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BLOCKS AND BLOCKWORK WALLS IN THE TROPICS

This Note has been prepared in the Overseas Division, Building Research Station. Reference may also be made to Note No. 34, of January, 1956 entitled "Concrete building blocks; their manufacture and use".

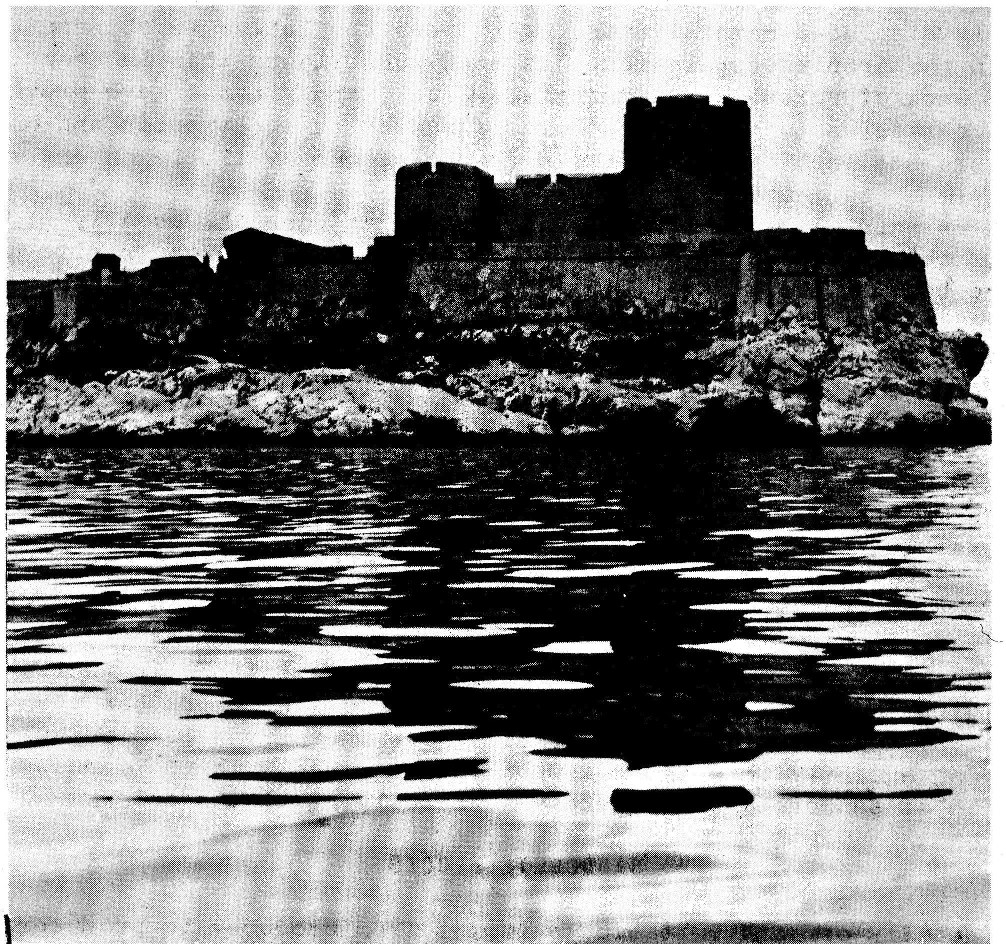

Fig. 1. Marseilles: the Chateau d'If (photo French Government Tourist Office).

Blocks and Blockwork Walls in the Tropics

By R. Sperling.

'When the people heard the sound of the trumpet, and the people shouted with a great shout, that the wall did fall down flat'.

Joshua Chapter 6, verse 20.

However one views the fall of Jericho, whether as an awe inspiring miracle or as a trumped up story with poor foundations, it is a touching tribute to our faith in the ability of the builders of walls through the ages. The sites of many of the world's ancient civilizations have been particularly well favoured in providing the stones with which the wall builders could pursue their craft. In other less well favoured regions including large areas of the tropics, there has been a dearth of durable materials and man has been obliged to build the walls of his dwellings with earth or with wood.

With the advent of Portland cement and its manufacture on a large scale it became possible to produce durable building blocks wherever they were needed. So convenient and versatile a building material is concrete that it has largely displaced natural stone even where the latter is abundant. However in the tropics development has been much slower than in temperate regions. Lack of suitable raw materials, fuel, and finance have proved difficult obstacles to the manufacture of cement in the tropics and only in recent years has locally manufactured cement become available on any scale.

Hand in hand with the shortage of cement has gone the equally difficult problem of obtaining suitable aggregates. Good limestone or granite aggregates have been in short supply in many developing countries, consequently the building unit most frequently encountered has been the sand-cement or sandcrete block, the high quality dense concrete block being reserved for those walls where high loading and exceptional durability are the prime considerations.

Considerable efforts have been made to make use of locally available soil, especially lateritic earth, as the aggregate to be mixed with the cement but though tests and pilot schemes have indicated that in many areas suitable building blocks can be made with relatively small percentages of added cement, the manufacture and utilisation of soil-cement blocks has made comparatively little headway (26). The cost of winning and screening the soil, adjusting its moisture content, testing and correcting for variations in quality together with the high density and smaller size of the block has meant that the use of soil is considered as a last resort where sand is difficult to obtain. Consequently this article will be concerned with the manufacture and utilization of sandcrete and concrete wall building blocks only.

SANDCRETE BLOCKS

The quality of sandcrete blocks varies from producer to producer and often from batch to batch for although blocks are occasionally supplied against a precise specification, few manufacturers in the tropics are able to exert satisfactory control over their products. Despite this, sandcrete blocks have generally managed to serve their purpose without undue trouble in the construction of single and two storeyed buildings. However as there are indications that the better the quality of the block the greater its durability and freedom from trouble, it would appear desirable even from the standpoint of the economical use of cement that the quality of the blocks should be controlled at a reasonable level. There are no official standards for sandcrete blocks as such but the British Standard B.S.2028, 'Precast concrete blocks' (2) can be regarded as extended to cover sandcrete blocks. The equivalent United States Standard A.S.T.M. Designation 55-55 'Standard specification for concrete building brick' (3) calls for a higher standard of quality and is warranted only for exceptionally high quality work.

Sandcrete blocks can be made from many sea sands to comply with the main requirements of B.S.2028 Type B category, if the mix is adequately compacted by vibrating or jolting. The more angular grained quarry and river sands, if clean, can yield blocks that readily meet the more stringent requirements of B.S.2028 Type A category, often without the necessity of vibrating (4). Whichever type of sand is available, appreciable economies in the use of cement can be effected by employing vibratory or jolting machines (5).

Raw Materials. *Cement.* Cement is now available from a wide variety of sources, including many only recently developed in the tropics. The cement should comply with an acceptable standard such as British Standard B.S.12 'Portland Cement (Ordinary and rapid-hardening)' (6) or British Standard B.S.146 'Portland-blastfurnace cement' (7). High alumina cement should not be used because of the loss of strength that occurs under tropical conditions. Supersulphate and sulphate resisting cements can be used, but they do not effect the same improvement in sulphate resistance in blocks as in poured in situ concrete largely because of the difference in compaction (8). In addition these cements should not be mixed with other cements or with lime. In the humid tropics cement powder should be stored in metal airtight containers, but fresh cement in bags can be used in these areas if kept dry and kept for no longer than a few weeks.

Sand. The requirements of British Standard B.S.882 'Aggregates from natural sources for concrete' (9) or of an equivalent standard should serve as a basis for selecting sands suitable for the manufacture of sandcrete blocks. In general it will be found that sea sands are inferior to river, pit and quarry sands mainly because of the roundness of the particles, the poor grading, and the inclusion of contaminating materials such as soft shells. Sea sands can often be improved considerably by the addition of river, pit or quarry sand, and in general it will be found that the more closely a sand complies with the requirements of B.S.882, the more economical and satisfactory it will be.

The grading requirements of B.S.882 are as follows:

B.S.410	% by weight passing sieves			
Test Sieves	zone 1	zone 2	zone 3	zone 4
3/8 in	100	100	100	100
3/16 in	90-100	90-100	90-100	95-100
No. 7	60- 95	75-100	85-100	95-100
14	30- 70	55- 90	75-100	90-100
25	15- 34	35- 59	60- 79	80-100
52	5- 20	8- 30	12- 40	15- 50
100	0- 10	0- 10	0- 10	0- 15

Although the limits are strictly defined in the case of the 3/8in and No.25 sieves the standard permits a small tolerance in the case of the other sieve sizes and the standard itself should be consulted when strict compliance is essential. In particular the limit of fines passing No.100 B.S. Sieve is increased to 20% in the case of quarry sand.

Washing may be necessary to remove excessive quantities of salt, clay, and other unsuitable ingredients. B.S.882 limits the quantity of clay and fine salt, determined in accordance with the test given in B.S.812 'Methods for sampling and testing of mineral aggregates, sands, and fillers' to 3% in the case of natural sand and crushed gravel sand and 15% by weight in the case of crushed quarry stone sand.

Sea shore sands are usually heavily contaminated with salts and it is advisable to reduce the salt content by washing, as it has been found in many cases that salt contamination has contributed to lime stain formation and will accelerate corrosion of steel reinforcement and other metallic building components. Some reduction in salt content can be achieved by allowing the heaps of sand to be exposed to the rain, but the heaps should be sited well above high tide level and protected from the salt spray mist blowing landwards from a surf shore.

Mix Proportions. The strength of sandcrete blocks increases with decreasing water/cement ratio so it is important to use the driest possible mix consistent with full compaction and the ability of the block to withstand damage during manufacture and subsequent handling.

Tests carried out in the United States of America (10) have shown that the moisture movement of the leaner mixes is less than that of the richer mixes. This supports the requirements of B.S.2028 which sets an upper limit of 1 part of cement to 6 parts of aggregate by volume for the richness of the mix, except in those cases where the thickness of the web is one-inch or less, when the proportion of cement to aggregate can be increased to 1 to 4½.

Blockmaking Machines. Although sandcrete blocks can be made with simple wooden or metal moulds, also with the aid of hand moulding and tamping machines, their economical manufacture on a large scale involves the use of considerable equipment and facilities in addition to the actual blockmaking machine. There must be sufficient storage for the raw materials as well as for the finished products, and space and equipment for mixing the ingredients and for curing blocks.

The blockmaking machines themselves have capacities ranging from about 100 blocks per hour for a small one to over 10 times that amount. Whatever the capacity of the machine it should be fitted with equipment to ensure good compaction as this is the key to quality as well as economical operation; blocks compacted by vibration have been found to require less cement than unvibrated blocks to obtain the same strength. Even where moulds are hand filled the provision of a vibrating table will be found well worthwhile. Care must be taken however not to over vibrate. Satisfactory production can be obtained without considerable capital expenditure by operating several hand filled moulding machines in conjunction with a mechanical mixer.

In the tropics, concrete begins to set within 15 minutes of mixing. Because of this it is essential to load the mixer quickly, the water being added at the same time as the other ingredients unless the mix has a tendency to 'ball'. The mixing time should be about 1½ minutes but it is advisable to carry out tests on the spot to determine optimum mixing times. If the mixture has a tendency to ball it is advisable to employ a pan mixer. Such a mixer, in which an open pan revolves at a different speed to a centralised set of mixing prongs or paddles, is most effective in producing consistent mixes.

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Details concerning types of block-making machine and the actual machines available will be given in the next issue. By whichever machinery and method used, the sandcrete block when formed has to be cured before it can be used in block-work wall construction.

