DETAILING AND OTHER IMPORTANT CONSIDERATIONS OF BLOCKWORK

by

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Abstract

Blockwork construction is of recent origin and its use is rapidly expanding. It is similar to brickwork in many ways but there are important differences, which preclude extension of brickwork construction and detailing techniques, blindly, to blockwork too. Many masons and middle-level supervisory staff have undergone little or no formal training or apprenticeship on blockwork construction techniques and this has encouraged them to construct blockwork using the same techniques of brickwork construction they are familiar with. In order to arrest this trend, engineers should exercise greater supervision of blockwork construction and disseminate knowledge down to the grass roots of the construction team. To accomplish this task, information on detailing and other important considerations of blockwork is welcome and valuable.

This study deals with multiplicity of situations, likely to be faced by an engineer in Sri Lanka, in which construction and detailing of blockwork are different from those of brickwork. In making recommendations, well proven international practices were reviewed and modified, where necessary, after assessment of the currently adopted practices in Sri Lanka.

The paper highlights the differences of blockwork and brickwork, provides guidance on blockwork in general, and recommends detailing and construction techniques, both structural and non- structural, suitable for Sri Lankan conditions.

1.0 Introduction

Masons in Sri Lanka are mostly given extensive training in brickwork and so are the middle-level supervisory staff. Limited exposure to blockwork encourages them to blindly extend techniques used for brickwork to blockwork too. Thus engineers are required to exercise greater supervision of blockwork construction and more information on detailing and other important considerations of blockwork will be valuable.

Blockwork is similar to brickwork in many ways but there are important differences. Treatment of corners and intersections, condition of unit before laying, limitations on possible bond patterns, greater care needed in embedding steel inserts such as holdfasts in hollow blockwork to minimise corrosion, and installation of services are some aspects where siginificant differences exist. Hence many techniques of brickwork cannot be simply extended to blockwork.

Use of hollow blockwork allows easier incorporation of reinforcement into the system than in brickwork. In many ways reinforced blockwork is similar to reinforced concrete but significant differences in detailing and grouting exist. Already these concepts have been applied in some applications of reinforced or grouted blockwork in Sri Lanka and a wider dissemination of these concepts will be beneficial.

Use of blockwork is expanding in single to two-storeyed buildings and in multistoreyed buildings as loadbearing or infill walls. Reinforced blockwork is being used in lower walls of multistorey blockwork buildings and in cyclone proof buildings. It was also used recently in a road drainage project in Colombo to eliminate shuttering where exposure conditions are severe. New applications are also likely in the near future such as in taller infill walls, retaining walls and taller boundary walls, all of which require placement of reinforcement. These developments can be promoted and accelerated by provision of in-depth information on blockwork.

Alterations to existing blockwork buildings are unavoidable due to new occupancies or the changing life style of the occupants. Fixing wall attachments, provision of openings and subsequent need to reinforce remaining wall portions, and provision of extensions are some possibilities. Proper detailing is an important ingredient in successful accomplishment of any such alterations.

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This paper addresses the above issues, reviews detailing with special reference to local conditions, and provides guidance on blockwork in general, structural detailing and non-structural detailing.

2.0 Important Considerations of a General Nature

Blockwork walls and their wall openings should be designed and constructed to dimensions which, minimise cutting and fitting of units at site, waste material, slow up construction and increase cost. All the horizontal dimensions should be in multiples of half the nominal length of the block which is usually 200mm, and vertical dimensions should be in multiples of nominal height of the block which is usually 200mm. Thus care is needed at the design stage in dimensioning the structure and openings, and failure to do so will result in considerable inconvenience and higher cost (Figure 1). It is noted that nominal length or nominal height includes one mortar joint.

Placement of hollow blocks, one above the other in consecutive courses, requires closer attention. In most hollow blocks, cavities are tapered even slightly to facilitate removal of the mould. During blocklaying, hollow block should be placed with flared ends of face shells and webs uppermost (Figure 2). This provides greater area to place the next bed of mortar; makes it easier for the mason to grip the block firmly during placement; causes less likelihood of mortar bed becoming narrower due to fallen mortar droppings as upper block is adjusted for alignment; and minimizes formation of entrapped air during grouting under the flared face shells or webs.

Mortar cannot be used as grout. While good mortar should stick to the bottom side of a trowel, it should be impossible for grout to do so (1). Grout differs from concrete in that concrete is poured with a minimum of water (low water-cement ratio) into non- porous forms, while grout with considerably more water (high water-cement ratio) is poured into considerably smaller spaces between porous forms (face and web shells of block). When introduced into the masonry, the high water-cement ratio of grout is rapidly reduced to an extremely low ratio effecting a compact mass having a density about equal to that of gunite. As grout must be sufficiently fluid to flow into grout spaces and fully surround reinforcement leaving no voids, a slump of 250mm is necessary. Sri Lanka Building Specification (2) requirements for high slump concrete should be observed, till the development of more appropriate methods.

In contrast to bricks, concrete units contain a gel that expands when moist and shrinks when drying out. Hence concrete units should be dry and not wetted with additional water prior to laying, because wetting will tend to cause expansion and then subsequent shrinkage, which will result in cracking. In very hot, dry climates with warm winds a light spray of water is applied (3) to cool the blocks so that they can be handled comfortably and to prevent dehydration of mortar. However, these extreme conditions are not existent in Sri Lanka to warrant wetting of blocks.

Two grouting methods suitable for Sri Lankan conditions are the two-wythe low lift and the hollow unit low lift methods, whichever is applicable, as high lift grouting requires provision of clean outs which are cumbersome and small diameter long poker vibrators. In the former method (3), one wythe is carried about 450mm, then the other is laid up and grouted in lifts not to exceed 200mm or six times the width of the grout space. In the latter method, units are laid up to about 600mm and then grouted. Lift height should be reduced to 600mm from the usual 1.2m as our blocklaying method, where mortar is laid on full mortar bedding will give rise to greater accumulation of mortar droppings than the face shell method (where mortar is laid on face shells excluding webs) used elsewhere.

Vertical reinforcement should be cut to pieces not longer than 1.5m to enable easy placement of block by passing the reinforcement through block cavities.

Variety of special steel placement accessories used in developed countries (Figure 3(a)) are not suitable due to higher fabrication and galvanizing costs. Instead, vertical reinforcement should be held in position by tying on to steel wire clips (Figure 3(b)) slightly longer than the cavity, which are tightened by horizontal rotation. Horizontal reinforcement outside bed joints should be held by short open links carrying cover blocks and placed on hollow block webs with these links tied to the horizontal reinforcement (Figure 3(b)). In beams with closed shear links, or groups of vertical reinforcement surrounded by links, reinforcement cage can be held in position with cover blocks inserted on to the links (Figure 3(b)).

