



## **Small-Scale Manufacture of Stabilised Soil Blocks (ILO - WEP, 1987, 204 p.)**

### **CHAPTER V. CURING AND TESTING**

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### **CHAPTER V. CURING AND TESTING**

#### **I. INTRODUCTION**

**Various natural building materials (e.g. wood, straw, foliage, soil) are used in developing countries for the building of what is often considered sub-standard housing of a temporary nature. The same view applies to low-cost urban housing built with a large variety of waste materials, such as scrap metal, cardboard, and so on. This being the case, the proponents of stabilised soil blocks emphasise that good-quality blocks should be considered as durable and as protective (against hot or cold weather, rain, wind, etc.) as building materials such as concrete blocks, fired bricks or building stones jointed with cement-based mortars. It is necessary, however, to choose carefully the materials for the manufacturing of stabilised soil blocks, to apply appropriate soil preparation and forming techniques, and to ascertain that freshly produced stabilised soil blocks are properly cured. The**

**production of good-quality blocks also requires careful testing of the raw materials, especially soil, as well as testing of the output in order to ensure that blocks of the right quality standard will be marketed. The purpose of this chapter is to describe the various curing and testing procedures now available. These procedures should help to improve the quality of the blocks produced and to minimise the probability of marketing sub-standard or defective blocks.**

## **II. THE NEED FOR CURING AND TESTING**

**A building structure is subjected to various forms of loading which fall into three distinct groups:**

- a static dead loading which is always present, made up of the self-weight of building components used within the structure plus the internal fixtures and fittings;**
- a live loading caused by the vibration effects of moving loads within the structure (usually taken as an added factor of the induced or dead-loading figure); and**

**- a dynamic loading caused by the application of external forces such as might occur in a natural hazard (e.g. wind or seismic forces). The dynamic loading is taken into consideration in the design of the building. In this case, the architect must refer to local codes of practice, which usually include a safety factor.**

**The above three types of expected loading are then combined and a detailed analysis determines the individual strength requirement of each of the different building elements used within a structure.**

**In the United Kingdom, compressive strengths of  $2.8 \text{ MN/m}^2$  are the minimum requirements for concrete blocks and fired clay brick products.<sup>1</sup> Legal building code requirements are usually clearly spelled out according to the nature of the material and its state at the time of testing (e.g. wet or dry). When considering the wet compressive strength of a concrete block, there is a small drop in strength from dry to wet conditions of about 10 per cent. There are numerous factors which may affect**

**compressive strengths including the type of mix and aggregate used, the method of curing after initial casting, and so on.**

**<sup>1</sup> See British Standards Institution BS6073, 1981 and BS3921, 1974.**

**The percentage drop in strength from dry to wet conditions for fired bricks is higher than for concrete blocks and can, on occasions, be as high as 20 per cent. This factor also depends upon the type of raw material used, mixing, drying and firing conditions, and other environmental variables.**

**In the case of stabilised soil building blocks, tests show that a drop of about 50 per cent between dry and wet strengths may be expected. The strength of a stabilised soil block depends on several factors, including the type of soil used, the amount of stabilising agent employed, the compaction pressure, the method of curing and the method of testing for strength. Consequently, it is of paramount importance that detailed consideration be given to the method of curing and the procedure of structural strength determination in order to**

**ensure that good-quality blocks are produced and marketed.**

### **III. METHODS OF CURING**

**To gain maximum strength, stabilised soil building blocks require a period of damp curing. This is a common requirement for all cementitious materials. As already discussed in Chapter II, various cementitious materials can be employed to stabilise clay-based soils. Therefore, only general guidance will be given in this chapter to ensure that good-quality blocks are produced, since proper curing is not the only factor determining the quality of a block.**

**Once a freshly moulded block is removed from the block forming device, it is imperative that the moisture of the soil mix is retained within the body of the block for a few days. If the block is left exposed to ambient conditions, the surface material will lose its moisture and the clay particles will shrink. This will cause surface cracks on the block faces.**

**One method of keeping the block moist is simply to insert the**

**block in a plastic bag. Another effective method consists in placing five or six freshly moulded blocks into a plastic refuse bag or dustbin liner (see background in figure V.1). Caution is necessary to prevent the corners of the blocks from breaking, since they will have little strength while being cured. After the bag has been filled with blocks, its open end should be closed in order to retain any free moisture. Alternatively, freshly moulded blocks can be laid out in a single layer, on a non-absorbent surface, and covered with a sheet (e.g. plastic sheets) to prevent the moisture from escaping.**

**After two or three days, depending on local temperatures, cement stabilised blocks complete their primary cure. They can then be removed from their protective cover and stacked in a pile, as illustrated in the foreground of figure V.1. If lime is used as a stabiliser, the blocks should be left to cure for about 7 days. Water should be sprinkled on the stack and a cover (e.g. plastic sheet, grass or reeds) placed over the top of blocks.**

**As the stack of blocks is built up, the top layer should always be wetted and covered, and the lower layers should be allowed to**

**air dry and achieve maximum strength. Figure V.2 shows a stack of curing blocks 1.5 m high.**





## Figure V.1. Curing stabilised soil blocks



**Figure V.2. Stack curing**

**The duration of curing needed varies from soil to soil and, more importantly, with the type of stabilising agent used. With cement stabilisation, it is advised to cure blocks for a minimum of three weeks. The curing period for lime stabilisation should be of at least four weeks. Stabilised soil blocks should be fully cured and dry before use in a construction project. If it is not the case, cracks will most probably appear either on the blocks or across the joints between blocks.**

#### **IV. TESTING STABILISED SOIL BUILDING BLOCKS**

**Stabilised soil building blocks should be considered as structural elements similar to fired bricks and concrete blocks. It is therefore important to submit them to testing procedures similar to those used for the latter materials.**

**The production of stabilised soil building blocks is often a rural activity. Therefore, it would be wise to consider site testing procedures in addition to laboratory test methods. In both cases, accurate records must be kept. These should include soil mix details, method of manufacture, block dimensions, age of**

## **sample and maximum crushing load.**

### **IV.1. Site testing procedures**

**It can be both time-consuming and expensive to send stabilised soil building blocks to a laboratory for structural analysis. Therefore, it is wise to use first simple, on-site tests that will give an indication of the suitability of a block as a structural element.**

**It is usual to test structural components at 28 days, though the same tests can be performed earlier (e.g. at 7, 14 and 21 days) in order to determine the strength-time relationship.**

**Considering the reasonably low strengths developed by stabilised soil building blocks, it is recommended to test them after 28 days. The following simple tests can be carried out on site:**

**Wet-dry cycling test: Once curing has been carried out, five stabilised soil blocks should be selected at random and**

**completely immersed in water for a period of 12 hours or overnight. They are removed from water and left to dry in the sun during the day. This procedure, whereby the blocks are wetted and dried, is repeated seven times. The total duration of the seven wetting and drying cycles is approximately a full week.**

**Inspection of the samples should indicate if anything is wrong with the original soil used or the stabilising agent employed. For example, blocks may slake or fall to pieces, crack, flake or even burst, indicating that the mix must be modified or, as a last resort, a different soil should be found. It is advisable, therefore, to produce first several sets of blocks with different amounts of stabiliser in order to determine whether the problems can be corrected by using an appropriate fraction of stabiliser. If the problems still persist, other mixes of soil and/or stabilisers must be tried out.**