Curing. The hardening of cement depends on the presence of moisture. Curing entails keeping the blocks moist after casting, followed by drying to a condition of equilibrium with the atmosphere.

Special care must be taken in the tropics, particularly in the hot dry regions, to prevent drying out during the early (wet) stages of curing. The cement and sand should be kept in the shade, and mixing and casting carried out in the shade, and preferably sheltered from drying winds. The freshly manufactured blocks should be stacked in such a way that free air movement around each block is possible, and the stack should be covered with hessian, palm leaves, or other material to keep the moisture in. The stack should be sprayed with water at intervals to assist the first (wet) stage of the curing process. This stage usually lasts for about four days although there is as yet little precise information on its optimum duration in tropical conditions.

At the end of the 'wet' stage the covering should be removed and the blocks allowed to dry out slowly in the shade. The blocks should be used only after they have reached a state of equilibrium with prevailing atmospheric conditions. It is known that the time required for the final (drying) stage of the curing process is less in the tropics than in temperate regions, but there is little precise information on its duration. However, some indication of the time required can be obtained by weighing sample blocks at intervals until there is little further change in weight. In the absence of local experience gained by means of this control method, it is advisable to adhere to the four weeks period recommended in B.S.2028 for overall curing.

Properties of Sandcrete Blocks. *Size.* Although sandcrete blocks are produced in all manner of sizes, the normal size is in the region of 18in x 9in x 6in, the weight being about half a hundredweight if solid.

Compressive Strength. The compressive strength requirements of B.S.2028 are that they should not be less than the following values in pounds per square inch;

	average of 12 blocks	lowest individual block
Type A	500	375
Type B	400	300

These requirements are well in excess of the compressive loads to which the blocks would be subject in one and two storey buildings. However these requirements should be taken as a guide until reliable standards are available for judging the quality requirements of wall building blocks in the tropics.

Moisture and Thermal Movements. Moisture movement of sandcrete blocks is of two kinds. There is the permanent or irreversible shrinkage that occurs after manufacture, and there is the reversible movement that takes place on wetting and drying. B.S.2028 permits a drying shrinkage of 0.04% for Type A blocks and 0.06% for Type B, and subsequent moisture movement on resoaking the dried blocks of 0.03% and 0.05% respectively. Although there is not much information on the moisture movement of sandcrete blocks it is anticipated that a well cured block made with a good lean mix will comply. However it has been reported (11) that poor quality concrete blocks can have a permanent irreversible shrinkage of up to 0.08%. By way of contrast a good burnt clay brick has no permanent shrinkage and its moisture movement is about 0.01% (12).

The coefficient of thermal expansion of sandcrete blocks is approximately 7×10^{-6} per degree Fahrenheit (4) so that a temperature change of about 70 degrees Fahrenheit would produce a movement similar in extent to that of a saturated block drying out. Thermal and moisture movements of sandcrete blocks are not cumulative, and in general moisture movements are more important than thermal movements.

CONCRETE BLOCKS

These are made in the tropics when the blocks are required to bear heavy loads and they differ from sandcrete blocks in that a coarse aggregate is used in addition to sand or other fine aggregate. A well graded coarse aggregate with the right proportion of well graded sand can yield a dense block of considerable strength with relatively low moisture movement. The greater the proportion of large aggregate that can be incorporated in the block the better, but a limit is set by the finish required and by the ability of the blockmaking machine to handle and compact the mix. B.S.2028 covers the minimum quality requirements of these blocks under Type A. They are suitable for external and internal load-bearing and non-loadbearing walls, are capable of receiving fixings, and can be chased to a limited depth.

Concrete blocks are manufactured in a wide range of sizes recommended by B.S.2028. In general they have a length of 17 5/8in, heights varying from 5 5/8in to 8 5/8in and thicknesses from 2in to 8½in. Modular blocks have a length of 16in, a height of 8in, and a range of thicknesses, but a standard size for concrete blocks has not yet been decided upon. Mixing, casting, and curing of dense concrete blocks are carried out in much the same manner as for sandcrete blocks.

Lightweight Blocks. These are made from either lightweight aggregates or from aerated concrete, and can comply with either B.S.2028 Type B classification in the case of blocks for load-bearing walls or Type C for non-loadbearing walls, although aerated concrete blocks are usually used only for internal blockwork. The lightweight aggregates used include foamed slag, expanded clay, pulverised fuel ash, and pumice. Lightweight blocks have high moisture movements and must be used with care that the movement does not cause cracking or structural failure.

Hollow and Cellular Blocks. Hollow blocks are formed with cavities extending right through the block whereas with cellular blocks the cavity does not extend completely through the block. Both types permit a considerable saving in material and are easy to handle. Considerable care must be taken in laying hollow blocks as the mortar can drop into the cavities but cellular blocks are designed to prevent this happening. Hollow blocks also have the disadvantage of providing shelter for vermin and rodents, and a means of access for termites. They can however prove most useful where reinforcement is required, for the reinforcement can be placed in the cavities and the latter filled with fine concrete.

Dry Wall Blocks. These blocks do not require mortar. They have inter-locking tongues and grooves, but as their manufacture and utilization require considerable care and skill they have as yet been used in only a few parts of the world.

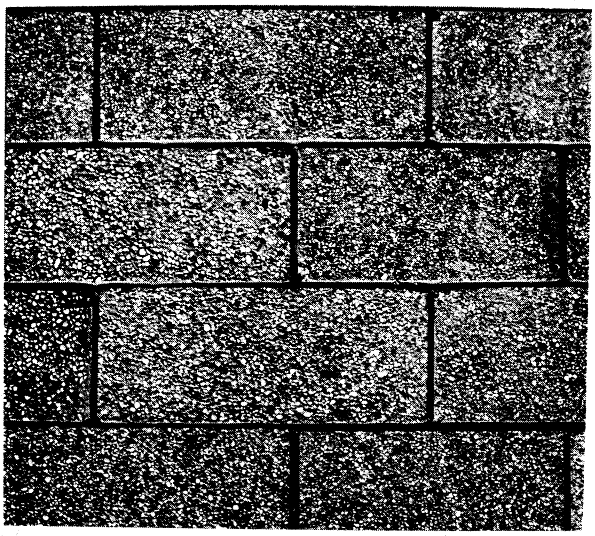


Fig. 2. Facing blocks: gravel aggregate exposed by brushing the concrete before it hardened.

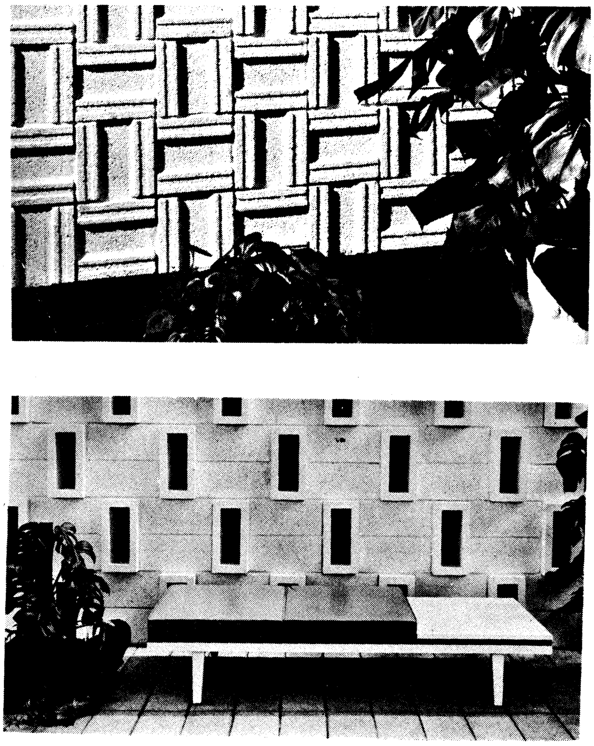


Fig. 3. Profiled and pierced Concrete blocks used internally.

Facing Blocks. With the increasing sophistication of building in the tropics more and more attention is likely to be focussed on the production and use of concrete facing blocks in the tropics. They can be produced in a wide variety of textures, profiles, shapes, sizes, and colours. The colours can be incorporated by the use of coloured cements, pigments, and aggregates, but it is difficult to produce blocks to a uniform colour, and ingenuity must be exercised in taking advantage of the variations in shade and colour that occur in manufacture. Blocks with geometrical profiles give interesting patterns of light and shade in sunny climates, and pierced blocks provide attractively patterned sun screen walls. Exposed aggregate blocks are produced by washing with water and brushing. The blocks can be cast face downward on a bed of sand when it is required to expose large fragments of facing material. Care must be taken in selecting facing blocks especially in those regions where there is a lot of dust or fine dirt in the atmosphere.

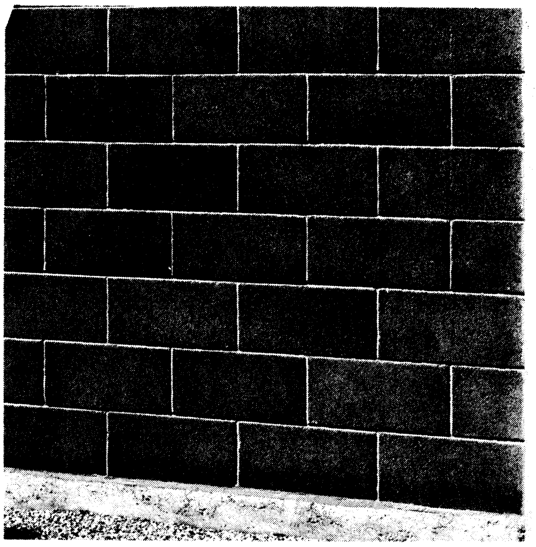


Fig. 4. Plain facing blockwork.

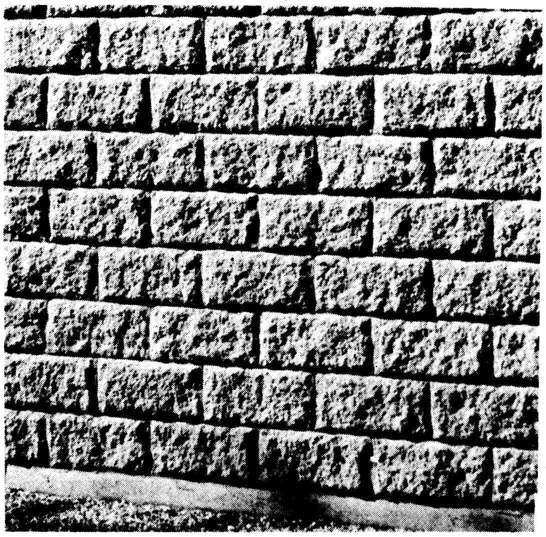
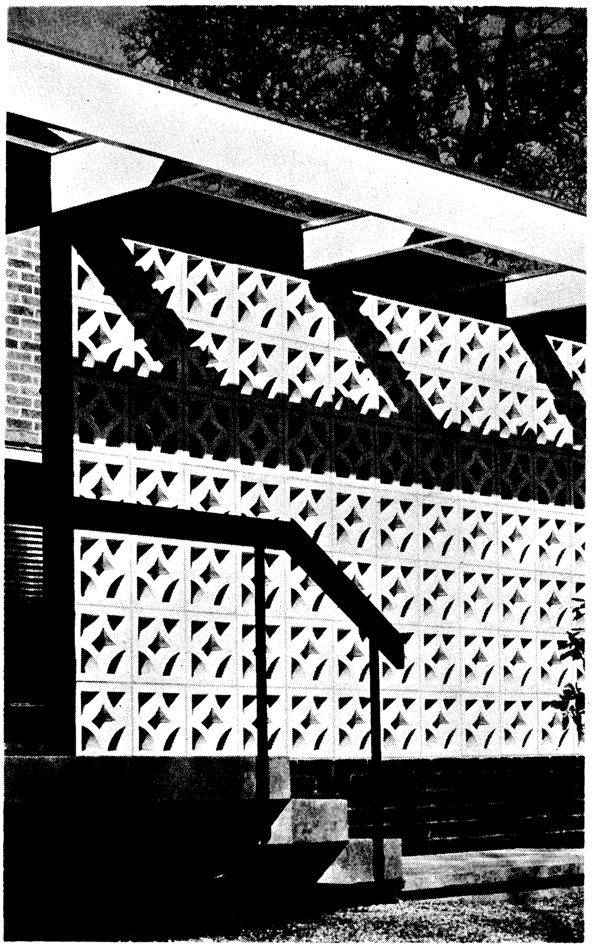


Fig. 5. Coarse-textured dense aggregate blocks.

