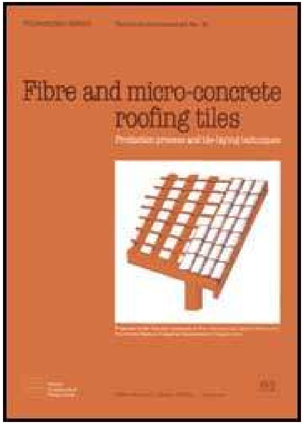
Home"" """"> ar.cn.de.en.es.fr.id.it.ph.po.ru.sw



Fibre and Micro-Concrete Roofing Tiles - Production Process and Tile-Laying Techniques (ILO, 1992, 172 p.)

RATIO

Fibre and Micro-Concrete Roofing Tiles - Production Process and Tile-Laying Techniques (ILO, 1992, 172 p.)

CHAPTER III EQUIPMENT

This chapter describes the equipment and tools required for the setting up of a micro-concrete or fibre concrete tile production unit. It gives a description of:

- hand-powered or electric vibrating tables: for vibrating and compacting of fresh mortar;

- screeding frame: for obtaining the right shape and thickness of moulded tile; interfaces: for transferring fresh mortar to moulds;

- moulds: for shaping of tiles during setting;

- quality control jig;

- batching boxes and mortar scoops;

- curing tanks;

- sieves.

In a number of industrial or developing countries, vibrating tables and moulds are made and sold on the local and export market. Such equipment may either be based on ITW technology or other processes.

Readers wishing to receive information concerning the address of equipment manufacturers may send their queries to ILO/INSTEAD, SKAT or GTZ(1) (see addresses cited in Annex II).

(1) GTZ is currently producing a brochure giving detailed analytical information concerning several types of tile-making equipment ("Production information FCR-MCR equipment").

Details of the vibrating table, screeds and moulds are essentially based on the equipment manufactured in the United Kingdom by Intermediate Technology Workshops. This firm initiated much of the research and development which led to the dissemination of this technology.

Moulds can often be produced locally in domestic plastics processing plants. Such local firms can be relied on to produce glass fibre moulds. As for hand tools, they can either be found on the local markets or made by local craftsmen.

I. ELECTRIC VIBRATING TABLE (figures 18 and 19)

The vibrating table is made of two parts:

- **a steel box chassis housing the motor;**
- **a screeding table receiving the screeding frame.**

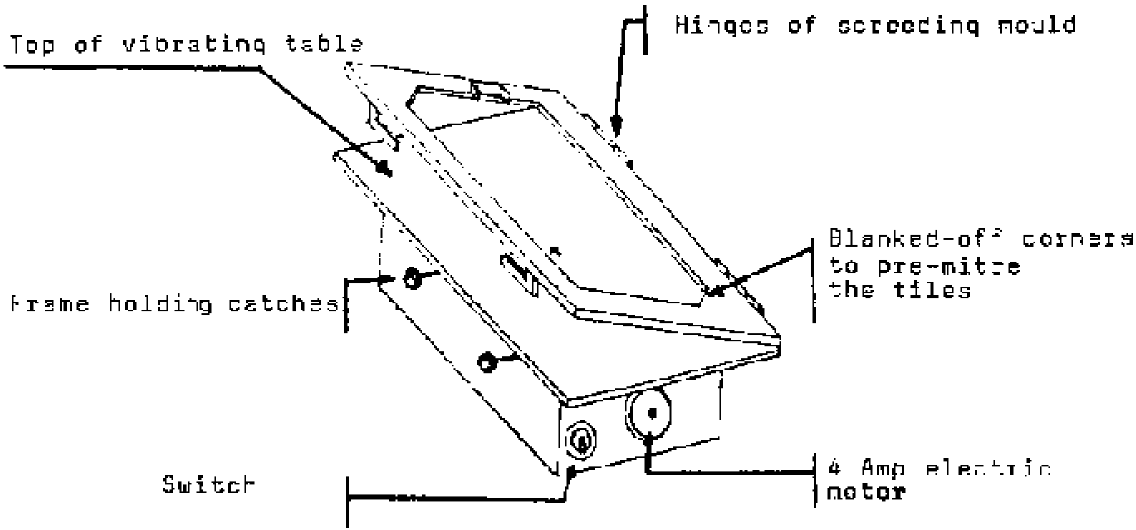


Figure 18. Electric vibrating table (ref. 25)

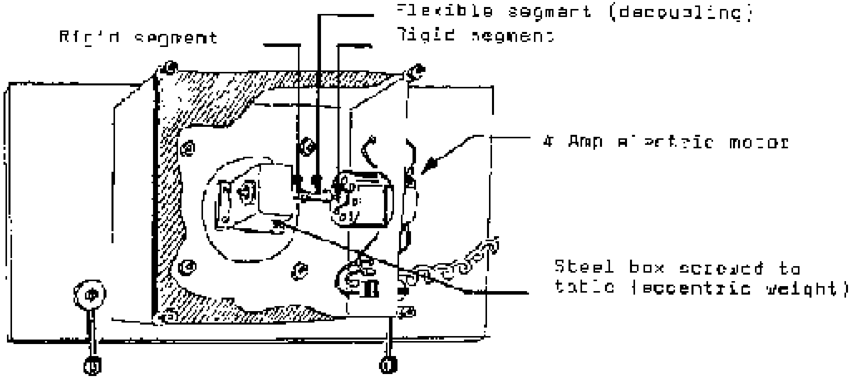


Figure 19. Vibrating assembly (bottom-up view) (ref. 25)

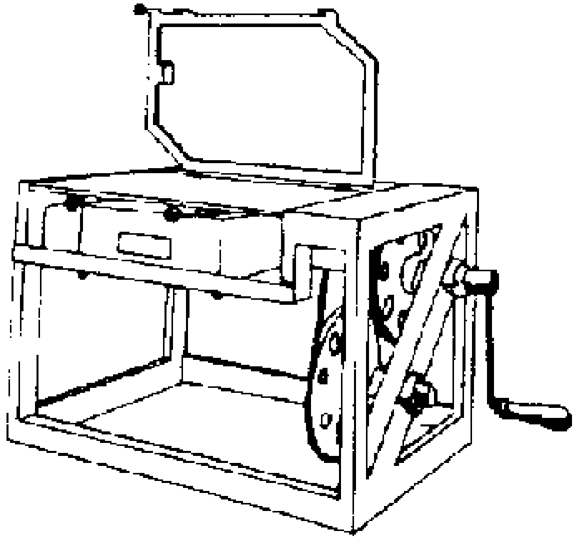


Figure 20. Hand-powered vibrating table

Electric power is supplied by a small 12 volt electric motor connected directly to a car battery. If the workshop is directly connected to a 220 volt power supply, the motor may be connected to the mains through a converter or even a battery charger.

The motor drives a three-segment shaft, with one rigid segment directly connected to the engine, a flexible segment and a second rigid segment.

The second rigid segment is mounted across a box. This part of the drive

is integral with the box. Inside the box, a block of metal is skewered on to the rod, slightly off-centre. The box is screwed on to the bottom of the table.

When the power is switched on, the block placed off-centre on the shaft rotates asymmetrically, thus producing vibrations in the box and the table. The flexible drive buffers the differential: although the segment inside the box rotates off-centre, the motor does not vibrate.

Four springs connect the table to the chassis. Two cylindrical catches receive the hinge pins of the screeding frame. Forward of the table, two rod and nut assemblies are used as locks to close and tighten the screeding frame on to the table top.

There are two types of chassis. The portable model consists of the motor assembly and table only. Four bolts placed on the under-side of the chassis are used to anchor the vibrating machine on the work-bench. A more sophisticated kit presents a complete work station with metal table, vibrating screeding machine, batching boxes, demoulding jig, etc.

II. HAND-POWERED VIBRATING TABLE (figure 20)

This model operates on the same principle as the power machine, the only difference being the power supply. This is generated by turning a

crank connected with a set of bearings. Two large pulleys act as reducers. One of the pulleys is connected with the three-segment shaft.

III. SCREEDING FRAMES

The screeding frames determine the shape and thickness of the tile. They are made of steel. The screeding frame is connected to the table by the hinges located at the back. The front part of the frame is equipped with two square hooks forming the upper part of the lock. Screeding frames come in three basic models as described below.

More research and development is needed to develop new shapes and dimensions for concrete tiles. The dimensions listed below are given as an example.

III.1 Screeding frame for flat tiles or pantiles (figure 21)

Pantile screeding frames are made of flat steel bars. Several thicknesses are available: 6 mm, 8 mm, 10 mm (see below Section V).

The two blanked-off corners make it possible to juxtapose two tiles flush without overlap. When the tiles are placed on the roof, each tile is covered over 10 cm by another tile in the same column. At the contact point between four tiles (two columns and two rows) the blanked-off

angle ensures a good fit and watertightness against run off-water.

The nib is formed with a small rectangular box fitted on the smaller left-hand side of the frame. The top and bottom parts are left open.

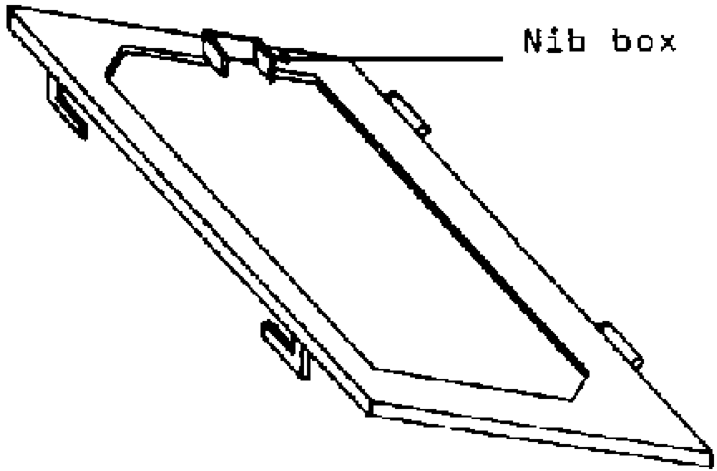


Figure 21. Pantile screeding frame

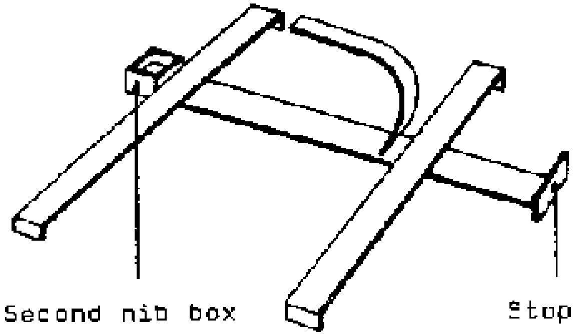


Figure 22. Second nib tool

III.2 Roman tile frame

Frame construction is the same as for pantiles. Only angle details may vary (see also section V).

III.3 Ridge tile screeding frame

This frame produces tiles 10 mm thick. It is rectangular shaped. Two centre marks on the large sides guide correct placing along the central line of the mould (figure 58).

III.4 Second nib tool

In areas exposed to strong winds, the tiles must be fastened to the roof

battens with an upper nib and a lower nib. The second nib is formed with the special tool. This additional jig is fixed to the screed with four claws which ensure correct positioning.

IV. INTERFACE

The interface is a transparent polythene sheet. The sheet is placed on the vibrating table under the screeding frame. The fresh mortar is scooped onto the plastic sheet. The mortar remains on the sheet during vibration. The sheet is then used to transfer the vibrated screed on the mould. Finally the polythene sheet prevents the fresh mortar from sticking to the mould and makes demoulding easier.

Specifications for the polythene sheet are as follows:

- <u>Thickness:</u> The interface must be fairly thick but flexible as well. Flexibility is necessary to adjust the fresh screed on the mould: the screed should fit snugly on the shape. The interface must be thick enough to stay flush with the bottom of the frame during vibration: the presence of air at the interface between the polythene sheet and the bottom of the frame would produce an uneven, rippled surface. A sheet thickness of 200 microns meets both requirements.

- <u>Dimensions:</u> The outer dimensions of the screeding frame are 55 cm × 35 cm. The interface should have at least the same size in order to remain tightly clamped between the table top and the frame.

- <u>Transparency:</u> The interface is larger than the developed tile (developed tile = inner measurements of screeding frame). The screed on its interface should be adjusted to ensure that its long edge follows exactly the raised line on the mould. Since this mark is located under the interface, the sheet must necessarily be transparent.

V. MOULDS

There are two main types of tile. The cross-section of pantiles is curved, thereby requiring less regularity in the laying process.

The cross section of Roman tiles is partly flat, in particular at the point in contact with the battens. Roman tile therefore requires more precision in laying procedures.

V.1 Pantile mould

This hollow shell is made of PVC or glass fibre. At the bottom of the

convex part and along the long edge of the tile, a raised line ensures that the tile is positioned centrally on the mould. This line is necessary to ensure that all tiles are exactly the same shape and will overlap neatly and accurately. The base of the mould is pyramid-shaped. Stops inside the base make it possible to stack the moulds for the initial twenty-four hour curing period. Under the base, a wooden frame confers added rigidity to the PVC mould.

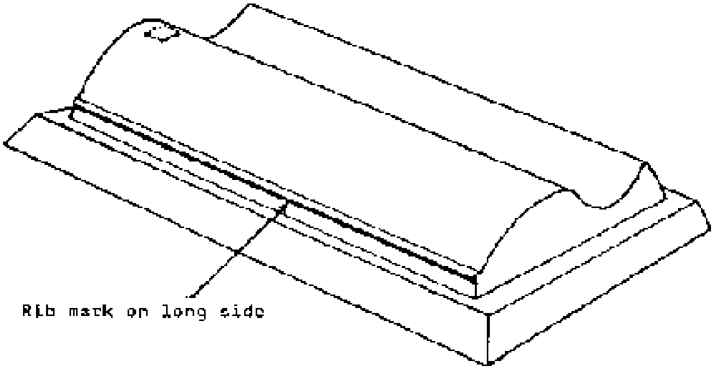


Figure 23. Rib mark on long side of pantile

Small plants with little start-up capital can get under way with the vibrating table and one PVC mould only. A print of the mould is taken and used to produce additional concrete moulds (cement/sand ratio = 1:1). This is a cheap and easy way to produce moulds but it presents

two major drawbacks:

- concrete moulds are heavy and difficult to handle;

- concrete moulds are solid, as opposed to hollow PVC moulds: they cannot be stacked and a large stacking area is required.

Other materials can also be used to produce the moulds. But the moulds must be shaped with absolute accuracy in order to ensure a good fit on the roof (regular overlap, watertightness).

V.2 Ridge tile moulds (figure 24)

Ridge tiles measure 26.5 cm across. They must adjust to the angle of the roof. The angle of a ridge tile must therefore be identical to that of the rooftop. Ridge tiles with a more acute (smaller) angle are acceptable. Tiles with a more obtuse angle (larger) are not acceptable.

The ridge angle may be calculated by applying the rule of the three angles of a triangle:	a + b + c = 180º
Example: the slope of the roof is 25º; the angle of ridge tiles should be:	180º -

	(25º + 25º) = 130º
Note: tiles are produced irrespective of the slope of future constructions. The technology is suitable for roof pitches ranging from 22º to 30º. Ridge tile production may be limited to those which are suitable for the steepest roof slopes (30º). In this case, the standard ridge tile angle should be:	180º - (30º + 30º) = 120º

Once the angle has been defined, moulds can be manufactured locally with the following technology:

> **Two wood profiles or metal angle bars are cut in a V-shape, the inner angle being equal to the angle calculated for the ridge tile (120º). The two shapes are kept parallel at a distance of 75 cm and nailed or screwed on two wood panels (figure 24).**
>
> **The thickness of the V-shaped profile allows for stacking of the moulds during curing (figure 25).**

V.3 Ridge tile demoulding jig (figure 26)

A special jig is required for demoulding ridge tiles. This demoulding tool must fit exactly into the "V" of the ridge tile. The demoulder is made of two wood panels nailed on two solid triangles with an angle identical to that of the ridge tile. The demoulding tool is shorter than the distance between the profiles of the ridge tile mould (figure 26).

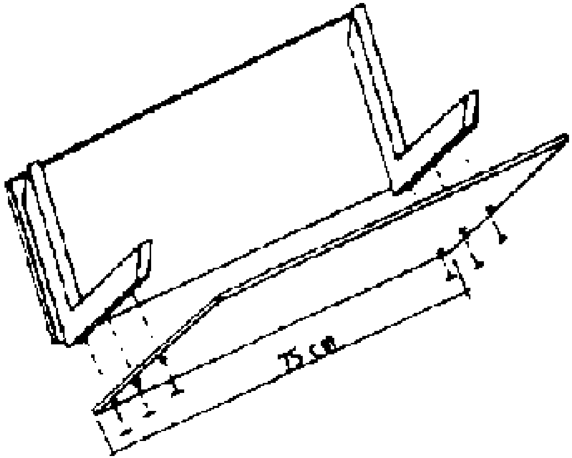


Figure 24. Ridge tile mould

The two V-shaped profiles form a 130º angle. Distance between the profiles allows moulding of two tiles.

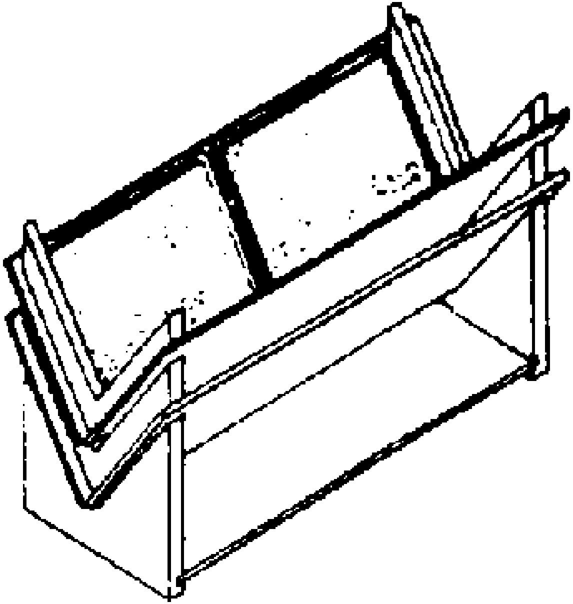


Figure 25. Stacking the moulds

V-shaped profiles can be stacked for mortar curing.

