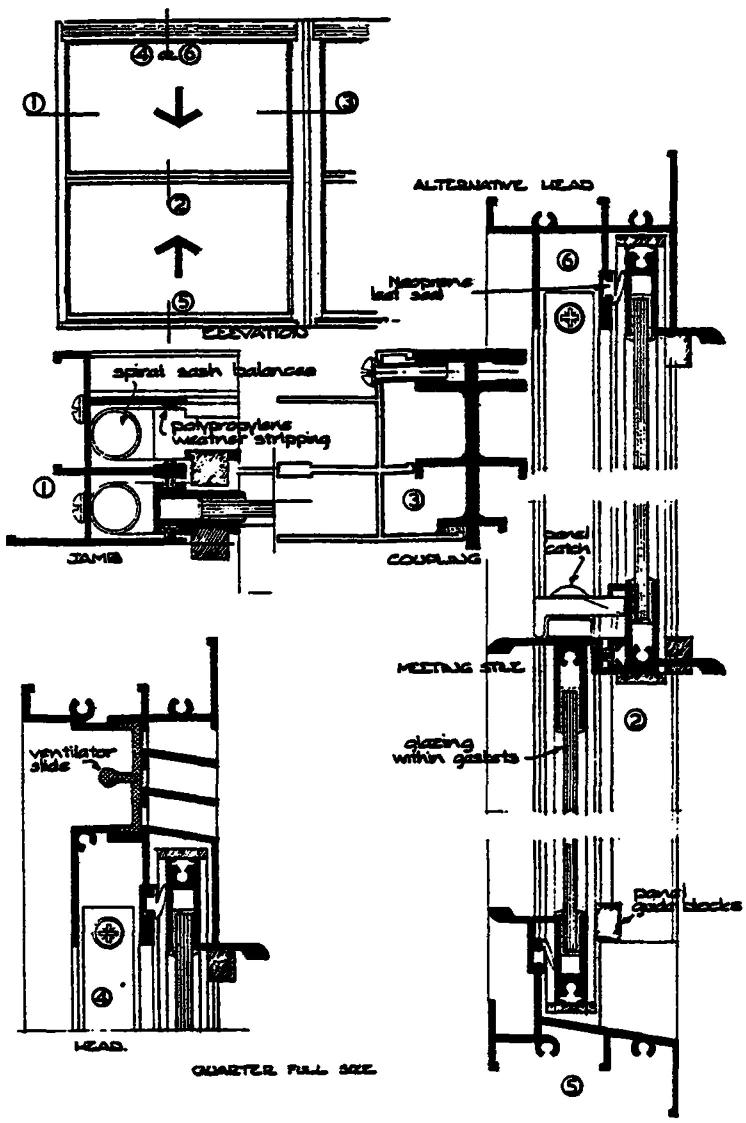
SLIDING SASH WINDOWS

14.2.6 Sliding sash windows:

VERTICAL

14.2.6.1 Vertical sliding windows (also called 'double hung sash windows'

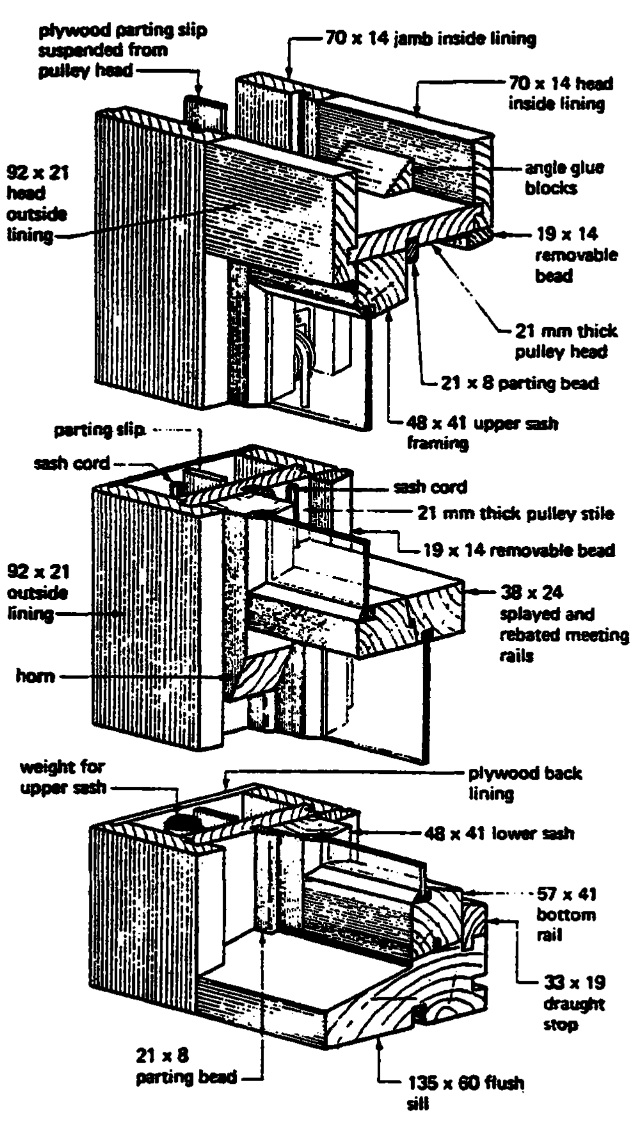
- consist of sashes, sliding vertically over one another.
- Are costly to construct but are more stable than side hung sashes and have better control over the size of ventilation opening, thus reducing the possibility of draughts.



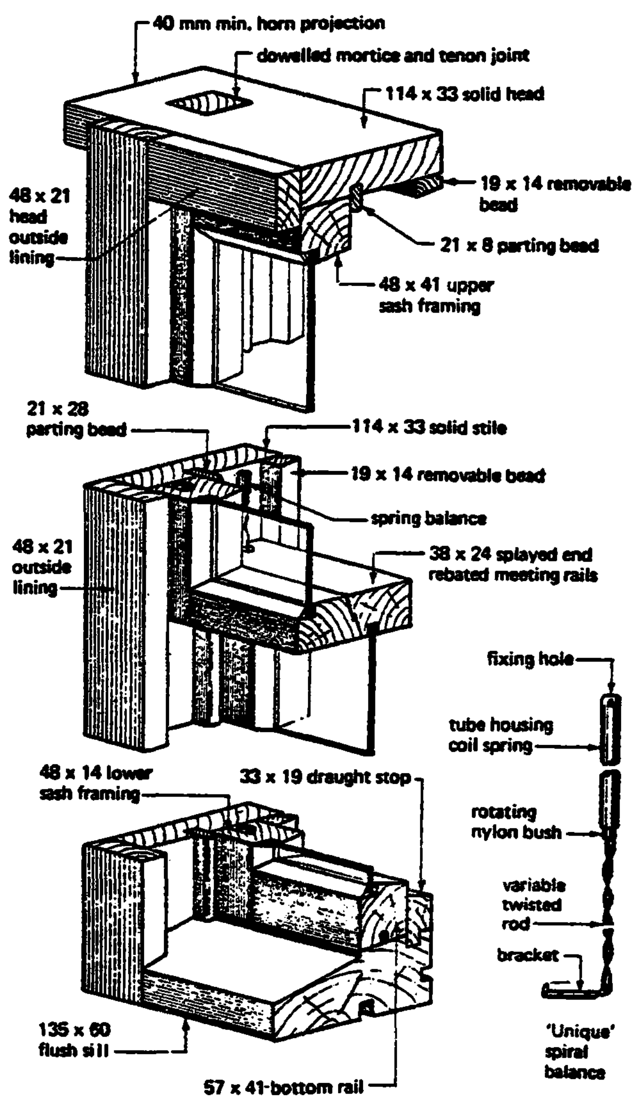
SLIDIND SASH WINDOWS

VERTICAL

- Two main types:
  1. Weight balanced type
  2. Spring balanced type
- No. 1 is the older method. The counter balance weights are suspended by cords and housed in a boxed framed jamb or mullion. No. 2 uses solid frames and needs less maintenance.