Fig. 7. Screen wall of pierced blocks.



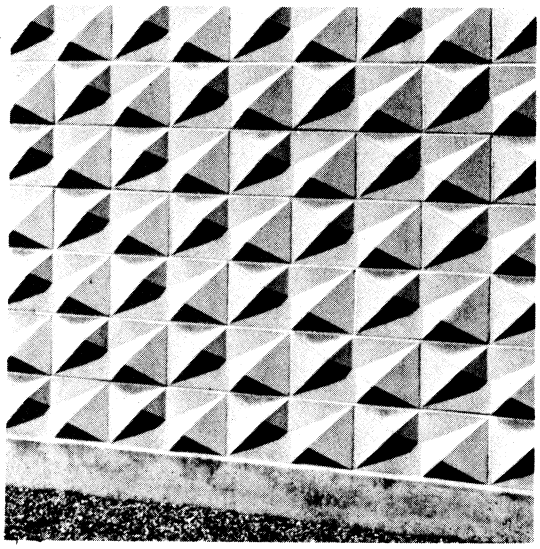


Fig. 6. Blocks with characteristic profile, faced with white cement and white calcined flint sand.

DESIGN OF BLOCKWORK WALLS

Walls must be designed to provide comfortable conditions within the building, to be stable, and to be free from cracks, although all these requirements are to some extent interrelated. Interrelated too is the contribution of the other parts of the building, the foundations, the floor, and the roof, to the performance of the building.

To provide comfortable conditions within the building the design of the wall must depend on the climatic conditions and on whether or not the building is to be air conditioned. In the hot humid tropics, comfort in a non-airconditioned building will depend during the daytime on the ability of the building to prevent internal temperatures rising above the ambient temperature. Walls therefore must be lightly built, containing louvres or adjustable windows to provide adequate ventilation, and they must absorb as little solar energy as possible. They must be shaded against the sun or painted white or in light colours to reflect sunlight.

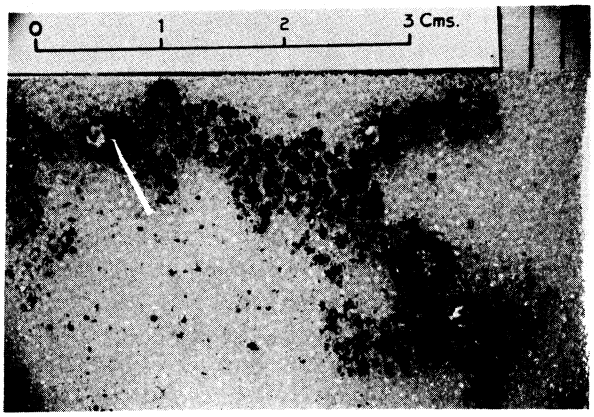
There is little need for insulation in the wall if it is painted white to reflect a high proportion of solar radiation, and adequate ventilation is provided. There is thus no basis for the provision of lightweight blockwork on the grounds of better insulation. At night the uninsulated walls lose heat more rapidly than the insulated ones and therefore provide cooler conditions. This could be particularly welcome in the evening and early part of the night but whether it would be an advantage later on would depend on local climatic conditions and on personal preference.

In the case of air conditioned buildings, the walls should be insulated and should also contain a vapour barrier to reduce the load on the air conditioning system. Adequate insulation can be provided by means of layers of expanded polystyrene glass fibre or of foamed polyurethane. The thickness should be at least one-half, and preferably one inch. In addition the insulating efficiency of the wall can be improved by using lightweight blocks. Cavity walls are not particularly recommended for the tropics, because of the danger that they can provide shelter for vermin and means of access for termites.

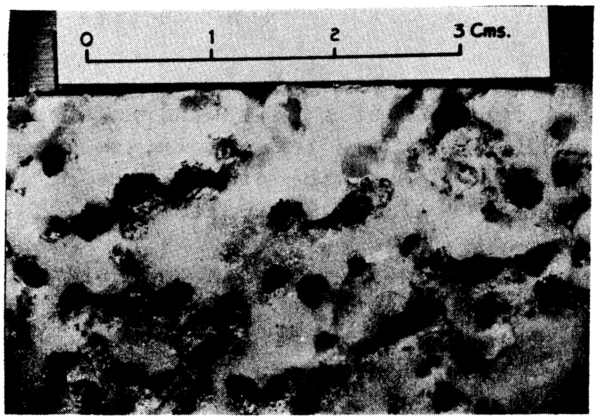
The insulation can be placed between two layers of blockwork or it can be incorporated in a lining panel for the inner face of the wall. The former is more suitable for buildings in which the air conditioning system is functioning continuously, as the inner layer of blockwork acts to stabilize the interior thermal conditions. Where the air-conditioning system operates only intermittently, it is advisable to have the insulation close to the inner face of the wall. The air in the building can then be cooled down rapidly with the minimum load on the system.

Lining panels of foamed polystyrene or polyurethene are usually faced on either side with hardboard, or preferably with asbestos board, and are fixed to timber battens; these in turn are fixed to the wall with the aid of wooden, nylon, or composition plugs. Plugs can be used without the battens, but it is very difficult to locate the fixing points and to obtain a neat appearance. Battens and wooden plugs must be made from timber well impregnated with a suitable preservative. The use of adhesives for fixing the panels is not recommended.

Foamed polyurethane is a better insulant than polystyrene and is more resistant to high temperatures but it is much more expensive. Considerably more information is required on the behaviour of expanded polystyrene in the tropics. The available evidence indicates that it can be used successfully in many cases if reasonable care is taken. Although expanded polystyrene of the densities used for insulation is now made sufficiently strong to



Polyurethane



Polystyrene

Fig. 8. Termite damage to insulating materials
(approx. $1\frac{3}{4}$ x linear)

withstand being walked upon without damage, it does nevertheless require care in handling as the sheets can be damaged by impact and by careless handling. Because it is normally well packed it usually reaches the site in good condition. Expanded polystyrene is also more inflammable than foamed polyurethane although grades are now available that retard the spread of flame. The sheets are very light and can easily be blown away from the construction site if not weighted down; spare blocks are useful for this purpose. It is essential to make certain that the surface temperature does not exceed 180°F otherwise the material will soften and melt. It is unlikely that most walls in the humid tropics would ever reach this temperature even when lined on the inside with insulation, but it is advisable to prevent any chance of this happening by painting the outside of the walls a light colour. The material should be stored in the shade and should not be covered with anything dark.

Although neither expanded polystyrene, nor foamed polyurethane is used by termites as food, they will burrow away happily within the material (Fig. 4), so that it iseessential to prevent the termites from using the insulation as a means of access to sources of food, such as untreated timber and cotton fabrics. Termites can be discouraged by treating the base of the wall with an emulsion containing 1% Dieldrin, applied at the rate of one gallon per 5ft run.

A vapour barrier is required in the wall in humid regions to reduce the load on the air conditioning plant. Except where relatively low temperatures have to be maintained, a sheet of polyethylene or of aluminium foil fixed to the warm outer side of the insulation should suffice. The aluminium foil is best laminated to bitumen-saturated paper, and should be coated with bitumen on both sides to prevent corrosion. The polyethylene sheeting should be 0.01-0.02 in thick, the thicker material havihg the advantage of being more robust and resistant to damage by abrasion and impact. All joints in the barrier must be sealed.

Where initial economy is essential, the vapour barrier can be omitted and reliance placed on the ability of the insulation itself to resist the penetration of water vapour. Both expanded polystyrene and foamed polyurethane, if manufactured satisfactorily for insulation, have a closed cell system and have then quite low water vapour permeabilities. It is important to seal the joints between the panels of insulation with a cold-applied bitumen emulsion specially formulated to provide a vapour seal.

In the hot dry tropical regions there is a wide daily temperature range and comfortable conditions can best be achieved by employing thick solid walls to delay the passage of heat into the building until the cooler part of the day. The optimum thickness of the wall and the need for protecting it against direct solar radiation are still matters for local experiment. The walls should have a minimum thickness of 9 inches, although a thickness of 12 inches will delay the heat cycle by eight to ten hours. The design of bedroom walls in these regions depends to some extent on local climatic conditions and on local preferences. It may be preferable to have thinner walls to provide rapid cooling in the evening, but in other cases people prefer to sleep out on the roof or in an open part of the building, often specially constructed for the purpose. Where there is a cool winter season, provision is frequently made for sleeping out-doors in the hot part of the year and indoors in the cool part, and the bedrooms for the winter should then have insulated walls.

Air conditioning in the hot dry tropics must depend on the local climate and on the use to which the building is put. Cooling may be required during the day and heating at night. Thick walls would still be advantageous for air conditioned buildings, and insulation should be provided either close to the inner face or sandwiched inside the wall. A vapour barrier would not be required in most cases.

Strength of Wall. The strength of a wall depends upon the ratio of thickness to height, the strength of the individual blocks, the loading of the blocks, the strength of the mortar, and the workmanship. Walls must remain stable under all conditions, and long or high walls may require lateral support to prevent overturning, although in most buildings this support is provided by the cross and return walls and by the floor and roof structures. If a block wall is long and straight, additional vertical support may be necessary and piers may have to be provided (See Code of Practice CP111; 1964). In an infilling panel to a framed building the end of the panel should be supported by the frame. Fig. 5 illustrates the methods used for providing this support.

The following table (13) gives the maximum dimensions for either the length or the height of a non-loadbearing partition wall supported at the top but without intermediate support.

Thickness of the blocks	2in	2½in	3in	4 or 4½in	6in	8¾in
Length or height of non-loadbearing blockwork wall (supported at the top) not to exceed	8ft	10ft	12ft	15ft	20ft	25ft

For a free-standing wall the height should not be greater than half the dimension given if the length is more than that figure; even so, long boundary walls should be provided with piers at appropriate intervals, usually at control joints, to provide support when there is uneven settlement of the foundations or exposure to strong winds.

A useful rough guide in the case of non-loadbearing walls not more than 10ft high is that the wall thickness should not be less than 1/24th the distance between vertical supports, with a minimum thickness of three inches.

Building regulations for small dwellings (1) in so far as they affect blockwork wall construction should insist on the following *minimum standards:*

The external walls and other load bearing walls not more than 10ft high above floor level shall be constructed of blocks of concrete or cement/fine aggregate, set in mortar and not less than 6 inches thick.