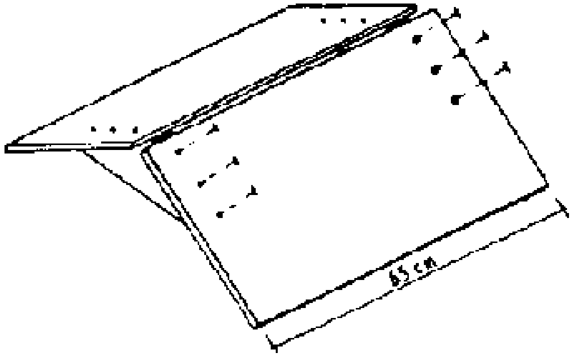


Figure 26. Demoulding jig

The profiles are solid triangles. Length of panels is inferior to distance between V-shaped profiles of ridge tile mould.

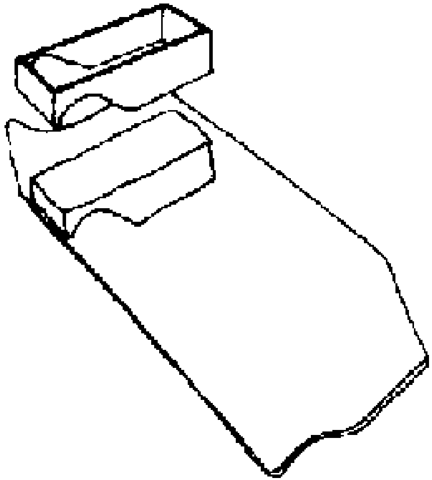


Figure 27. Bar mould for first row of ridge tiles.

V.4 Bar mould for first row tiles (figure 27)

The usefulness of this mould is explained in chapter IV, section IV. The mould is composed of metal flats soldered in the shape of a hollow rectangle. It is used to mould bars which are placed at the top of the upper side of the first row of flat tiles. As the bar should not interfere with tile overlap, the bar does not extend across the full width of the tile. It starts from the edge of the convex part and stops at two-thirds of the channel.

The underside of the bar mould is cast as a negative of the pan tile so as to ensure a perfect fit between the two surfaces.

VI. QUALITY CONTROL JIG (figure 28)

The quality control jig is a small metal tool. Two metal rods are bent to follow the negative curvature of the tile. They are connected by three cross-pieces. The demoulding jig is mounted on a pivoting axis which facilitates the transfer of the screed from the mould to the jig. The screed is laid on the jig after a 90º rotation and demoulded after a second 90º rotation, thereby completing a full 180º (see chapter IV, section 11.5, step 13).

When demoulding, two specifications should be carefully checked:

- **the tile must lie flush with the curved metal rods;**

- **at the same time the long edge of the tile must be in contact with the right-hand rod (see figure 52).**

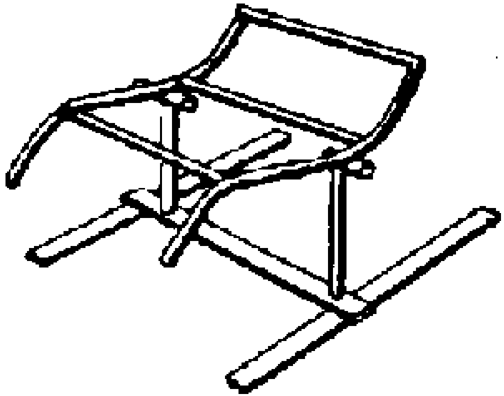


Figure 28. Demoulding jig

VII. BATCHING BOXES AND SCOOPS FOR RAW MATERIALS

Non-standard containers such as buckets, barrows, plastic basins, etc. are not suitable to measure accurately the appropriate quantities of sand, aggregate and cement for a good mix. This inaccuracy may have a negative impact on tile strength; the amount of sand, aggregate and cement used has an influence on the final ratio (see chapter II, section IV).

The weight and bulk of raw materials changes with a number of factors, such as water content and bulking. It is therefore necessary to use standard batching containers to ensure that the quantity of raw

materials used is as close as possible to the ideal theoretical ratio. These batching boxes determine the quantity of sand, aggregate and cement required to make a given number of tiles. Once the mix ratio is calculated, each batch of mortar will be mixed with "z" volumes of cement and "n × z" volumes of sand. Mixing ratios for sand, cement and fibre are discussed in chapter II, section IV.

VII.1 Standard ratios: good quality raw materials

Batching boxes meeting these criteria are usually supplied with the vibrating table. Their content corresponds to the correct quantity of sand and cement for approximately ten tiles. Their dimension is calculated to give an average

cement : sand/aggregate ratio = 1:3 in weight
1 : 2.5 in volume.

The dimensions of batching boxes are shown in table 11.

Table 11. Dimensions of batching boxes for the production of ten tiles

Batching box	Length cm	Width cm	Height cm	Volume cm3
Cement	24	24	5.1	2,937

Sand	26	25	12	7,800

VII.2 Non-standard ratios: poor quality raw materials

For poor quality raw materials, special batching boxes must be built to take account of the actual volume of materials to be used. Appropriate dimensions should be worked out by trial and error until the right ratio for a quality mix has been found (see Chapter V). Table 12 shows various extreme volumetric densities for sand and cement.

Table 12. Volumetric mass of cement and sand

	Real volumetric mass kg/m3 (1)	Dry apparent volumetric mass kg/m3 (2)	Moist apparent volumetric mass kg/m3 (2)
Sand	2,450 - 2,650	1,300 - 1,400	1,600 - 1,800
Cement	3,000 - 3,100	1,200 - 1,600	-

(1) Real volumetric mass expresses the density of the material only.

(2) Apparent volumetric mass expresses the density of the

bulked, dry or moist material. The air trapped between the grains increases the volume of space occupied by an identical "weight" quantity of raw material.

The following calculation is given as an example for a standard batch of sand:

1. Data

- Volumetric mass of slightly moist loose sand: 1,650 kg/m3

- Volume of 1 kg sand: .... $\frac{(1m3)}{1,650}$ **: 606 cm3**

- Cement: .... CPA 35

- Suggested cement : sand ratio: .... 1 : 2.5

- Weight of 6 mm tile: 1.600kg

2. Calculation

- Calculation of proportions:

(per tile)

cement: 1.600 kg + 3.5 = 0.457 kg

sand: 0.457 × 2.5 = 1.143 kg

- Calculation of standard volume:	606 cm3 × 1.143 kg = 692 cm3
- Measurements of sand batching box for 10 tiles:	24.5 × 24.5 × 11.5 cm

VIII. MORTAR SCOOPS

The kit usually includes mortar scoops giving the exact quantity of mortar for the production of one tile. Scoops are rectangular boxes sawn off diagonally (figure 29). The triangular section facilitates scooping and the levelling of excess mortar with the moulding trowel.

The exact volume of mortar required for each tile is the same as that of the screeding frame (table 13).

<u>Table 13. Volume of screeding frame for various tile thicknesses</u>

Tile thickness mm	Length of frame cm	Width of frame cm	Thickness of frame cm	Gross volume cm3	Pre-mitred corners(1) cm3	Net volume cm3
6	49	26.5	0.6	779	39	740
8	49	26.5	0.8	1,039	49	990
10	49	26.5	1.0	1,299	59	1,240

(1) The pre-mitred corners of pantiles should be subtracted from the gross volume of a plain rectangular screeding frame.

The inner volume of the frame should be increased by approximately 15 per cent to allow for compaction during vibration.

Standard mortar scoop sizes for tile thicknesses of 6 mm, 8 mm and 10 mm are given in table 14.

Table 14. Dimensions of mortar scoops for one tile(1)

Tile thickness mm	Volume of mortar (+ 15%) cm3	Length of scoop cm (L)	Width of scoop cm (1)	Height of scoop cm (H)
6	850	19	15	6
8	1,140	19	15	8
10	1,425	19	15	10

(1) The mortar scoop is triangular shaped.

Its volume is equal to

$L \times 1 \times \frac{H}{2}$

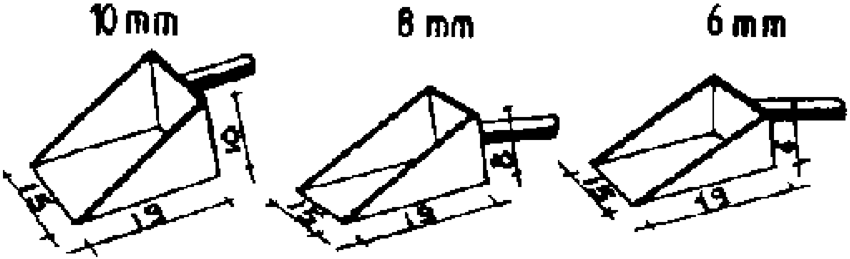


Figure 29. Mortar scoops

IX. CURING TANKS

Curing tanks are built either above ground level or sunk in the ground. Above ground curing tanks are easier to drain. The bottom of the curing tank should be slightly inclined to allow the water to flow into the drain hole.

The dimensions of curing tanks vary with plant size. Tanks should be located in such a way as to allow free circulation and handling. The width of the tank should be such as to ensure easy access when stacking and removing the tiles.

The density of stacked tiles may be as high as 150 to 200 units per square metre. The capacity of the curing tanks must therefore be calculated on the production capacity. For an average curing time of five days (ie. one week) the curing area should be large enough to accommodate one week's production. The dimensions of curing tanks for three different weekly production capacities are given in table 15. The height of tanks does not vary: it should be at least 60 cm to 70 cm.

Table 15. Dimension of curing tanks for various production capacities

Weekly production	Surface m2	Length m	Width m	Height m
1,000	5 to 6.5	3.5 to 4.5	1.5	0.7
2,000	10 to 13	6.5 to 8.5	1.5	0.7
5,000	25 to 33	16 to 22	1.5	0.7

The inside of the tank may be partitioned to provide compartments corresponding to one day's production. This makes turnover operations easier.

Other curing systems also exist. These are portable containers such as plastic containers or large crates pierced with holes and wrapped in large black plastic sheets (see chapter IV, section 11.7).

X. HAND TOOLS

X.1 Sieves and screens

Aggregate and sand sieving will eliminate big grains which are not appropriate. For the fibre concrete tiles, aggregate of size over 2,5 mm will be eliminated. The sieving mesh for this technology will be between 2 and 2,5 mm. For micro-concrete tiles, aggregate of size over two-thirds of tile thickness will be eliminated. Hence, the selection of the sieving mesh will depend on the thickness of the tiles to be produced. For an 8 mm thickness tile, the mesh will be 6 mm maximum.

There are two types of screens, square mesh and round mesh. In practice, a 1 mm square mesh is equivalent to a round mesh of 1 × 1.25: the amount of particles passing through a 1 mm square mesh is 25 per cent higher than for a 1 mm round mesh.

Sieves and screens are classified by mesh sizes and described in various national standards. Table 16 gives a comparison of five different mesh measurements.

- AFNOR standard (French):	- "M" module for square and round mesh sieves and screens;
- ASTM standard (US):	- square mesh sieves;

- ASTM number.

There are several methods of sieving sand (ref. 14):

- The sieve is placed at an angle on the ground and propped up with a piece of wood (figure 30);

- The sieve is placed directly over the transport device (wheelbarrow), thus avoiding intermediate handling (figure 31);

- The sieve is slung across two bars, a system which facilitates the shaking motion (figure 32).

Table 16. Comparison of various measurements for sieves and screens

AFNOR			: ASTM			
Sand	"M" module AFNOR No.	Square mesh size mm	Round mesh size mm	: :	Square mesh size	ASTM number
	38	5	6.3	:	4.76	3/16 inch
	37	4	5.0	:	4.0	5
	36	3.15	4.0	:	3.36	6

				:	2.83	7
Coarse	35	2.50	3.15	:	2.38	8
	34	2.0	2.50	:	2.0	10
	33	1.6	2.0	:	1.68	12
				:	1.41	14
	32	1.25	1.6	:	1.19	16
	31	1	1.25	:	1.0	18
	30	0.8	1.0	:	0.84	20
				:	0.71	25
Medium	29	0.63	0.8	:	0.59	30
	28	0.50	0.63	:	0.50	35
	27	0.40	0.50	:	0.42	40
				:	0.35	45
	26	0.315	0.40	:	0.297	50
	25	0.250	0.315	:	0.250	60
	24	0.200	0.250	:	0.210	70
				:	0.177	80
Fine	23	0.160	0.200	:	0.149	100
	22	0.125	0.160	:	0.125	120

	22	0.125	0.160	:	0.125	120
	21	0.100	0.125	:	0.105	140
	20	0.08	0.100	:	0.074	200
Fillers	Sedimentometry		0.06	:	0.1	

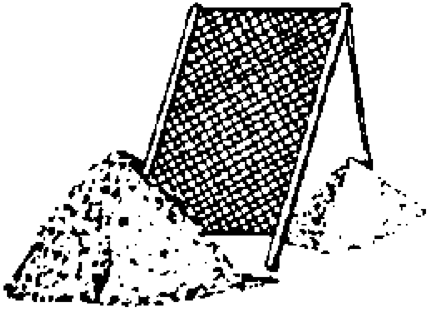


Figure 30. Sieve propped on the ground

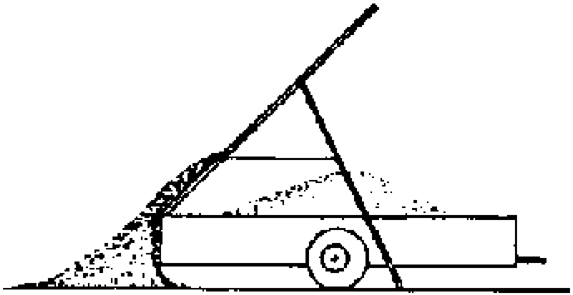


Figure 31. Sieve placed over wagon

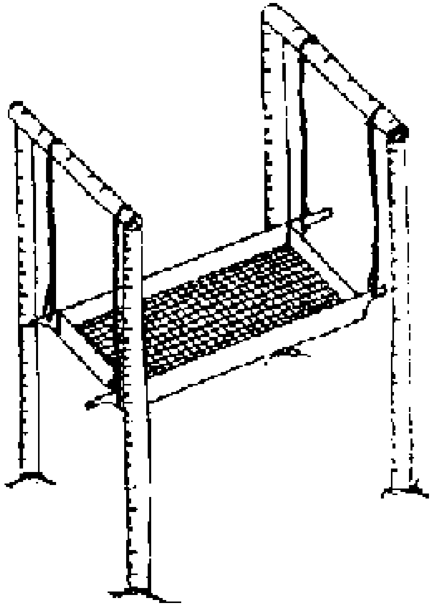


Figure 32. Slung sieve

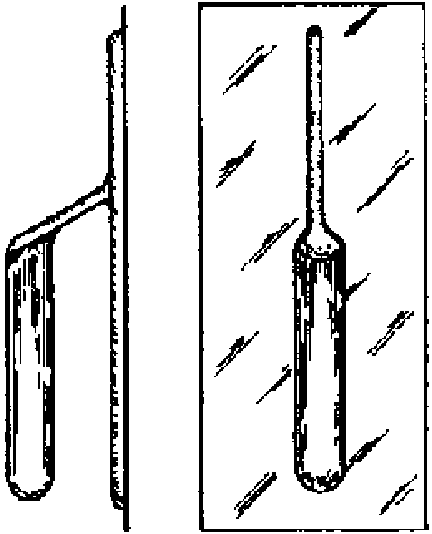


Figure 33. Trowel (or float)

X.2 Trowel (or float)

A float is a large trowel used by plasterers for rendering. It is made of a thin metal plate approximately 12 cm wide and 30 cm long. A handle is fitted to one side of the metal plate (figure 33).

XI. OTHER MOULDS

Research and development around this technology produces fresh

solutions for specific problems. Each region has its own building habits. New models and shapes of tiles must be found to meet specific requirements:

- Hip roofs require special hip tiles;
- Roofs on L-shaped buildings require special valley tiles;
- Roof edges require special edge tiles;
- Chimney stacks also require special tiles.

The concrete (fibre or aggregate) mix remains the same for all types and models of tiles.

XII. PLANT EQUIPMENT/PRODUCTION RATIO

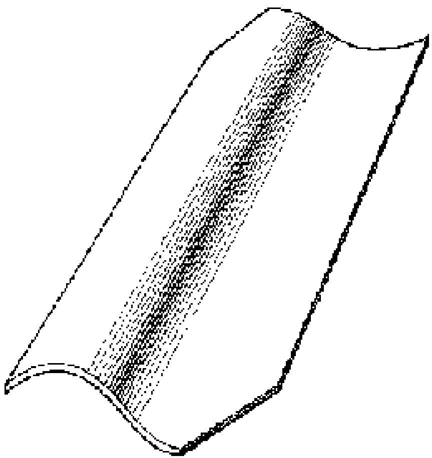
Table 17 shows the plant capacity required for a given weekly production. The corresponding curing tank areas are given in section IX of this chapter (table 15).

Table 17. Plant capacity for various weekly productions

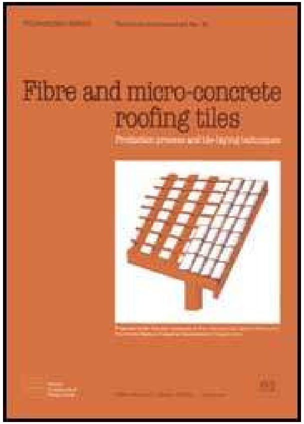
Tiles/ week	Vibrating table	Moulds (Pantiles)	Interfaces (per year) (1)	Ridge tile moulds (2)	Frames (Pantiles)	Frames (Ridge tiles)	Demoulding jig
1000	1	200	600	4	1	1	1

2000	2	400	1.200	8	2	1	1
3000	3	600	1.800	12	3	2	2
4000	4	800	2.400	16	4	2	2
5000	5	1.000	3.000	20	5	2	2

(1) You need 3 interfaces per mould; each interface lasts at least 4 months.
(2) In general, you make one ridge tile for 25 pantiles.



Concrete tile; overhead view



Fibre and Micro-Concrete Roofing Tiles - Production Process and Tile-Laying Techniques (ILO, 1992, 172 p.)

Fibre and Micro-Concrete Roofing Tiles - Production Process and Tile-Laying Techniques (ILO, 1992, 172 p.)