**Water absorption test: This test can be conducted in conjunction with the wet-dry cycling test. Prior to the first water immersion, each block is weighed and, after overnight immersion, weighed**

**again. A simple calculation can then be performed to determine the percentage moisture absorption by weight:**

$$\% M = \frac{W_W - W_D}{W_D} \times 100$$

where: % M<sub>C</sub> = Percentage moisture absorption

W<sub>W</sub> = Weight of wetted sample

W<sub>D</sub> = Weight of dry sample

**Experience shows that, if a block has less than 15 per cent moisture absorption, it is likely to exhibit good, long-term durability.**

**Wet-dry density test: Immediately after making a stabilised soil block, it should be weighed and its dimensions noted in order to determine its wet or freshly moulded density.**

**At day 28, prior to the wet-dry cycling test, the block is again**

**weighed and its dimensions noted in order to determine its dry or fully cured density. As previously mentioned, a block should have a minimum specific density when freshly moulded of 1,870 kg/m<sup>3</sup>, although the recommended specific density is 2,200 kg/m<sup>3</sup>. The minimum dry specific density of a block should be 1,700 kg/m<sup>3</sup>, with a recommended density of 2,000 kg/m<sup>3</sup>.**

**If the measured wet and dry density are lower than the minima specified above, the soil mix should be adjusted and/or the processing method revised.**

**Ring test; If after the required 28 day cure period, two blocks are knocked together and a good 'ringing' sound is heard, the blocks should be reasonably dense and weather resistant.**

**Compressive strength determination using a CINVA-Ram press: It has been stated earlier that a wetted block 290 mm long and 140 mm wide should ideally have a compressive strength of 2.8 MN/m<sup>2</sup>. Testing of the block will, in this case, require the application of a load of 11.6 tonnes. This type of loading is**

**excessive for a simple site compression machine. Therefore, it is necessary to reduce the load needed to crush a block. This may be achieved by testing a smaller square block with 100 mm sides, leaving the block height untouched. The crushing load needed would then be reduced to about 2.86 tonnes. The test block may be cut from a normal size stabilised soil block.**

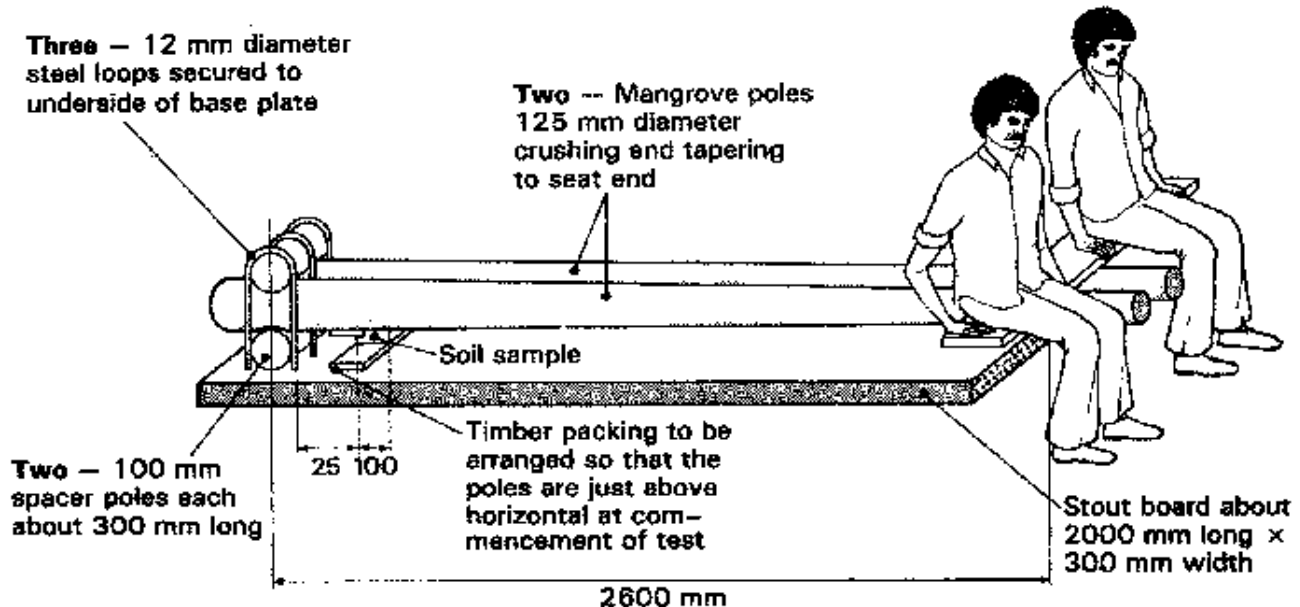
**A CINVA-Ram machine, with a 25 kg weight hung on the main operating handle, can exert a maximum vertical compaction force of about 3.25 tonnes, when the handle is in the horizontal position. Such a machine may then be used for the compressive strength test using a block with 100 mm sides and 90 mm or 100 mm thickness. The block is placed into a CINVA-Ram mould and a weight of 25 kg is hung from the machine handle. A good-quality strength block should support the load applied without crushing when the handle of the press is in the horizontal position.**

**If other types of block pressing machines are available, the resulting compacting pressure would have to be determined.**

**Compression test with a simple lever mechanism: A wetted stabilised soil block sample of 100 mm × 100 mm × 90 mm or 100 mm thick is placed under an operating arm and two men weighing a total of 140 kg sit on the seat provided at the end of the operating arm. A good-quality strength block should withstand the force applied. The apparatus used for this test is shown on figure V.3. It can be manufactured locally.**

**An alternative, simple machine to carry out dependable compression tests on site has been developed by the United States Department of Housing and Urban Development. This machine can crush 2-inch diameter and 2-inch high cylinders made from unstabilised soil. A slight modification to this machine, as shown on figure V.4, would allow testing of 50 mm cubes of stabilised soil. The test is carried out in the following manner:**





**Figure V.3. Simple site lever crushing machine**

**Note that the operating arm is made from two mangrove poles which should be notched to sit over the two spacer poles. This will prevent the arm from any horizontal movement.**

**A 50 mm cube of stabilised soil, cut from a solid block, will be**

**crushed by a force of about 710 kg, if it is to have a working stress of 2.8 MN/m<sup>2</sup>. This characteristic determines the testing procedure. After soaking the sample in water for 24 hours, the centre of the sample is placed at 85 mm from the beam pivot of the testing machine (see figure V.4). The timber beam, which has a total length of 1.8 m and a cross section of 100 mm × 50 mm, weighs about 5 kg. Let  $W$  be the weight of the bucket (filled with either sand or water) suspended on the beam. If moments about the beam pivot point are taken:**

**Cube crushing force ×  $A$  =  $W$  × (distance between pivot and bucket suspension point) + (self weight of beam × distance from pivot to centre of gravity of beam).....Equation (1)**

where  $W$  = weight of bucket plus content (sand or water);

$A$  = distance between pivot of the beam and point of application of the force on the cube = 85 mm

Cube crushing force = 710 kg;

Distance between pivot and bucket suspension point = 1,676 mm;

Self-weight of beam: 5 kg

Distance from pivot to centre of gravity of beam = 838 mm.