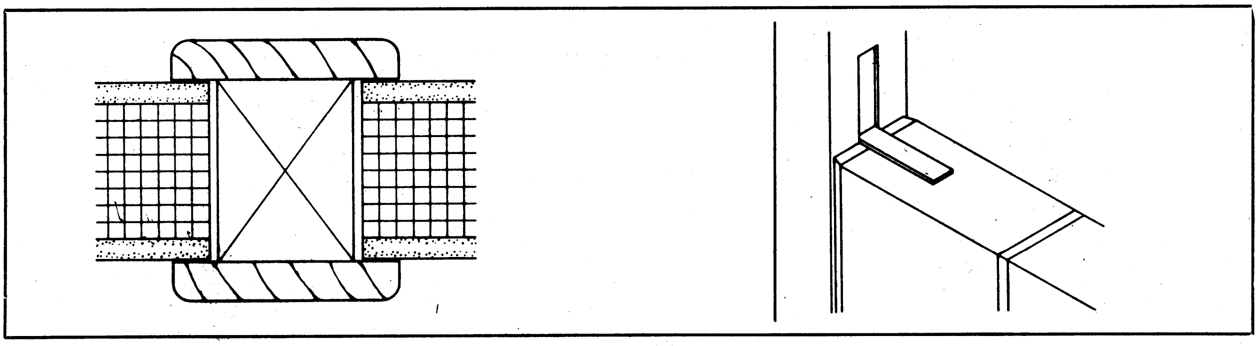


Fig. 9. Lateral supports for in-filling panels.

Buildings that are two-storeys high should have the upper storey external and other load bearing walls constructed as above with a minimum thickness of 6 inches, but the lower storey ones should be at least 8½" inches thick.

Internal single storey walls which carry no load other than their own weight should be constructed of blocks of concrete, lightweight concrete, or cement-fine aggregatesset in mortar and not less than two inches thick.

All walls shall be supported at right angles to the wall by means of intersecting walls, piers, or buttresses. The distances between such lateral supports for blockwork shall not exceed 20 times the wall thickness for solid load-bearing walls, and 36 times the thickness for non load-bearing walls, taking the thickness as that of the wall without surface finish or rendering.

These regulations are a useful guide to the minimum standards that should be taken, even in thoseaareas where building regulations are not in force.

It is also advisable to refer to the British Standard Code of Practice C.P.111 for more detailed information on permissible stresses and other design considerations (14).

Control of Cracking. Blockwork walls crack as a result of moisture and thermal movement of the blocks and of the mortar. Foundation movement caused by over-loading, by improper backfilling of excavated soil, or by soil movements resulting from earthquakes or from changes in the moisture content particularly in clay soil, can also cause cracking. It has already been stated that thermal movements are usually smaller than moisture movements in the case of blockwork, but though the risk of temperature changes causing cracking is low in the humid tropics it is much greater in the hot dry regions where the daily temperature range can be very considerable. Moisture movement of blockwork walls can arise from permanent or irreversible shrinkage as well as from reversible drying-wetting movement. Permanent shrinkage as a cause of cracking can be practically eliminated by allowing the blocks sufficient time to dry and reach equilibrium with the atmosphere before the blocks are used.

The best methods for preventing cracking caused by reversible moisture movement have yet to be decided upon, and at present it is advisable to rely upon the judicious use of bond beams, control joints, and reinforcement. The possibility of preventing cracks by methods involving prestressing is under investigation at present (26). In addition to moisture movement, carbonation of the cement can cause blockwork walls to shrink and crack, but carbonation is a very slow process.

Cracking can also be caused by the excessive deflection of supporting walls or of floor slabs, and by the undesirable movement of other structural elements such as roof slabs, spandrels, and columns. Adjacent walls should be as free as possible and any anchorage with members in providing lateral support should be as flexible as possible.

Control Joints. Control joints are intended to relieve horizontal tensile stresses, and are the most effective means for preventing cracks from forming elsewhere in a wall system. They divide the wall into a series of rectangular panels (Fig. 6), and should be located in those areas where cracking is most likely to occur. Examples of such stress concentration areas are where walls abut (except at corners), connect or frame into each other or where there are changes in wall height, or in thickness, or at intersections in L, T and U shaped buildings, also at jambs of openings in the walls such as at doors and windows (Fig. 8). The areas above doors and above and below windows should be treated as separate panels. A straight vertical joint should separate panels of blockwork. Cracking is most likely to occur if the length of a panel exceeds about 1½ to 2 times its height, shape being more critical than size (13).

Finishes applied to the blockwork should form a clear break at the panel joints and the visual effect of these joints should be integrated wherever possible into the design of the wall so that the joints do not mar the overall appearance. Joints should preferably be dry and self-draining, but simple joints can be formed by raking out the mortar to a depth of not less than ½ in and sealing the joint with a suitable joint sealing compound. The best material for this purpose is a subject for investigation, for most oil, bitumen or butyl rubber-based compounds fail when there is any appreciable movement of the joints, and little is known as yet of the behaviour of the more elastic sealing compounds under tropical conditions.

Reinforcement. Reinforcement may be used to control cracking, as a supplement to control joints or where it is impracticable or unsafe to subdivide the wall into panels. Reinforcement does not prevent cracking, but it distributes the shrinkage stresses more uniformly throughout the wall, and is particularly beneficial above and below windows and above doors, the reinforcement being placed in the two horizontal mortar-bed joints (Fig. 9) immediately above lintels and below sills, extending a minimum of two feet beyond the opening. Alternatively the joint reinforcement need not extend beyond the opening if vertical control joints are provided on either side of the opening. (15). Normally reinforcement should not be placed across control joints.

Bond beams. Bond beams are special concrete units filled with reinforced concrete. They bond or integrate the components of a blockwork wall into a structural unit, providing a portion of the required lateral stability when designed to transfer lateral loads to columns. They are usually made in place by using special U or trough shaped beam blocks which are placed in the wall, with the cavity uppermost and reinforcement laid in the cavity. The cavity is then filled with concrete forming a continuous reinforced beam or bond (Fig.7). They function as a more or less continuous lintel and will to some extent reduce movement in the adjacent courses. They act in much the same manner as reinforcement.

It has been recommended (15) that bond beams should be cut through at 50ft maximum intervals, or 25ft only from the corners of buildings. Bond beams should be located at the top of the wall immediately below the roof framing structure and below each floor slab in the case of multistorey buildings. They should also be placed in the top of foundation walls. A vertical control joint should be placed in the wall below a cut in a bond beam.

Consideration should be given to the likely deflexion of members of the frame against which block walls may abut, usually columns and beams, as a result of changes in load and in temperature and humidity; it may then be necessary to provide resilient packing between the edges of the panel of blockwork and the frame, to prevent the panel from being subjected to excessive stresses which could cause cracking or even spalling and disruption.

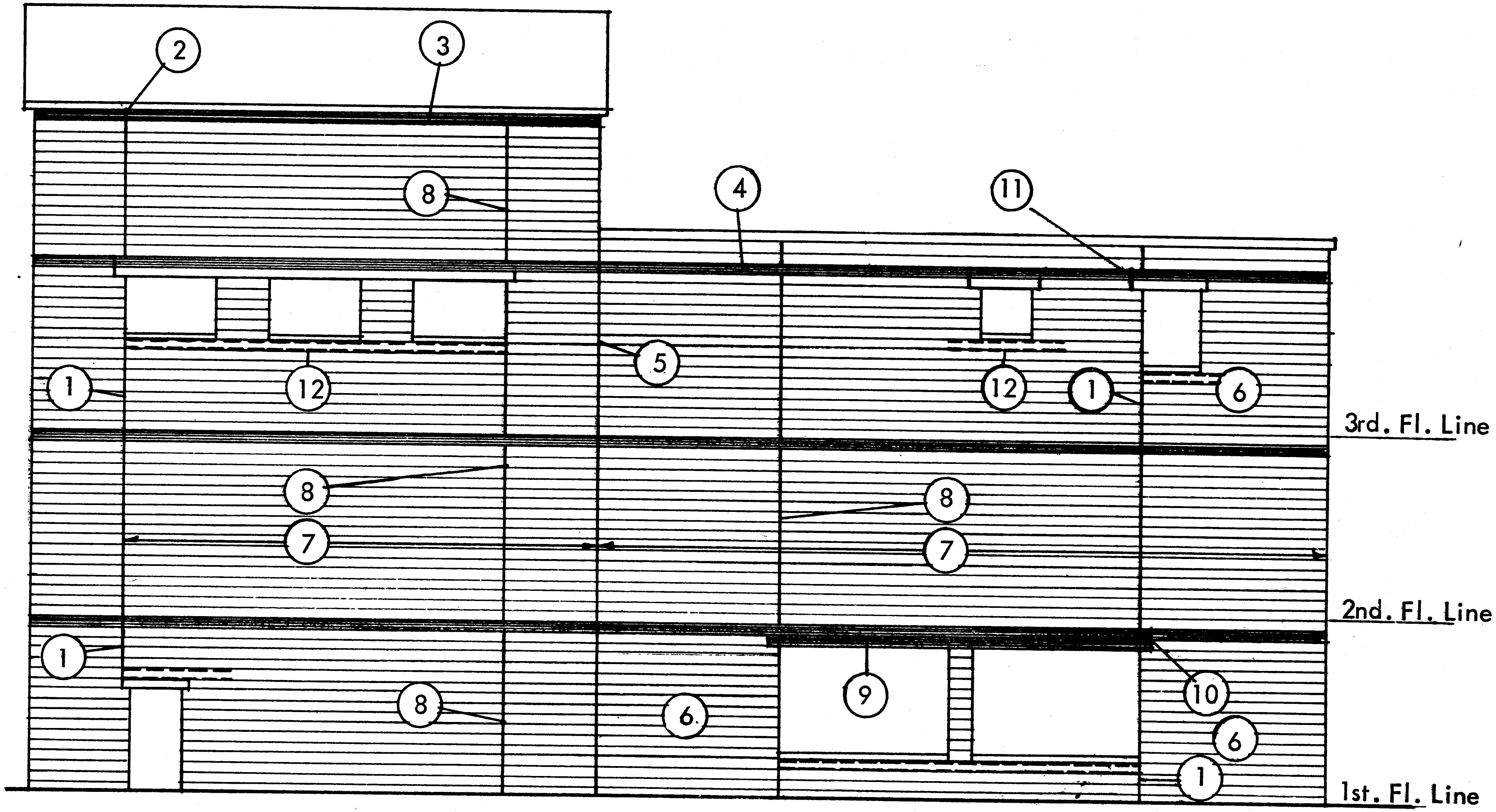


Fig. 10. Combination of control joints and joint reinforcement.

Key to Figure 10

1. Control joint at jamb of opening.
2. Bond-beam cut, to coincide with control joint. Although closer than need be to corner, a cut here makes a cut over lintel unnecessary.
3. Bond-beam placed in course immediately beneath roof framing (load-bearing walls).
4. Bond-beam placed in third course beneath roof framing (non-load-bearing walls only). Gives crack control in top two courses without need for joint reinforcement. A two-course beam could serve as lintel if there were enough openings.
5. Control joint and bond-beam cut at change in wall height.
6. Joint reinforcement.
7. Control joints and reinforcement as required by bond-beam cuts.
8. Control joints added for symmetry should not cut bond-beams.
9. Two-course bond-beam serving as both bond-beam and lintel.
10. Bond-beam lintel cuts near edge of opening but with sufficient beaming surface for portion of beam spanning the opening.
11. Cut coinciding with control joint at jambs.
12. Joint reinforcement substituting for control joint at jamb.