Double hung weight-balanced sash windows



NB if 114 x 60 solid stiles are used balances can be housed in grooves within the stile thickness

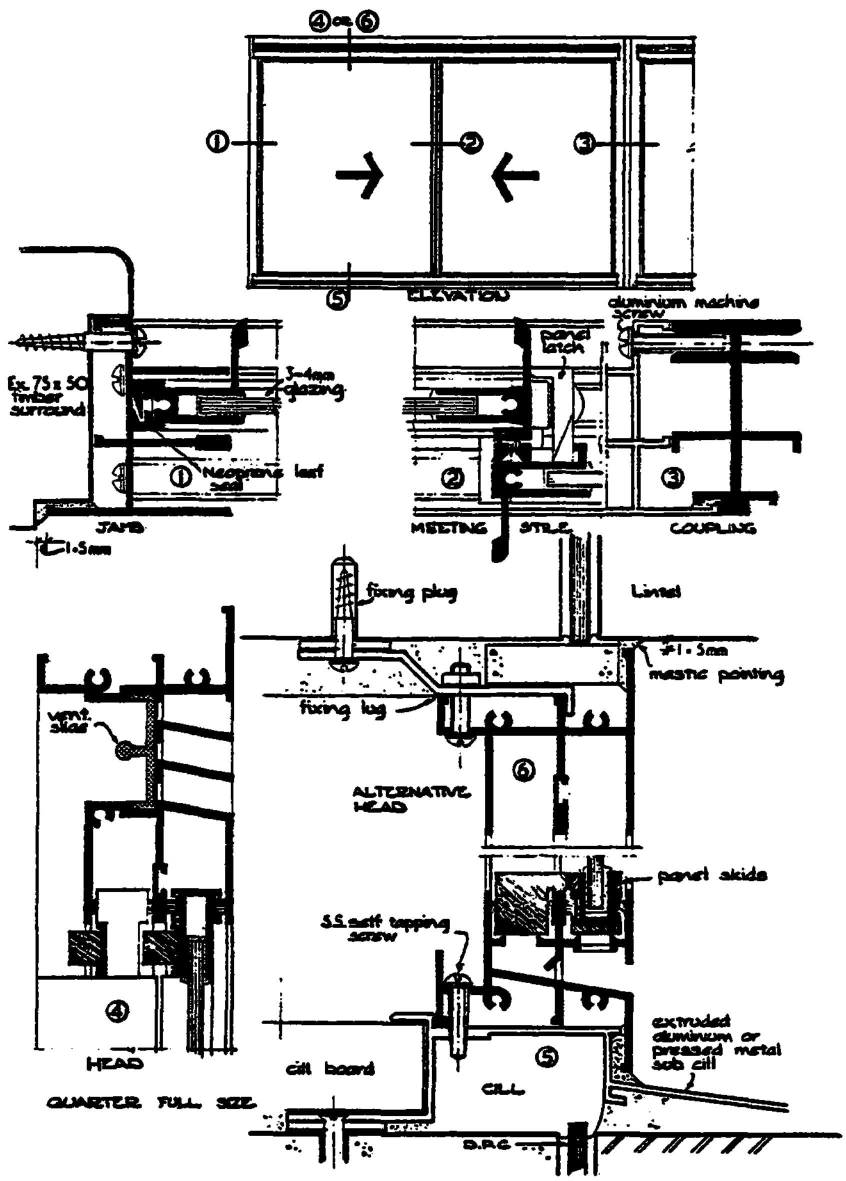
Double hung spring-balanced sash windows

SLIDING SASH WINDOWS

HORIZONTAL

14.2.6.2 Horizontal sliding windows.

- consist of a window frame (wood or metal) with at least 2 sashes. One or both can be opened by sliding horizontally.
- The sashes are made to slide on wood/metal/or compressed fibre runners fixed inside the frame.
- Disadvantage: Sashes tend to jamb in the frame (especially if they are large).



14. DOORS & WINDOWS compiled : D. VOLKE JAN. '83	WINDOWS	BUILDING CONSTR. LECTURE CET 8031/1 14.233
TCA TECHNICAL COLLEGE ARUSHA CHUO CHA UFUNDI ARUSHA	CIVIL ENGINEER. DEPARTMENT	33

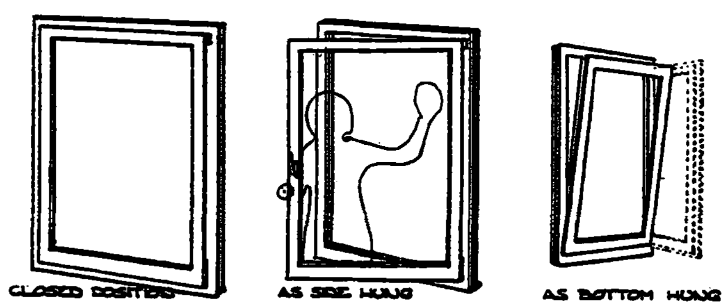
PIVOT WINDOWS

14.2.7 Pivot windows

- The basic construction of the frame and sash is similar to that of a standard casement frame and sash.
- The sash can be arranged to pivot
  - horizontally or
  - vertically

  on friction pivots housed in the jambs or in the sill and head.
- These windows give good adjustment for ventilation purposes.
- Both faces of glazing can be cleaned from the inside of the building.
- Disadvantages:
  - horiz. pivot: Ventilation in high buildings = hot air, which moves upwards along the facade is directed into the rooms.
  - vertic. pivot: (the same as casment windows opening to the inside) restrict the use of the rooms when opend.