CHAPTER IV PRODUCTION PROCESS

This chapter describes the manufacturing process for pantiles and different types of ridge tiles. Pantile production is described step-by-step. For ridge tiles, most production stages are similar to those of pantiles. Ridge tile manufacturing will therefore be described only where it differs from pantile production.

I. INTRODUCTION

I.1 Influence of climate

Climatic conditions may affect cement setting. Three factors are of major importance:

- **air moisture;**
- **air temperature;**
- **wind speed.**

A combination of all three factors is detrimental to tile quality: wind combined with a low air moisture and high temperature speed up the evaporation of mixing water. This will result in micro-cracks which impair the quality of tiles.

Excess loss of mixing water through evaporation results in:

- **reduced hydration of the binder: lack of efficiency of binder and reduced strength of the end-product;**
- **increased porosity;**
- **excessive shrinkage during setting.**

For a mortar of constant consistency, there exists a relationship between air temperature and the amount of water to be used for the mix (figure 34).

If tile production is to be started in an area where wind speed,

temperature and air moisture are likely to impair the manufacturing process, it is essential to assess the effect of these factors on the mix water. Wind speed may be estimated as shown in table 18.

Table 18. Wind speed

Speed	Light breeze	Breeze	Stiff breeze	Very stiff breeze	Moderate gale	Gale	Storm	Hurricane
m/s	2	4	6	10	15	20	30	36 +
km/h	7	14	21	36	54	72	108	130 +

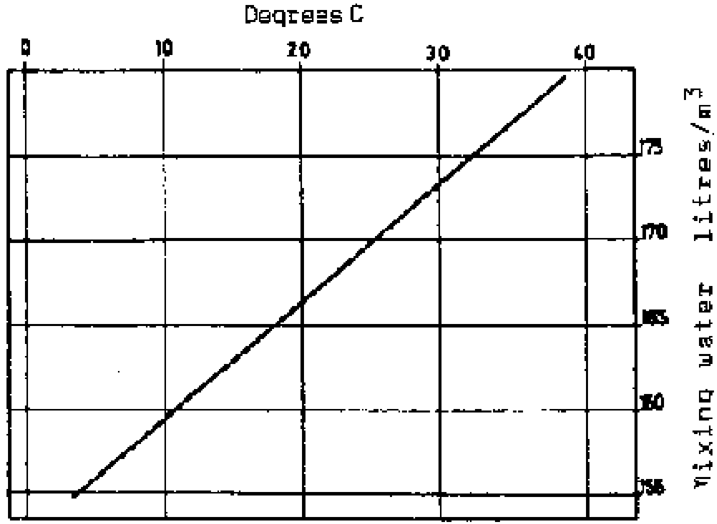
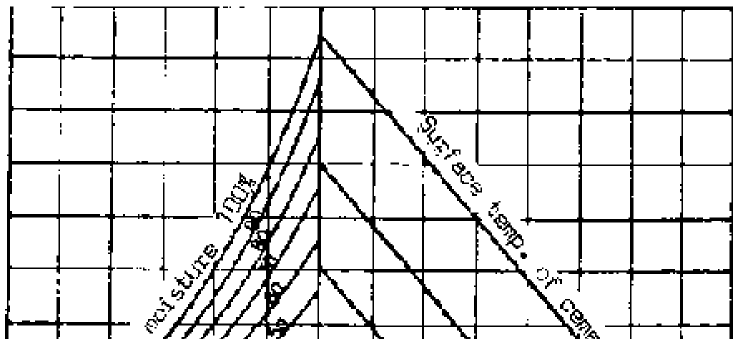
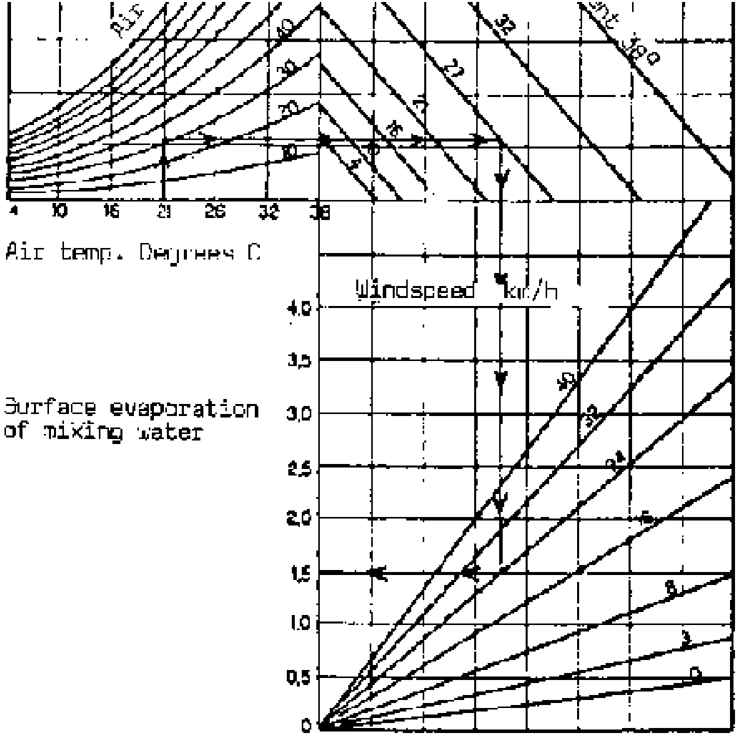


Figure 34. Approximate relationship between quantity of mixing water required and ambient temperature for constant mortar plasticity (ref.9)





<u>Figure 35. Surface evaporation of water in mortar</u> (ref. 21)

To calculate evaporation plot parameters following example (arrows)

The evaporation of water from the mortar as a result of the air moisture content, air temperature and wind speed is quantified in the abacus on

figure 35.

In order to calculate evaporation resulting from air temperature, the parameters should be plotted on the abacus following the sequence of the arrows in the example.

Evaporation is excessive if it exceeds one litre per square metre per hour. In this case, the mortar must be covered to prevent drying.

I.2 Calculating quantities by weight and volume

This section is a summary of the major steps described in chapter II, section IV, and chapter III, section VII.

1. <u>Sand, aggregate and cement</u>

The amount of cement used in the mortar mix determines the end characteristics of the finished product. An accurate proportioning of sand and cement is critical to the economics of tilemaking and the strength of the finished product.

Two major factors directly affect the quantities required:

- **moisture content (of sand and aggregate);**

- the degree of compacting (sand and/or cement).

The moisture content of the sand or aggregate depends on their origin, mode of transportation, storage conditions and air moisture. The degree of compacting of the sand, the aggregate and/or cement depends on the way the batching boxes are filled.

The key to an accurate proportioning of the materials consists in measuring the sand, the aggregate and the cement in standard containers. The content of the containers is calculated on the basis of the average volumetric mass of the materials concerned (see chapter II, section IV).

In order to avoid major deviations due to excessive bulking (loose material), each batching box should be slightly shaken or tapped on the sides with a piece of wood. This will ensure that the batching boxes are filled with consistently identical quantities of materials.

2. Fibre

Fibre presents exactly the opposite difficulty: the bulk of the raw chopped fibre is far greater than its final volume in the end-product. The bulking effect and compacting potential are such that the only acceptable unit of measurement for fibre is a weight unit (see chapter

II, section IV.2).

II. STEP-BY-STEP MANUFACTURING PROCESS - PANTILES

II.1 Stocking of raw materials

Cement is supplied in 50 kg bags and stored in a dry place. One bag of cement is sufficient to produce approximately 100 to 125 tiles.

Sand and aggregate are generally supplied in truck-loads of "x" tons or per cubic metre. They can be stocked outside, preferably under shelter.

Fibre is supplied in bunches or bales. It should be kept in dry storage and protected against rodents.

II.2 Preparation of raw materials

STEP 1: Sieving of sand

Before mixing the mortar, the coarser gravel should be removed. For fibre concrete production, the sand should be sieved with a mesh-size of approximately 2mm. For micro-concrete production, sand and aggregate should be sieved with a mesh-size of approximately two-thirds of the tile thickness. The choice of mesh-size also depends frequently on what

the local hardware stores have to offer.

Screening should be performed close to the storage area, on a clean surface. Sieving may be carried out in several ways: the sieve may be placed on the ground, on a transport device or slung on posts, trees, etc. (see chapter II, section X.I).

If the tests for clay and micro-organisms reveal an excessive amount of impurities, the sand should be washed out with water. This should be done carefully: excessive water pressure or flooding might result in a loss of all the finer particles and produce a coarse end-product. In such cases, a given amount of very fine sand may be added, although this technique produces very unpredictable sand grades.

STEP 2: Chopping of fibre

Fibres are generally very long and must be cut down to pieces of approximately 15 mm. Chopping may be done with a machete and block. A chopper may also be used to chop the fibre into pieces of identical size. This operation should produce enough fibre to last the whole day.

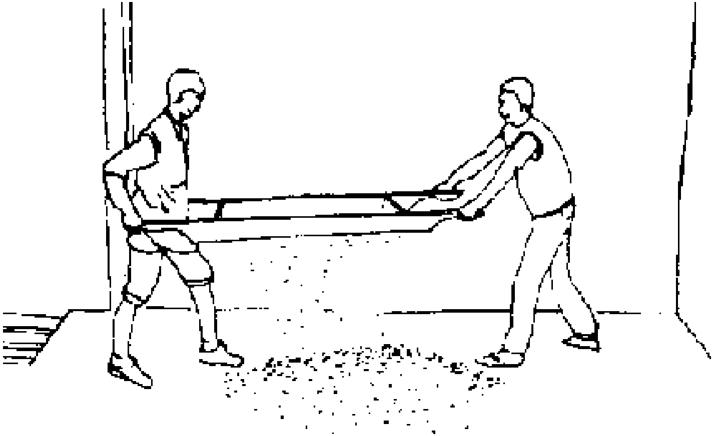


Figure 36. Sieving of the sand

II.3 Mixes and ratios

The blending of the various components of the mix is an important operation which must be carried out very carefully.

The materials are mixed in a clean area, either by hand or in a mortar mixer. If a mixer is used, several large hard spherical stones should be placed in the mixing tank. These stones will crush the aggregates formed by the moist sand, aggregate and cement. After blending, the mix should be smooth and homogenous, both in appearance (colour) and consistency.

STEP 3: Sand/aggregate plus cement mix

The sand and cement and aggregate are mixed together in the first stage. The various cement/sand ratios and tile thicknesses are given in chapter II, section IV.

Inaccurate measurement of proportions results in the following defects:

- too much cement:	- development of micro-cracks due to insufficient sand content;
	- increased costs;
- too little cement:	- brittle and porous end-product.

STEP 4: Mixing in the fibre (for fibre or micro-concrete only)

Once the sand/cement mixture is homogeneous, the fibre is added to the mix. The quantity of fibre is in the range of 0.5 to 1 per cent of dry mortar weight.

Fibres should be sprinkled into the mix in order to avoid bunching. A good distribution of fibres in the mortar gives added strength and resistance to the material during handling.

Inaccurate fibre proportioning results in the following defects:

- too much fibre:	- bunching, poor distribution of fibres, development of non-reinforced, brittle and porous areas in the tile.
- too little fibre:	- breaking during demoulding, handling, transport and placing on roof; - development of micro-cracks due to cement shrinkage during setting.

STEP 5: Adding water

The mortar must be workable and lend Itself to several operations: moulding, compacting, etc; it should therefore be soft enough, though not too wet. Water should be added gradually and sparingly.

The exact amount of water to be added to the dry mix (sand + aggregate + cement + fibre) is difficult to assess beforehand. It varies essentially with the moisture content of the sand and aggregate. A consistency and workability test should therefore be carried out: if the mortar contains too much water, it will tend to run. In theory the ideal cement: water ratio (in weight) is 0.65 (see chapter II, section IV.3). The Abrams cone slump test gives a measurement of mortar consistency. A description of the test follows.

A frequent mistake at this stage consists in not using the mortar soon

enough and adding water to the mix the moment it starts hardening. The adjunction of water at this stage perturbs the ongoing chemical process. This will result in impaired tile strength after curing. This defect is particularly marked at higher temperatures.

Using the wrong proportions will result in:

- excess water	- poor shaping on the mould: the mortar slum] down from the convex part into the channel;
	- increased porosity;
	- reduced stress and strain strength.
- too little water	- poor blending of materials;
	- presence of air pockets.

Abrams cone slump test

This test is frequently used to measure mortar consistency. A sheet metal truncated cone is used. The dimensions of the cone are: D = 20 cm, d = 10 cm, H = 30 cm (D = diameter of large base, d = diameter of small base and H = height). The cone is placed on the ground on its large base. It is filled with mortar through the small opening in four

layers, each layer being spiked several times. Once the mould is completely filled and the top levelled, the metal cone is removed carefully and placed next to the mortar cone. Immediately after demoulding, mortar slump is measured with a measuring rod. Slump is expressed in centimetres. By way of an example, a mortar with good workability should produce a slump figure of 4 to 8 cm (figure 37).

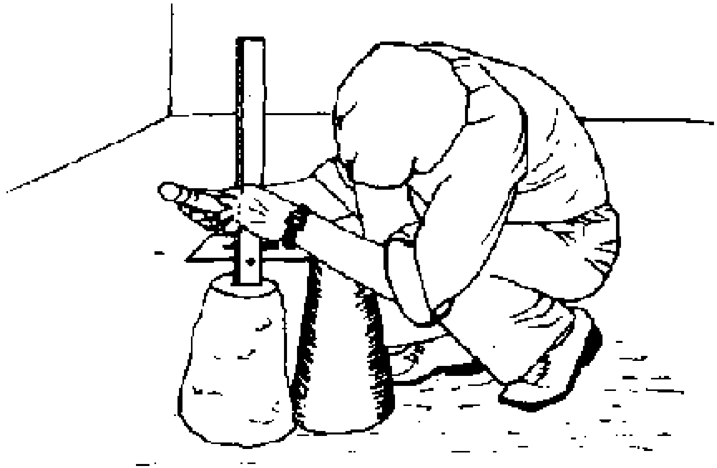


Figure 37. Measuring slump with Abrams cone test

II.4 Moulding

STEP 6: Preparation of materials

The first step consists in selecting and fixing the appropriate screeding frame for a normal tile (6 mm), medium tile (8 mm), thick and heavy-duty tile (10 mm), ridge tile. For normal climates, a 6 mm or 8 mm frame should be used. For hurricane or monsoon climates, 10 mm tiles will be required.

The top of the vibrating table should be clean and free of mortar residues. After each vibration, mortar projections and spillings should be removed from the table and frame. The presence of residues prevents a tight fit of the screeding frame on the table.

Moulds and polythene interface sheets should also be kept scrupulously clean. Before each moulding the interface sheet should be checked for holes by transparency. The use of punctured interfaces causes the cement milk to leak during vibrating. Punctured polythene sheets should therefore be rejected.

When the screeding frame is fixed on its hinges, it is in an upright position. An interface sheet is placed on top of the vibrating table (figure 38). The frame is lowered on the mould and locked. The interface sheet remains clamped between the frame and the table.

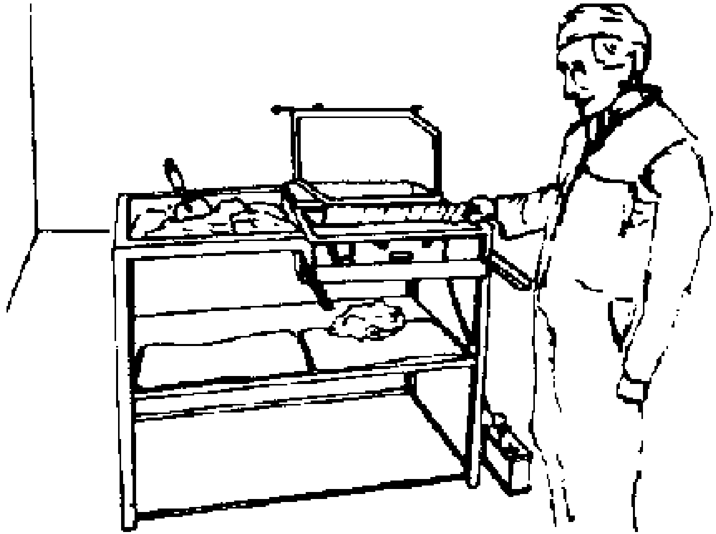


Figure 38. Placing the interface sheet on the vibrating table

STEP 7: Vibration: compacting

The standard mortar scoop gives the exact quantity of mortar for one tile. Excess mortar is levelled off with the trowel. The mortar is placed on the interface covering the screeding frame (figure 39).

The following step consists in vibrating and compacting the mortar. The motor is switched on (or manual vibration started by turning the handle). During vibration, the mortar is evened out with a trowel (figure

40). The trowel is used to:

- push the mortar into the corners of the frame, which tend to fill up more slowly;
- even out the surface of the screed.

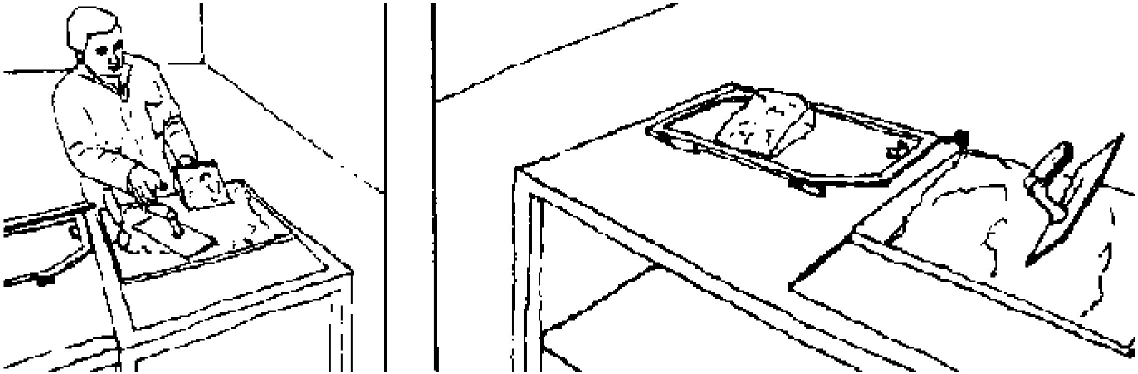


Figure 39. Transfer of standard quantity of mortar on to the vibrating table

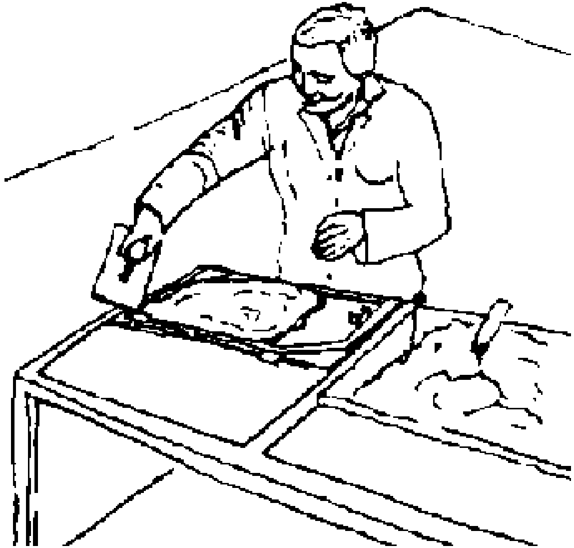


Figure 40. Screeding the mortar in the frame

The layer of mortar is shallow enough for any fibre lump to show up during vibration. The fibre may tend to bunch up and form small balls which run through the thickness of the mortar, thereby making the tile brittle and porous. These lumps should be picked out and replaced by an appropriate quantity of homogeneous mortar. Vibration should be continued for a few seconds in order to blend the extra mortar with the screed.