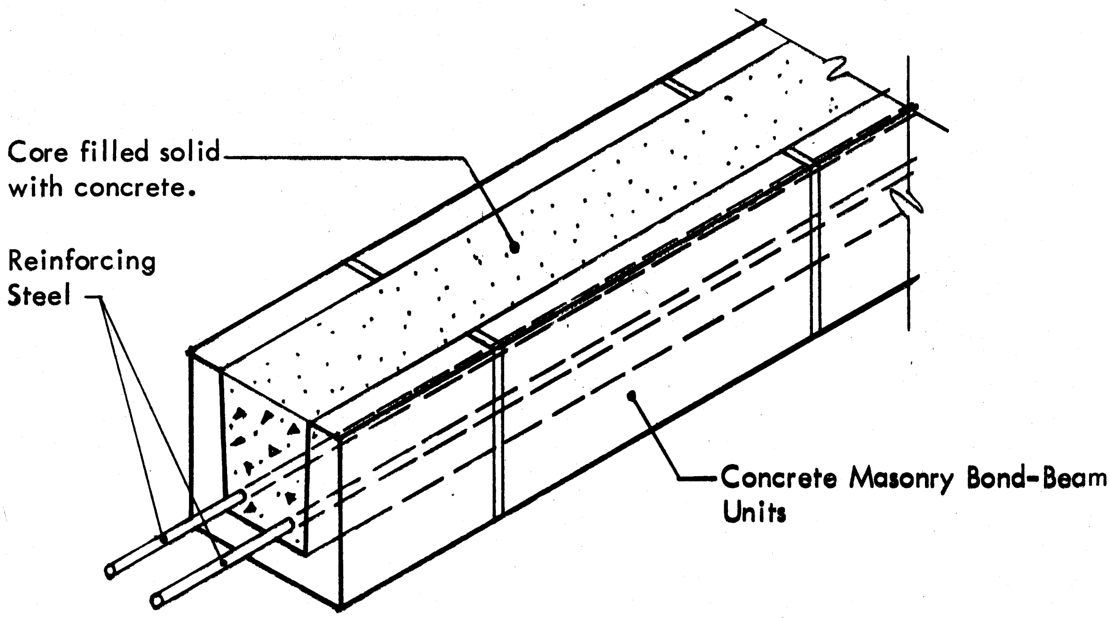


Fig. 11. Typical concrete bond-beam.

General Considerations. Opinions differ on the extent to which various methods for controlling cracking in walls should be introduced. The cheapest construction will rely mainly on adequate curing of the blocks and the use of as little water as possible in the construction of the blockwork walls. The use of control joints and of some reinforcement in the walls particularly around windows and doors is considered necessary in medium cost houses; all three methods, control joints, reinforcement, and bond beams could be employed in the more elaborate buildings.

The extent to which they are used depends upon many factors, and while the recommendations of some authorities are relatively modest (13), others are quite elaborate (15). Factors in addition to available finance come into play such as the nature and quality of the subsoil and foundations, also as to whether the area is subject to earth tremors. In an earthquake area the provision of either continuous reinforcement or bond beams around the top and bottom of the walls is a minimum recommendation, and additional bands of reinforcement or bond beams are frequently included. Special requirements apply to buildings constructed on expansive clay soil (27) and to buildings in hurricane areas.

Where long blockwork walls have to be built, an Australian authority (16) recommends the insertion of control joints at intervals of about 17 feet and experience in West Africa tends to support this (4). Walls built with light-weight blocks will require control joints at even shorter intervals.

Resistance to Rain Penetration. As it is not possible in practice to construct a wall that is free of small cracks and capillary channels in the joints through which water can find its way, the exterior walls must be waterproofed by applying a suitable external rendering. Where feasible this rendering should be given a suitable surface treatment to improve its rain-shedding properties and its appearance, and to reflect as much solar radiation as possible.

It is advisable to provide proper flashings under horizontal surfaces where water may collect and enter the wall, also at roof and wall intersections, and drips should be provided on all projections to shed the water clear of the wall surfaces. This also serves to prevent unsightly algal growth.

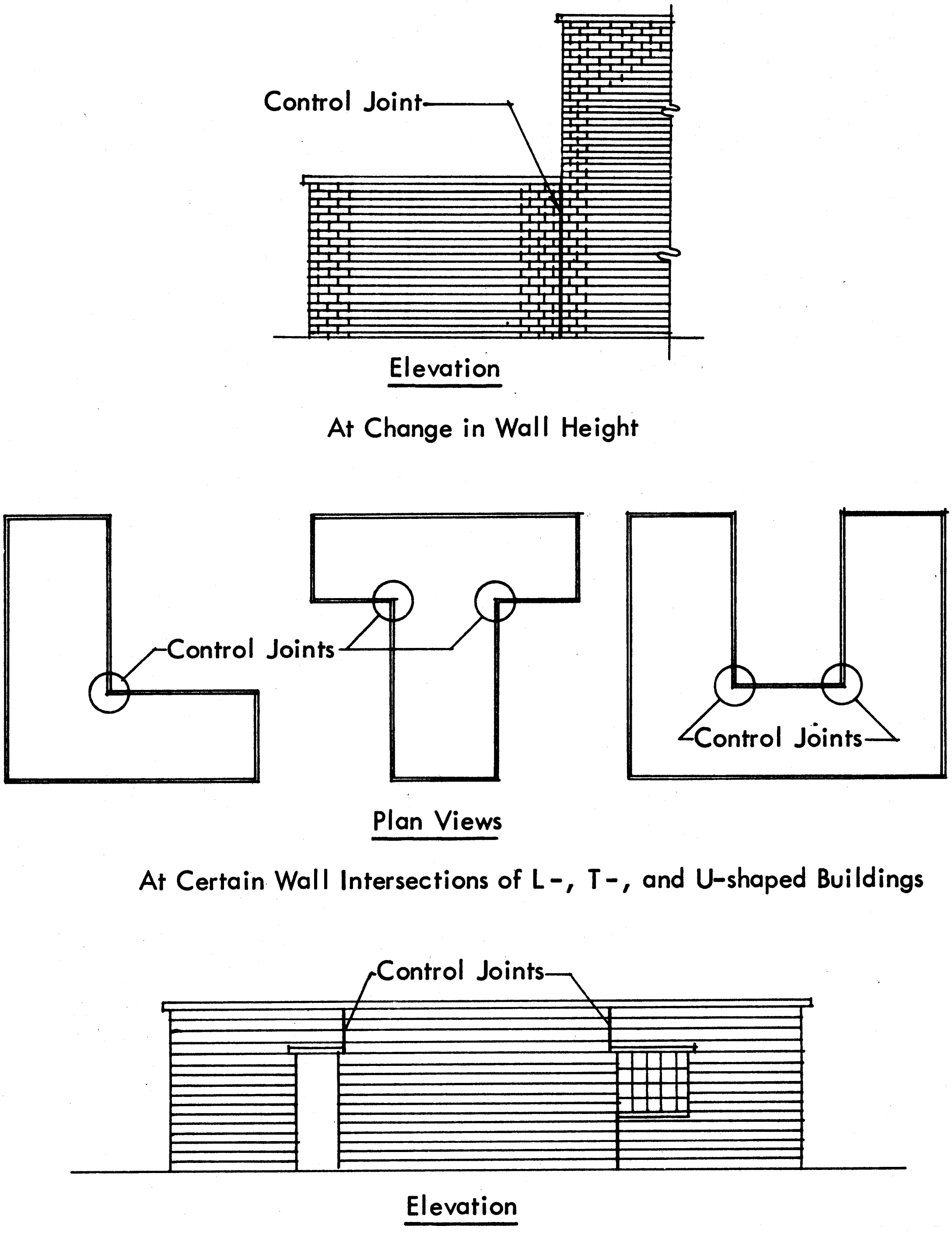


Fig. 12. Control joints at typical areas of stress concentration.

The insertion of a damp-proof course in walls in the humid tropics has been the subject of some controversy, but in general such damp-proof course probably contributes to the durability of the blockwork, and helps to reduce the amount of lime bloom staining above the damp-proof course. Wherever the water table is high, or where the soil contains quantities of soluble salts, the insertion of a damp-proof course is advisable.

BUILDING BLOCKWORK WALLS

The blocks should have dried out thoroughly and have reached a condition approaching equilibrium with the air before they are used. They should be protected against mechanical damage in transit and against rain and dirt. On site they should be stacked as near as possible to the place where they are to be used, and protected against sun and rain. If they cannot be stacked under cover, they should be stacked on a raised surface and in a manner that the air can blow between the blocks.

Mortar Mixes. The type of mortar to be used will depend on whether or not the wall is to be load-bearing, on its position within the building and on the degree of exposure to the weather.

Good mortar is necessary to good workmanship and good wall performance. It must bond the blocks into a strong well-built wall. The strength of the bond is affected by several factors including the type and quantity of the cementing materials, the workability or plasticity of the mortar, the surface texture of the mortar bedding areas, the suction of the blocks, the water retentivity of the mortar, and especially the quality of workmanship in laying the blocks. The mortar, although it must be consistent and of good quality, must not be too strong, otherwise if the wall does tend to crack, a few large cracks would be produced instead of many small ones. A mortar mix of 1:1:6 cement : lime : sand or its equivalent incorporating a mortar plasticiser in place of the lime is used, but in many cases it will be found possible, because of the nature of the local sand available, and because of the high ambient temperatures, to employ weaker mixes satisfactorily. Mixes based on lime, and lime - sand mixes, are not recommended as they are too weak.

Wherever possible the mortar should be mixed in a mechanical mixer but hand mixing can be employed for small jobs. Mortar that has stiffened on the mortar board because of evaporation can be made workable again by thorough remixing and adding water if necessary. However in no circumstances should mortar be used in the tropics later than 2½ hours after original mixing. In certain cases the concrete or sandcrete blocks may need to be wetted on their bedding faces in order to reduce their suction, but this should only be done as a last resort as it is bad practice because of its responsibility for the subsequent cracking of the walls. Whenever possible the consistency of the mortar should be adjusted to suit the suction of the blocks and not the other way round.

Laying. Blocks should normally be laid on a full bed of mortar and the vertical joints should be filled; sufficient mortar must be used to ensure that all keys in the jointing surfaces are properly filled. In laying the blocks particular care should be taken to ensure that the deep vertical joints are completely filled. The blocks should be laid line to line and the faces plumbed frequently. In the case of facing blocks the mortar should be laid about ½in back from the face of the block. The mortar can then be squeezed forward as the block is tapped into position, any mortar that exudes from the joint being lifted away carefully with the trowel. On no account should the surplus mortar be scraped into the face of the facing block. In the case of hollow blocks 9in wide, shell bedding is recommended, the mortar being laid in a 2in strip along the front and back of the block.

When reinforcement or dowel bars are used they should be placed at least 3/4in back from the face of the mortar to ensure adequate cover and bond. The reinforcement should normally be kept away from the furrow in the bed of mortar so that it will be able to develop bond with the mortar over its complete surface. The dowels however should normally be at the middle,

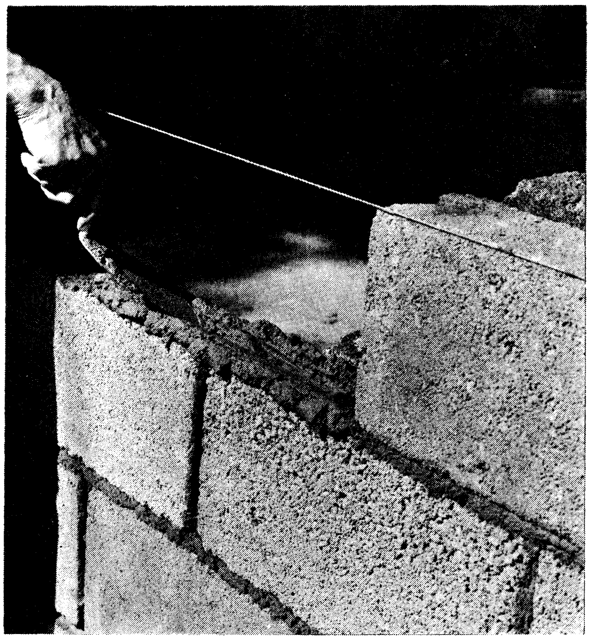


Fig. 13. Bedding concrete blocks : the block is laid on a full bed of mortar.