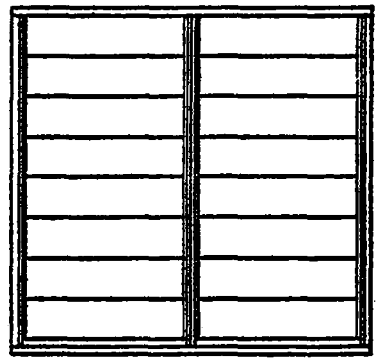
TURN &.TILT WINDOWS

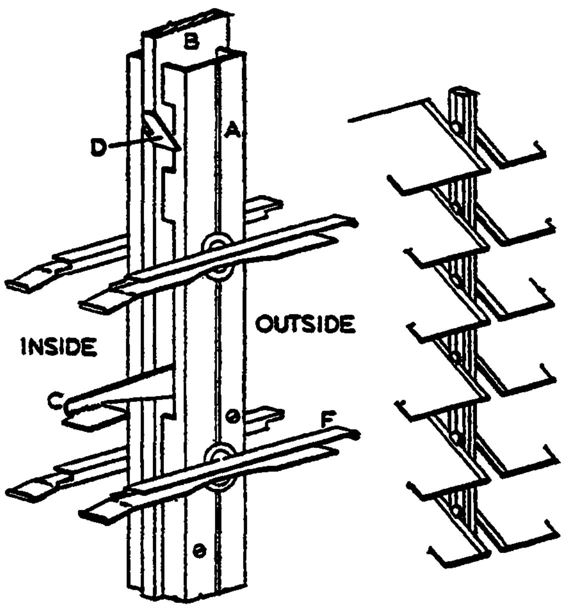


LOUVRES

14.2.8 Louvres

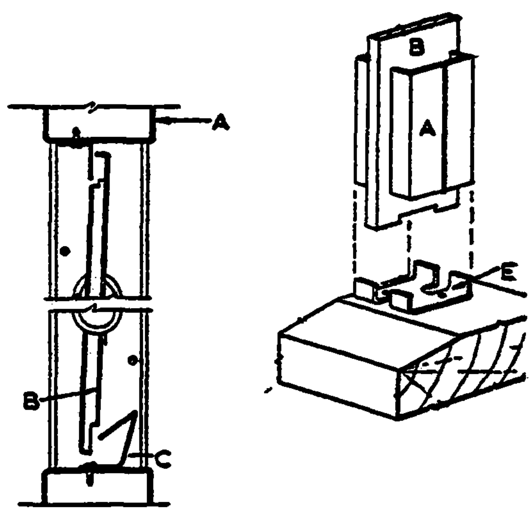
- Adjustable louvres are available in a number of sizes and patterns.
- A louvre blade on a jamb unit is screwed to a galvanized channel surround. The channels and louvres are supplied 'knocked down' and assambled on side.
- another alternative: 'selfmullion' (i.e. 2 jamb units with a spacer bracket between.





Typical glass louvres in aluminium carriers
A Pressed steel frame
B Glass louvre carrier
C Pressed steel stop

The glass ranges from 3 to 6mm plates depending on the size of the window; but in order to prevent breakage the glass should not be less than 5mm.
- 5mm glass blades should not be longer than 30"(762mm) length
- 6mm glass blades should not be longer than 36"(914mm).



Mullion with steel core

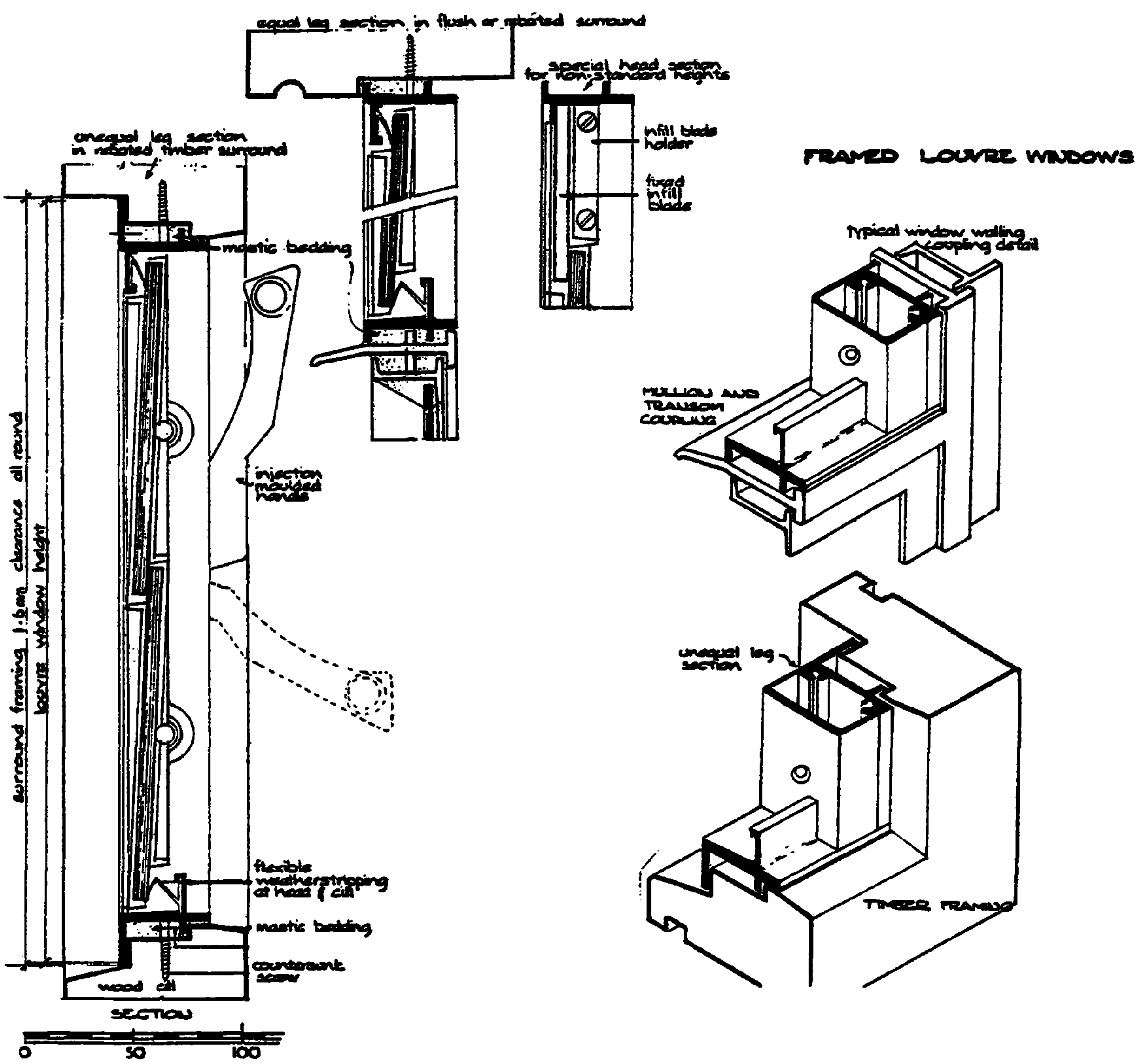
A 1¾ in × ½ in (44 mm × 13 mm) jamb
B 2 in × ¼ in (51 mm × 6 mm) steel core
C Operator
D Lock (sometimes combined with the operator)
E Core clip
F Blade carrier

- For high windows, steel mullion strips are available to which the alluminium jamb units may be fixed.
- The glass blades are normally 4" (or 10cm) and 6"(or15cm) wide, although 9"(23cm) blades are often used.

LOUVRES

This is exceeded in sheltered positions. The lap between 15 cm blades is 12mm and between 23 - 25 mm.

- The height of self-supporting mullion varies according to the length and width of the glass blades (i.e. 6" or 9") and the max wind velocity expected.
- Where the mullion spacing is small (18" or 46 cm) twenty -one louvres with 6" blades may be carried.
  But with a spacing of 4'(1.22m) only fourteen louvres may be carried.



LOUVRES

- With tall windows the jamb units may be easely joined, although care has to be taken to marry the louvres accurately.
- Standard heights of windows for louvres with 15 cm blades range from 12 1/2 in (with 2 blades) to 78 1/2 in (198,4cm) with 14 blades (also with self - mullions, if required)
- Operating handles or 'operators' are usually supplied for every six blades, although this varies with different makes.
- Locking catches may be either seperate (as shown) or incorporated with the operator.

Advantages:
- adaptability to existing openings
- stand. heights to fit any size of opening
- ease of operation
- neat oppearance
- free air flow etc.

Disadvantages:
- not as secure as fixed wood or metal louvres (glass baldes are easily removed)
- not water tight
- often mullions are not fixed plumb nor the blades are truly horizontal. Poor fixing causes breakage!
- They frequently slip out of their clips.

But there is no doubt, that their advantages far outweight their disadvantages(especially in hot-humid areas like i.e. the coast region in TAN).