3.0 Structural Detailing

Control Joints :

The movement of blockwork walls is due to changes in moisture content, changes in temperature, movements of other parts of the structure, and contraction due to carbonation. This movement may lead to failure of masonry. Distress to masonry is overcome by continous vertically weakened sections for the full height built into the wall, called control joints. If stresses or wall movements crack the wall, cracks will occur at the control joints and thus be inconspicuous. A control joint provides ready movement of the wall in a longitudinal direction and seals against vision, sound and weather (if exposed). Sometimes it is also required to provide for shear transfer.

Control joints suited for Sri Lankan conditions are the plain, Michigan, and steel rod types (Figure 4) with plain type only suitable for movement without shear transfer. All these joints consist of two stopped ends adjacent to one another within the wall. If a control joint is exposed to view or weather, the mortar at the continous vertical movement joint should be left to become reasonably stiff before a recess is raked out to a depth of about 20mm, so that mortar remaining forms a backing to confine the caulking compound placed later. Plain type consists of two stopped ends (Figure 4a), sometimes separated by easily deformable synthetic sheet. Plain type can be formed (9) as the work proceeds or may be cut in completed blockwork with a power driven carborandum wheel to approximately one third of the wall thickness. Michigan type (4) uses flanged units (Figure 4b) where mortar plug is bonded to one block while building paper prevents bond to the other block. Steel rod type (Figure 4c) uses 250 or 300mm long galvanized steel rods across each face shell with each rod greased on only one side of the joint to prevent bond. This is recommended (9) where plain type would reduce the stability of the wall.

Control joints on either side of the wall are normally about 10mm wide and 20mm deep and should extend through the plaster, if any. Maximum spacing of control joints recommended (5,9) are:- (i) 6.0m for panel length/height of 2.0; (ii) 6.75m for panel length/height of 2.5; (iii) 7.5m for panel length/height of 3.0; and (iv) 9.0m for panel length/height of 4.0. Within those maximum spacings, control joints should be placed at the following points of weakness or high stress concentration:- (a) at all abrupt changes in wall height; (b) at all changes in wall thickness such as those adjacent to columns or pilasters or pipe chases; (c) at joint locations in the rest of the structure; and (d) at a distance not over one-half the allowable joint spacing from bonded intersections or corners. Further, all large openings in walls should be recognised as natural and desirable joint locations, and one side of door or window opening can be used for a control joint with joint above the opening offset to the end of the lintel. However, control joint between openings should be avoided since it will not function properly due to development of horizontal cracks from the openings.

Corners :

Corner construction in blockwork is different from brickwork. Although 200mm thick walls do not pose problems, the thicker or thinner walls require careful consideration so as to preserve the 100 or 200mm module. Recommended corner layouts are shown in Figure 5.

Intersections :

Connections at intersecting walls depend on whether the wall will require lateral support and whether control joints are located there. The two joints A (a, Figure 6) show intersecting walls providing lateral support to one another. These should be securely anchored to resist all forces that might separate them, and hence require a connection with true masonry bond so that half of units of each wall are embedded in the other wall. As masonry bond with walls other than 200mm thick is cumbersome, a joint reinforced by galvanized wire mesh placed in every other course (b, Figure 6) can also be used. B and C (a, Figure 6) are full control joints allowing movement in N-S and E-W directions and intersections of them should be as for control joints. At D(a, Figure 6) the N-S wall requires lateral support from the other as well as freedom of movement in its plane. This requires a hinged control joint (c, Figure 6) made with embedded galvanized wire mesh, at every course, which is cut into a thin strip and tucked into the head joint of the first block as shown (c, Figure 6).

Wall-Floor Joint :

Detailing of wall to floor joints is shown in Figure 7. The detail 'a' exposes the concrete slab and disrupts the bond pattern while in 'b', bond pattern is maintained by faking head and bed joints on the concrete beam of same height as a block unit. All the single-wythe exterior walls of hollow block should contain at least one weep hole per block in the mortar bed. In cases 'a' and 'c', cavities are grouted after placing a layer of building paper on a galvanized chicken mesh, positioned earlier at the lower mortar joint. Details 'd' and 'e' deal with non- loadbearing walls.

Wall-Roof Joint :

For the wall-roof joint, the cavities of the top course of blocks should be grouted. In the case of a timber roof, wall plate can be placed on the strengthened top course and roof structure fixed to the wall plate. In the case of block walls with piers supporting timber or steel trusses, cavities of blocks on the piers and on either side of piers should be grouted for at least top three courses to distribute the concentrated load. In addition, anchor bolts are ambedded in the grouted cavities of the piers to fix the trusses.

Narrow Wall Sections :

In buildings, narrow wall sections occur between door and window openings. Particularly in 2-storey buildings, this limits the use of loadbearing masonry and, hence, many designers employ a reinforced concrete structural frame instead. However, the more economical solution is to embed vertical reinforcement in the cavities of the narrow hollow block wall section and to grout those cavities.

Columns :

If an unreinforced column has insufficient structural strength, it can be reinforced (a, Figure 8). To place lateral ties chases should be cut at their locations in hollow blocks. Other option of placing lateral ties in bed joints is not very effective as only small galvanized wires can be placed in the bed joints as mortar of local blockwork is porous. A similar approach can be used for piers of walls (b, Figure 8). For large column sizes, as cutting chases in many blocks is laborious, type shown (c, Figure 8) should be used which simplifys placement of lateral ties.

Bond Beams :

Bond beams are reinforced courses of blocks which serve two important functions by (i) tying the structure together around its perimeter, and (ii) acting as a deep beam, thereby developing its moment of resistance. They are usually placed at top of the walls, but can also be located above doors and windows if they are at the same height. Bond beams are usually not necessary unless cyclonic winds, numerous openings, differential settlement of foundation or need to eliminate movement joints require special treatment. Normally bond beams are constructed with special channel or U units, but in Sri Lanka these are not freely available. Hence chases should be cut in hollow block shells to allow placement of reinforcement horizontally. Amount of reinforcement should be obtained by structural calculation. When special bond beam units are not used, cavities of the course of hollow blocks below the bond beam should be plugged. Easiest way is to plug these with concrete before placement in the walls. Alternatively, plugging can be done by placing about 75mm deep concrete above building paper (placed in cavities) held over thin galvanized wire mesh of small apertures, placed in the mortar bed below the block course to be plugged. In the latter case, it will be easier if blocks are placed with flared (enlarged) ends of face shells and webs lowermost. Detailing of reinforcement at corners and intersections is similar to that of reinforced concrete (6) with the exception that no shear links are used.