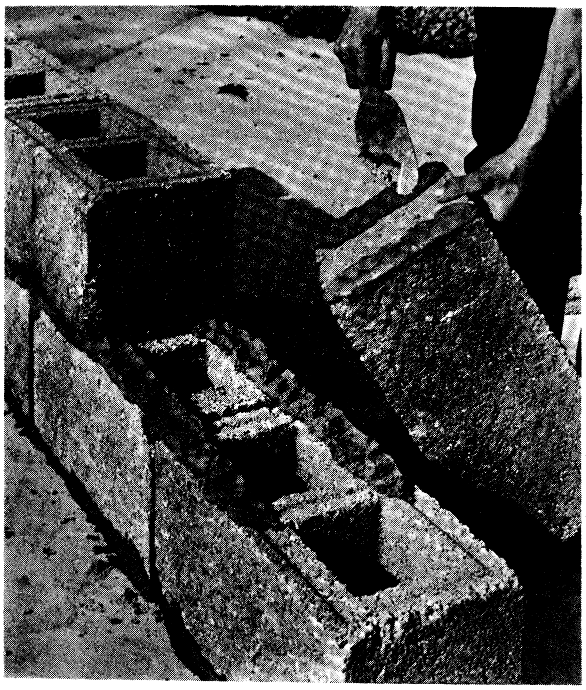


Fig. 14. Shell bedding used to improve the waterproof quality of a single leaf wall built of 9in hollow blocks.

and precautions may be needed to prevent bonding between the dowels and the mortar so that sliding will take place. The joint reinforcement usually takes the form of two longitudinal wires tied together with cross wires, the centre-to-centre distance of the longitudinal wires depending on the width of the blocks, bearing in mind that they should be at least ⅝in from the face of the block. The cross wires should be spaced not more than 6in apart and they should be welded to the longitudinal wires at the top or bottom points of the perimeter so that their centre lines should lie in different horizontal planes (17). The cross wires should not extend beyond the outer edge of the longitudinal wires (Fig. 9).

In the dry tropics the blockwork walls can remain unrendered. Concrete block walls in the humid tropics can also be left unrendered if the joints are made weathertight by tooling, but with sandcrete and lightweight blocks rendering is necessary. Even where good quality concrete blocks are used, a rendering should be applied if the skilled labour necessary to make well-tooled mortar joints is not available. If the wall is to be rendered, it is not essential to rake out the joints unless the block face is unusually smooth.

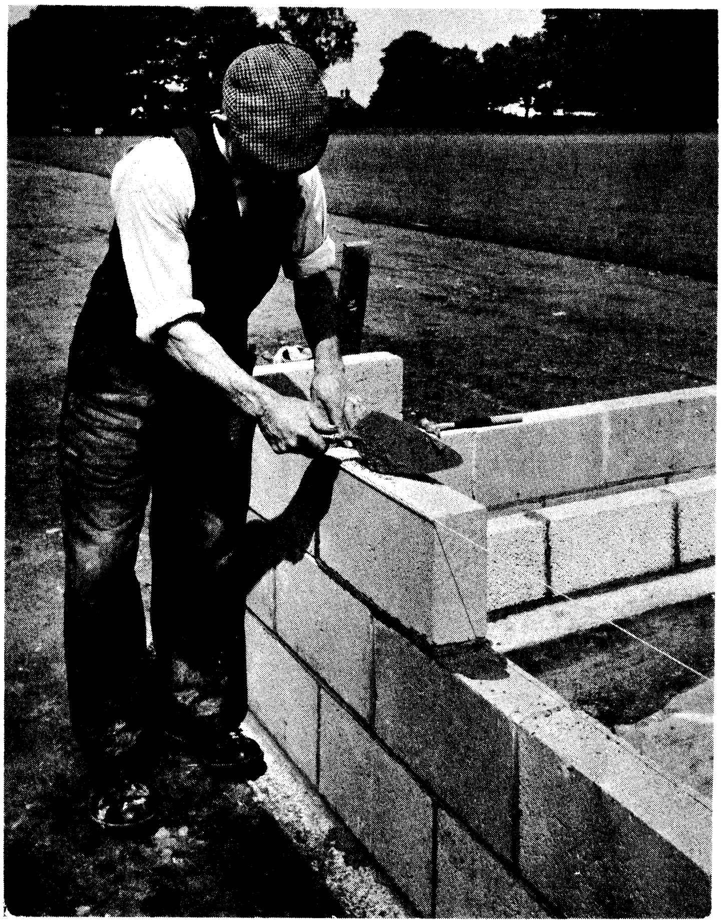


Fig. 15. Laying blocks to line.

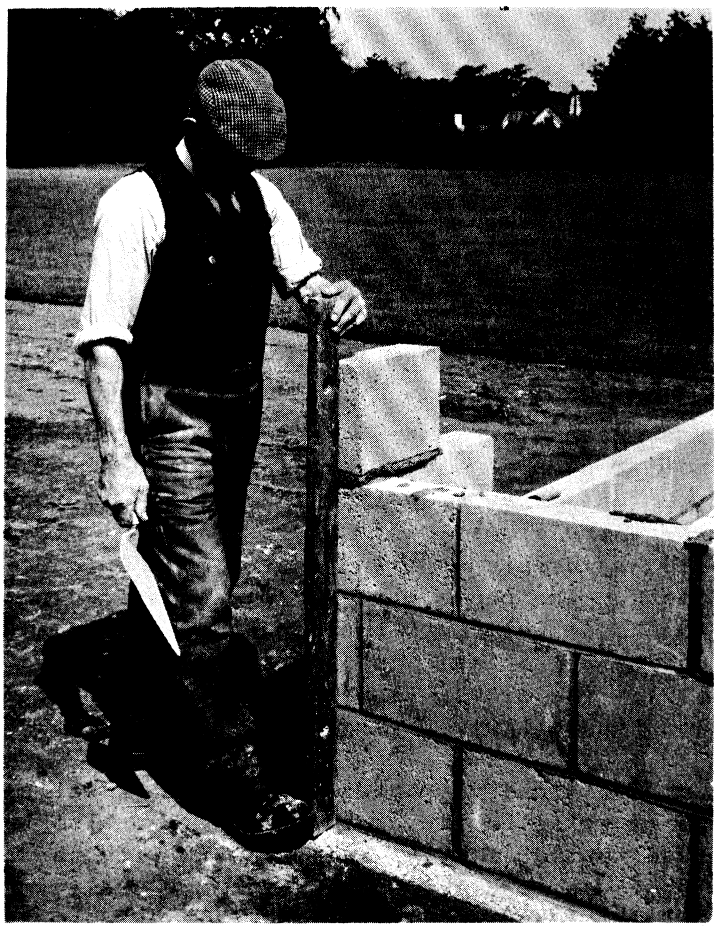


Fig. 16. Plumbing a quoin.

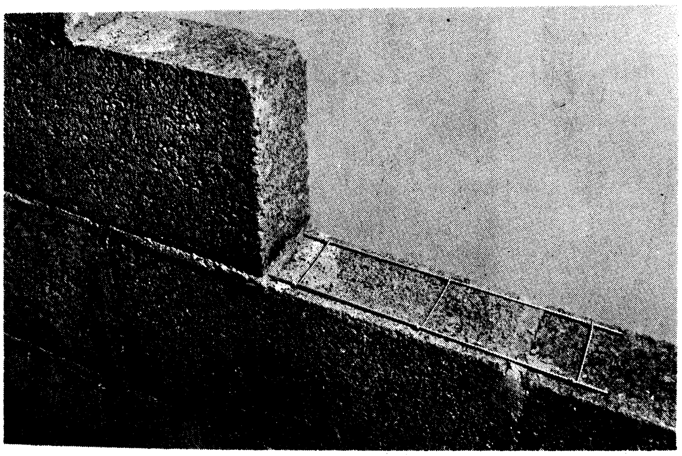


Fig. 17. Reinforcement in bed joints.

Tooling or Pointing. The mortar joints should be pointed or tooled when the mortar has become 'thumb print' hard. The tooling operation compacts the mortar and forces it tightly against the blocks on either side of the joint. Proper tooling also produces joints of uniform appearance with sharp clean lines. The jointer for tooling horizontal joints should be at least 22 in long and upturned on one end to prevent gouging the mortar. A suitable handle should be located near the centre of the tool. For concave joints a tool made from 5/8 in round bar is satisfactory and for 'V' shaped joints a tool made from ½ in square bar can be used (Figs. 10 and 11). The horizontal joints should be tooled first followed by the vertical joints using a small 'S' shaped jointer and any mortar burrs should be removed with a trowel. The blocks must not be moved or straightened in any manner once the mortar has even partly stiffened, otherwise the mortar bond will be broken and water will be able to penetrate. (25)

Rendering. External rendering is the application of two or more coatings of a mixture of cement, lime, and sand to the outer surface of buildings. Besides a weather proof surface, it can have a pleasing texture and colour that contribute to the overall appearance of the building. Because of the unsuitability of gypsum plaster in many parts of the tropics, it is customary to render the internal walls as well as the external ones with cement-lime-sand mixture. External rendering can be either smooth or rough finished, whereas internal rendering is usually smooth finished. Ingredients for colouring the rendering satisfactorily are expensive and not easy to obtain, so that where a coloured finish is required it is best to paint the rendering.

The character of the blockwork wall should be considered before deciding on the mix and the method of applying the rendering.

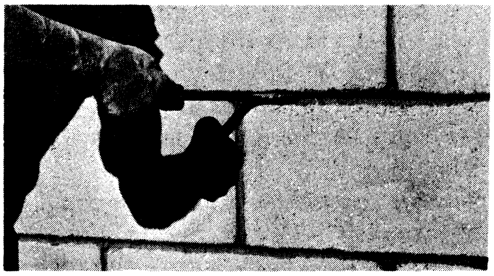
In most cases the wall will be sufficiently rough to provide an adequate key for the rendering, but in the case of smooth surfaced dense concrete blocks it would be advisable to rake out the joints to a depth of ½ in and to apply a coat of spatter-dash before rendering.

The mix used can range from 1:1:6 cement:lime:sand to 1:2:9, although it may be possible to use even weaker mixes in some circumstances. In the case of internal renderings it should be possible if desired to substitute an appropriate amount of mortar plasticiser for the lime. The mix should not be stronger than is indicated by the above mixes and additional cement must never be added to increase plasticity. The sand should if possible comply with the requirements (18) of British Standard B.S.No. 1199. The sand should be well washed to remove clay, salt and soluble impurities.