Duration of vibration

The main objective of vibrating-compacting is to remove the air bubbles trapped in the mortar. The compressive resistance of the dry mortar is in inverse relation to the amount of voids or air bubbles (figure 41).

In view of this relationship there seems to be an argument for vibrating the screed until all the air has been removed and maximum compactness has been obtained. Two limiting factors, however, make it necessary to time the vibration phase accurately:

- **the components of mortar have varying densities: when vibrated, the various components will segregate, with the lighter materials (fibres) rising to the surface, and aggregates falling to the bottom;**

- **the frame does not lock with the vibrating table with a watertight fit. During vibration, the mortar milk will tend to seep through the cracks.**

An excessively long vibrating phase can therefore result in reduced tile strength.

For adequate compacting, the screed should be vibrated between 45 and 60 seconds, depending on the materials used for the mortar (sand grading, water ratio, quantity of fibre). For correct timing of vibrating, the various components of the mortar should be monitored:

- the cement milk should not leak under the frame;
- the screed surface must remain smooth;
- the number of air bubbles breaking out at the surface should be less than when vibration is initiated;
- the fibres should not come up to the surface.

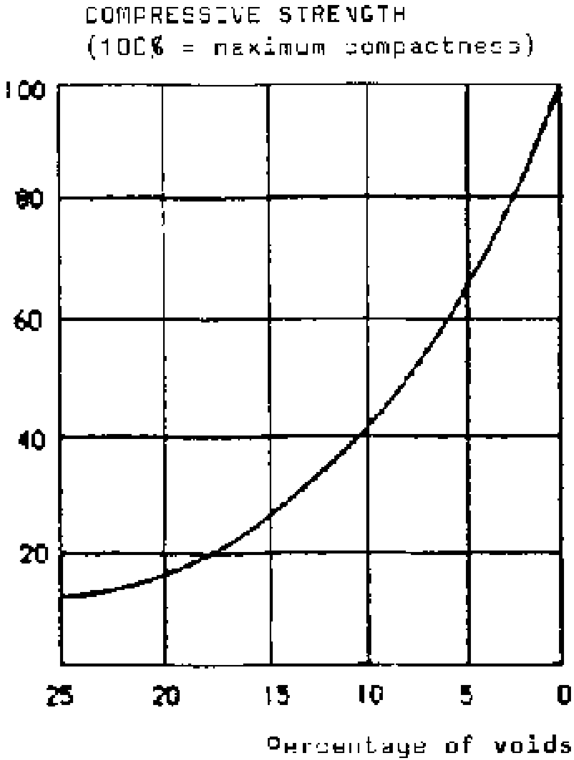


Figure 41. Relationship between compressive strength and compactness of screed (ref. 29)

STEP 8-a: Nib making

Once the tile surface is even and smooth the nib may be formed on the tile. The nib box is filled with mortar. This can be done either during vibrating if the operator is sufficiently skilled, or after vibrating (with motor switched off).

Extra mortar should be added on the top of the nib moulds. The vibration should be switched on again for a few seconds for good adhesion of the nib with the rest of the screed. During the second vibration the extra mortar will settle. If the second vibration is too long the base of the nib will run into the screed.

The motor is switched off and the top and side of the nib are evened out with the trowel until smooth surfaces are obtained (figure 42). This will ensure a tight fit of the tiles on the roofing laths.

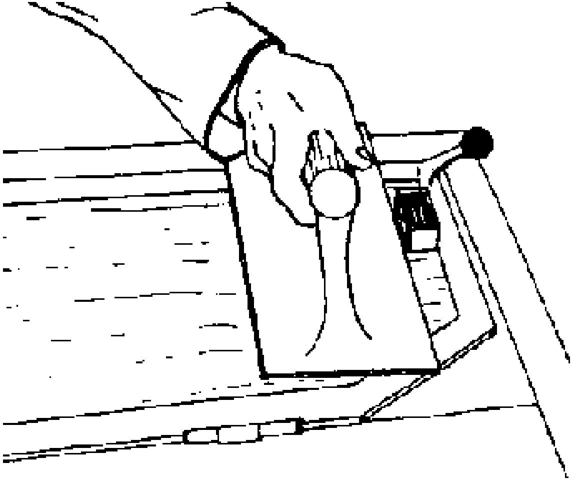


Figure 42. Making the nib

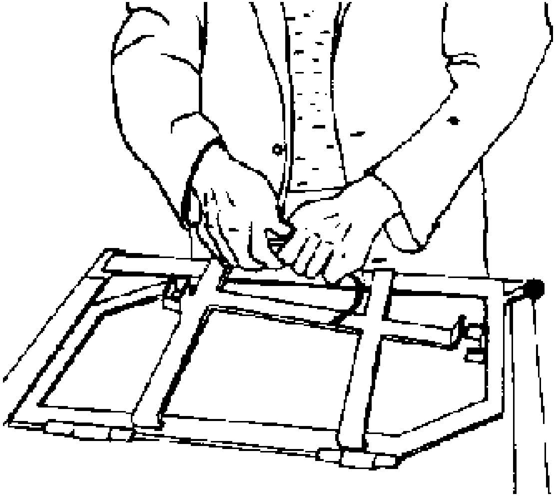


Figure 43. Making the second nib

STEP 8-b: Making the second nib

A second nib should be moulded on the tiles for heavy-duty roof cladding. With sufficient speed and precision, a skilled operator can mould both nibs in one operation.

The second nib jig is placed on the frame (figure 43). A four-arm clamp holds together the flat part of the pantile frame.

STEP 9: Opening screeding frame

The locked screeding frame is opened. The mortar in the nib jigs will be wrenched off from the rest of the screed if the frame is lifted without precaution. To obviate this the frame should be lifted whilst holding down the nib mortar with one finger (figure 44).

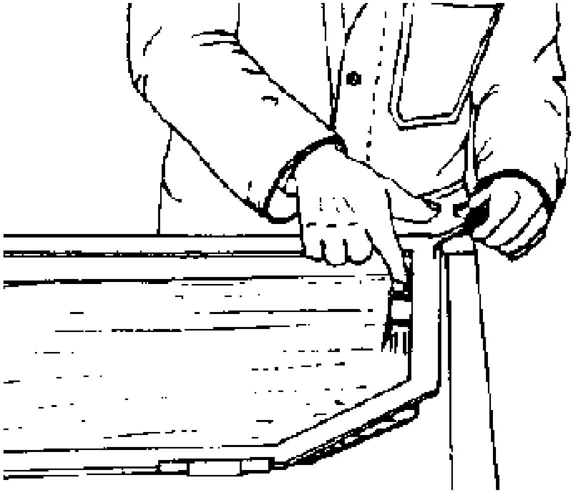


Figure 44: Opening screeding frame

STEP 10: Moulding

There are two ways of positioning the screed on the mould. If the mould is close to the vibrating table, the transfer sheet is transferred on the mould by holding it diagonally at opposite corners. An appropriate

balance should be found between the weight to be lifted and the shape to be retained. The transfer sheet is placed on the mould and positioned correctly along the marker lines.

If the mould can be positioned forward of the vibrating table, either on a board or on protruding brackets, the transfer sheet may be simply slipped from the frame to the mould (figure 45).

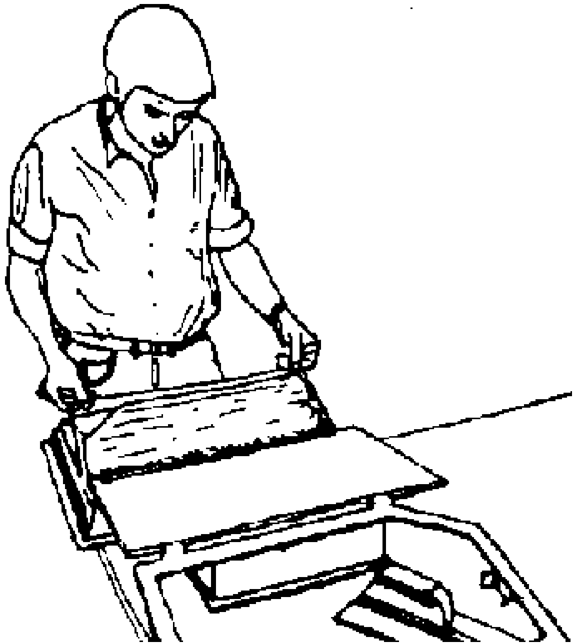


Figure 45: Transferring the screed on the mould

Utmost care should be taken when positioning the tile on the mould. Once the mortar starts setting on the mould this determines the final shape of the tile. For perfect overlapping of the tiles on the roof, the transfer sheet should be carefully positioned on the mould so that the long side of the tile is flush with the ribbed mark on the mould. The tile must also be laterally centred on the mould in order to keep the comers from collapsing and setting in the wrong position.

In order to facilitate correct positioning of the screed, the mould bears two marks (figure 24).

- a preformed rectangular mark in the mould shows the correct position for tile nib.
- a raised line on the long side of the mould shows the exact positioning of the near edge of the tile.

Correct tile moulding has a twofold influence on profitability: the quality of the end-product has a direct impact on the reputation of the production unit and the percentage of rejects at the quality control stage is a determining factor of cost-effectiveness and pricing.

If the tile is not correctly positioned with regard to these marks, three

defects will prevent a correct fit of the tile on the roofing structure:

- if the edge of the tile is not correctly positioned along the ribbed line, the tiles will not overlap, the outside curve of the tile not being identical;

- incorrect positioning of the nib will result in irregular tile/batten interface, hence irregular overlap;

- poor centering will result in collapsed edges and/or comers.

STEP 11: Checking the nib

The positioning of a level screed of mortar on a curved mould produces surface tensions. The curve of the fresh mortar produces marked tensions on the external surfaces of the nib base. Cracks may develop. It is therefore essential that the nib base be uniformly blended with the main body of the tile. The cracks on the two lateral sides of the nib should be smoothed out and closed with a long nail for perfect nib/tile cohesion (figure 46).

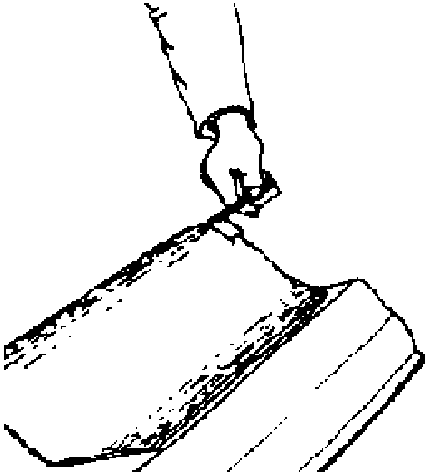


Figure 46. Finishing the nib

STEP 12: Tile fixing methods

At this stage the method of fixing will have been decided. Several fixing methods are possible (see chapter VIII, section V).

- the nib is left without fixing device. The tile will then be placed directly on the roof laths. The tiles are kept in place and relatively stable by the fit and overlap;

- the tile may be nailed to the laths through the nib. Allow the tile

to dry for one hour and pierce the nib before the mortar has set completely. This cannot be done when the mortar is fresh since the mortar would slump and block the hole. The nib is pierced with a roofing nail by passing it through the tile nib several times (figure 47). The nib should be kept in place on the tile by pushing it down gently with a finger during piercing;

- the tile may be fixed with a galvanized wire loop or plastic string sunk in the nib mortar. A loop is formed with a segment of galvanized wire. The loop is closed by a twist. The twist should be 15 mm to 20 mm long. It should be bent at a right angle at a 3 mm to 4 mm distance from the base of the loop. The twist is sunk into the mortar in the centre of the nib, from the inside to the outside of the tile. The nib should be kept down with a finger. The gap created by piercing the mortar with the wire twist should be carefully closed with extra mortar. The base of the loop should be level with the upper surface of the nib (figure 48).

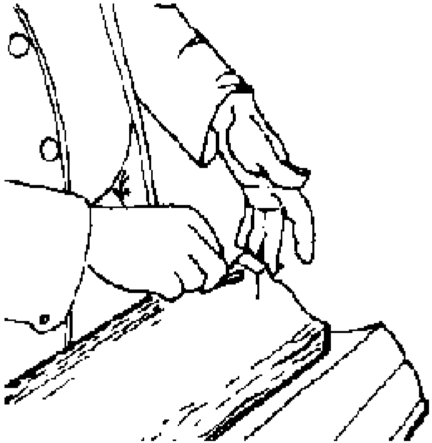


Figure 47. Piercing a hole in the nib

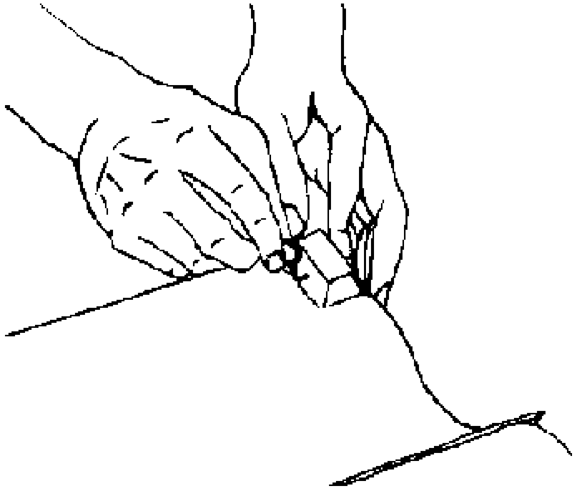


Figure 48. Wire loop cast in the nib

II.5 Setting of the mortar

STEP 13: First curing

During an initial 24-hour period, the moulds are stored for initial mortar setting. Curing should under no circumstances be carried out in inappropriate external conditions, i.e. excessive heat or dryness (see section I. 1 in this chapter). Setting should be slow in order to avoid the development of micro-cracks due to quick cement setting.

If the air is not sufficiently humid or a strong wind dries the mortar too quickly, the tiles should be watered regularly on their moulds. Alternatively, the stacked moulds may be covered with plastic sheets in order to retain the evaporation water and create an appropriately damp environment.

II.6 Demoulding

STEP 14: Demoulding of tiles

After 24 hours cement setting time, the tiles are ready for demoulding. The mould should be held on either side with both thumbs pressing upward (figure 49). The mould is rotated towards the operator to a vertical position. The tile is placed flush against the demoulding jig (figure 50). The jig and the mould are rotated by another 90º. The tile is then in horizontal position between the jig and the mould. The mould is removed and stored for cleaning. The transfer sheet on top of the tile is lifted or peeled off and also stored for cleaning (figure 51).

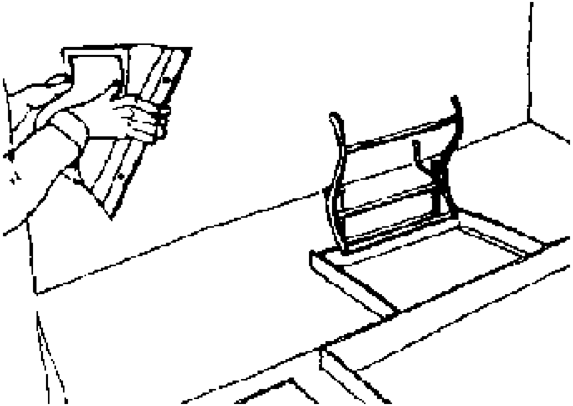


Figure 49. Carrying the mould to demoulding jig

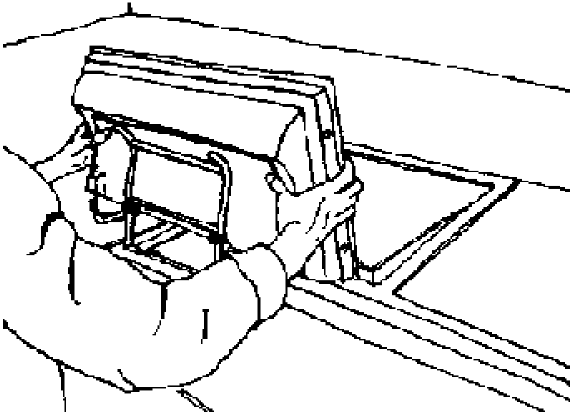


Figure 50. Positioning of mould against demoulding jig

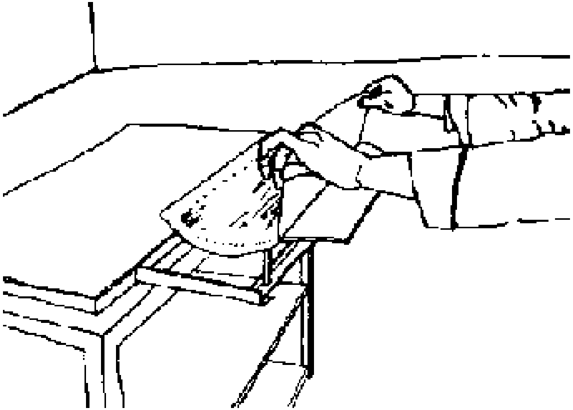


Figure 51. Peeling off the interface

STEP 15: Initial quality control

At this stage several quality controls may result in the reject of defective tiles:

- the surface of the tile must be smooth, ripple and wrinkle-free. Minor surface defects may be corrected. If the defects are too important (holes, wrinkles, etc.) the tile should be discarded;

- the long edges and sides of the tiles should be parallel two by two and form a 90º angle;

- tile parallelism is checked with the control bar of the demoulding jig. If the tile is warped, it will not overlap correctly. It should be discarded (figure 52);

- the curve of the tile is correct if the long side of the tile lines up with the edge of the control bar. If the gap between tile and bar is too wide (several millimetres) the tile should be rejected.