Lintels :

These are reinforced horizontal members that span openings in walls and act as beams supporting weight of the wall and other loads over openings. These can be constructed similar to bond beams with the inclusion of shear links for larger openings or can be precast and lifted into position. Lintels should have a minimum bearing of 150mm at each end and a rough rule of thumb (4) is to provide 25mm of bearing for every 300mm of clear span.

Foundation details :

Recommended foundation details (7) are shown in Figure 9. Thicker walls have deeper and wider foundations as they carry greater load per unit length. Cavities earmarked for filling can be filled by concrete mixes specified in Figure 9. A high slump concrete is preferred to offset absorption likely by block walls.

Wall Attachments :

The two types of wall attachments (3) widely used are shown in Figure 10. They are solidly grouted in place. Direct bearing of heavy concentrated loads on the face shell of the unit should be avoided by placing grout around the bolt shaft. Appropriate face shells of hollow blocks should be cut to receive bolts. If attachment is to be fixed after construction of the wall, then upper block should be removed for concrete placement and timber shutters should be used for solid walls as in Figure 11. Procedure of concrete placement is similar to that described for door and window details (see below).

4.0 Non-Structural Detailing

Door and Window Details :

Treatment of door details in a hollow block wall is shown in Figure 11(a) with the middle holdfast different from the type used in brickwork to provide better protection against corrosion. In the case of wall construction after placement of the door frame, blocks a1, a2/a3 and a4 are grouted when the wall construction reaches that course. When door frame is placed after construction of the wall, blocks a1, a2/a3, a4, b1, b2 and b3 should be left out during wall construction (or removed if already constructed as in repair or alteration work). Then blocks a1, a2/a3 and a4 are placed in position with the door frame and spaces grouted as shown. Finally blocks b1, b2 and b3 are placed in position.

Treatment of door details in a solid block wall is shown in Figure 11(b) with the middle holdfast, going over half a block, similar to the type used in brickwork. In the case of wall construction after placement of door, blocks a1 and a2 are grouted after wall construction reaches each such course using the formwork arrangement shown (Figure 11(b)). Holes left by greased rods of the shuttering are later dry packed with mortar. When door frame is placed after construction of the wall, blocks a1, a2, b1 and b2 should be left out during wall construction (or removed if already constructed as in repair or alteration work). Then blocks a1 and a2 are grouted using the formwork arrangement and finally, blocks b1 and b2 are placed in position. Middle holdfast is fixed as in brickwork.

Treatment of window details are similar to above. It should be noted that in plastered blockwork, the holes made for spurstone, holdfast and horn can be filled with bricks or stone pieces in mortar at considerably lesser effort.

Acoustics :

Good acoustical design (4) in residences and offices can be achieved with absorptive surfaces such as curtains and carpets, relatively heavy wall and floor construction, and insulation of noise producing equipment. Blockwork is an excellent sound barrier because of its density and requires no special treatment. However, joints between wall/slab and wall/opening should be carefully sealed to cut off direct passage of sound.

Electrical and other services :

The easiest way to run electrical and other services is outside the wall. When this option is precluded, methods shown in Figure 12 can be adopted. In solid block walls, when a service conduit runs down vertically treatment is similar to two adjacent stop ends and chases should be cut out or cast in the abutting blocks. Abutting blocks should be modified similarly at bed joints where a service conduit runs horizontally. In the case of hollow block walls, vertically run service conduit should be placed in any continous hollow cavity. Horizontally run conduit can be placed in a bed joint with abutting blocks cut out or cast with chases as shown.

Small electrical or other service accessories can be fixed to the wall directly with special screws with plastic expanding anchorage devices. Heavy accessories should be fixed as in Figure 10.

Fire Resistance :

Various code requirements with respect to fire ensure structural safety during fire and containment of the fire. Blockwork is well suited to firewall construction and a fire resistance of 4 or more hours can be achieved. Locally available blocks are well suited due to high quality of aggregates used and adequate face shell or solid block thicknesses. However, in special situations, fire resistance can be further increased by filling the hollows with a dry granular material like sand.

Weep Holes :

In external walls of one block thick hollow blockwork, weep holes should be provided at the base of the wall (a,b,d - Figure 7). At least one weep hole per block cavity is necessary and the hole should pierce through the mortar bed under the face shell of the external face of the wall allowing drainage of accumulated water from the cavity. It can be cast in the mortar bed by placement of a short, greased or oiled rod (which is slightly bent to a large radius of curvature) during blocklaying. It should be removed before hardening of mortar but after initial set by moving it to and fro to leave a clear hole.

Cavity Walls :

Cavity walls are rare in Sri Lanka, but are useful in locations where increased rain penetration resistance is required such as in certain tourist hotels and other tall buildings subjected to high intensity rainfall and high wind. Detailing is similar to brick cavity walls, where two leaves separated by a cavity are connected by galvanised metal ties, with external leaf preferably of solid blocks.

Connection of a Timber Partition Wall :

A timber partition wall can be connected securely to a block wall by at least two bolts embedded in the block wall and passing through a timber stud. Bolts can be anchored in the wall as described under wall attachments.

5.0 Closure

The paper dealt with detailing and other important considerations of blockwork, where treatment differs from well known practices of brickwork, with particular reference to special conditions prevalent in Sri Lanka.

6.0 References

1. Chandrakeerthy, S.R. De S. and Hamid, A.A., "Partially Reinforced Concrete Masonry as an Alternative Building Material in Developing Countries", Proceedings of the 3rd International Conference on Structural Masonry in Developing Countries, Mauritius, July 1990.

2. Ministry of Housing and Construction, "Sri Lanka Specifications for Building Works", Colombo, Sri Lanka, 1983.

3. Schneider, R.R. and Dickey, W.L., "Reinforced Masonry Design", Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1987.

4. Randall, F.A. and Panarese, W.C., "Concrete Masonry Handbook", Portland Cement Association, Skokie, Illinois, 1985.

5. ACI-ASCE standard (ACI 530-88/ASCE 5-88), "Building Code Requirements for Masonry Structures", ACI and ASCE, 1988.

6. Chandrakeerthy, S.R. de S., "Detailing of Some Widely Used Joints in Reinforced Concrete Structures", Engineer, March 1990.

7. Elmiger, A., "Architectural and Engineering Concrete Masonry Details for Building Construction", National Concrete Masonry Association, P.O. Box 781, Herdon, Virginia, USA, 1976.