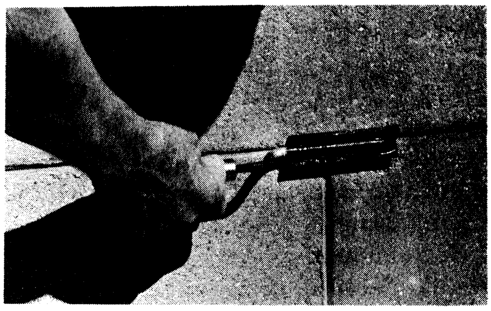
The main types of finish are as follows:

Smooth (floated). The surface is made level and smooth with a wooden float. This is the finish most frequently encountered in the tropics. It is easy to paint and to clean down (Fig. 13).

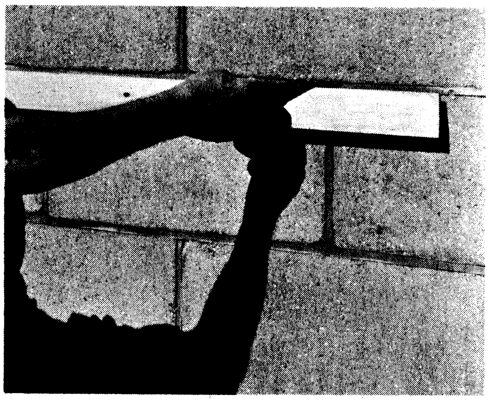
Struck joint, mortar compacted with trowel stroke.



Rubbed or keyed joint: a flush joint rubbed afterwards with a piece of round metal bar.

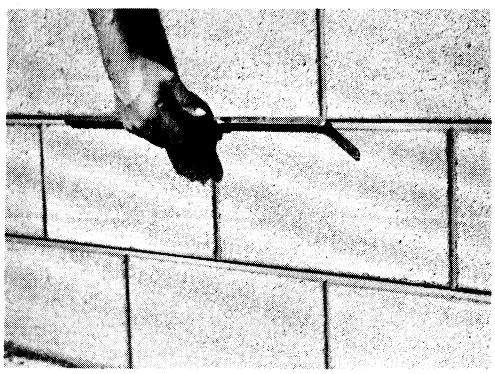


V joint being formed with special V tool.

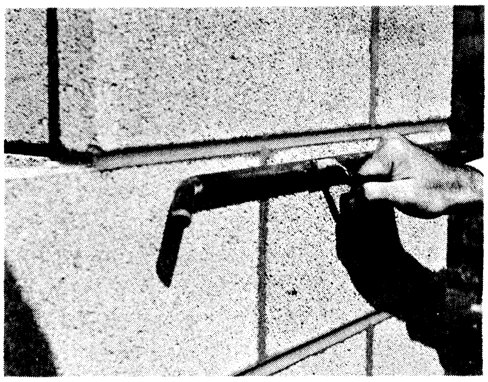


Weatherstruck joint being formed with a straightedge and frenchman.

Fig. 18. Methods of pointing.



For V-shaped joints, a tool is made from ½ in. square bar.



For concave joints, a tool is made from 5/8 in round bar.

Fig. 19. Tooling of mortar joints.

Tool the horizontal joints first, then strike the vertical joints with a small S-shaped jointer.

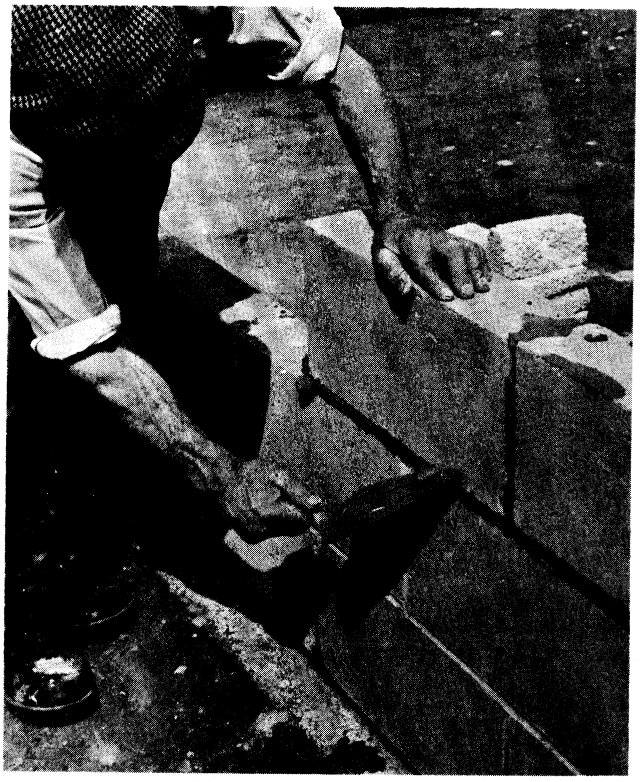


Fig. 20. Use of the trowel in laying facing blockwork.

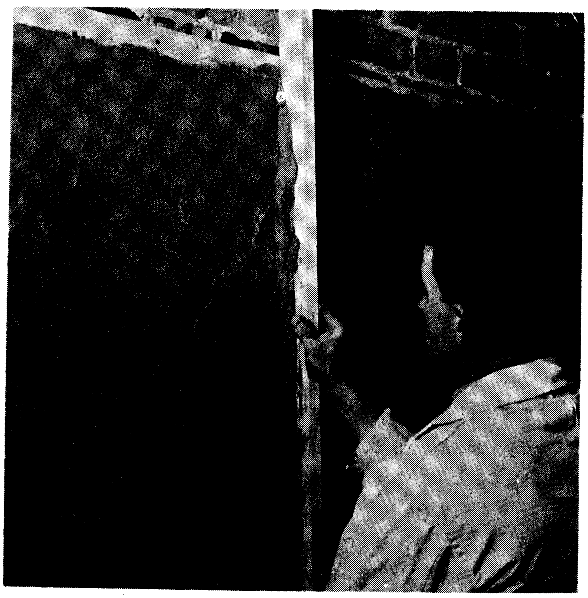


Fig. 21. Working the first coat to a plane finish with a floating rule.

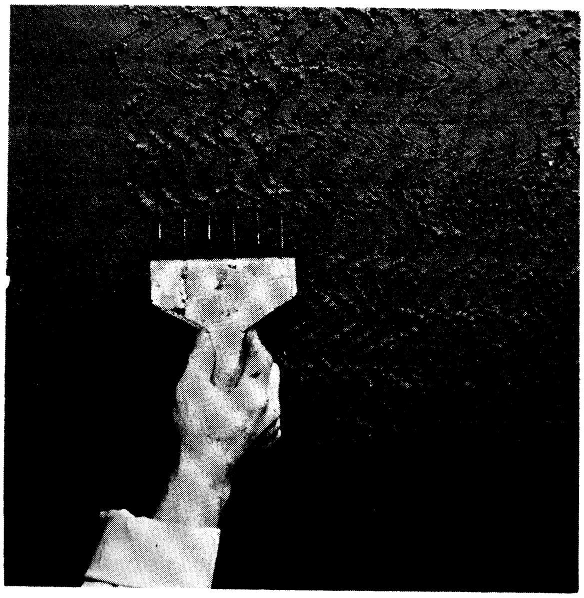


Fig. 22. Combing the first coat to provide a key for subsequent coats.

Scraped. The final coat of mortar when it has stiffened, is scraped with a steel straight edge, a saw blade, a board studded with nails, or some other tool to give a roughened surface.

Textured. A patterned surface is obtained by treating the freshly applied final coat with various tools such as sash tools, wide toothed combs, corrugated rubber, or even with an ordinary trowel or float (Fig. 15).

Roughcast. The final coat containing a proportion of coarse aggregate is thrown on by hand as a wet mix and left in a rough condition.

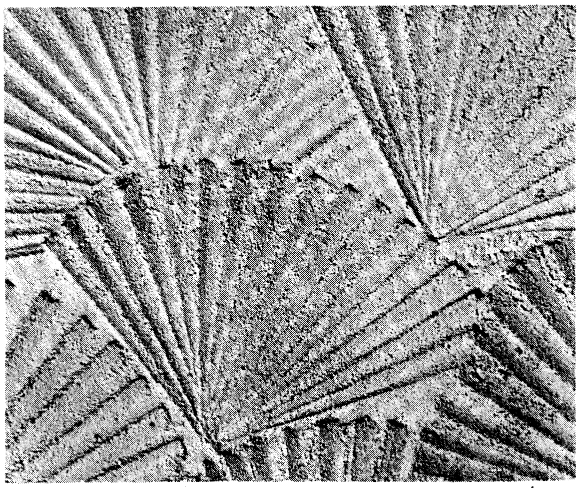


Fig. 23. Fan texture (approx. one-quarter size).

Fig. 24. Machine-thrown finish: coarse texture (approx. full size).

Machine-applied. A variety of finishes of which the final coat is applied by a machine, often hand operated, which spatters or throws the material on to the wall (Fig. 16).

Tyrolean. This is a machine applied finish incorporating coarse sand. It gives a pleasant rough finish and has given good results in the tropics although it tends to gather dirt more rapidly than a smooth finish.

Pebble-dash. A finish in which small pebbles or crushed stone are thrown on to the freshly applied final coat and left exposed. It is rarely used in the tropics.

As already indicated the most suitable finish for the majority of tropical regions is the smooth one. It is easier to paint and gathers dirt more slowly than the rougher finishes.

Application. Before applying the first coat, the wall should be clean and should be brushed down to remove any loose material, and then damped sufficiently to ensure uniform suction. Care should be taken to see that patches which dry out after the initial damping are remoistened, but no free water should be left on the surface. Where possible, work should be started on the shady side of the building and continued round following the sun.

The ingredients are mixed dry either by hand on a clean platform, or in a mechanical mixer until uniformly mixed, and sufficient water is then added to provide a workable consistency. The mix must be used within an hour of adding the cement. The thickness of the first or straightening coat should not be less than 3/8 in or more than 5/8 in. When the coat has begun to dry and harden it should be combed with evenly distributed wavy combings (Fig. 14). The indentations should be about ¾ in apart and not more than ¼ in deep. The combing can be omitted if the second coat is to be machine applied.

The first coat should not be allowed to dry out too quickly, and in case of rapid drying it can be remoistened with the aid of a fine spray. The coat should then be allowed to dry out for as long as possible, to allow the initial shrinkage and any cracking to take place before applying the final coat. Under reasonably dry conditions this should take about two days. The final coat should be not less than 3/16 in and not more than 5/16 in thick. With smooth finishes it is essential not to overwork the material otherwise it will craze. Precautions should also be taken with the final coat to prevent it drying out too quickly. The rendering can then be left as it is, or preferably painted either white or in light colours to reflect solar radiation.

It is important to take care when applying rendering to a wall with a damp-proof course that the rendering does not cover and thus bridge the edges of the damp-proofing material. In addition it is advisable to form a 'V' groove in the rendering over control joints in order to prevent the formation of unsightly crack marks.

The following table gives a useful guide to the quantities of materials required to cover 10 sq yd to the thickness specified.

			thickness in inches			
mix	material		1/8	¼	3/8	½
1:1:6	Cement	lb.	13½	27	40½	54
	Lime	lb.	5½	11	16½	22
	Sand	cu. yd.	0.9	1.8	2.7	3.6
1:2:9	Cement	lb.	9½	19	28½	38
	lime	lb.	8½	17	25½	34
	Sand	cu. yd.	0.9	1.8	2.7	3.6

There are several informative publications on rendering that can be consulted (19, 20, 21, 22), including the British Standard Code of Practice CP.221.

PAINTING OF RENDERED WALLS

General Considerations. External rendered walls are painted for the purpose of decoration and to reflect solar radiation. White paints provide the maximum reflectivity for solar radiation although light coloured paints are able to reflect appreciable amounts. The appearance and reflectivity of a painted wall can deteriorate as a result of algal growth and the accumulation of dirt, in addition the development of patches of efflorescence or 'lime bloom' can mar the appearance.