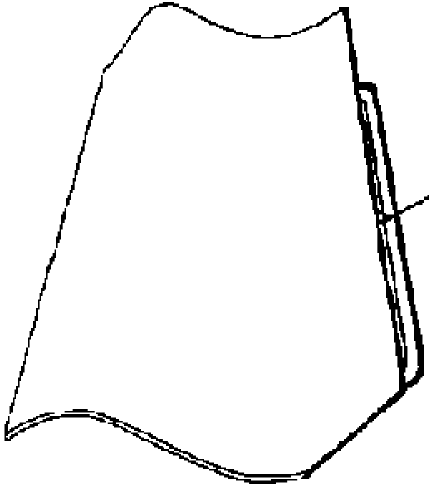


Figure 52. Checking parallelism

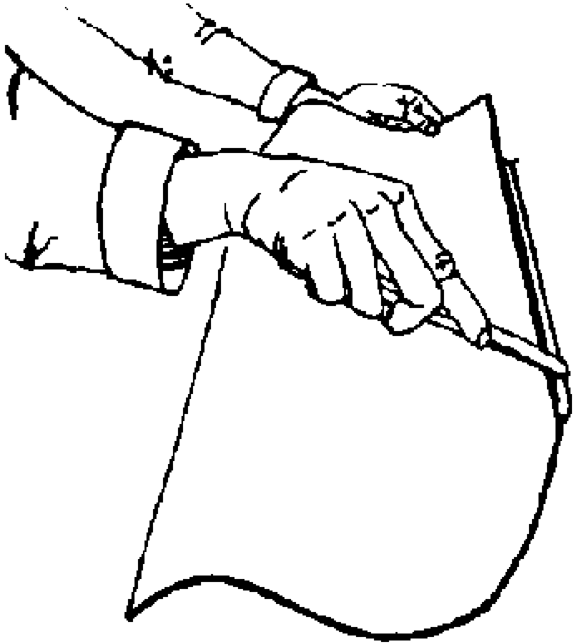


Figure 53. Trimming the edges

STEP 16: Trimming the edges

During vibration, the cement milk runs off through the cracks between the frame and the vibrating table. The cement milk produces an untidy fringe. At this stage of demoulding, the mortar is still fresh enough for this to be corrected: with a blade or rigid piece of metal the four sides

may be trimmed and smoothed (figure 53).

STEP 17: Transfer to curing tanks

The tiles should then be carried to the tanks or containers for curing. Each tile should be carried with both hands in a vertical position and placed carefully in the tank. During transfer the tile should be kept level. The mortar being still fresh, the tiles will break if these precautions are not taken.

The tiles are up-ended on their small side and stacked vertically against each other. Space can also be saved by stacking them in threes with the nibs overlapping. In this case more caution is required since the tiles are handled in threes (figure 54).

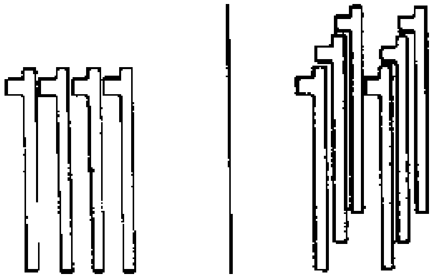


Figure 54. Cross-section of two stacking methods

II.7 Curing

STEP 18: Immersion or airtight packing

Curing of the tiles in water tanks or airtight plastic sheets prevents the water used in the mix from evaporating too quickly. Curing is necessary for the cement to set properly and maximize tile strength. The consequences of insufficient curing are:

- excessive shrinkage;
- development of cracks;
- reduced tensile strength.

Curing may be carried out by either of two methods:

The first method consist in packing the freshly demoulded tiles hermetically (figure 55). The tiles are placed vertically in wooden racks. A large plastic sheet, preferably black (to capture radiating heat) is used to wrap the crates. A small amount of water should be poured in the plastic sheet before wrapping so as to maintain a high degree of humidity in the pack through the action of heat on the black plastic material.

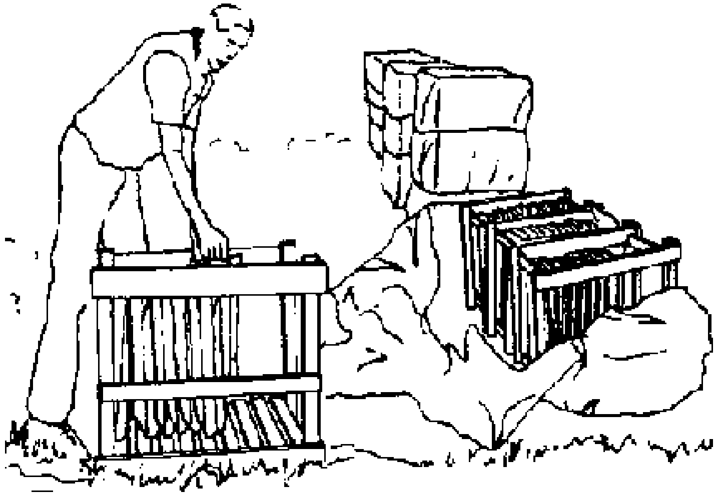


Figure 55. Airtight packing of tiles

The second method consist in immersing the tiles in large water tanks (figure 56). Curing tanks are often built above ground level but they can also be buried. In the first instance, drainage will be easier. In both cases the curing water should be drained twice a month since it would otherwise become caustic.

The tank should be filled with water until all the tiles are fully immersed. No part of the tiles should be left uncovered: this would produce differential strengths in the tile and induce micro-cracking. The tiles

should be placed in the tank day after day and each batch clearly marked in order to check immersion time.

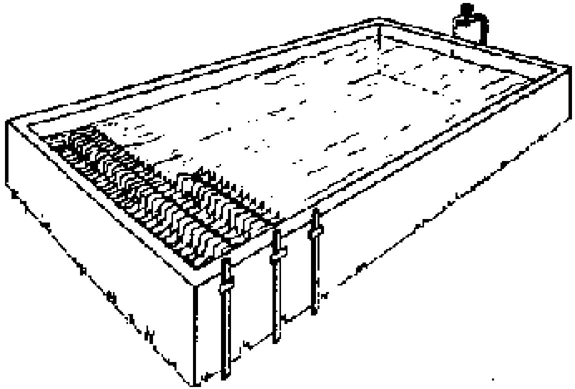


Figure 56. Immersion of tiles

Curing time

Curing time in immersion tanks or plastic wrappings depends on the quality of the cement, temperature and air humidity. In theory, the tiles should be sampled for various curing times and tested to define the ideal duration of curing (see chapter V). In practice, however, a curing time of five to six days is considered appropriate.

II.8 Storage

STEP 19: Drying and air curing

A certain time is required for the mortar to achieve maximum strength. Four weeks after hydration (mixing the mortar), the increase in strength begins to slow down. As a rule, final strength will be achieved after 24 months (figure 57).

The production cycle, from mortar mixing to the end of immersion or airtight stocking, lasts six days. It is usually considered that the tile should be stored for another three weeks before handling. During this period of air curing, handling is very delicate and requires a high degree of caution.

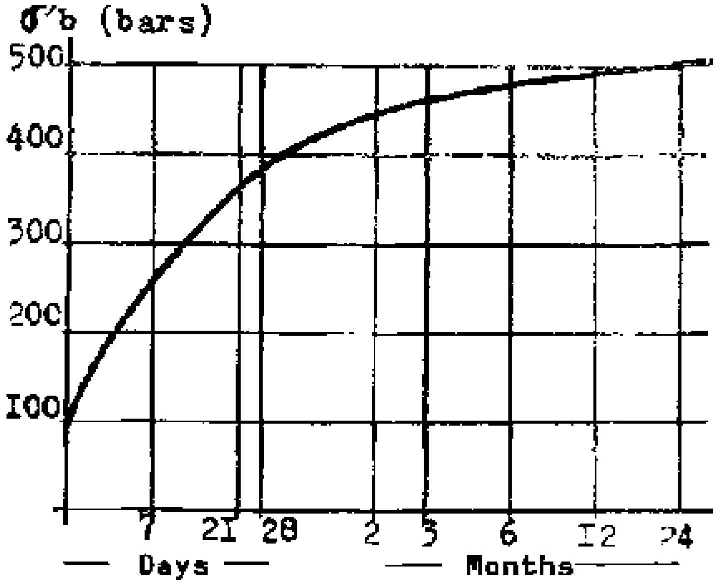


Figure 57. Strength of a high quality mortar over two years (350 kg cement per cubic metre) (ref. 9)

The tiles are stacked vertically resting on their small edge. The rows are stacked against a solid support. They may be stacked up to three layers thick provided each layer is covered with a protective material such as straw. However, if there is enough space available around the production unit, it is preferable to stack them in single layers. As in wet curing the tiles may be stacked in groups of three with the top tiles

resting on the lower nibs. This method gives a storage capacity of 200 tiles per square metre.

The curing area should be protected from the wind and direct exposure to the sun in order to prevent the tiles from drying too quickly.

III. RIDGE TILE AND HIP TILE

There are several types of ridge tiles. They differ in their mode of fixing or thickness. Hip tiles follow the same principle as ridge tiles. If their dimension is not different for architectural reasons, they will be identical with ridge tiles.

III.1 Ridge tiles jointed on the roof

The process for ridge tile production is similar to that of Roman tiles, although the frame and mould are different. The screeding frame is thicker for ridge tiles (ridge tiles should be 10 mm thick) and is rectangular in shape (without the blanked-off corners which are necessary for pantiles). Two marks are etched half-way along the long side of the screeding frame. Once the vibration is over, a line is drawn on the screed with the trowel, joining the two marks (figure 58).

This line marks the exact folding line for correct placing on the mould

(figure 59).

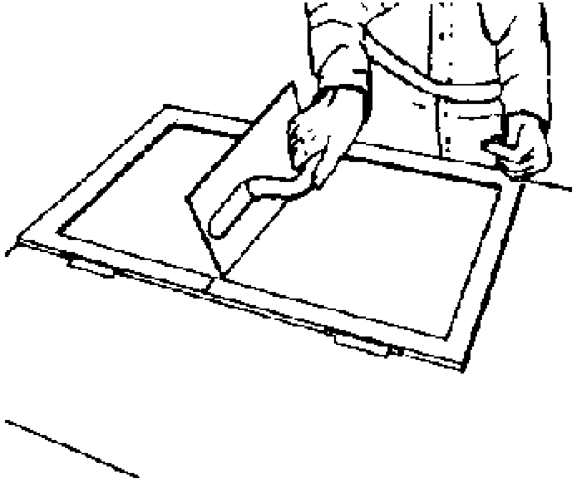


Figure 58. Fold mark

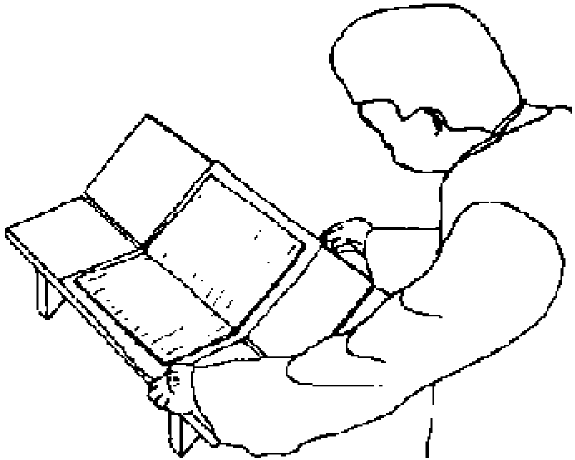


Figure 59. Shaping ridge tile on the mould

When the tile is placed in the mould the wire loops should be cast in the angle of the tile. For secure fixing a small lump of mortar should be added (figure 60).

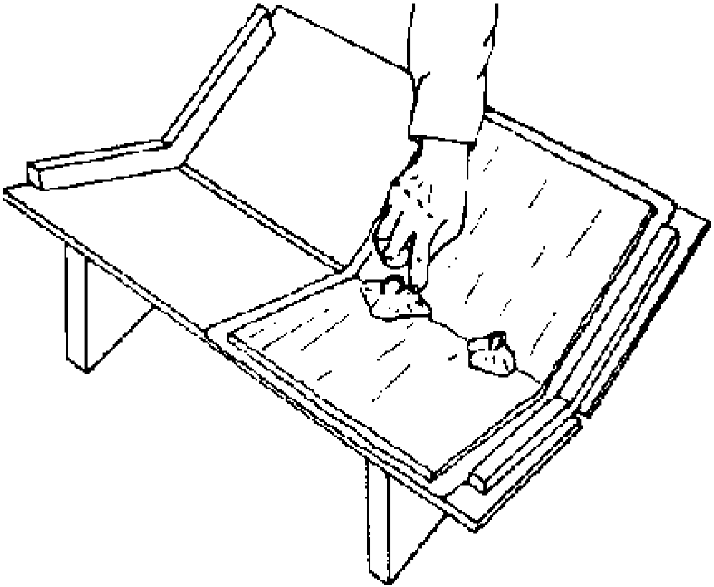


Figure 60. Placing wire loops

Two ridge tiles may be formed side by side in a mould. For demoulding, a "negative" jig is placed in the mould. The mould and tile are given a 180º flip. The mould is then in a topmost position and may be removed. The ridge tile is now resting on the demoulding jig. The interface sheet is removed.

Curing and storage for ridge tiles are the same as for pantiles.

III.2 Ridge tiles with overlap

Ridge tiles with single overlap ensure improved watertightness. They are made of two layers of screed of 6 mm to 10 mm thickness (depth of frame to be adjusted). The two screeds are joined together, leaving a small space at either end for the overlap. They are made in two stages:

- The first screed is made as for a normal ridge tile, including casting of the wire loops and initial 24-hour curing (figure 61);

- Twenty-four hours later, a second 10 mm screed is vibrated and positioned on the mould. The tile moulded the day before is immediately demoulded and placed on the fresh screed of the second tile (figure 62). The first tile has already set and is pressed gently flat against the second tile (figure 63), leaving a few centimetres on the side of the fresh tile before bonding the hardened tile. This will create an overlap ensuring a tighter fit of the ridge tiles (figure 64).

After allowing to dry for another 24 hours, curing and storage are carried out as for pantiles.

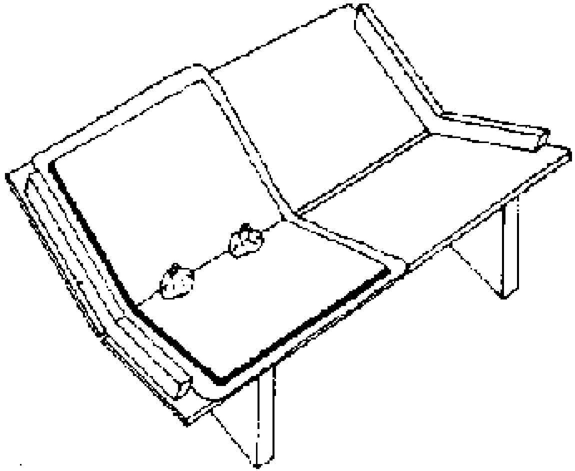


Figure 61. First standard ridge tile

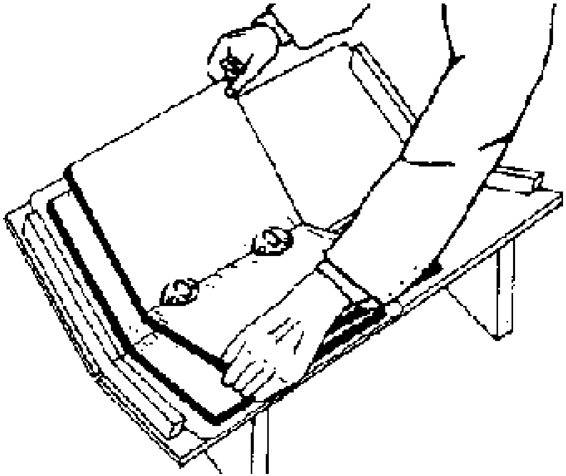


Figure 62. Placing the first tile on fresh tile

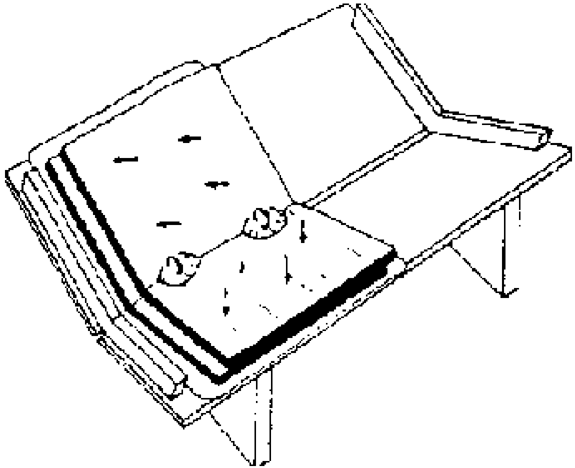


Figure 64. Overlap

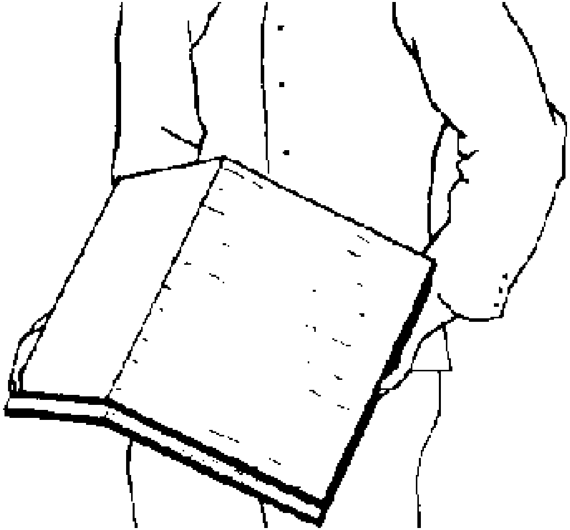


Figure 63. Joining first tile on second tile

III.3 Joint between ridge tile and hip tile

These connecting tiles are shaped specifically to form the joint between the ridge and the hip. They cannot be made beforehand and should be formed on the roof by joining the ridge and edges of the roofing with identical mortar.