8. Amrhein, J.E., "Reinforced Masonry Engineering Handbook", Masonry Institute of America, Los Angeles, California, 1972.

9. CP 121: Part 1: 1973, "Code of Practice for Walling - Brick and Block Masonry", British Standards Institution.

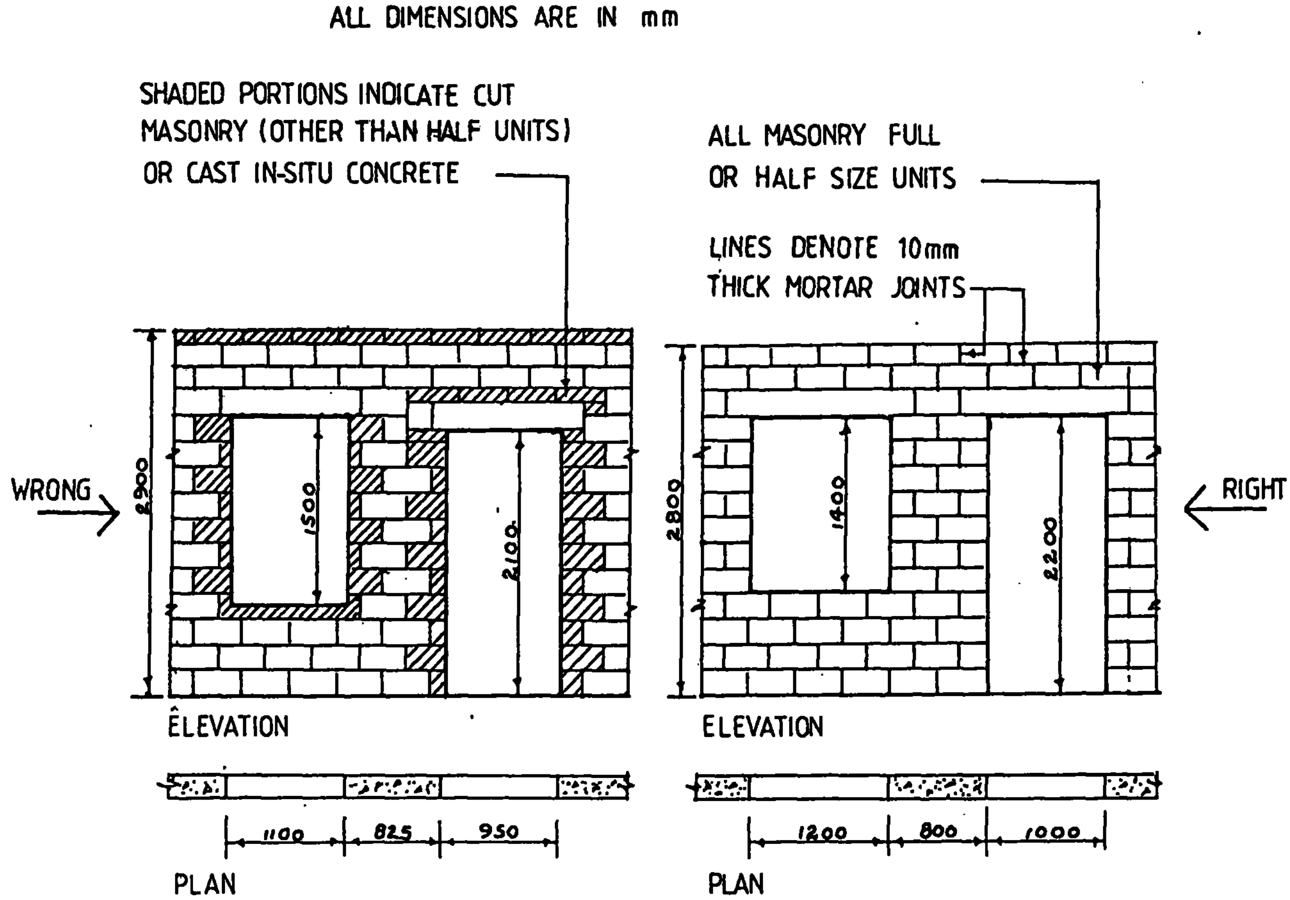


FIGURE 1- WRONG AND RIGHT PLANNING OF WALLS AND WALL OPENINGS

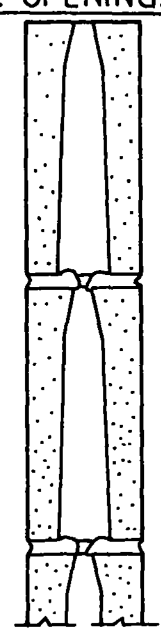
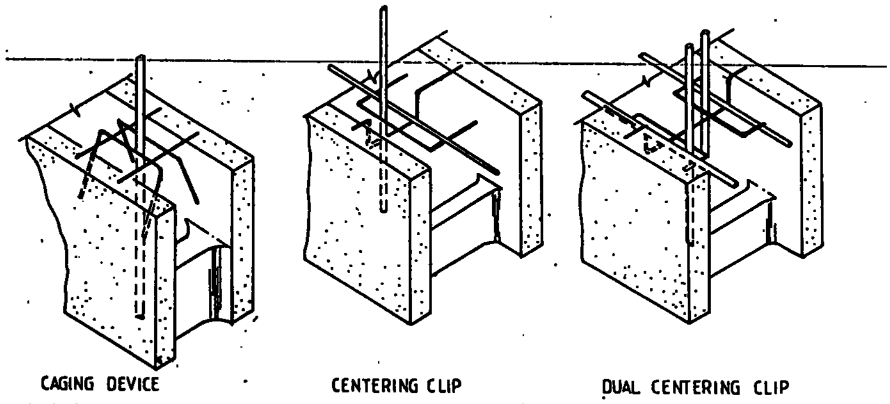
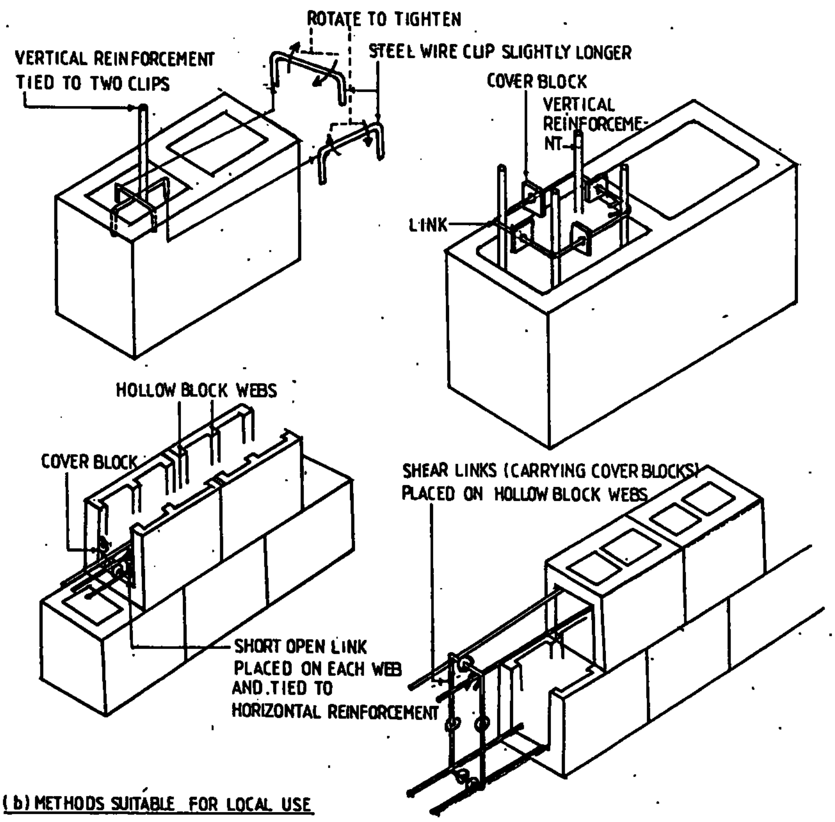