**Using the above figures in equation 1 gives:**

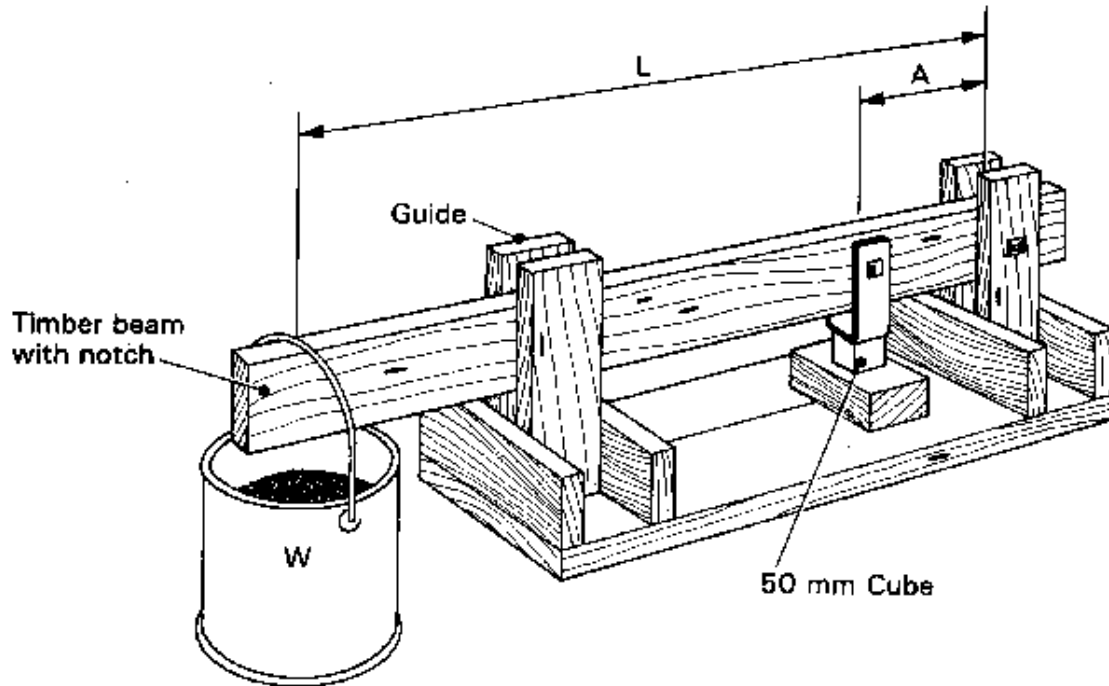
$$710 \times 85 = (W \times 1,676) + (5 \times 838)$$

**Solving equation 1 gives  $W = 33.5$  kg. This value of  $W$  indicates that the block has the required working stress of  $2.8 \text{ MN/m}^2$ . A lower value will indicate a lower crushing force and therefore a lower working stress.**

**The advantage of using a machine of this type is that the applied weight  $W$  can be slowly increased and, by means of the above equation, an approximate crushing load or stress can be determined for the stabilised soil sample. If, for example, the resulting blocks are to be used in a dry climate, the wet compressive stress can be lowered from  $2.8 \text{ MN/m}^2$  to  $2.0 \text{ MN/m}^2$ ; this is equivalent to a crushing force of approximately 507 kg and to a value of  $W$  of 23.2 kg. In practice, the producer**

**must first obtain information on local requirements for wet compressive stress. Then, the value of W is calculated on the basis of equation 1, as long as the testing equipment is identical to that shown in figure V.4. Otherwise, the equation must be revised to take account of different characteristics of the testing equipment (e.g. different lengths of the various components of the equipment, different sample sizes). The value of W is obtained from the relationship:**

$$W = \frac{(\text{Crushing force in kg} \times 85 - (5 \times 838))}{1,676} \text{ .....Equation (2)}$$



**Figure V.4. Site compression test machine for 50 mm cubes**

**Timber beam: 100 × 50 × 1,800 mm length**

**A = 85 mm**

**L = 1,676 mm**

**W = Weight of hanger and contents**

**In the above equation, the crushing force is calculated on the basis of the adopted compressive stress. As an approximation, one may use the following relationship between the crushing force and the adopted compressive stress:**

**250 kg crushing force applied on a cube with a 50 mm side = 1 MN/m<sup>2</sup>**

**For example, if the local requirement for compressive stress is 3.5 MN/m<sup>2</sup>, the crushing force should be equal to 875 kg (250 kg × 3.5). If equation (2) is used, the value of W is then equal to:**

$$W = \frac{(875 \times 85) - (5 \times 838)}{1,676} = 41.9 \text{ kg}$$

**A value of W lower than 41.9 kg will therefore indicate that the compressive stress of the block is lower than required by local building regulations. This decision must be taken by a qualified engineer who knows the local climatic conditions and possible existing regulations.**

**These tests will give only approximate results. If more accurate estimates are needed, the blocks must be submitted to laboratory tests, possibly far from the production site, and at a higher cost. The increased accuracy level must therefore be justified before deciding whether to carry out such tests.**

#### **IV.2. Laboratory testing methods**

**When using the facilities of a laboratory, it is wise to obtain both the dry and wet compressive strengths of a stabilised soil block. As previously mentioned, there will always be a drop of strength from dry to wet conditions. Thus, it is advisable to ensure that the capacity of a machine is large enough to crush the strongest block.**

**Ten blocks should be tested for each set of conditions. The time taken before failure of the block should occur within 0.5 to 1.5 minutes for blocks with an expected strength higher than 7 MN/m<sup>2</sup>. For compressive strengths lower than 7 MN/m<sup>2</sup>, the time taken before failure of the block may be increased to between 1 and 3 minutes.**

**A crushing load must be continuously applied without shock to the sample at a rate of 5.0 0.5 MN/m<sup>2</sup> per minute on blocks whose expected crushing strength is less than 7 MN/m<sup>2</sup>. For blocks with an expected crushing strength above 7 MN/m<sup>2</sup>, the loading rate can be increased to 10 1.0 MN/m<sup>2</sup>. Other convenient rates of loading up to 35 MN/m<sup>2</sup> per minute could be applied. However, once half the expected maximum load has been applied, the rate should be adjusted to 15 MN/m<sup>2</sup> per minute and maintained until the maximum crushing load is reached.**