Another solution consists in cutting out the hip tile and ridge tiles in such a way as to ensure the tightest fit possible (figure 65).

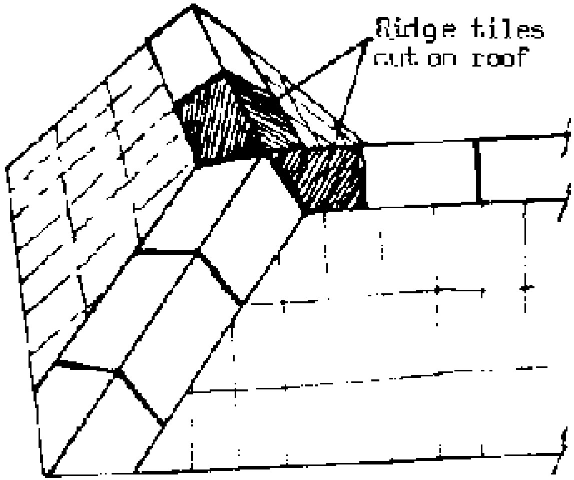


Figure 65. Angle joint tile for hip-roof

IV. FIRST ROW OF TILES

The first row of tiles is placed at the top of the roof under the ridge tile. The lower edge of the ridge tile rests on the concave part of the pantile. The channel part of the pantile or roman tile thus leaves a gaping hole connecting with the roof structure. In order to avoid the wind pushing under the roof through these openings, and/or wind suction on the roof, a small bar should be moulded on the uppermost side of the pantile. The lower part of the bar follows and adheres to the hollow part of the tile, whilst the upper part is level. Together with ridge tiles, this first row of

tiles provides a tight fit across the whole length of the ridge (figure 66).

The bar is moulded on a pantile after the initial 24-hour curing period. Once the bar is moulded, curing and storage of the tiles are the same as for pantiles.

V. VALLEY TILES

Valley tiles, are used to dispose of run-off water in the roof angle of L-shaped structure. Ridge tiles placed upside down may be used as valley tiles. In such a case, no wire loops should be placed in the angle of the tile.

Valley tiles may also be moulded on special moulds (figure 67 b). The same screeding frame as for ridge tiles may be used. The mould (figure 67 a) may be produced locally, e.g. from wood.

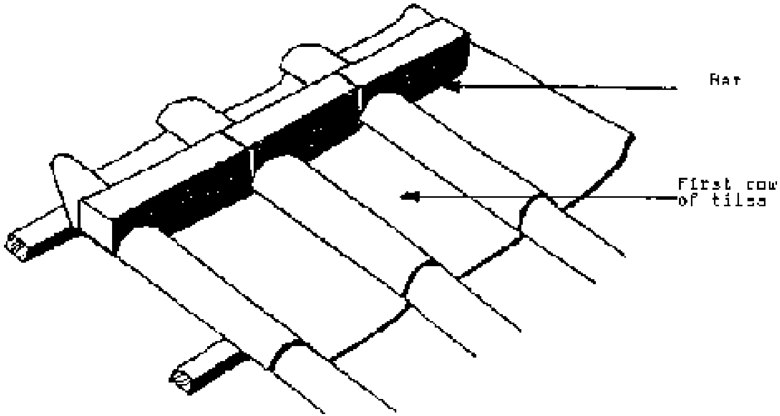


Figure 66. First row of tiles

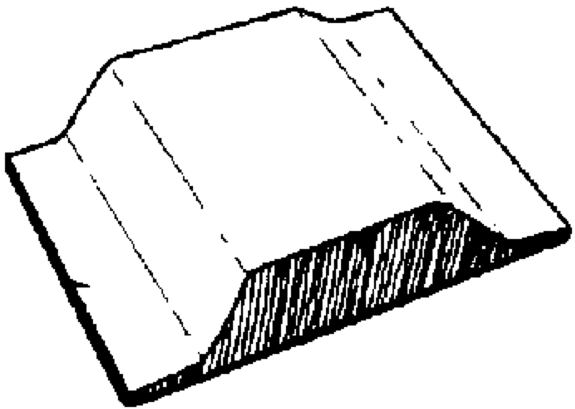


Figure 67 a. Valley tile mould

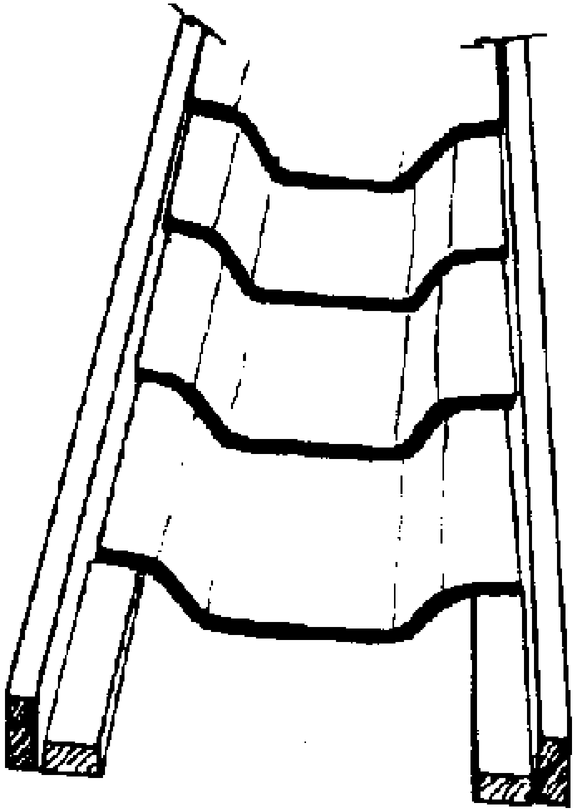
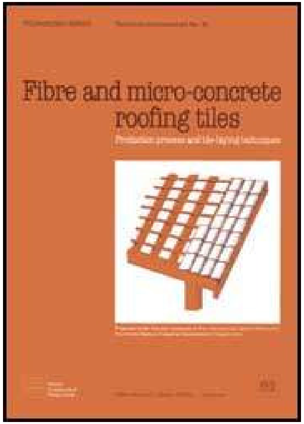


Figure 67 b. Valley tile



Fibre and Micro-Concrete Roofing Tiles - Production Process and Tile-Laying Techniques (ILO, 1992, 172 p.)

CHAPTER V QUALITY CONTROL

I. STANDARDS

I.1 Rationale

One of the major constraints standing in the way of the production and widespread use of local materials is the absence of standards or technical specifications allowing for strict quality control and the delivery of a quality label.

Where the standards do exist, they are at times too stringent. A frequent mistake consists in referring back to texts produced in different socio-economic and technical environments: existing standards applying to imported materials or materials produced in large-scale industrial units are taken as such or slightly adjusted to apply to quality tests for local materials. The basic information on which the standard is based does not take into account the specific circumstances of the local environment: type and quality of available raw materials, production process, building methods, roofing methods, labour, etc. The application of inappropriate standards results in unduly stringent criteria which are simply not relevant to local building conditions.

Where there are no standards, more specifically in connection with government tenders, control institutions are reluctant to extend a ten-year guarantee, or indeed refuse it. As a consequence, architects,

contractors and customers hesitate to insist on local materials.

In both cases this prevents the use of appropriate materials. Standards are legal instruments which should encourage the promotion of acceptable and competitive materials on the market for building materials, thereby promoting economic, safe and durable constructions.

Several government institutions involved in the building industry find themselves confronted with this problem. Work is under way to collect as much technical information and reports of first-hand experience as possible. Some public works test laboratories are carrying out surveys. An expert meeting on the drawing up of standards for local materials has developed a special methodology to cope with this problem (ref. 15).

At present, in the absence of official standards, quality criteria have been developed to ward against defective materials. These criteria are based on national or international standards and adjusted to suit the specific technologies,[1] which are appropriate to the socio-economic and climatic circumstances of developing regions. Sections II and III present a number of tests defining the quality of fibre or micro-concrete tiles.

[1] **Recommendation ISO No. R393, 1964. British Standards, BS 4624, BS 690, 1973; American National Standard ANSI/ASTM 221.77, 1977; Deutsche Normen, DIN 274, 1972; Danish Standard DS/R 1112-1114, 1979; Norwegian Standard NS 831,1956; Swedish SIS 226 801, 1966.**

I.2. Example of standard specifications

Standard specifications for fibre and micro-concrete pantiles have been developed in Kenya by a "Fibre Concrete Tile Technical Committee" with the guidance of the Civil Engineering Industry Standards Committee of Kenya. These specifications specify the acceptable characteristics of raw materials as well as the various norms which should apply to these tiles. The list below indicates the various items to be covered by the standard specifications.

1. Scope

2. Definitions:

- **2.1. Acceptable**
- **2.2. Defective**
- **2.3. Sample**
- **2.4. Measurements (length - width)**

2.5.- Upper-side
2.6. Under-side
2.7. Type of fibre

3. Materials:

3.1. Cement
3.2. Aggregate
3.3. Water
3.4. Admixtures
3.5 Pigment
3.6. Fibres

4. Requirements:

4.1. Dimensions

4.1.1. Length
4.1.2. Width
4.1.3. Thickness

4.2. Nib
4.3. Overlap
4.4. Fixing devices

4.4.1. General
4.4.2. Nailing
4.4.3. Loops

4.5 Colour
4.6. Surface defects
4.7. Surface coating
4.8. Compressive strength
4.9. Permeability
4.10 Porosity

5. Marking:

5.1. Manufacturer
5.2. Dealer
5.3. Standard number
5.4. Production date

6. Sample
7. Conformity
8. Frequency of tests

II. RAW MATERIALS

Quality control of raw materials consists in checking whether the materials supplied are suitable for the technology (in other words, whether their characteristics meet the requirements described in chapter II). Tests should be carried out at regular intervals on samples taken from sand deliveries, in particular to check particle size, organic matter content and clay content. Special care should be taken when changing suppliers or sources of supply. Samples should be taken and tested for each new delivery.

If the samples taken prove unsatisfactory, sampling should be increased. If the samples fail the tests, the delivery should be cancelled, with a request to supply materials consistent with specifications.

III. FINISHED PRODUCTS

III.1 Shape and dimension

Each tile is checked for correct shape after demoulding by positioning it on the control jig. Tile dimensions are usually correct since they are moulded in a metal frame. The outside measurements of a pantile (produced with the equipment described in chapter III) are 49 cm × 24 cm. In some cases the trimming of rough edges may be excessive (see chapter IV, step 16). If so, tile width being reduced, the tiles will not fit correctly and the overlap will not be regular. Differences in tile widths

should not exceed 5 mm.

The main source of error is due to poor positioning of the screed on the mould, a frequent source of warped tiles (see chapter IV, step 15).

III.2 Tile strength

The tiles should be strong enough to withstand transport and handling. Once they are in position on the roof they should resist minor impacts. In special circumstances, such as frequent hailstorms, debris blown by violent winds, proximity of sports grounds or trees bearing heavy fruit, standard tiles should be replaced with heavy-duty tiles. Heavy-duty tiles are either thicker (8 mm to 10 mm) or made with a higher cement/sand ratio (see chapter II, section IV).

Four tests are available to check tile strength. Three tests concern the tile itself and one the tile nib.

All strength control tests should be carried out after three to four weeks of curing.

1. <u>Ring test</u>

The tile is held by the nib and tapped lightly with a coin. It should have a

clear and sharp ring. In the presence of micro-cracks the tile sounds a dull note.

2. Impact test

The impact test is carried out with a 200 g ball. The tile is placed flat on a table. The ball is dropped from a height of 20 cm, from the base of the ball to the surface of the tile (figure 68).

The impact of the ball on the tile should not produce any internal micro-cracks. A second ring test should then be carried out.

For heavy-duty tiles which must withstand more severe impacts (hailstones, various objects, fruits, etc.) the ball should be dropped from 50 cm.

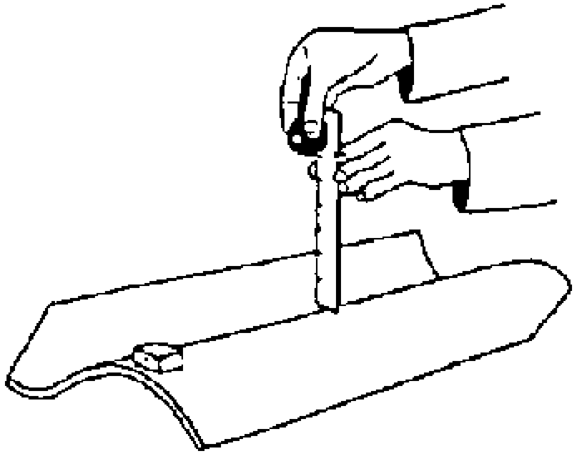


Figure 68. Impact test

3. Load test

The tile is placed across two supports (two bars, two tables side by side), separated by a gap of 37.5 cm. A wooden jig 25 mm thick and cut out to follow the contours of the tile is placed half-way between the supports, i.e. 17.5 cm away from each support. The jig should be slightly wider than the tile in order to avoid touching the side of the tile. A load is hung on the jig below the tile (figure 69). The tile should withstand the load. The minimal acceptable load depends on tile thickness (table 19).

Table 19. Minimal acceptable load for different tile thicknesses

Tile thickness	6 mm	8 mm	10 mm
Load	30 kg	50 kg	80 kg

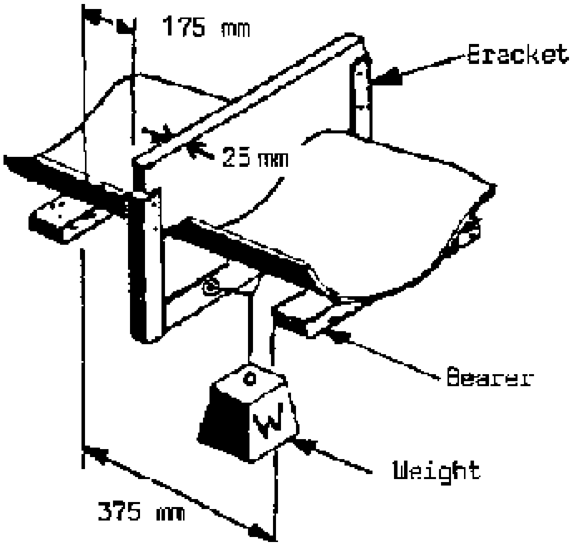


Figure 69. Load test (ref. 25)

4. Nib load test

The tile is laid on the edge of a table with its nib side overhanging the

edge of the table by 5 cm. The nib faces downward. The tile is maintained on the table by a strap or a weight heavier than that of the test load (figure 70). The load to be applied to test the tensile strength of the nib depends on the tile-fixing method.

- **if the tile is fixed to the lath by hammering a nail through the nib, a 15 kg load will be sufficient;**
- **if the tile fixing is a galvanized wire loop, a 20 kg load will be required (see figure 70).**

The tile should remain intact; the nib should not break; the wire loop should not break nor be torn away from the nib.

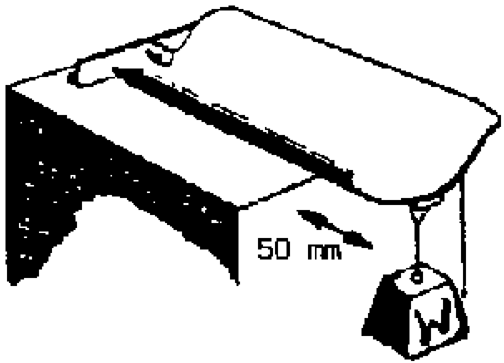


Figure 70. Nib load test (ref. 25)

5. Moat frequent causes of low strength

- **inadequate mixing of mortar;**
- **insufficient cement;**
- **poor quality cement;**
- **tiles tested before curing is completed;**
- **deficient immersion (incomplete or too short);**
- **fibre contaminated by a substance weakening concrete setting;**
- **inadequate sand characteristics;**
- **balling of fibre.**

III.3 Porosity test

Porosity tests should also be carried out after three weeks' curing.

Two tests may be carried out to check the watertightness of the tile. A third test measures absorption resistance.

1. Flooding tile channel (figure 71)

The tile channel (concave part) is blocked on either side by two lumps of wet mortar or clay. The pool between the two weirs is filled with water. The tile is allowed to stand on supports for one day. This exposure is equivalent to a continuous 24 hour rainfall. The under-side of the tile is

carefully examined. No free water (drips) should seep through the tile. Signs of dampness are acceptable but the less the better. British Standards 473 and 550 specify that less than 25 per cent of the under-side of the tile may show dampness stains.

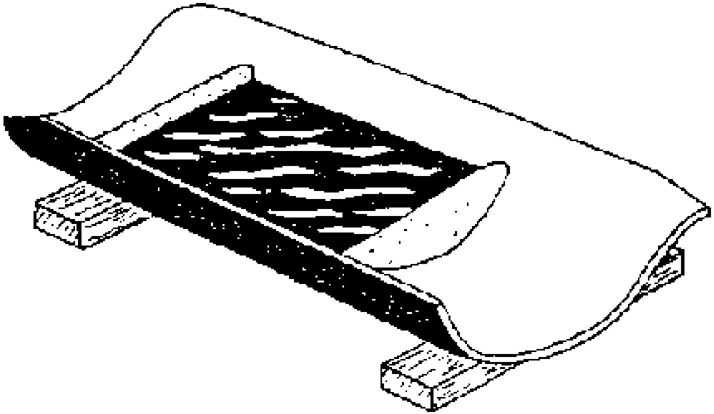


Figure 71. Porosity test; pool is formed in channel, water allowed to stand for 24 hours

2. Water column (figure 72)

A water column is built with a glass tube of 300 mm height and 35 mm inside diameter, open at both ends. The glass tube is placed vertically in the channel of the tile. The base of the tube is joined to the upper-side of the tile with a watertight seal. The tube is filled with water up to 250

mm. The tile should be dry when the test starts and submitted to a 24 hour exposure. No droplets should show on the under-side of the tile. A damp stain is acceptable.