FIGURE 2 - PLACEMENT OF BLOCKS IN CONSECUTIVE COURSES

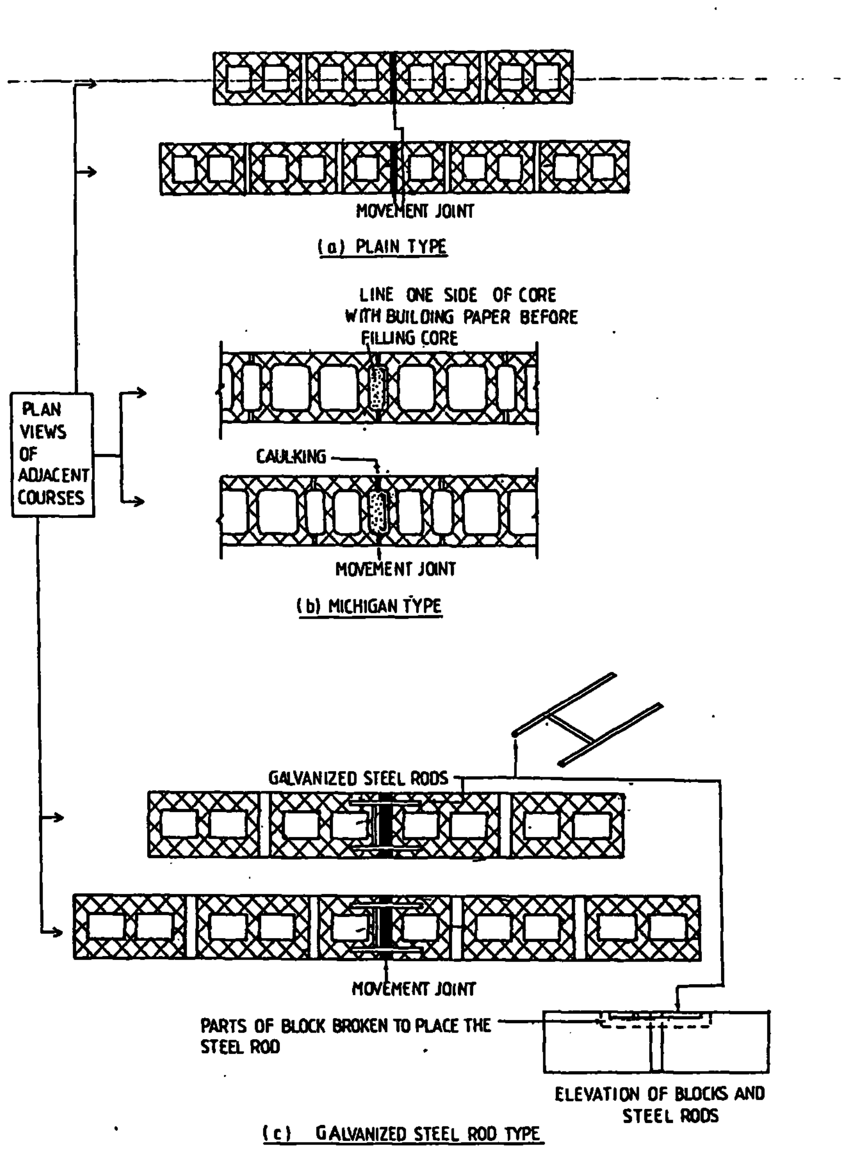


(a) CENTERING AND CAGING DEVICES USED IN DEVELOPED COUNTRIES



(b) METHODS SUITABLE FOR LOCAL USE