14.2.9 Glass and Glazing

14.2.9.1 Glass

- Drawn clear sheet glass

- There are 2 principal methods of producing drawn clear sheet glass
  (1) vertical drawing from a pool of molten glass which, when about 1m above the pool level, is rigid enough to be engaged by a series of asbestos rollers, that continue-to draw the ribbon of glass up a tower some 10 m high, after which the ribbon is cut into sheets and washed in a dilute acid to remove surface deposits.
  (2) the glass is initially drawn in the vertical plane but it is turned over a roller so that it is drawn in the horizontal direction for some 60 m and passes into an annealing furnace, at the cold end of which it is cut into sheets.
- it is a transparent glass (85% light transmission) with a fire finished surface, but because the two surfaces are never perfectly flat or parallel there is always some distortion of vision and reflection.

B.S. 952 recommends 3 qualities for sheet glass:
1. Ordinary glazing quality (O.Q.) to be used for general glazing purposes.
2. Selected glazing quality (S.G.Q.)for hight grade work (such as cabinets).

- Generally 6 thicknesses are produced(from 2-6 mm thick). The 2 mm thickness is not being recommended for general glazing.

- Float glass

- is a transparent glass (85% light transmission) and is a truly flat glass with undistorted vision.
- it is formed by floating a continuous ribbon of molten glass over a bath of liquid metal at a controlled rate and temperature.
- a general glazing quality and a selected quality are produced in <u>six</u> thicknesses (from 3-12mm).

- Rolled and rough cast glass

- is a flat glass produced by a rolling process
- generally the glass produced in this manner is translucent, which transmits light with varying degrees of diffusion, so that vision is not clear.
- a wired transparent glass with 80% light transmission is produced generally in one thickness of 6mm.
- the glass is made translucent by rolling on to one face a texture or pattern which will give 70-85% light transmission.
- Rough cast glass has an irregular texture to one side.
- wired rough cast glass comes in 2 forms:

  (a) georgian wired (12mm square mash elt.-welded wire reinforcement or
  (b) hexagonally wired which is reinforced with hexagonal wire of approx. 20mm mese.
- rouge cast glass is produced in 5,6 and 1o mm thickness and is made for safety and fire resistante glazing purposes.

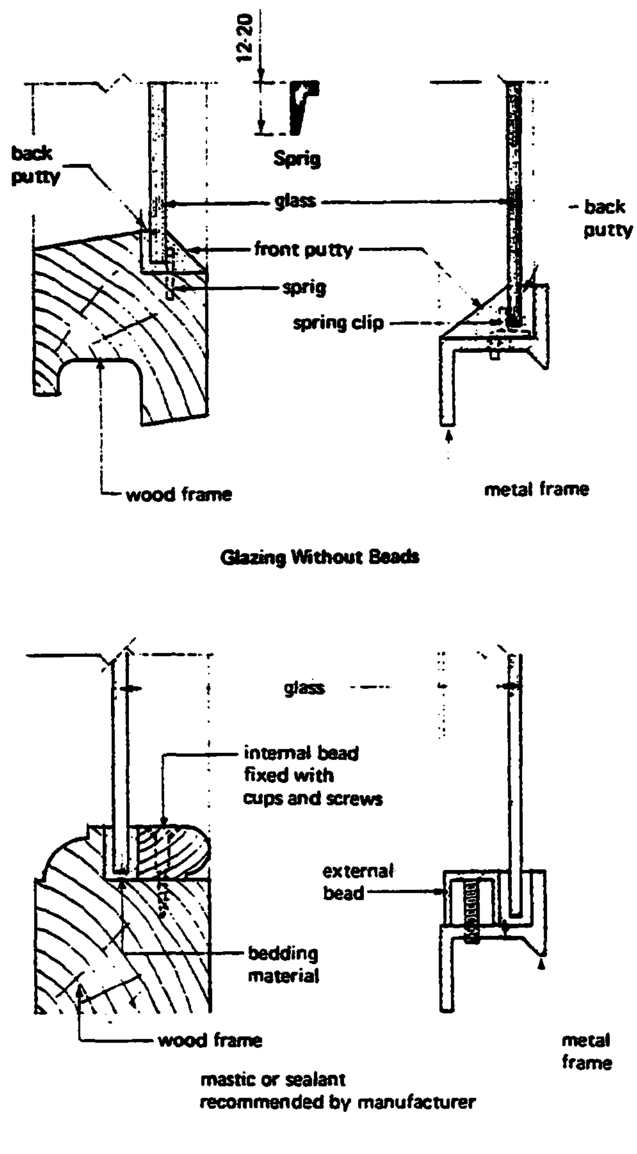
GLASS and GLAZING

14.2.9.2 Glazing

(a) Glazing without BEADS
- is a suitable method for general domestic window and door panes.
- the glass is bedded in a compound and secured with sprigs, pegs or clips and fronted with a weathered surface putty.
- putty is glazing, compound which will require a protective coating of paint as soon as practicable after glazing.
- two kinds of putty are generally used:
  1. Linseed oil putty: for use with primed wood members and is made from linseed oil and whiting.(B.S.544)
  2. Metal casement putty:for use with metal or non-absorbent wood members and is made from refined vegetable drying oils and finely ground chalk.
- The glass pane should be cut to allow a min. clearance of 2 mm all round for both wood and metal frames.
- Sufficient putty is applied to the rebate to give at least 2mm of back putty when the glass is pressed into the rabate, any surplus putty being stripped off level or at an angle above the rabate.
- The glass should be secured with sprigs or clips at not more then 440mm centres and finished off on the front edge with a weathered putty-fillet, so that the top edge of the fillet is at or just below the sight line.

(b) Glazing with BEADS
- is generally applied to good class joinery
- the beads should be secured with
  - panel pins or
  - screws

  for hardwoods it is usual to use cups and screws.
- The glass is bedded in a compound or a suitable glazing felt mainly to prevent damage by vibation to the glass
- Beads are usually mitred at the corners to give continuity of any moulding.
- Beads for metal windows are usually supplied with the sourround or frame, and fixing of glass should follow' the manufacturers instructions.



Glazing details

MOSQUITO SCREENING

14.2.10 Mosquito screening
(Fly screens)

- mass production of copper wire and nylon screens have made complete proofing very common.
- Green-tinted gauze is available which reduces glare considerably.
- Nylon gauze (although cheap) is not as transparent as copper and tends to produce a foggy outlook. Such sceens are not designed to resist damage caused by fly swatting and should be left undisturbed when once in position.
- Fibre glass is an excellent material for screening. It will resist corrosion and rust and will not stain walls and sills.
  This material
  + does not deteriorate in industrial areas,
  + is not affected by mildew
  + resists salt air and
  + will withstand heat up to 150°C before becoming soft.
  + it provides good fire protection.
- When fly screens are inteded for glass-louvre windows, it is necessary to make the window frame wide enough to clear the louvre when fully open (the screen may be fixed direct to the frame).
- removable screens (secured by wing nuts) are used where mosquitos or other pests occur only at certain times of the year.

  A neater solution, however, lies in the use of roll-up insect screens which may be fixed permanently.
  These consist of light alu-frames with fibreglass screens which roll up into a headbox (= 60mm²).
  They may be fixed to either wood or metal frames.