3. Absorption test

The absorption capacity of the tile may be measured by a simple test. The tile should be previously dried at a high temperature (e.g. in an oven) and weighed. After exposure to driving rain (or other criteria to be defined), the tile is again accurately weighed. Absorption is quantified by the following formula:

$$\frac{(\text{Humid weight} - \text{Dry weight})}{\text{Dry weight}} \times 100$$

However, in view of a number of environmental factors having an impact on humidity (temperature, wind, evaporation), this measurement cannot be used as such as a selection criterion.

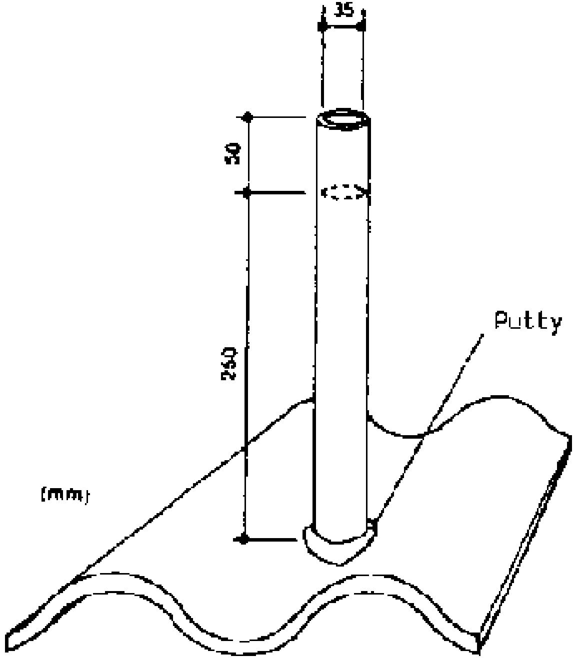


Figure 72. Porosity test: 24 hour water column exposure (ref. 10)

4. Causes of deficient watertightness

- **deficient blending of materials (balling of fibre);**
- **excess fibre;**
- **excess water;**

- excess vibration;
- insufficient or incomplete immersion;
- inappropriate sand grading.

IV. PROBLEMS AND SOLUTIONS1

Problems occurring in tile production and quality control may be due to various causes. Problems do occur from time to time during production. They are spotted by means of quality control or on the occasion of unforeseen events in production. This section describes the various problems which may occur, their causes and possible solutions.

PROBLEMS	CAUSES	SOLUTIONS
Delayed or slow mortar setting	Use of cement held in stock for too long Contaminated fibre	Use fresh cement Check fibres for impurities
	Sand contaminated by organic matter or clay	Check sand for impurities
Mix too thick, not sufficiently workable	Fibres too long Too much fibre	Shorter fibres Reduced fibre content
	Too many large particles	Sieve sand Change sand supply
	Not enough fine particles	Add fine particles or

	Not enough fine particles	Add fine particles or cement
	Mix too dry	Add water
Mix requires a high cement: water ratio	Sand contaminated by organic matter or clay	Check sand
	Sand contains too many fine particles	Add large particles
Runny mix	Excessive water: cement ratio	Reduce water
	Not enough fine particles in sand	Add cement or fine particles
Segregation of materials during vibration	Not enough water	Increase water
	Not enough fibre	Increase fibre
	Not enough intermediate particles	Check/increase/change sand
Fresh tiles develop cracks	Mixing water evaporates too fast	Cover moulds with plastic sheets
	Not enough fibre	Increase fibre content
Tiles porous and brittle	Too much water	Reduce water
	Not enough cement	Increase cement

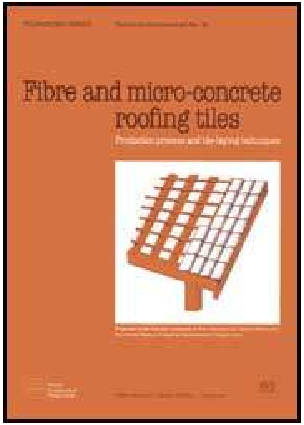
	Not enough cement	Increase cement
	Too many fine particles in sand	Add large particles
	Too much pigment	Reduce pigment
	Mix not correctly compacted	Increase vibration time
	Insufficient water curing	Increase immersion time
Pock marks (holes) on tile surface	Excessively dry mix	Add water
	Incomplete compacting	Increase vibration time
Tile does not fit on roof	Incorrect spacing of battens	Check spacing of battens
	Screed incorrectly placed on mould	Check moulded tile for warp
	Untidy fringes	Trim edges when demoulding

1/ This section is translated and supplemented from reference 29.

<u>SUMMARY:</u> The problems described above may be avoided by carefully respecting the following rules:

- **carefully measure the correct proportion of raw materials;**
- **never use a water: cement ratio above 0.65;**
- **choose sand carefully;**
- **use recent cement;**
- **respect timing for immersion and curing;**
- **test tile strength, porosity and shape;**
- **clean equipment frequently, including plastic transfer sheets.**

Home"" """"> ar.cn.de.en.es.fr.id.it.ph.po.ru.sw



Fibre and Micro-Concrete Roofing Tiles - Production Process and Tile-Laying Techniques (ILO, 1992, 172 p.)

CHAPTER VI ORGANIZATION OF PRODUCTION

I. PREREQUISITES

A number of factors should be checked prior to investing in a fibre or micro-concrete tile production unit. These factors are briefly described hereafter.

A market survey should be carried out to confirm the existence of an unmet demand for roofing materials. If the demand is punctual, it shall not warrant the setting up of a long-term operation. No production unit should be set up unless there is a steady and sufficiently high demand for tiles.

A lasting demand for roofing materials may also be confirmed by reviewing housing projects, social housing programmes, government plans and applications for building permits. In addition, the current supply of roofing materials should be less than the estimated demand.

Other parameters to be reviewed carefully are the availability, uses, cost and quality of fibre or micro-concrete tiles. An important factor in assessing future profits is the relative superiority of concrete tiles over other roofing materials, in terms of technical performance and total production cost per square metre of roofing.

II. INFRASTRUCTURE

No special conditions are required for the setting up of a fibre or micro-concrete tile-making unit. The basic requirements to be met are as follows:

- Easy access to raw materials. Cement and sand are supplied in truck-loads of 7 tonnes or more. If the distance from the tile-making unit to the sand quarry is short, smaller quantities may be delivered. Storage places for these materials should be close to roads or tracks suitable for this type of transport;

- Loading of tiles on trucks or other vehicles should be facilitated by providing access for trucks to the place where the tiles are kept;

- Sufficient surface for tile storage. Depending on the availability of investment funds, a sheltered storage place affords better

curing conditions. It should also be recalled that in the rainy season tile production should be carried out in a sheltered place;

- Close access to a water supply system;

- If the unit can be connected to the electrical network, the vibrating tables may operate on 220 volt power through a transformer (the same motor also operates on 12 volt batteries);

- A small covered shed should be available to keep the workers from harsh weather conditions. The shed will include a well-ventilated workshop with a lock, to serve as a storeroom for cement, fibres and tools;

- The sand pit should not be too far removed from the tile-making plant (transport costs must be added to the production cost of tiles).

III. TRAINING

The technology for fibre or micro-concrete tile production is simple. It does not require highly specialized manpower. However, strict observance of all the production parameters is essential for a quality product. Most of the problems detected in the course of assessing

production units, particularly in terms of end-product quality, result from non-observance of manufacturing standards. Mistakes may be made at all stages: incorrect proportioning of raw materials resulting in incorrect ratios; uneven distribution of fibres in the mortar; insufficient vibration; nib quality control omitted; incomplete curing, etc.

When developing a new technology in a given environment, success hinges on the appropriate use of know-how. Whatever care is given to the setting up of the production unit (purchase of equipment, installation of a site, credit lines, market survey, etc.) high quality training and constant supervision are essential.

Training of workmen and foremen or managers may be carried out in several ways. An in-depth study of a production manual can only impart a theoretical knowledge of the technology. On-the-job training also is vital. On-site training may be dispensed by an expert or a well-trained user. Training can also be organized in regional centres set up jointly by several plant owners. Finally, training courses may also be organized in the countries which produce the equipment or countries where the technology is well established.

Initial training of workers employed in tile-making is not sufficient in the long term. Plant owners will find it useful to retrain these workers after

an initial period of time in order to correct any deviations which may appear after several months of production. Follow up training may be carried out in the same way as initial training: consultancy, group training courses, training of workmen on other production and/or training sites.

In most cases only one skilled worker is required for each production unit. In each firm (or cooperative) only one foreman or one manager should be sufficiently conversant with the technology to understand the implications of each production stage and supervise production in order to ensure a quality product. Workers in charge of such operations as mixing, moulding, vibrating, demoulding, curing, storing and delivering should be trained specifically for these tasks. They should be supervised on an ongoing basis. Quality controls carried out on the finished tiles will identify the defects in the finished product and make it possible to improve incorrect procedures.

Good management is also of vital importance. The plant manager or president of a cooperative should also be trained to manage the production unit. He should be capable of working out production costs, assessing demand, calculating orders for raw materials and managing the stock of finished products.

IV. MANPOWER

The ratio of direct job creation resulting from a given volume of production depends on the type of equipment, organization of production and structure of the production unit. The unit should be managed by a plant manager who is also able to act as a foreman. The average labour-output ratio depends on a variety of criteria: labour efficiency, quality of training, quality of management. It is also related to the number of production cycles per day. Table 20 shows the average labour inputs required for two types of production: one-shift production cycle (i.e. one 8-hour shift per day) and two-shift production cycle (i.e. two shifts totalling 16 hours per day).

Table 20. Average job: output ratio

	Production cycle: one shift			Production cycle: two shift		
Number of machines	Tiles/week	Workmen	Foremen	Tiles/week	Workmen	Foremen
1	1,000	2	1	2,000	4	2
2	2,000	3	1	4,000	6	2
3	3,000	5	1	6,000	10	2
4	4,000	6	2	8,000	12	4

4	4,000	6	2	8,000	12	4

V. ORGANIZATION OF PRODUCTION

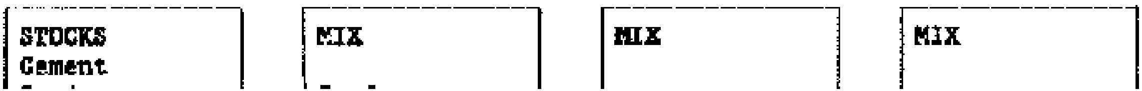
V.1 General

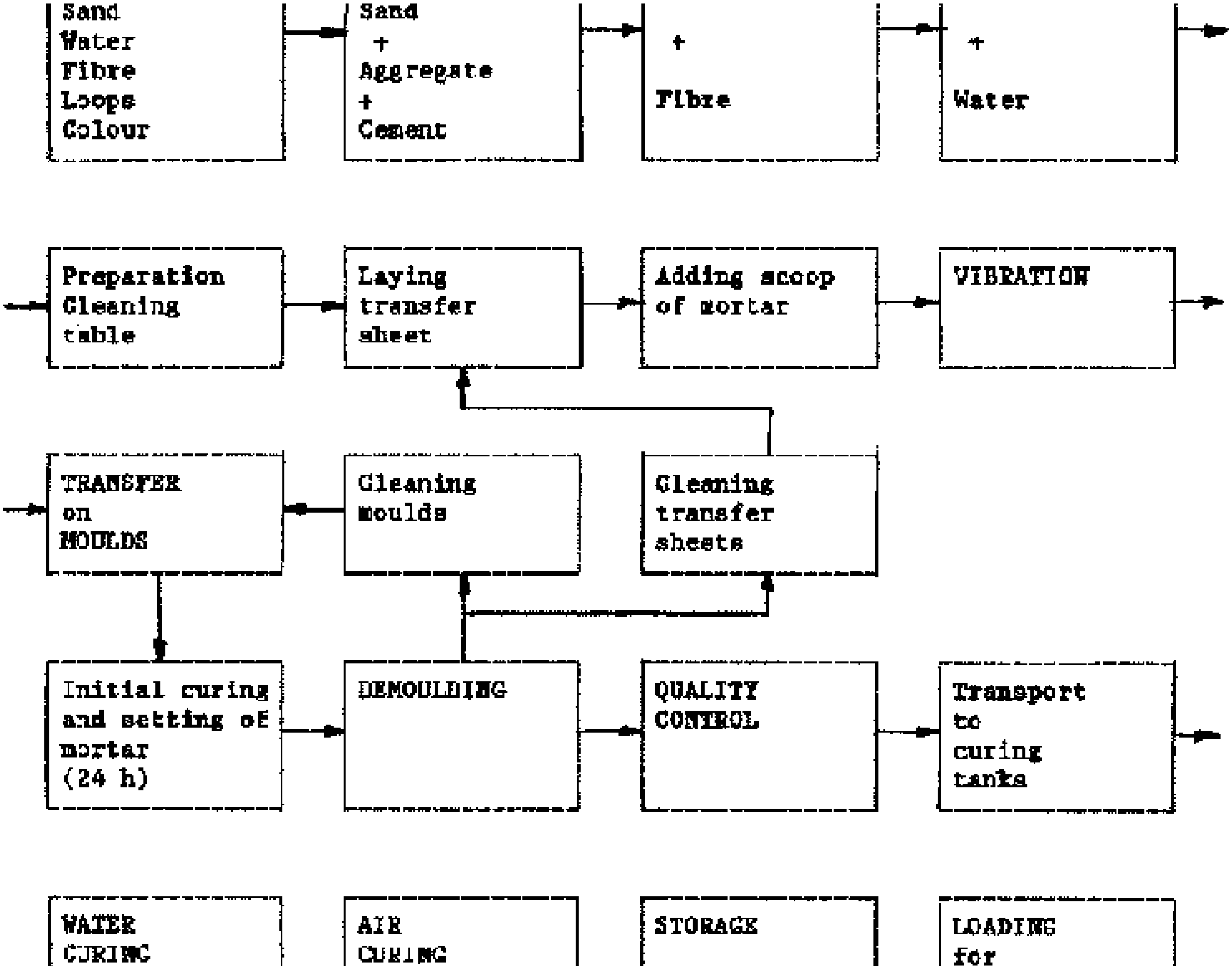
As in any other production process, work organization should follow the logical sequence of production stages. Distances between work stations and distances separating the handling of raw materials from finished products should be kept to a minimum.

Tile production should be carried out away from rain and wind. Tile curing in tanks, PVC containers or under plastic sheets may be carried out in the open. Finally, the three-week curing period after which the tiles achieve maximum strength before sale can also be organized outdoors. However, the tiles should preferably be sheltered from direct exposure to the sun.

V.2 Production chart

The production stages for fibre or micro-concrete tiles are summarized in the production chart below (figure 73).




Sand
Water
Fibre
Loops
Colour
Sand
+
Aggregate
+
Cement
+
Fibre
+
Water
Preparation
Cleaning
table
Laying
transfer
sheet
Adding scoop
of mortar
VIBRATION
TRANSFER
on
MOULDS
Cleaning
moulds
Cleaning
transfer
sheets
Initial curing
and setting of
mortar
(24 h)
DEMOULDING
QUALITY
CONTROL
Transport
to
curing
tanks
WATER
CURING
AIR
CURING
STORAGE
LOADING
for

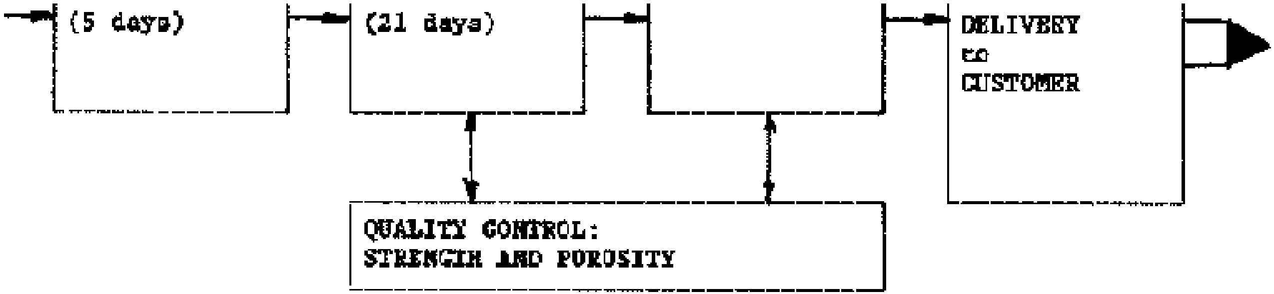


Figure 73. Production chart

V.3 Typical production layouts

The production chart suggests several possible layouts. The choice of layout will depend on available land or premises, access, areas available for tile storage, location of water supply, etc.

The first layout presented as an example (see figure 74) is that of a plant with available access road and direct connection to electricity and water supply system. The sand should also be stored in the covered area.

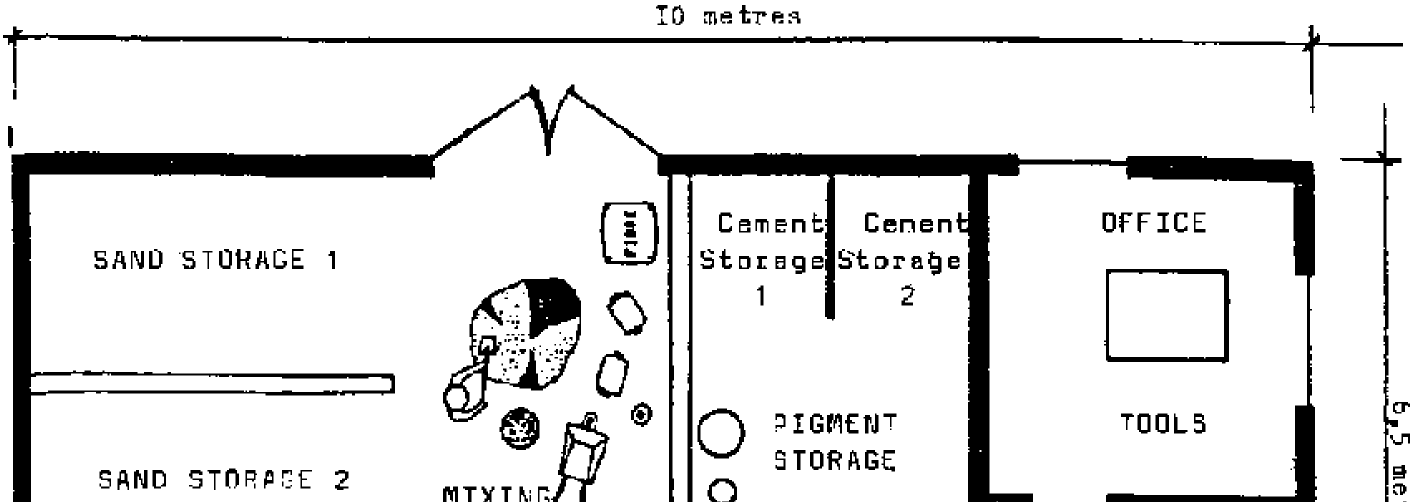
The second layout (see figure 75) applies to a larger production unit. A number of work stations may be laid out as a series of parallel production lines. Expansion can thus proceed by adding a production line without reorganizing the whole plant.