FIGURE 3 - METHODS FOR HOLDING REINFORCEMENT IN POSITION



NOTE - MORTAR JOINTS ARE ENLARGED FOR CLARITY

FIGURE 4 - CONTROL JOINTS

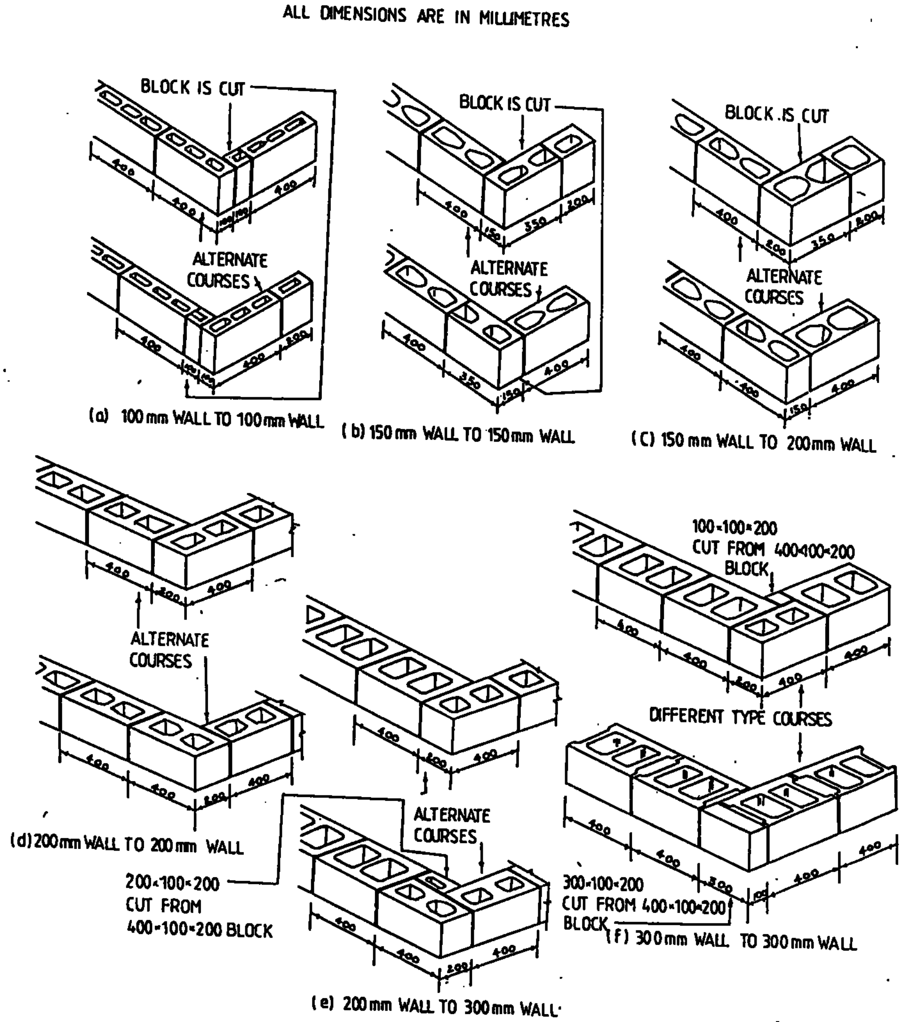
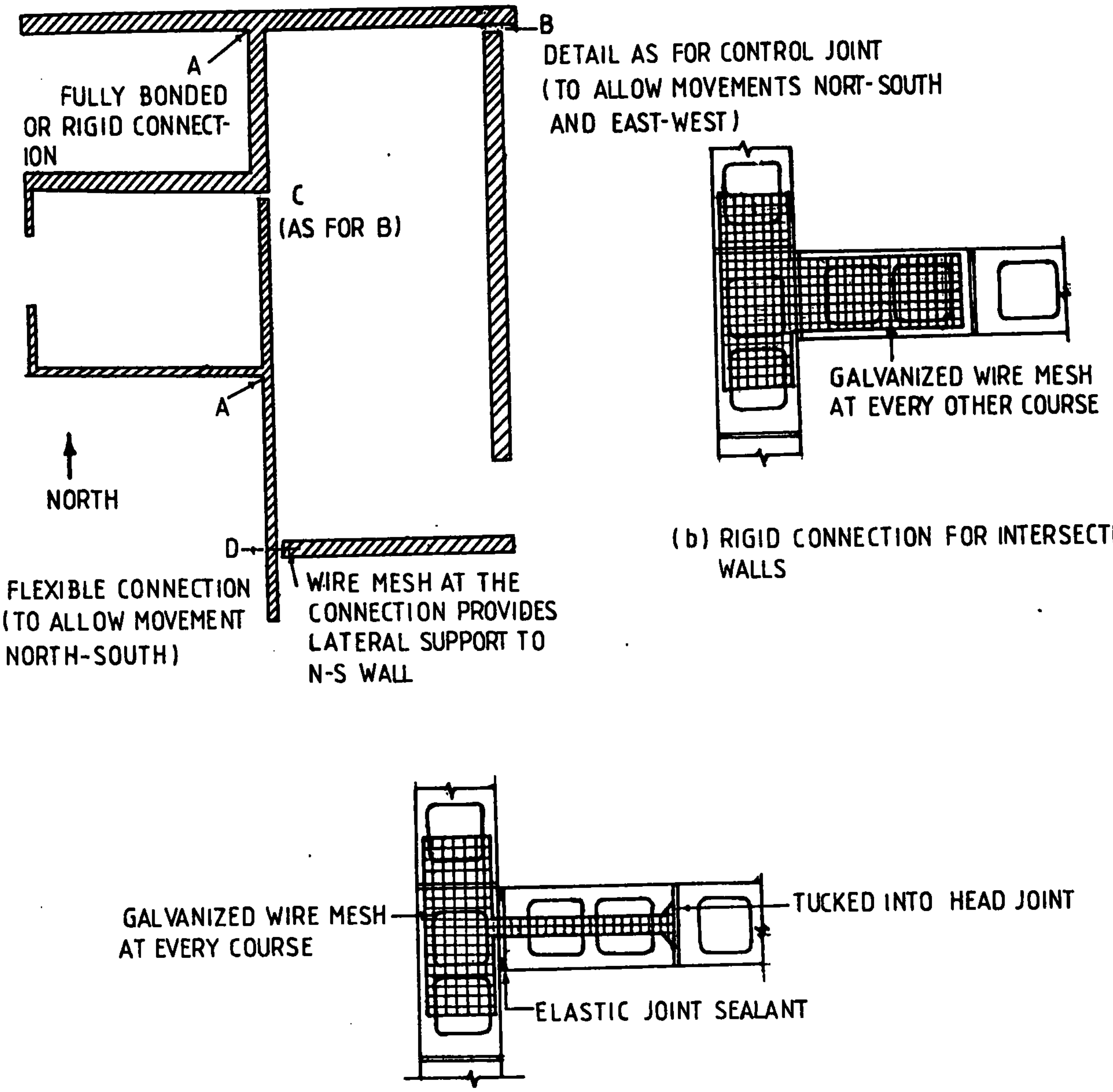