Algal growth usually forms unsightly black patches on the wall, but can also appear in green and red forms. It can be effectively controlled by preventing access of water to the wall surfaces by good design and maintenance. Wide eaves, parapets with the top surface sloping inwards and with good damp-proof courses, well raked canopies and fully controlled water shedding are of the utmost importance. Leaks and drips from pipes, sills, gutters, and air conditioning units must be avoided. Good drainage at the footings and the incorporation of a damp-proof course also help. Freestanding walls should have copings with a wide overhang, and it is advisable not to have trees and shrubs growing too close to a wall.

Dirt accumulates more readily on the rougher finishes especially on the windward side. In many regions it may be necessary to paint such surfaces red to hide the effect of red lateritic dust. Dirt splashed up on to the wall by heavy rain can also be disfiguring but the provision of tiles, slabs, or of a layer of gravel at the foot of the wall can disguise this.

In the case of internal walls, the main emphasis is on decorative effect; solar radiation is not important, and algal or fungal growth is rarely encountered apart from some bathroom and kitchen walls where poor ventilation may cause high moisture contents. Easy cleaning and the prevention of efflorescence or 'lime bloom' are important considerations.

Note. Tropical Building Studies No. 4 *Recommendations for Painting in Tropical Climates* (23) contains a comprehensive account of the choice and application of paint finishes to walls.

Choice of Finish. *Exterior Walls.* Although lime and colour washes are cheap, they cannot be recommended as their durability is poor. In addition they must be removed completely from a wall before a better quality paint can be applied. White cement paint is fairly durable in the tropics and is particularly suitable for application to a rough surface. On smooth surfaces many cement paints craze although the pattern is not easily seen unless one is very close to the wall. Coloured cement paints fade and cannot be recommended.

Although emulsion paints are more expensive than cement paints, their use has gained favour in the tropics because they are easier to apply, require less skill to produce a satisfactory result, are available in a wider range of colours, including pastel shades, and suffer less from patchiness, crazing and algal growth (24). Emulsion paints have been largely based on polyvinyl acetate but the newer formulations based on acrylic polymer have proved particularly effective in preventing lime bloom. This is particularly important, for though a paint system based on a good exterior quality emulsion paint may last for four years or even more in the tropics, the chief cause of early unsatisfactory performance has been the appearance of disfiguring white patches of lime bloom. The use of a suitable alkali resisting wall primer or sealer can also help in preventing lime bloom.

The practice of applying a first coat of cement paint followed by a coat of exterior quality emulsion paint gives good results on well weathered walls, but there is a tendency for fine crazing to occur, and occasionally some lime bloom.

Although the application of either cement paint or exterior quality emulsion paint will make a wall waterproof to some extent, when a waterproof coat of paint is specifically required an exterior wall paint based on chlorinated rubber should be used. It is important to realise that a waterproof coat applied over a rendering can cause serious trouble if through any cause cracks form in the coating. Water is then able to penetrate into the underlying rendering, and may then take a long time to dry out. The situation can be even more serious if there is an impermeable finish such as glazed tiling on the interior face. Here moisture in the wall can lead to the breakdown in adhesion of the waterproof paint film.

Interior Walls. Emulsion paints are recommended for painting the inside walls. They have good appearance and durability, and good quality products are largely unaffected by washing. They are affected by lime bloom and it is recommended that an acrylic based paint be used when this can be afforded. Alternatively a first coat of alkali-resisting primer or sealer should be applied.

Where economy is essential the cheaper vinyl water paints can be used in place of emulsion paint. Although in general they are not quite as washable or durable they are better than either distempers or oil-bound water paints. They should not be used in bathroom or kitchen or where subject to wear or abrasion. The relatively expensive wall paints based on chlorinated rubber are useful in rooms where considerable condensation of moisture is possible such as in bathrooms, shower rooms, and some kitchens.

Application. *Exterior Walls.* Walls should be allowed to weather for as long as possible, preferably a year, before painting so as to permit the free lime in the wall to come to the surface and carbonate. In many instances this is not possible, and in such cases the wall should be given one coat of a white or light coloured paint and the main painting programme deferred until much later. Emulsion paint can be used for this first coat. Where economy is essential cement paint can be used instead, but should not be applied too thickly otherwise the brush marks will show through subsequently-applied coats. With cement paints there is also greater risk of crazing which will affect the appearance of following coats. If the painting programme must be completed soon after construction, then providing four weeks have elapsed an emulsion paint system can be applied as described below, but although lime bloom will be reduced by the application of an alkali resisting primer or sealer, it will be more pronounced than if the wall had been allowed to weather beforehand.

The method of painting the wall will depend upon whether emulsion or cement paint is being applied, but in either case it is advisable to paint in the shade, following the sun.

Emulsion Paint. The wall should first be scrubbed down with water to remove dirt, dust, and loosely adhering particles. Any remaining lime bloom should be scraped or brushed off. When the wall is clean and dry apply one coat of an appropriate alkali-resisting primer or sealer followed by two coats of emulsion paint. Where an earlier coat of cement or emulsion paint has been applied, one coat of alkali-resisting primer or sealer followed by one coat of emulsion paint should be applied, a second coat of emulsion paint being added only if the colour is deficient.

The manufacturer's instructions must be closely followed, except that any special instructions for diluting the first coat of emulsion paint should not be followed for coats applied over the primer or sealer, the paint in this case being diluted as instructed for the final coat.

Cement Paint. The wall must be well cleaned by brushing, and by scrubbing with water if necessary. The wall must be well wetted before applying the first coat. Wet the surface with a fine spray or with a large brush until the rendering no longer soaks up water rapidly. Two or more applications of water may be necessary during the hour before painting but there must be no excess moisture on the surface. Do not mix too much cement paint at a time as the paint should be used up within 30 minutes of mixing; any thickened paint left after this time should be thrown away, not thinned with more water. Apply with a coarse distemper brush, almost scrubbing the paint into the wall. Do not apply two coats on the same day, and do not apply if rain threatens, as the freshly applied film may be washed off. The painted wall should be kept moist, if necessary by spraying with a fine water spray, for a whole day following painting. This cures the coating and prevents it powdering. Cement paints should not be applied on walls that have been treated with a wall primer or sealer.

Chlorinated Rubber Paint. The wall should be clean and free of loose particles. It is essential that the wall should be as dry as possible, and a newly constructed wall should be allowed to dry out for as long as possible before painting. The paint should be applied in dry weather to a dry wall and each coat must be allowed to dry thoroughly before the next coat is applied. No primer is needed with chlorinated rubber wall paint.

Rough Surfaces. Rough surfaces absorb a lot of emulsion paint and after painting have a poor appearance; accordingly they should be given one coat of cement paint followed by one or two coats of emulsion paint. A coat of alkali-resisting primer or sealer can be applied over the cement paint to reduce the incidence of lime bloom. Tyrolean type rough finished rendering (Fig. 16) can be painted with two coats of cement paint.

Interior Walls. Emulsion paints are applied in the same manner as described for exterior application, but it is not necessary to wait for a long time before first painting. Lime bloom can occur, but can be prevented to a considerable extent by the application of a first coat of alkali resisting primer or sealer.

Vinyl water paints also require the prior application of such a primer sealer. These paints should be applied in strict accordance with the manufacturer's instructions.

Repair and Redecoration of Walls. Frequently repairs are needed for external finishes that have cracked or have suffered damage or neglect or have deteriorated through the use of unsuitable materials. More frequently the walls require cleaning and redecorating.

Repair to cracks and damaged areas. Where only fine cracks are present and the work appears to be otherwise sound, the application of a fresh coat of paint may be sufficient to close and conceal the cracks. Narrow cracks can be filled with a paste made of fine sand or stone dust and emulsion paint, prior to repainting.

Cracks which do not extend below the rendering should be treated as follows. The area around the crack should be tested for hollowness by tapping the surface and the hollow areas should be cut out. In other areas the material on both sides of a crack should be cut out to a total width of not less than 3 in. The edges should be cut square or undercut. The edges and base should be well brushed to remove any loosely adhering material, the clean surfaces given a coat of cement slurry, and the rendering made good with a mix similar to that originally used. The patches are kept damp for several days by covering with wet hessian or leaves.

New techniques based on the use of epoxy resin adhesives have been developed for the satisfactory repair of cracks in concrete. These have been successful in promoting satisfactory adhesion between old and fresh concrete but information is not yet available on the use of these methods in tropical conditions.

Where the crack penetrates through the blockwork, the cracked base material must first be made good.

If it is not possible to repair the cracked blockwork completely it is advisable to cut back the rendering on either side of the crack for a distance of at least 6 in and light expanded-metal should be fixed to the blockwork and embedded in the undercoat of the rendering. This will not prevent further cracking but will reduce its severity.

Damaged patches should be cut out cleanly, preferably to rectangular areas, down to the blockwork, and the areas made good as described above for dealing with cracks.

Repaired areas should be repainted so as to blend in with the general background. The application of a coat of alkali-resisting primer over the patch is essential in the case of emulsion paints and in all cases it is advisable to delay painting as long as possible.

Repainting. The treatment given to a wall before redecoration with either cement or emulsion paint will depend on its condition.

If covered with an unsuitable material such as lime wash or distemper this must be removed as completely as possible by scraping and brushing. Old cement and emulsion paint should be well rubbed down, and washed down if necessary to remove dirt, lime bloom, and loosely adhering materials. The wall should be allowed to dry and then tested for the absence of loose powder and lime bloom by rubbing clean fingertips against the wall. Apply this fingertip test here and there, and not merely to one part of the wall. If more than a trace of powder adheres to the fingertips the wall must be scrubbed again.

Where algal and mould growth has developed it must be removed by brushing and washing, and the wall treated with a 1% solution of copper sulphate in water (1½ oz. per gallon) before repainting. Sources of leaks or drips must be dealt with before this treatment.

If repainting with cement paint the wall should be well wetted before applying the new coat. Cement paint should not be applied to a wall previously painted with either an emulsion paint or paint that is water resisting.

Emulsion paint can be applied over sound cement paint as well as over emulsion paint. Unless previously free from lime bloom, the cleaned wall must first be allowed to dry out and is then treated with one coat of alkali resisting wall primer or sealer. This is followed by the application of one coat of emulsion paint or of two coats if the colour of the first coat is deficient.

Coverage. So much depends on the condition of the surface, the viscosity of the paint, and weather conditions that the following is only a rough guide to the covering capacity of wall paints.

Alkali resisting wall primer-sealers. 40-50 sq yd per gallon per coat

Emulsion paints = 60-80 sq yd per gallon per coat.

Cement paints = 350 sq yd per cwt per coat.

Note: The original specimens shown in Fig.8 were kindly supplied by Dr. W. V. Harris, Commonwealth Institute of Entomology, The British Museum (Natural History), London, S.W.7.

Figures 10 and 11 are reproduced from National Academy of Sciences Publication No.1198, *Crack control in concrete masonry unit construction*, by permission of the Building Research Advisory Board. (The complete publication may be obtained from the Printing and Publishing Office, National Academy of Sciences, National Research Council, 2101 Constitution Avenue, N.W. Washington D.C. 20418, price $2.00).

Figure 19 is reproduced from Recommended Practice for Laying Concrete Block, published by the Portland Cement Association, Chicago, Illinois.

Other figures have been supplied by the Cement and Concrete Association, 52 Grosvenor Gardens, London, S.W.1.

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