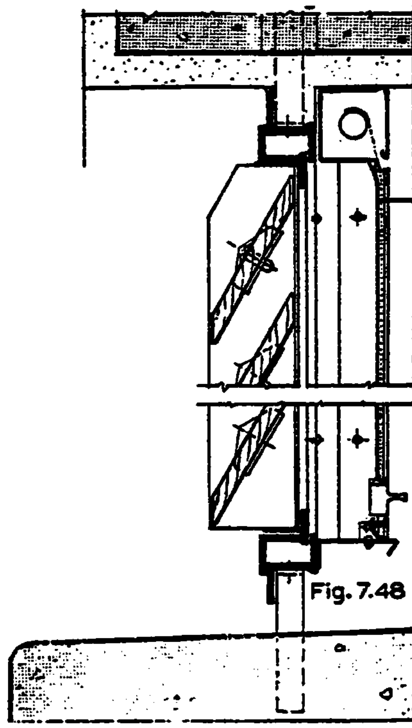
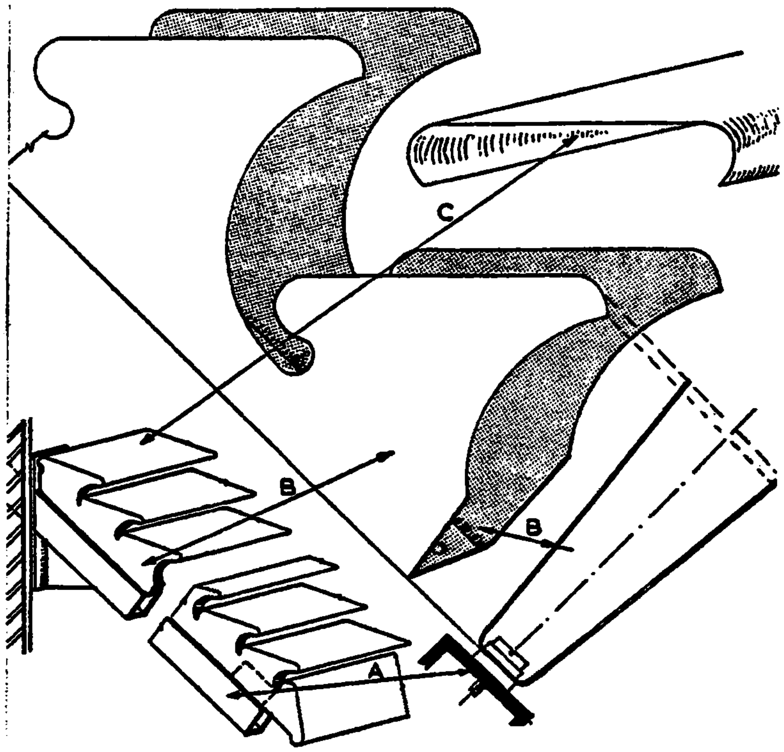


Fig. 7.48

- Flat insect screens in alu-frames are also available
  - fixed
  - hinged or
  - sliding.
- Gauze doors may be made of timber framing or in alu-frames.
  + When such doors are used, they should be arranged to open outward, if possible, otherwise disturbed insects on the screen will tend to fly inwards as the door is opened.
  + The doors may be installed on the face, or in the reveal and should not interfere with the normal door.

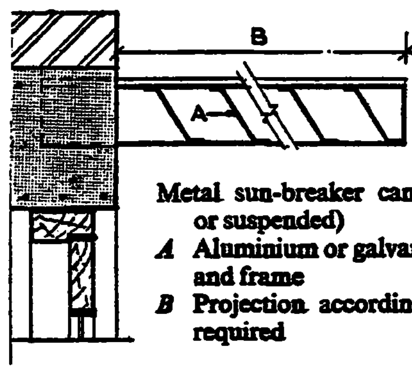
SUN-BREAKERS



Aluminium sun-breakers
A Steel box section (size to suit span)
B Stringer (size and shape to suit climate)
C Aluminium panels (clip-on)

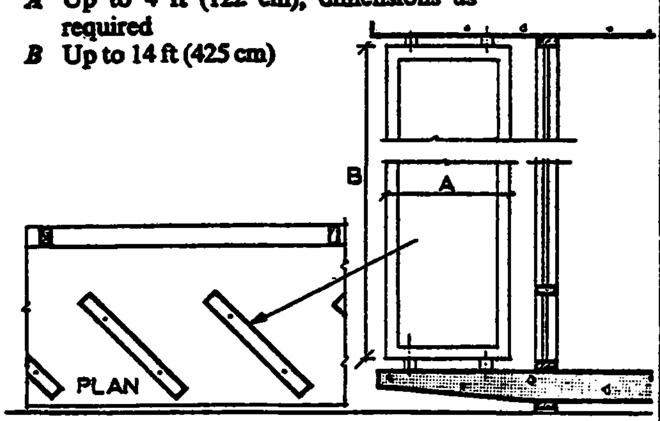
14.2.11 Sun-breakers

- Sun control is frequently necessary and many diff. systems have been developed to effect this, such as
  - pierced panels of brickwork or blockwork
  - overhanging eaves
  - canopies
  - painted or coloured glass
  - metal louvres
  - vertical slats of concrete, extending the full height of the building, arranged at a suitable angle to defeat direct entry of sunlight.
- Before adequate sun control can be achieved, several factors require consideration:
  - orientation of the building
  - the latitude of the country
  - the hours of sunlight against which protection is needed
  - the position of the building regarding the prevailing winds and rains.



Metal sun-breaker canopy (cantilevered or suspended)
A Aluminium or galvanized steel blades and frame
B Projection according to shade angle required

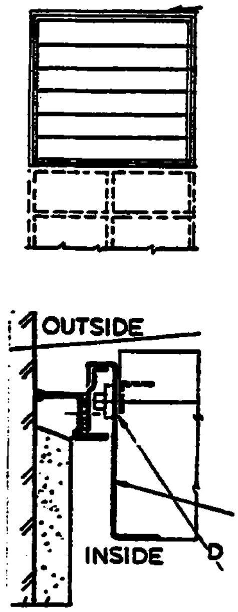
Aluminium fixed sun panels (also in pressed steel)
A Up to 4 ft (122 cm), dimensions as required
B Up to 14 ft (425 cm)

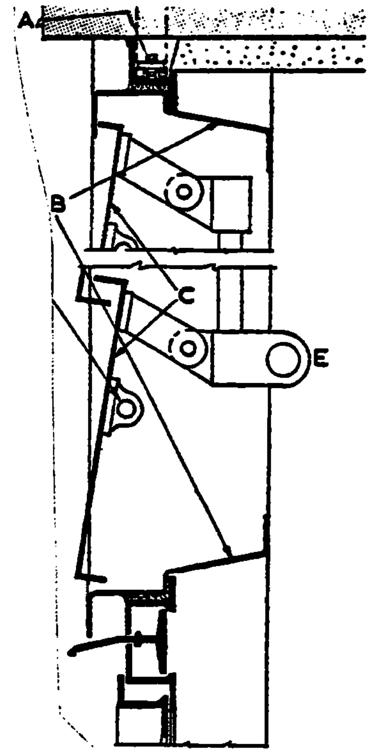


SUN-BREAKERS

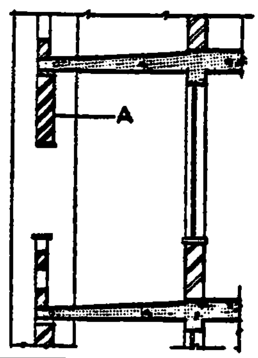
- Sun breakers can be
  either fixed or
  pivoted
  either horizontal or
  vertical
  If pivoted they can be
  either manually or
  mechanically
  operated.
- pivoted sunbreakers are very useful, as the area of sun surface can be considerably reduced. They can also exclude rain.
- For determining the angle and size of sunbreakers various charts and other aids are available (It is advisable to deal with methods of determining shadow angles in building openings in order to design sunbreakers, which are effective at all seasons and any hour of the day.
- Sunbreakers are obtainable in many styles and patterns.
- A common method consists of a V-shaped stringer shaped to take alu-strips. The stringers are produced at diff. angles to suit the required latitude. They are adoptable to a wide variety of uses (including cladding panelling, sun-louvres, canopies, roofs etc).
- Another design is that of pressed steel sunbreakers. A similar section will permit ventilation but is shaped to act as a gutter which prevents the entry of rain.
- A vertical sun panel can be made in a variety of heights, widths and thicknesses. This can be made in pressed steel, or aluminium and is designed to resist high wind. The angle of fixing is designed to give maximum sun protection.