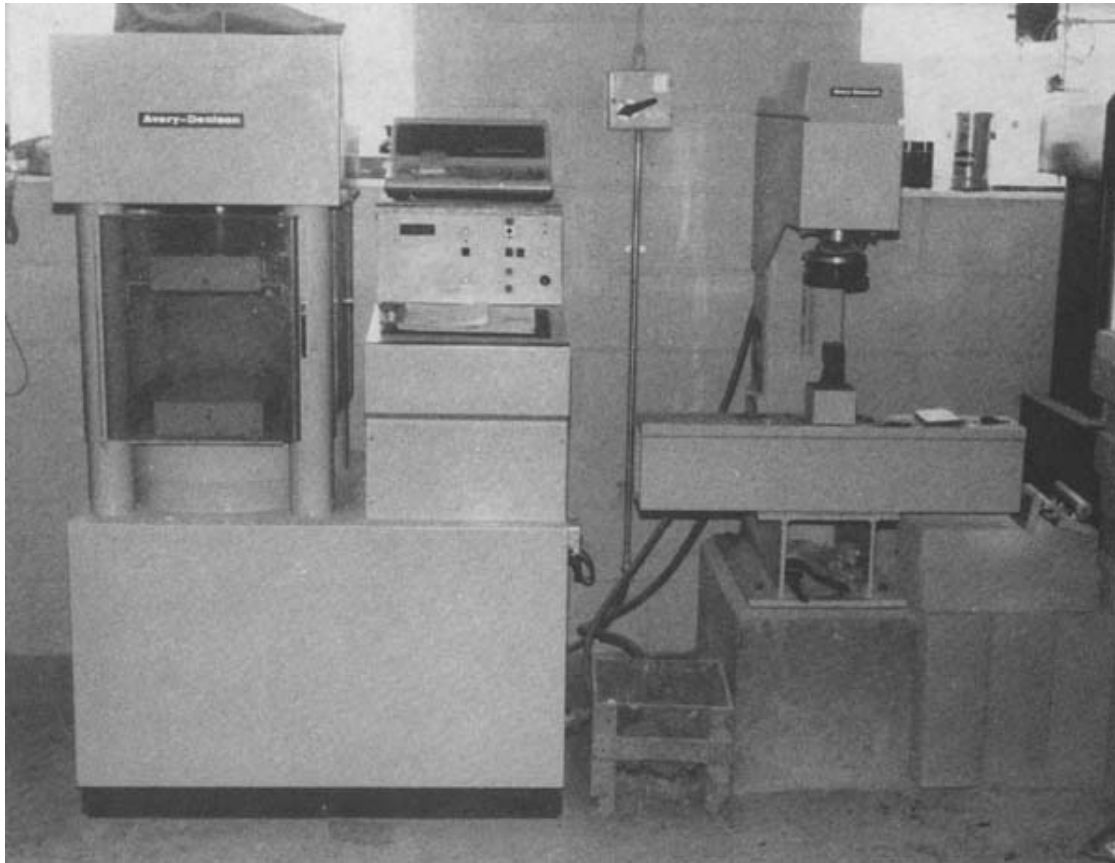
**The above two standards have been developed for known products (i.e. concrete blocks and fire clay bricks). Since stabilised soil blocks fall between the two conditions stated, experience has shown that a load application within the range of 200 kN and 300 kN per minute is acceptable. Ideally, this loading application should be automatically controlled. A suitable compression testing machine would have two ranges: a 3,000 kN range with 1 kN increments and a 750 kN range with**



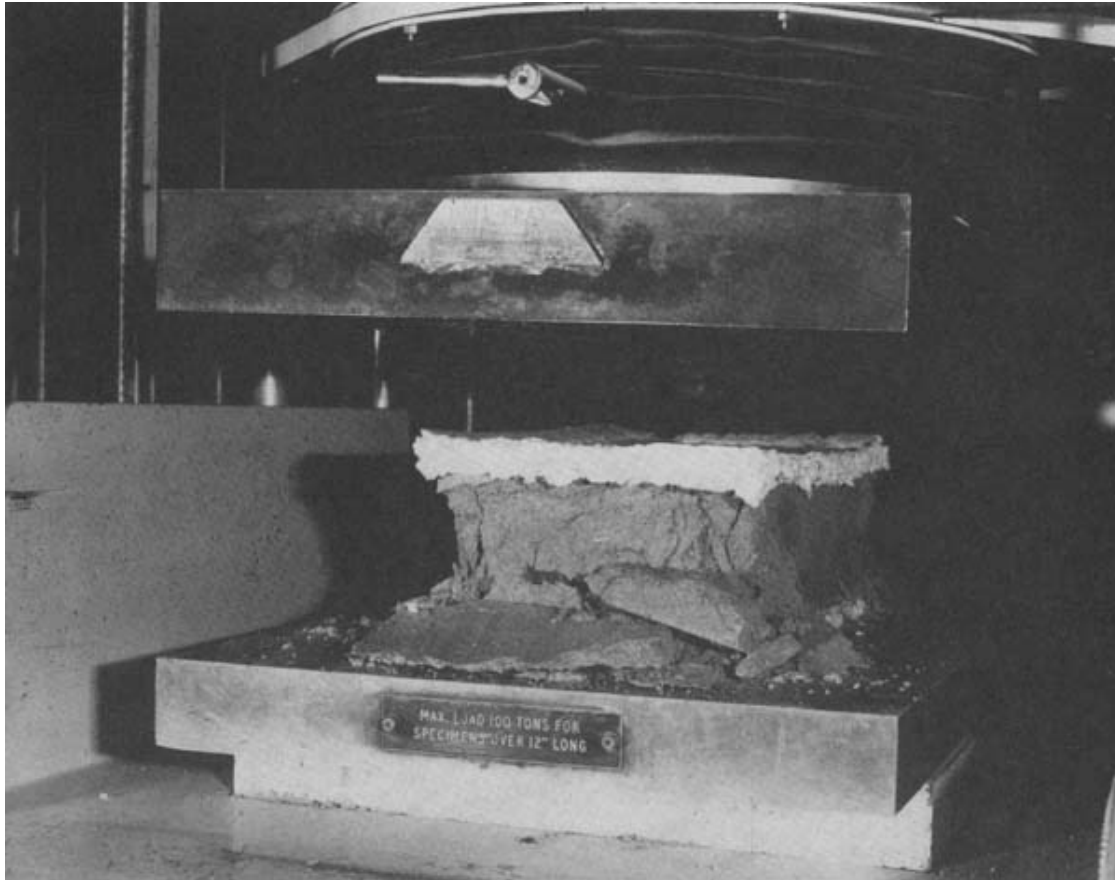
**0.1 kN increments. The upper platen of the machine should be attached to a double ball seat mounting. A suitable machine that would comply with the above specifications is illustrated in figure V.5. This machine can be used for a variety of tests. The unit on the left is the main compression test frame, while the unit on the right is used for transverse testing and the application of small loads. Figure V.5 also illustrates a 50 mm diameter cylindrical stabilised soil specimen after crushing on the transverse testing side of the machine.**

**Figure V.6 shows how a stabilised soil block 290 mm × 140 mm × 100 mm fails when subjected to loading in the main compression frame of the machine. It should be noted that compression test specimens should be 'capped' during the test; the block shown on figure V.6 is capped with fibre board.**

$$\mathbf{1\text{ kN} = 1,000\text{ N} = 0.001\text{ MN.}}$$



**Figure V.5. Laboratory compression testing machine**



**Figure V.6. Stabilised soil block after compression test**

**After the maximum crushing load has been obtained, the crushing strength is determined by dividing the crushing load by the cross sectional area of the block.**

### **IV.3. Durability tests**

**Two laboratory tests indicate the long-term durability properties of stabilised soil blocks: the water-spray test and the abrasive wear test. These two tests are briefly discussed below.**

#### **Water-spray test**

**The water-spray test is a visual test only. It involves the use of a horizontal spray of water from a 100 mm diameter spray head under a pressure of 1.5 kg/cm<sup>2</sup>. A cured stabilised soil block is placed 200 mm from, and parallel to, the face of the spray head. Water is sprayed continuously for 2 hours onto the block, which is then examined visually for erosion and pitting. Test results are indicative only and slight erosion and pitting should not be interpreted unfavourably. Figure V.7 shows the effect of water spray test on a CINVA-Ram manufactured block made from lime**