FIGURE 5 - STANDARD CORNER LAYOUTS FOR WALLS 100, 150, 200, & 300 mm THICK



(b) RIGID CONNECTION FOR INTERSECTING WALLS

(c) FLEXIBLE CONNECTION FOR INTERSECTING WALLS

FIGURE 6 - INTERSECTIONS

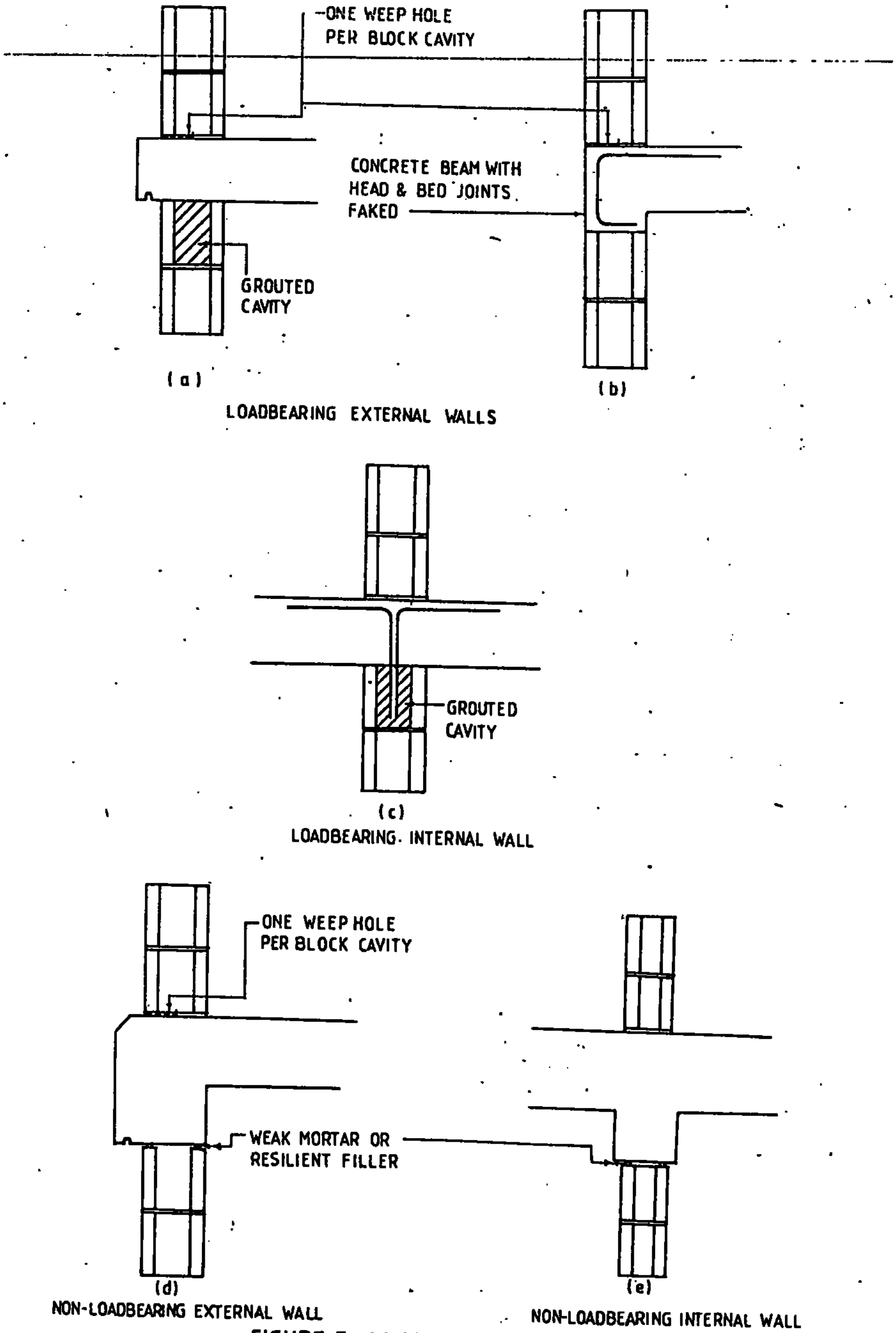


FIGURE 7 - WALL TO FLOOR JOINTS

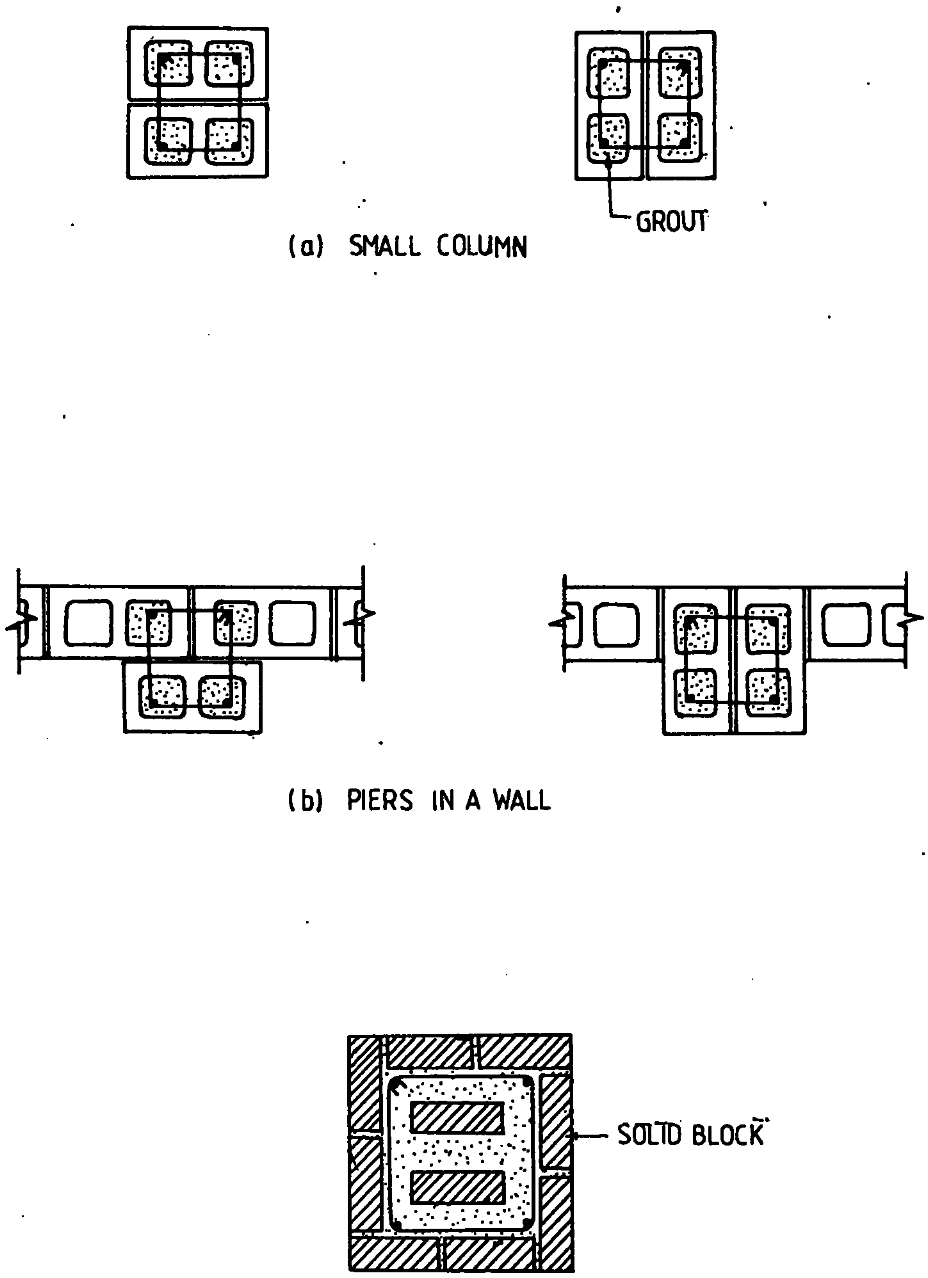


FIGURE 8 - REINFORCED COLUMNS