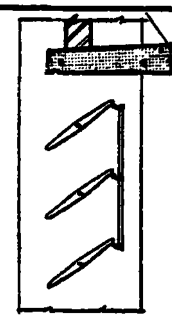
Adaptors for metal sun-breakers
A **Standard fixed metal casement**
B **Adaptor frame of pressed steel**
C **Ventilated pressed steel movable sun-breakers**
D **Pivot**
E **Operator ring**





Section through a typical balcony
A **Wood-louvred sun-breaker (height and angle of louvre as required)**

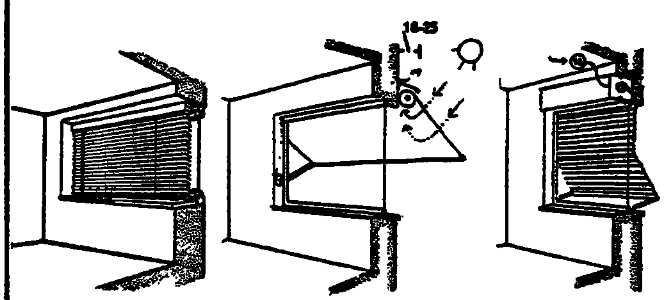




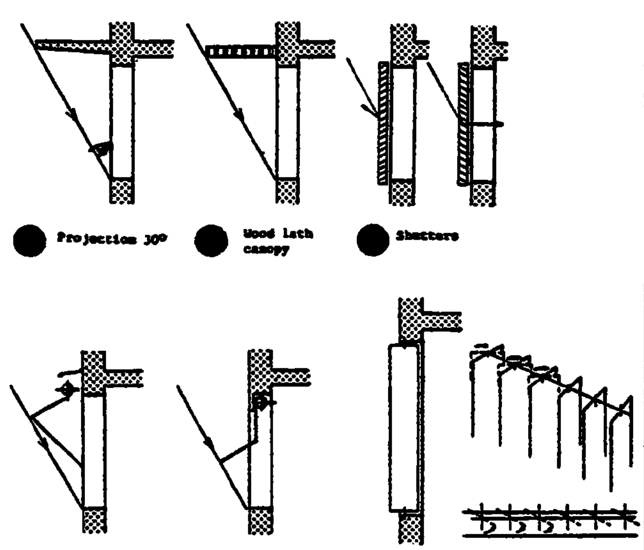
Pivoted aluminium sun-breakers

SUN-BREAKERS

- Rolling window shutters are frequently used in some countries.
  These consist of fine slates running vertically in guide channels which themselves can be pivoted to clear the window and let in light and air.
- Sund-blinds of the venetion type are extensively used where no other method is available or where permanent control is not warranted.
- An example showing plan + section of a pressed steel sun-breaker set in a frame, adapted to fit a standard metal window.
  A bank of 6 louvres is pivoted and linked to one operator.
- The normal type of wood louvre in a frame is supported by concrete sun 'fins' at approx. 3 m centres.
- Aerofoils may also be used, although they are more costly. They are insulated and can be pivoted to give maximum protection. They can be made to various dimensions and can be fixed either horizontally or vertically.
  When closed, they also give wind and rain protection.
- Vertical alu-sun-breakers.
  These are designed to fit standard blade carriers by using an adapter.
  In order to prevent twist between the top and bottom blade carriers, a torsion bar is required. This is fixed in the nearest carrier to the operator.

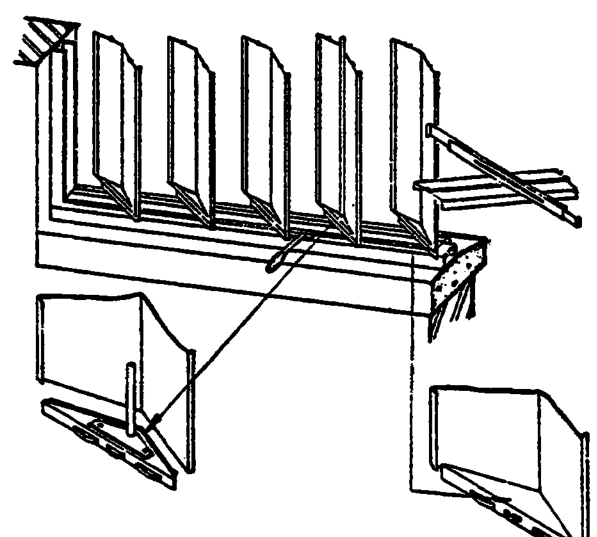


Venetian blind — Awnings stop sunrays and heat, → (4). — Lath shutters act as awnings and protect against break-in, → (8)