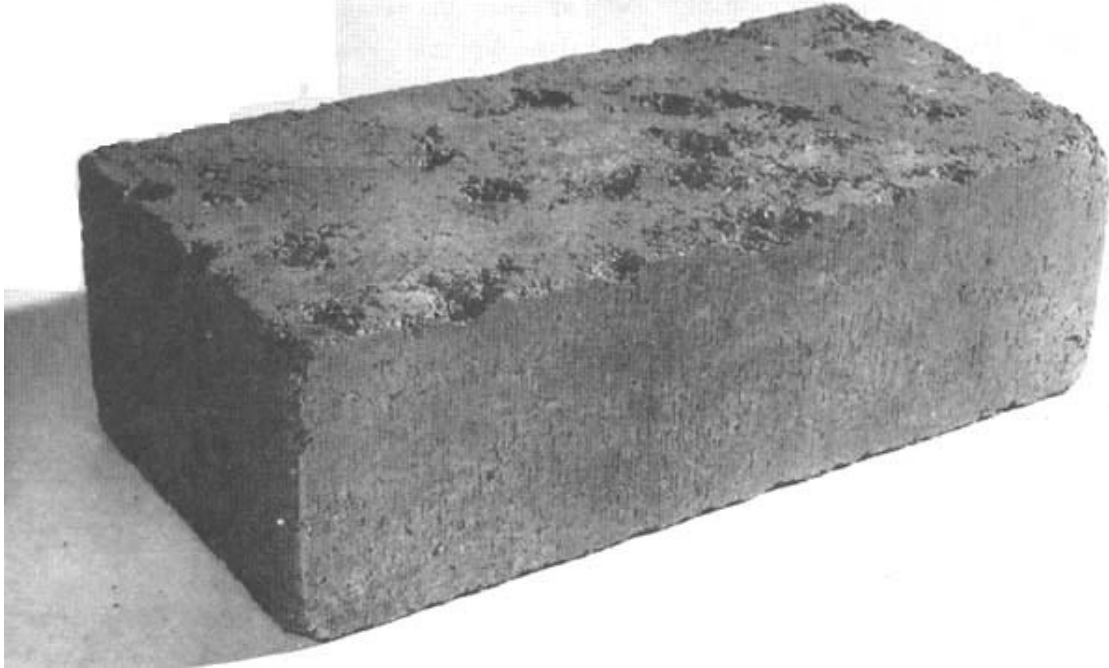
**stabilised soil. This block, which was manufactured under a compacting pressure of  $2 \text{ MN/m}^2$ , shows considerable erosion and pitting after a 2-hour spray test. The same soil, also stabilised with lime, but subjected to a compacting pressure of  $8 \text{ MN/m}^2$ , is much less affected by the 2-hour spray test (see figure V.8). This block is about 10 per cent heavier than that shown in figure V.7. It may therefore be concluded that the strength or durability increases as the dry density increases.**

### **Abrasive wear test**

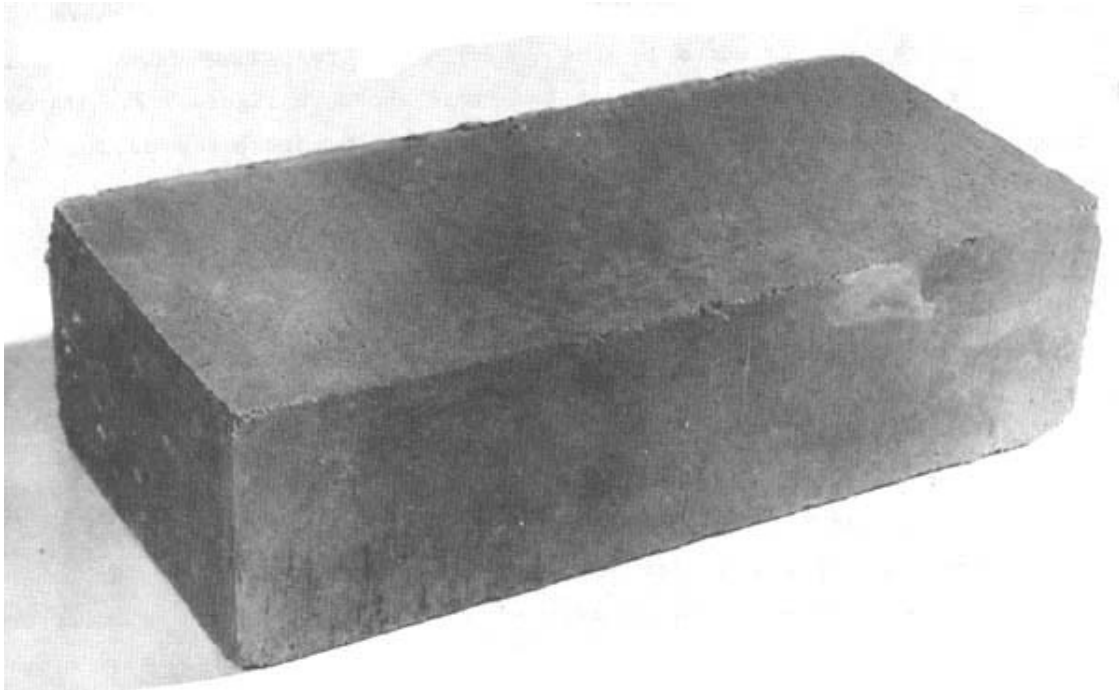
**The external face of a building will always be subjected to harsh weather conditions. The spray water test attempts to simulate conditions in rainy and humid areas. In dry arid areas, erosion could occur under the abrasive action of wind-borne sand. Several types of brushing test have been developed to duplicate these conditions. They involve the application of a specified number of brushings with a wire brush, nylon brush heads, or other abrasive materials. However, no firm recommendations have been specified or established for the determination of the**

## **resistance of a stabilised soil block to the abrasive action of wind-borne sand.**

**In the early 1950s, the British Standards Institution introduced a new test for chemical stoneware to determine resistance to abrasion. In this test, eight block samples (each 100 mm × 150 mm × 25 mm) are reciprocated horizontally underneath eight static hoppers containing a fine sand. The sand rubs against the upper face of each sample (which is in contact with the lower face of each hopper) giving rise to an abrasive action. At frequent intervals, each sample is weighed to determine the amount of material abraded away. This weight loss is a good indication of the abrasion resistance of a product.**



**Figure V.7. Effect of a spray test on a block compacted at  $2\text{MN/m}^2$**



**Figure V.8. Effect of a spray test on a block compacted at  $8\text{MN/m}^2$**

**Figure V.9 shows the results of an abrasive test run on various unstabilised and stabilised soil samples, as well as a**



**sand/cement mortar sample. It gives a clear indication of the relative abrasion qualities of different samples and substantiates the fact that stabilised soil products have good abrasion characteristics.**

#### **IV.4. Long-term exposure tests**

**Many building materials, including stabilised soil products, undergo physical and chemical changes when exposed out-of-doors for a long time. Various short-term site and laboratory tests (such as those described earlier in this chapter) have been devised to simulate the action of weather. However, long-term exposure tests, in which stabilised soil building blocks of known origin and composition are subjected to natural climatic conditions, are a more reliable method for assessing the durability of these materials. Unfortunately, few such long-term exposure tests have been carried out on stabilised soil blocks as they are a relatively new building material.**