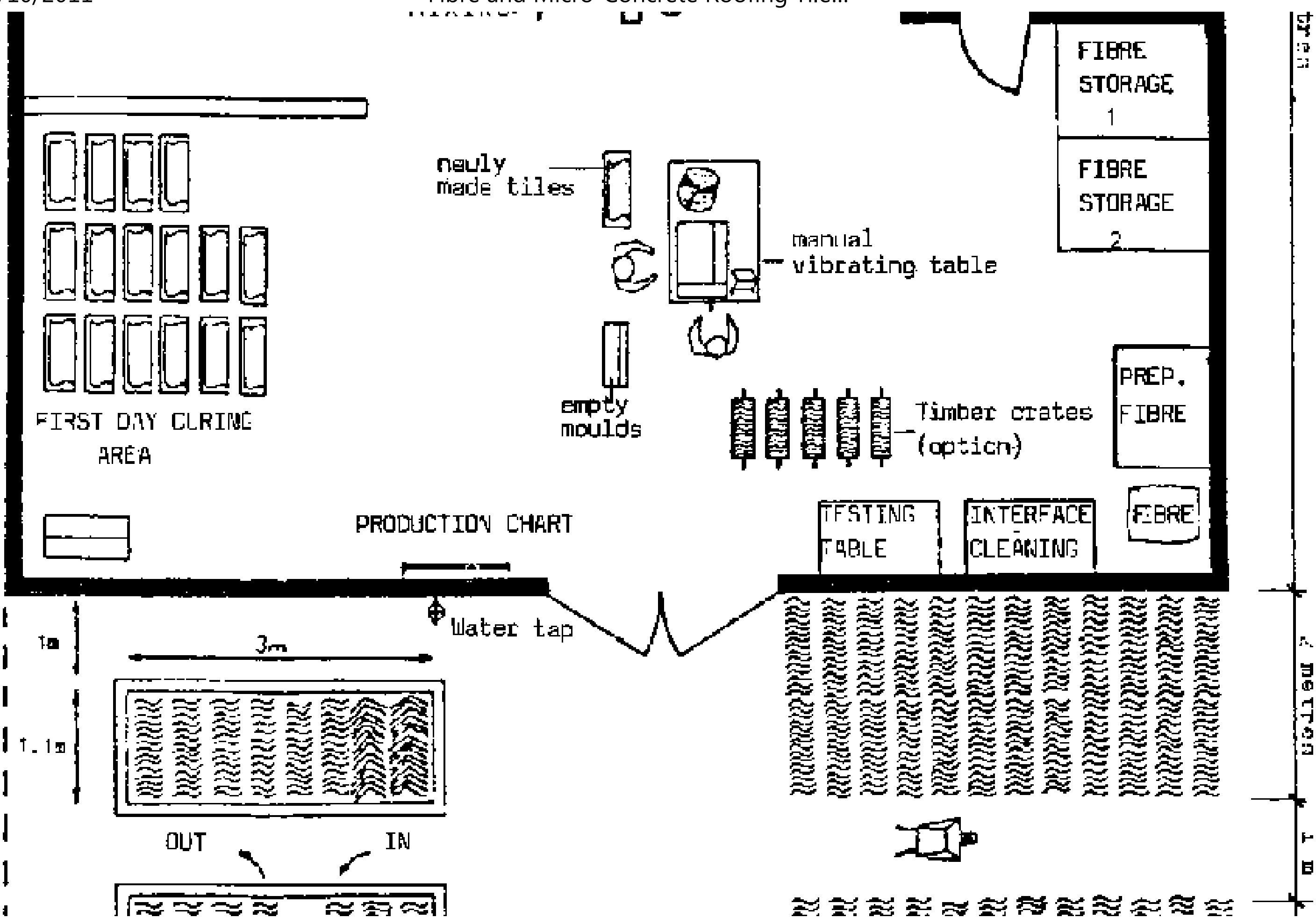
<u>The third layout</u> (see figure 76) shows a plant installed in an existing facility (San Pdro unit, Cte d'Ivoire). This arrangement was conditioned by three factors:

- existing water supply points;

- access to road on one side of the site only;

- The storage shed was to be covered with tiles in order to serve as a demonstration roof: good visibility when arriving at the plant was therefore necessary.




FIBRE STORAGE 1
FIBRE STORAGE 2
newly made tiles
manual vibrating table
empty moulds
Timber crates (option)
PREP. FIBRE
FIRST DAY CURING AREA
PRODUCTION CHART
TESTING TABLE
INTERFACE CLEANING
FIBRE
Water tap
1m
3m
1.1m
OUT
IN

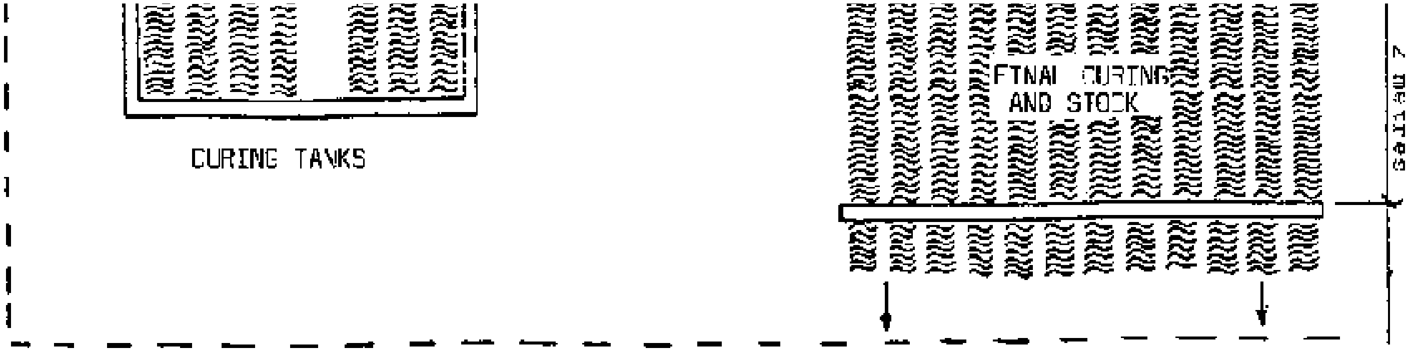
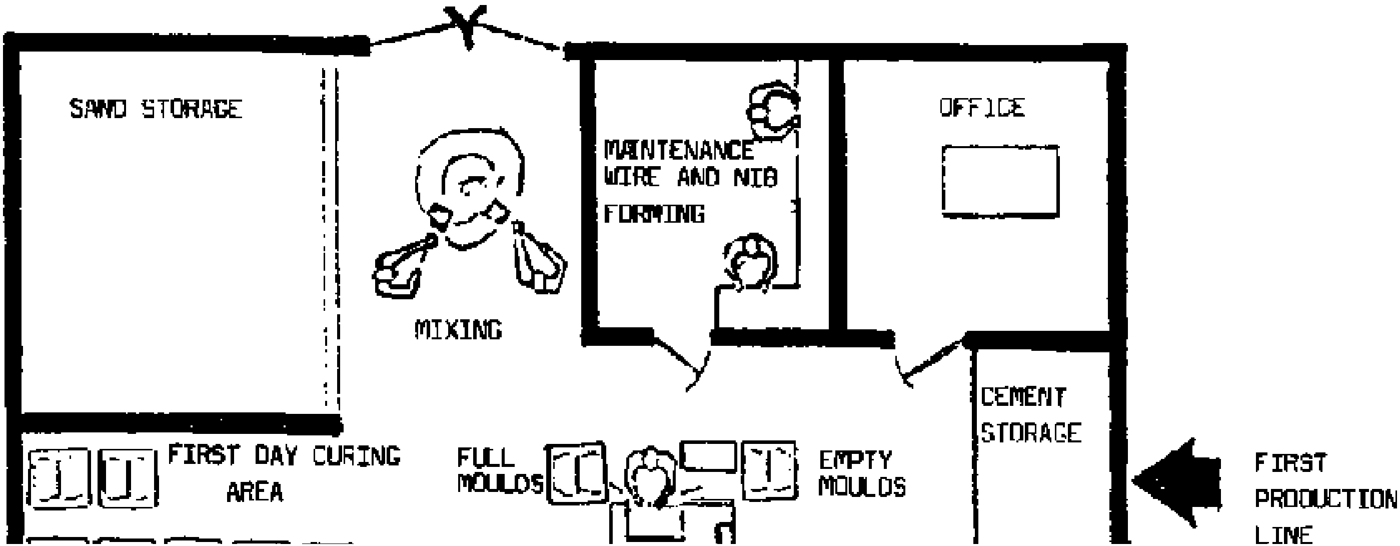


Figure 74. Layout of plant with ready access on all sides



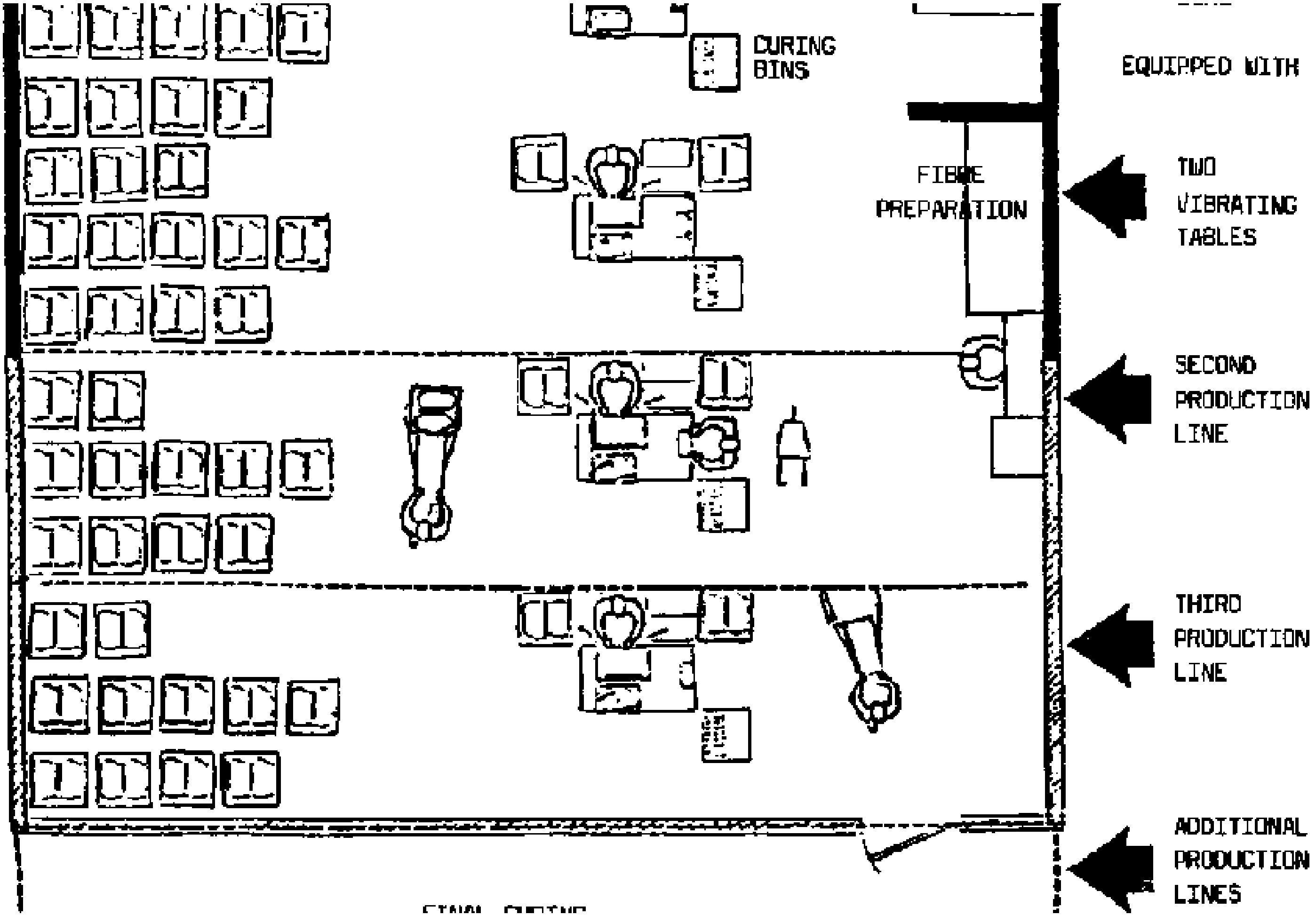
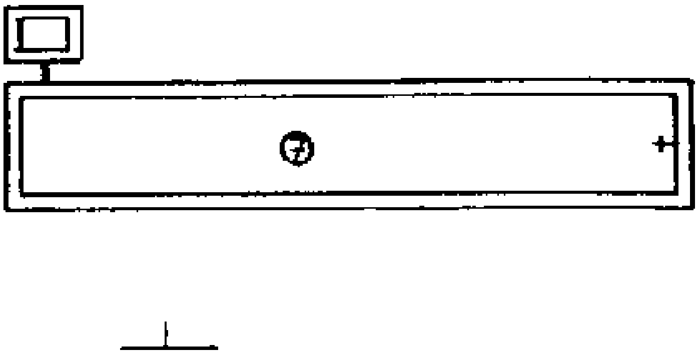

CURING
BINS
EQUIPPED WITH
FIBRE
PREPARATION
TWO
VIBRATING
TABLES
SECOND
PRODUCTION
LINE
THIRD
PRODUCTION
LINE
ADDITIONAL
PRODUCTION
LINES

Figure 75. Layout of plant allowing expansion of production

ORGANISATION OF TILE PRODUCTION

1. MIXING
2. VIBRATING TABLE
3. EMPTY MOULDS
4. FULL MOULDS
5. CURING 24HRS
6. DEMOULDING
7. CURING TANK
8. CLEANING MOULDS
9. SAND
10. FIBRE CHOPPING
11. STORAGE CEMENT + FIBRES
12. OFFICE
13. STOCK OF TILES



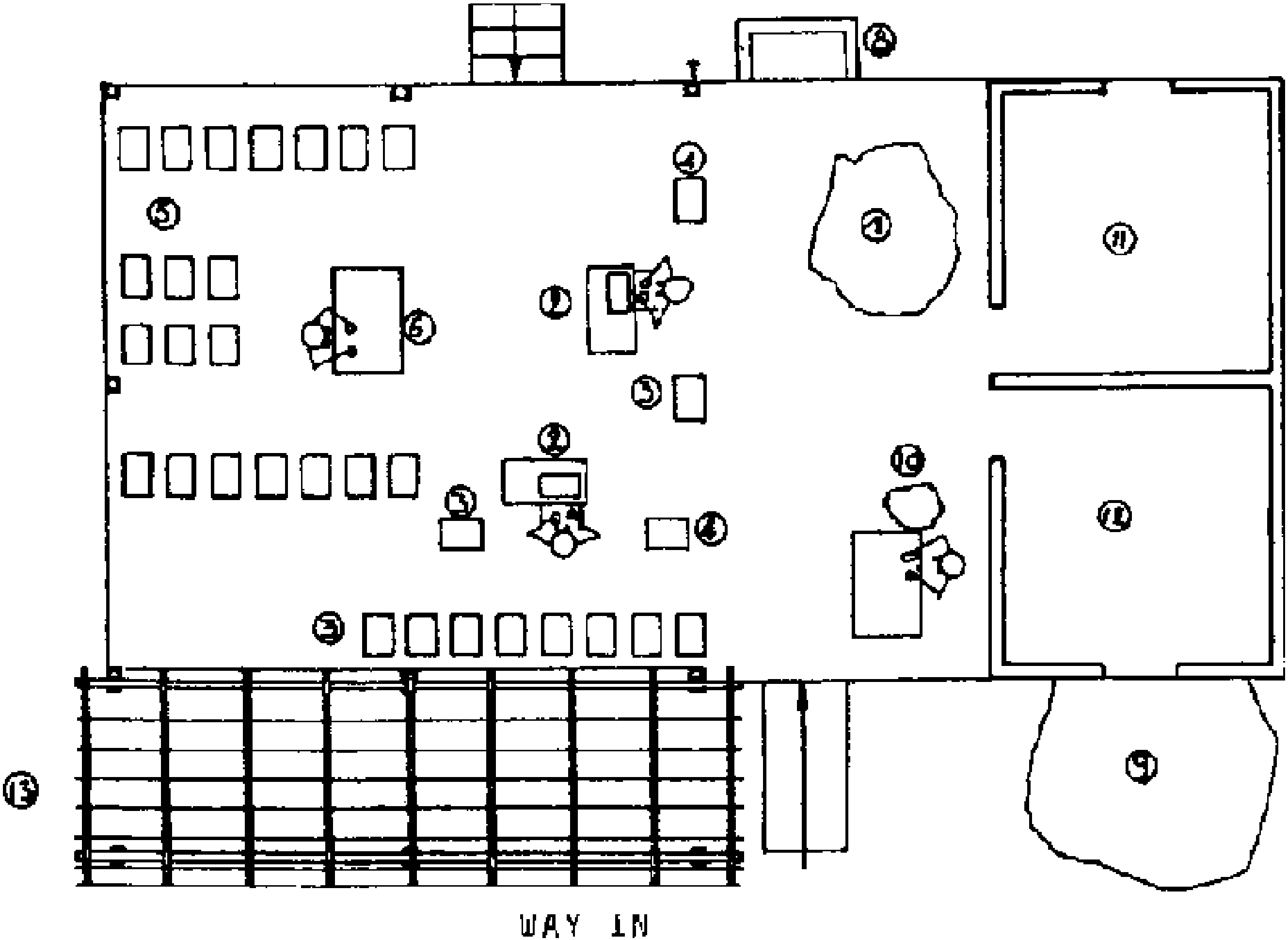

WAY IN

Figure 76. Layout of plant with prior constraints