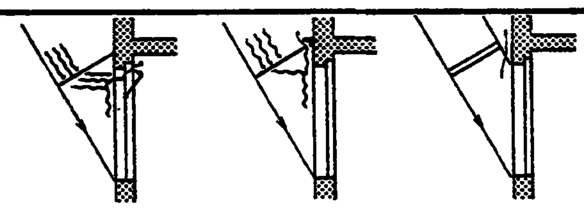


Projection 30° — Wood lath canopy — Shutters

Adjustable awning — Roller blind — Sun-break

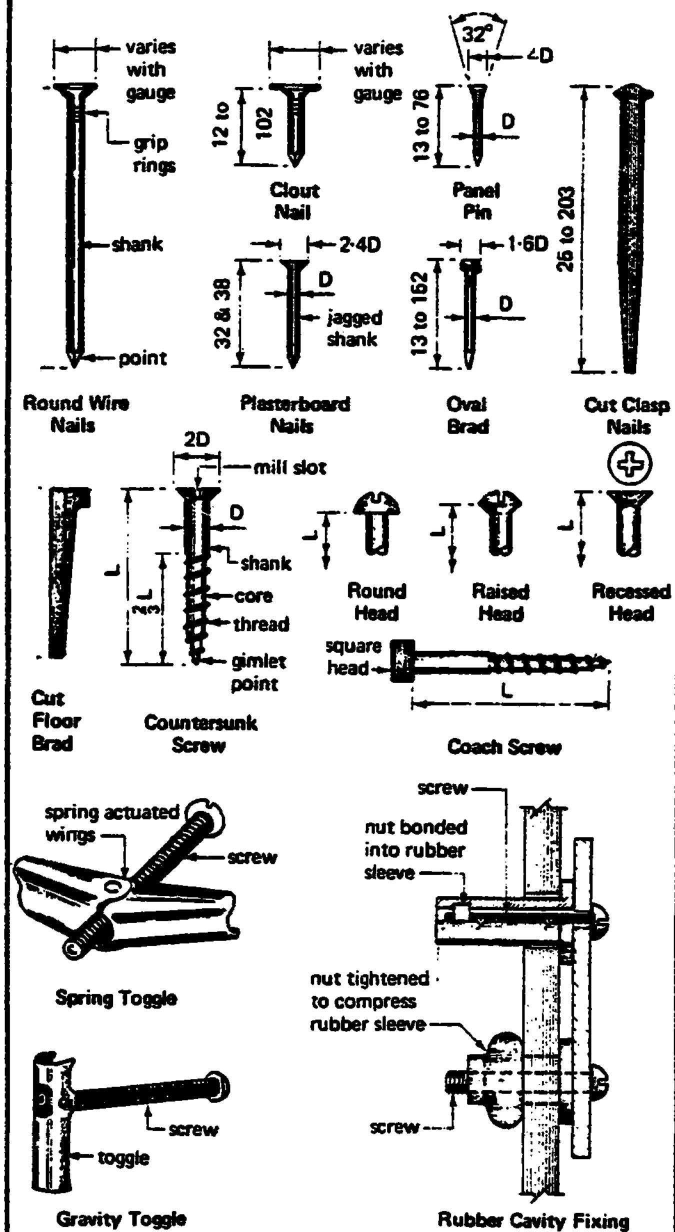


Vertical metal sun-breakers



Incorrect — Correct — Correct arrangement of a fixed screen

IRON MONGERY



Nails, screws and cavity fixings

14.3 Iron Mongery

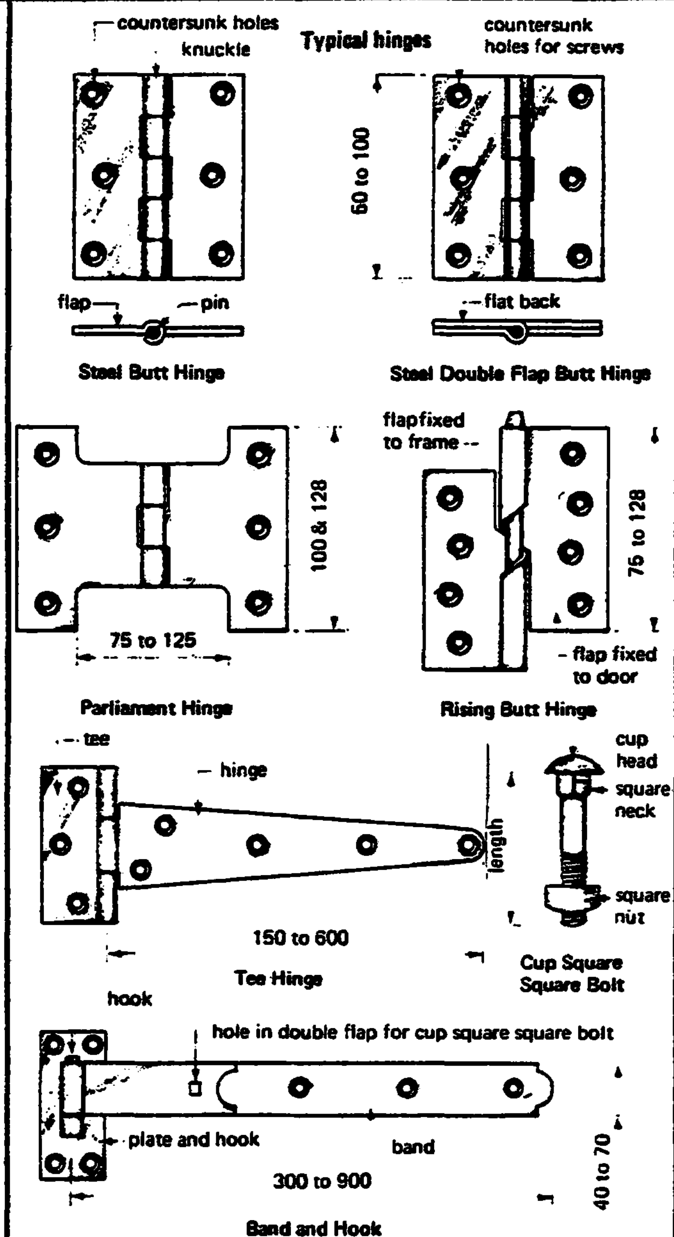
- Iron Mongery or HARDWARE covers a wide field, so that we have to concentrate on those items only which are in common use (in Tanzania) in the field of design and construction, such as:
  14.3.1 Hinges
  14.3.2 Locks and Latches
  14.3.3 Miscellaueous

HINGES

14.3.1 HINGES

are made for hanging doors, casements and ventlights. There are different types available.

- Most commenly used are the cheap pressed steel butt hinges
  They are made from steel strip which is cut and pressed around a PIN. The PIN is fixed inside the Kunckle.
- Loose pressed steel but hinges
  have the advantage that by taking out the loose pin the door can be taken off its hinges whereas with standard steel butts a door can only be taken off by unscrewing its hinges from the frame.
- Double pressed steel butt hinges
  are made of two strips of steel, each folded back on itself around the pin. They are stronger than ordinary steel butt hinges and are used for heavy doors.
- cast iron butt hinges
  are heavier and more expensive than steel butts of similar size and shape; but have longer useful live, as the bearing surface of the kunckles are more resistand to wear.
- Brass butt hinges
  are more expensive than steel or cast iron hinges, used mainly for decorative purposes.
- Steel skew butt hinges (rising butt)
  The bearing surfaces of the kunckles are cut on the skew, so that, as the hinge opens, one butt rises.
  These hinges are used for hanging doors and are fixed so that the flap screwed to the door rises as the hinge opens.
  Purpose:- To ride over carpets
  - self closing (fire cheded)
- Steel tee hinges
  consist of a rectangular steel flap and a long tail with knuckles around a pin.



The flap is fixed to the frame and the tail to the door. They are used mainly for matchboarded doors, as they assist in bracing the ledges against sinking.

- Hook and band hinges
  consist of a rectangular steel plate in which a pin is fixed and a steel band folded around the pin.
  They are made of heavier steel than tee hinges and are used for hanging heavy doors such as garage and workshop doors.

- Projecting steel windows
  Metal casements are often hung on projecting steel hinges.
  Reason: To make it possible to clean the glass in the casement on both sides from within the building.
- Casements are secured with a single pivoted cock spur type fastener and a peg stay is fixed to the frame and casement so that the casement can be kept open in windy weather.
- Ventlights are hung on ordinary steel hinges and are fitted with a peg stay similar to that used for casements.

HINGES

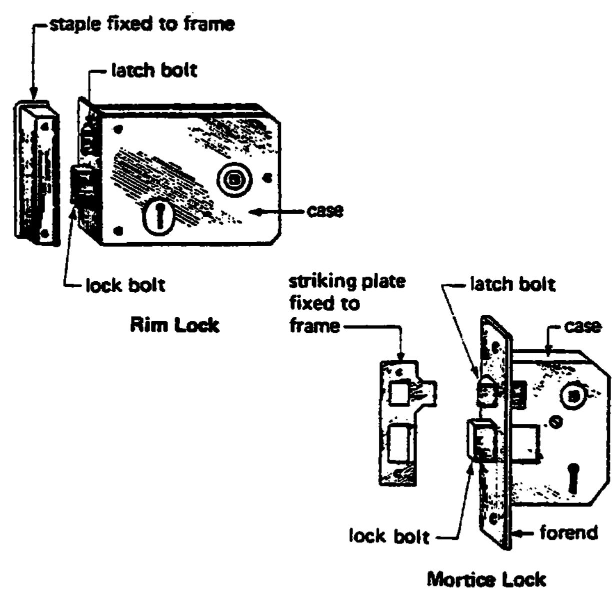
LOCKS and LATCHES

14.3.2 Locks and Latches

- Lock: any device of wood or metal attached to a door which can be used to keep it closed by the use of a loose key
- Latch: any device of wood or metal attached to a door to keep it closed and which can be opened by the movement of a handle lever or bar.