**The Building Research Establishment (United Kingdom) set up a weathering site in 1925 so that various buildings materials could**

**be tested for long periods of time under natural climatic conditions. Figure V.10 shows this exposure site, situated near Watford in the South-East of the United Kingdom.**

**An experimental building constructed from cement stabilised soil bricks was erected in 1950 on this exposure site (in the background of figure V.10). It was reported in 1974 that the building was still serviceable after 23 years of use.<sup>1</sup> Recently, this experimental building, now used as a general store, was inspected again. It still shows very little deterioration. This indicates that, even in temperate climates, stabilised soil blocks can have a long service life of at least 50 years.**

**<sup>1</sup> See R.G. Smith, 1974.**

RAMMED EARTH

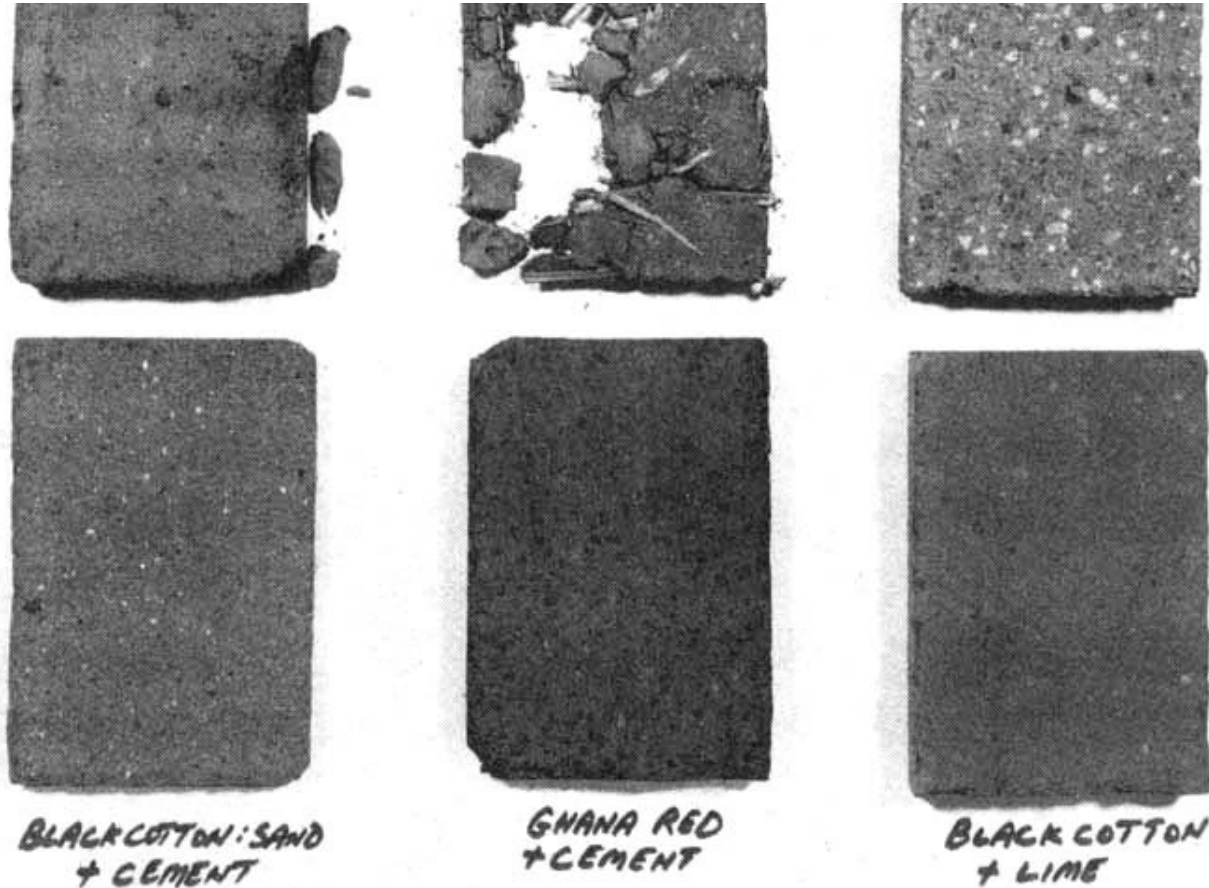


ADOBE

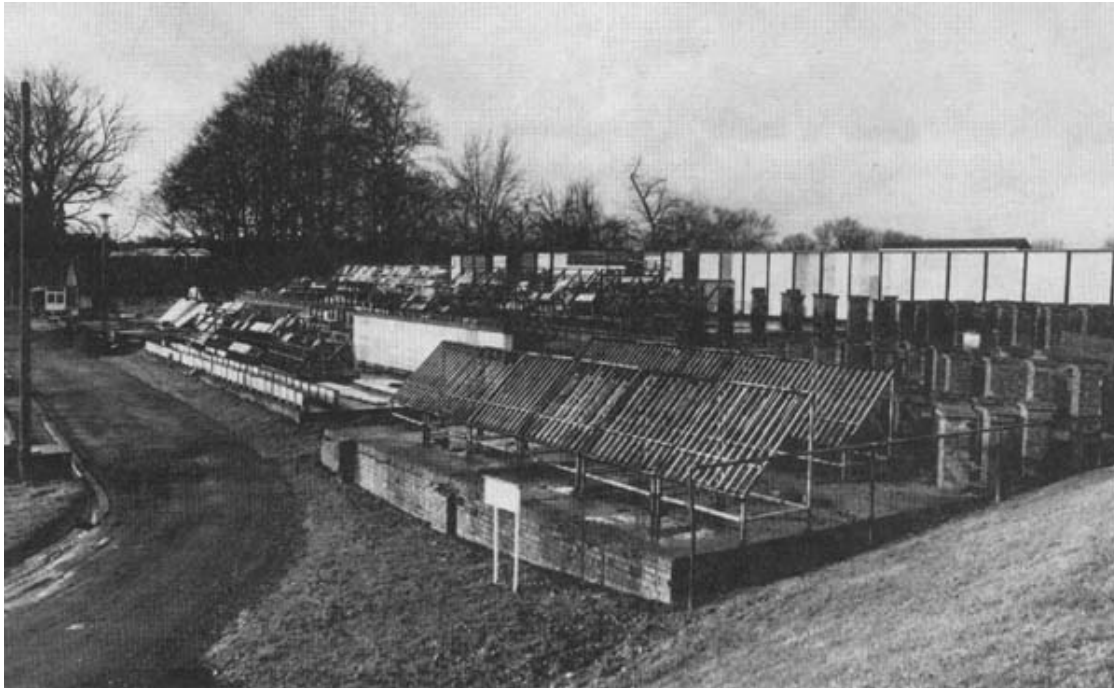


SAND:CEMENT  
MORTAR





**Figure V.9. Results of an abrasive test on various samples**



**Figure V.10. The exposure site at Building Research Establishment, United Kingdom**

**It is desirable to set up a long-term exposure site in countries wishing to expand the use of stabilised soil blocks in order to determine the long-term effects of natural climatic conditions.**

**This would also provide an opportunity to test other forms of soil construction (e.g. adobe, wattle and daub and rammed earth) in order to compare the relative merits of one type of construction against another.**

**When the CINVA-Ram and Tek-Block machines were being investigated in Ghana (in the late 1970s), a small exposure site was built for long-term exposure tests (see figure V.11). Preliminary results from this exposure site indicate the need for the external protection of some forms of earth construction.**

#### **IV.5. Selection of an exposure site**

**An exposure site should preferably be sited on flat, open ground. If it has to be near trees or buildings, it should not be significantly sheltered from sun, prevailing wind or rain. Sometimes, an exposure site may be used for assessing a variety of building materials. If these include organic materials (e.g. plastics, paints or wood), the site should face the sun (i.e. north-facing in the southern hemisphere and south-facing in the northern hemisphere) in order to irradiate test samples with the**

**maximum of ultra-violet rays. Stabilised soil blocks laid on a flat surface and test walls, such as those shown in figure V.11, should be orientated in such a way as to be subjected to a maximum heating effect of the sun. They should also present maximum exposure to wind and wind-driven rain.**

**The exposure site should be safeguarded against trespassers or any other form of interference.**

**After the installation of samples and wall panels, periodic inspections should be carried out to monitor the rate of erosion and general degradation. Results must be recorded for later reference.**

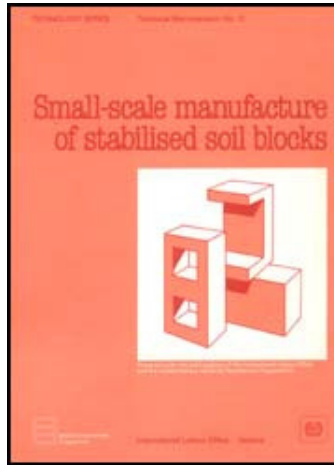
**For the duration of exposure tests, measurements of meteorological conditions should either be made at the exposure site or be available from an existing meteorological station which is near enough to have similar weather conditions. Comparisons with observations on other exposure sites may then allow some correlation between durability of samples and prevailing local weather conditions.**



**Figure V.11. Exposure site in Ghana where soil block are being weathered**



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 **CHAPTER VI. MORTARS AND RENDERINGS**



 **I. NEED FOR MORTARS AND RENDERINGS**

 **II. MORTAR TYPES**

 **III. TYPES OF RENDERING**

 **IV. MIXING AND USE**

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**CHAPTER VI. MORTARS AND RENDERINGS**

**I. NEED FOR MORTARS AND RENDERINGS**



**Mortars are used primarily to accommodate slight irregularities in size, shape and surface finish of blocks, thus providing accuracy and stability to a wall. In so doing, gaps between blocks are also closed, thus excluding wind and rain from passing through the wall. The mortar has a further advantage in that it improves both the shear and compressive strengths of a wall. Mortars commonly have some adhesive characteristics which improve the shear resistance but do not add significantly to the tensile strength of a wall. In general, mortars need not be stronger than the building blocks.**

**Rendering applied to the external surface of walls can help prevent ingress of rainwater into a building, and is often used to cover uneven blocklaying. However, if blocks are of good quality and blocklaying techniques are correct, rendering is usually unnecessary. Rendering is preferred in some countries for mainly aesthetic reasons while bare, fair-faced work is preferred in others.**

**Renderings should be well mixed to minimise shrinkage cracking, then applied to the prepared wall to ensure good**

**surface adhesion. It is advisable to apply a second coat of render, once the first coat has dried and shrunk.**

**In principle, a good average mix should contain four to five parts sand to one part binder, such as ordinary Portland cement. If insufficient cement is used, the wet mix will be less workable and less strong when set. If too much cement is used, greater shrinkages will occur, the risk of cracking will increase and the cost will be unnecessarily high.**

**Mortars for laying stabilised soil blocks are often made from the same mix proportions of soil and stabiliser as those used for making the blocks. Many other options exist for the choice of materials used for making mortars and renderings.**

## **II. MORTAR TYPES**

**There is a large number of mortar types used in the construction industry. The main types are briefly described in this section.**

### **Mud**

**The most elementary mortar, mud, is made from soil mixed with water. It may be suitable for laying adobe, but is not recommended for stabilised soil blocks. Mud mortar exposed to the weather in fair-faced work will quickly be eroded by wind-blown sand and rain. A good-quality pointing or rendering is essential if mud mortar is used. However, cement used in rendering is preferable for making a more durable mortar.**

### **Soil mixed with stabiliser**

**The soil and stabiliser used for making blocks may be used in similar proportions for the mortar in which to lay them. As explained earlier, the addition of asphalt or bitumen as a cut-back or emulsion makes a soil more water-resistant. Such mixes can be used as mortars.**

### **Lime and sand mixes**

**Many countries use lime and sand mixes as rendering materials or mortars. Lime varies in purity and thus gives different types of mortar. If the lime is very pure, consisting of a large**

**proportion of calcium hydroxide, the hardening of the mortar will be due solely to carbonation caused by the slow reaction with carbon dioxide from the air. On the other hand, limes are often impure and contain a proportion of siliceous material from clay contained in the limestone. In this case, lime burning yields a hydraulic lime which will set under water, if necessary. The hardening is, in this case, caused by a pozzolanic reaction between silica and calcium hydroxide which gives calcium silicate. Hydraulic limes also carbonate in air. This type of mortar can be fairly good, but slow hardening makes it less attractive than cement mortars. Replacement of some lime by cement gives a useful increase in early strength.**

**It is essential that lime be completely slaked before use. Lime is often marketed in a slacked form. The quality of the latter is often satisfactory. Alternatively, quicklime can be used, but it must first be slaked by mixing with water in a pit. A slight excess of water should be added to the quicklime and the mixture covered to prevent drying. Several days in the slaking pit are needed for the complete hydration of quicklime. If any**

**particles of unslaked material remain, they may slake later, after setting. Since slaking is accompanied by expansion, this may spoil the mortar or render.**

**Lime is often used together with ordinary Portland cement, and mixed with sand.**

### **Pozzolime**

**Naturally occurring volcanic ashes may contain siliceous material which will react with lime. In the United Republic of Tanzania, three parts of ash and one of lime are mixed together to form a cementitious material. The latter is then mixed with sand for the production of mortar.<sup>1</sup>**

**<sup>1</sup> For more details, see R.J. Spence, 1980.**

### **Rice husk ash cement**

**Rice husks burnt at temperatures below 750°C yield approximately 20 per cent of their weight in pure ash. A cement-**

**like material can be produced by mixing two parts by weight of the powdered ash with one part of lime<sup>2</sup>. One part of this rice husk ash cement may then be mixed with three parts of sand (by volume) and water for the production of mortar or rendering. Alternatively, one part of ash may be mixed with two parts of ordinary Portland cement in the production of a Portland/pozzolanic cement.**

**<sup>2</sup> For more details, see R.G. Smith, 1983.**

**A similar material can be made from rice husks and lime sludge waste derived from the sugar or paper industries.**

### **Brick-dust/lime mixes**

**Brickmaking clays fired to only 700°C produce a pozzolanic material when crushed to a fine powder. Two parts of the latter (known as surkhi in India) are mixed with one part of lime for the production of a cement-like material. The latter may then be mixed with sand for the production of mortar.**