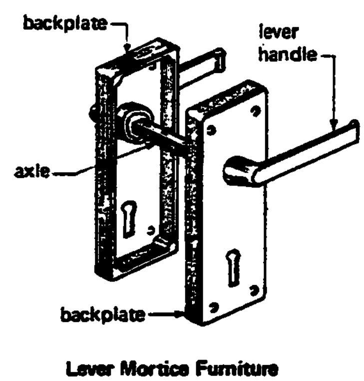
Mortice Lock
is the mechanism which is most used today. It comprises
a latch and
a bolt.
The former being operated by handles; the latter by means of a loose key.
Mortice locks:
Because they fit in a mortice cut in the door, so that the lock case is hidden.

Rim Lock:
is screwed to one face of a door. They are not much in use today, as they spoil the appearance of the door. Sometimes they are used as an additional lock for safety purposes.



Rim Lock

Mortice Lock



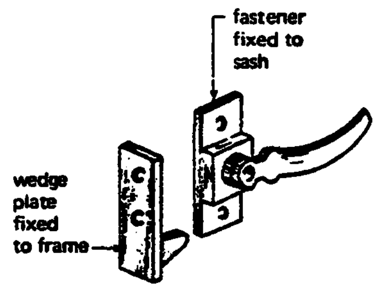
Lever Mortice Furniture

LOCKS and LATCHES

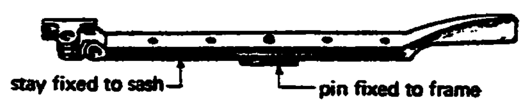
Cylinder night latch:
consists of a metal cylinder which is housed in a metal case which is fixed to the inside face of a door. The cylinder fits in a hole in the door. The latch can be opened by a knob from inside. The levers inside the cylinder are arranged in a way that only the key cut to fit a particular cylinder will open its latch. These latches are commonly used for front doors to houses and flats.

Mortice dead lock:
consists of a case inside which is a single bolt shich can only be operated by a loose key. These locks are fitted to a mortice in the door and the lock bolt shoots into a hole in a lock plate fixed to the door frame. These locks are used in addition to cylinder night latches or locks for entrance doors to houses and flats, because they are more difficult to force or prise open then cylinder night latches.

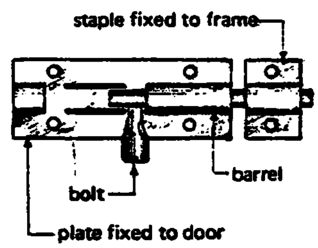
Cylinder Lock:
has a safety-mechanism which is separate from the lock mechanism. It can be fit in an ordinary mortice or rim lock in order to take over the function of an ordinary loose key.
The functioning of a cylinder lock depends on the principle, that while unlocking with the heavily profiled key, a number of pins (which are under spring-compression) is brought in the only one position, which allows a turn of the cylinder core, on which the lock bit is fixed.
The quality of the cyl.-lock depends on the number of pins (=number of grooves of the key bit). The min. No. should be 5 pins, in order to provide a safe lock.



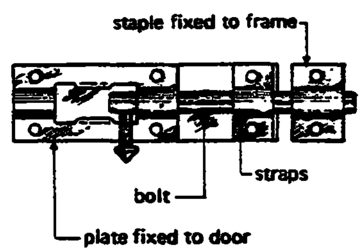
Casement Fastener



Casement Stay



Barrel Bolt



Tower Bolt

●REPETITION●● exercises ●●REPETITION●

Try to answer the following questions and use sketches where-ever necessary and possible

14.1 Doors

What is the function of a DOOR?
Which materials may be used for construction?
Which methods may be used for construction?

Compare EXTERNAL DOORS and INTERNAL DOORS and describe the differences!

What are PURPOSE MADE DOORS and where are they mainly used for?

Define the following terms by using sketches for illustration.

- horn
- toprail
- glass panel
- glazing bars
- frieze rail
- solid panel
- lock o middle rail
- stile
- intermediate rail
- muntin
- bottom rail

Explain in the form of sketches the basic types of PANELLED and GLAZED WOOD DOORS.
What are dowelled joints and what are mortice and tenon joints?(use sketches for explanation!)

Explain in the form of sketches methods of construction of FLUSH DOORS.

What are FIRE-CHECK FLUSH DOORS?

Explain in the form of sketches methods of construction of MATCHBOARDED DOORS.

Sketch and explain the construction of TIMBER DOOR FRAMES as well as for METAL DOOR FRAMES and compare their advantages and disadvantages.

Sketch a typical DOOR LINING

14.2 WINDOWS, GLASS and GLAZING

What are the primary functions of WINDOWS?
Which materials may be used for construction?
Which methods may be used for construction?

Where do the regulations K1,K2,K3 and K4 deal with?
What are the basic requirements for ventilation openings?

Sketch an elevation and sections of a TRADITIONAL CASEMENT WINDOW and give brief explanations!

Sketch an elevation and sections of a STANDARD WOOD CASEMENT WINDOW and give brief explanations!

Sketch an elevation and sections of a STEEL CASEME NT WINDOW and give brief explanations!

Explain BAY WINDOWS and describe the main difference in details to casement windows (use sketches for illustration)

●REPETITION●●exercises●●REPETITION●

Write notes on SLIDING SASH WINDOWS and explain (by using sketches for illustration) VERTICAL and HORIZONTAL sliding windows.

What are PIVOT WINDOWS?

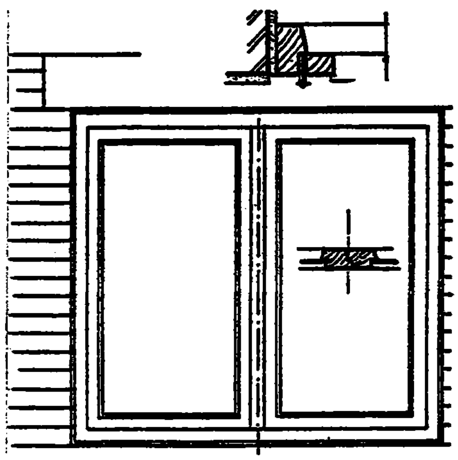
Write notes on LOUVRES, compare advantages and disadvantages and use sketches for illustration.

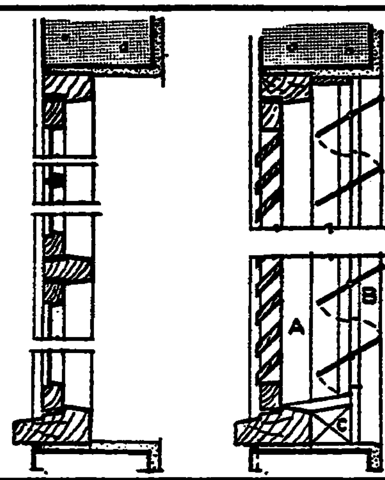
Which methods of producing
- DRAWN CLEAR SHEET GLASS
- FLOAT GLASS
- ROLLED and ROUGH CAST GLASS
do You know?

There are two main ways of GLAZING. Describe both and compare their advantages and disadvantages (use sketches for illustration)

Write notes on MOSQUITO SCREENING

List different SUN-BREAKER systems!
Classify the different types of SUN-BREAKERS and give brief explanations about their construction. (Use sketches for illustration whereever possible!)





14.3 IRON MONGERY

Define the following terms and use sketches for illustration:

- pressed steel butt hinges
- loose pressed steel butt hinges
- double pressed steel butt hinges
- cast iron butt hinges
- brass but hinges
- steel skew butt hinges
- steel tee hinges
- hook and band hinges
- projecting steel windows
- mortice lock
- rim lock
- cylinder night latch
- martice dead lock
- cylinder lock