## **Ordinary Portland cement/sand mixes**

**Ordinary Portland cement (OPC) mixed with sand in various proportions is widely used for mortars and renderings. Excessively strong mixes may be harmful and unnecessarily expensive. There could be a risk of some spalling of the edges of block faces, and any cracking will probably go through the blocks themselves if shrinkage movement takes place. A weaker mortar might yield a little more under stress, thus reducing the risk of spalling. Furthermore, any cracking would probably go through the mortar joints which are easier to repair than the blocks.**

**Mixes of ordinary Portland cement and sand are made more workable if lime is substituted for some of the cement. The wet mix is then buttery and easy for the masons to spread. In addition to this beneficial improvement in plasticity, the set of the mortar is retarded, reducing the risk of flash set which may occur in hot climates.**

## **Pulverised fuel ash**

**Pulverised fuel ash from modern coal-fired, electricity generating plants exhibits pozzolanic properties. Thirty per cent of this material may be mixed with 70 per cent of OPC for the production of pozzolanic cement. Pulverised fuel ash may also be used with lime. The Indian standard specification for this and other pozzolanic materials requires that mortar cubes made up from one part pozzolanic mixture and three parts of sand by weight show an initial set in no less than two hours, and a final set within one to two days, depending on grading. For three selected grades of materials, 28 days compressive strengths should be at least  $4.0 \text{ MN/m}^2$ ,  $2.0 \text{ MN/m}^2$  and  $0.7 \text{ MN/m}^2$  respectively.**

**<sup>1</sup> See Indian Standards Institution, 1967.**

## **Plasticisers**

**Instead of adding lime to OPC, very small amounts of purpose-made vinsol resins may be added. The latter form minute bubbles during mixing. However, it is difficult to obtain a mortar**



**with the required properties since the mixing operations cannot be easily controlled. Factors affecting the properties of the mortar include the amount and hardness of water in the mix, cement quality and quantity, grading of the sand, and the efficiency and duration of mixing which is best done in a high speed mixing machine. Unless all these factors are properly controlled, problems may arise. For example, the mortar may squeeze out after several courses have been laid and the blockwork may get out of vertical alignment if too much air is incorporated in the mix. Furthermore, strength may decrease and the mortar may become too permeable to water after setting. On the other hand, too little air will reduce the mortar workability. Thus, spreading of mortar may not be carried out properly, resulting in low strength blockwork and poor resistance to rain penetration.<sup>1</sup>**

**<sup>1</sup> For more details, see N. Beningfield, 1980.**

**Ready-made masonry cements (e.g. cements made with OPC, finely ground mineral filler and plasticisers) are available in**

**some locations. Those which comply with British Standard Specifications<sup>2</sup> can produce strong mortars. Thus, mixes should not contain excessively large proportions of such cements.**

**<sup>2</sup> British Standards Institution, BS5224, 1976.**

### **Gypsum plaster**

**Any substance which sets from a fluid into a solid may be regarded as cementitious. Gypsum plasters, made by heating naturally-occurring (or industrially produced) gypsum will set quickly. However, because they are slightly soluble in water, they are not suitable for exterior use in wet climates. Gypsum plaster is mostly used for interior wall finishes.**

### **III. TYPES OF RENDERING**

**Strong renderings are more likely to shrink and crack than weaker ones. Cracks in rendering result in the moistening of blocks by rain, and therefore in slowing down the drying of walls.**

**Most of the material types used for the production of mortars may also be used to produce rendering. However, gypsum is not suitable for outdoor rendering in wet climates. Mud renderings may be made more weather-resistant by the incorporation of cow dung. A thin paste, made by adding water to a mix of one part cow dung with four to five parts of soil may also be used to wash over a mud rendering.<sup>3</sup> Soils stabilised with lime or cement would not normally be recommended for use as renderings.**

**<sup>3</sup> For more details, see R. Stulz, 1981.**

**Water resistance of renderings may be improved by bituminous washes. External rendered finishes of cement/lime/sand mixes are fully described in other publications<sup>1</sup>.**

**<sup>1</sup> See, for example, building Research Establishment, 1976.**

**Properly made stabilised soil blocks will not require a rendering**

**to protect them from the weather.**

#### **IV. MIXING AND USE**

**Dry ingredients of mixes should be measured out carefully. Although weighing may be preferred, gauge boxes are often used to obtain constant proportions by volume. However, if the water content of sand varies, gauge boxes may not provide accurate mixes.**

**Sand should generally be clean, free of organic material and salts and well-graded. However, a coarse sharp sand is preferable for a first coat of rendering in two-coat work.**

**The dry ingredients should be mixed thoroughly prior to final mixing with water. Mixing may be done by hand with spades, or in a mortar mixing machine.**

**Table VI. 1 shows the properties of various mixes of ordinary Portland cement, lime and sand. OPC/lime/sand mixes tend to develop a better bond with blocks, and consequently better**

**resistance to rain penetration. Mixes may be used both for mortars and renderings, the choice of mix being made to suit required properties.**

**Table VI.1. Mix proportions for the production of mortars and renderings**

<b>Mix proportions by volume</b>					<b>Typical compressive strength 28 days (MN/m<sup>2</sup>)</b>	<b>Ability to accommodate movement</b>		
			<b>Masonry</b>	<b>With plasticiser (small amounts)</b>				
<b>OPC</b>	<b>Lime</b>	<b>Sand</b>	<b>cement</b>	<b>Sand</b>	<b>OPC</b>	<b>Sand</b>		
1	0.5	4-4.5	1	2.5-3.5	1	3-4	4.5	Least able

1	1	5-6	1	4-5	1	5-6	2.5	↓
1	2	8-9	1	5.5-6.5	1	7-8	1.0	Most able

**Source: British Standards institution, BS5628, 1978.**

**The mix should be used while still fresh, especially if based on OPC. A good mortar will hang on a mason's trowel, then spread easily on the blocks. It may be necessary to kill the suction of the blocks by dipping or splashing them with water, thus preventing a large proportion of the mixing water being instantly pulled out of the mix as soon as it touches the blocks. Similarly, water may be splashed onto a wall with high suction before rendering is started. If much water is sucked out by the blocks, it will not be possible to spread the mix as either mortar or render, and there may also be insufficient water in the mix to allow the hydration reactions to take place properly. For the same reason, it is preferable to avoid working in the full sun, and to keep the work damp for 24 hours to allow curing to take place. On the other hand, if the mix is too wet, it may have**

**higher porosity, greater shrinkage and lower strength, and the appearance of the finished work may be poor.**

**Wide mortar joints are sometimes necessary if blocks are badly shaped. With well made blocks, joints should not be wider than 10 mm. This will economise on both materials and labour. If the mortar bed is furrowed, the strength of the wall will be reduced.<sup>1</sup> Vertical joints (or perpends) between blocks should be completely filled with mortar to obtain the best resistance to rain penetration, and to ensure structural integrity between the elements.**

**<sup>1</sup> For more details, see B. Butterworth, 1953.**

**Renderings should be applied after the wall surface has been prepared either by hacking the blocks or raking out the mortar joints to a depth of approximately 10 mm, and then brushed free of excess dust, to provide a good key. Renderings may be applied in one or two coats, depending upon the required quality of surface finish. The second coat can be used to fill any cracks**

**in the dried first coat, and to improve the, finished quality of the work.**