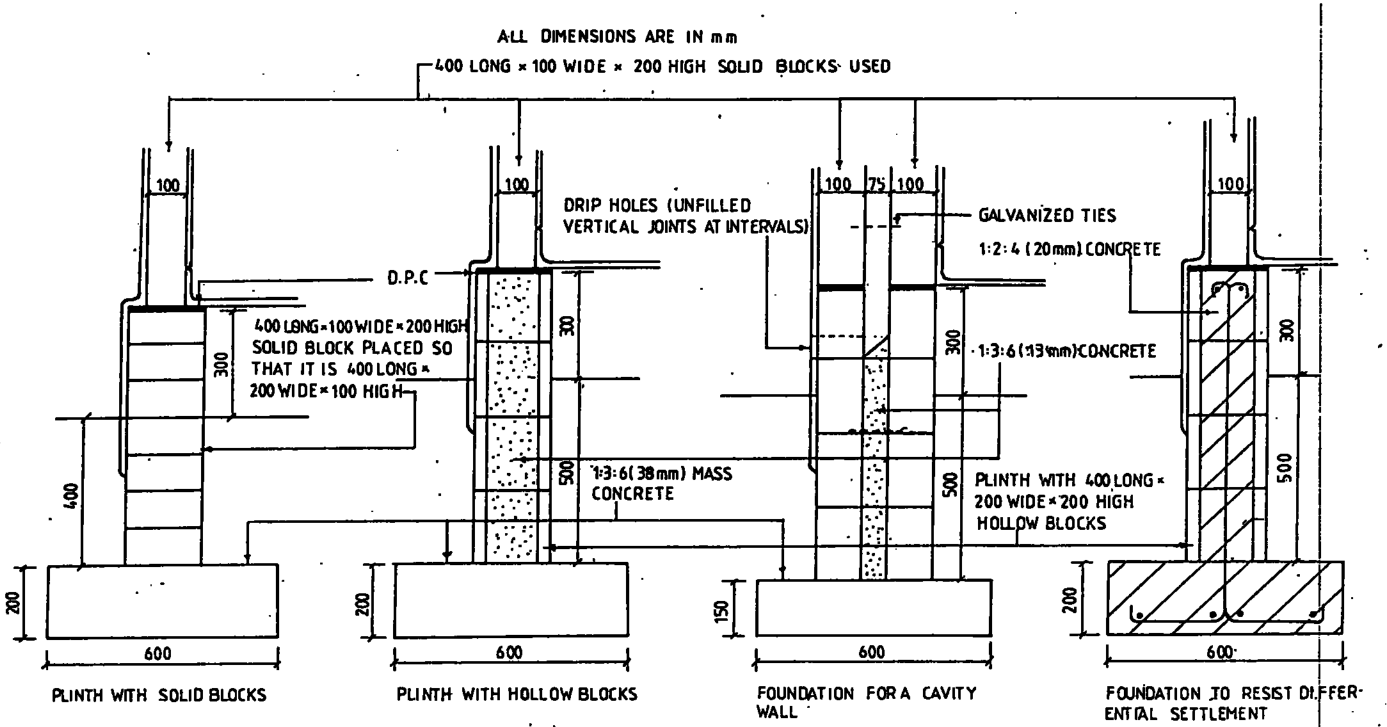
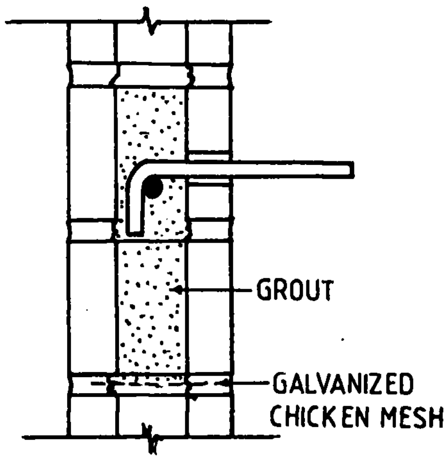
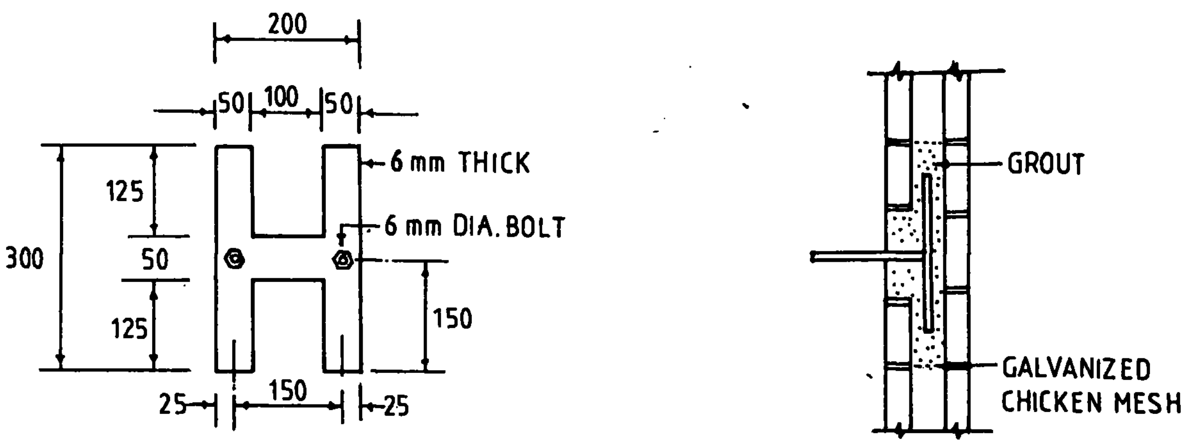


FIGURE 9 - SOME FOUNDATION DETAILS



(a) BOLT HOOKED OVER A REINFORCEMENT



TEMPLATE ENLARGED FOR CLARITY
ALL DIMENSIONS ARE IN mm
(b) BOLTS WITH TEMPLATE ANCHORAGE

FIGURE 10 : WALL ATTACHMENTS

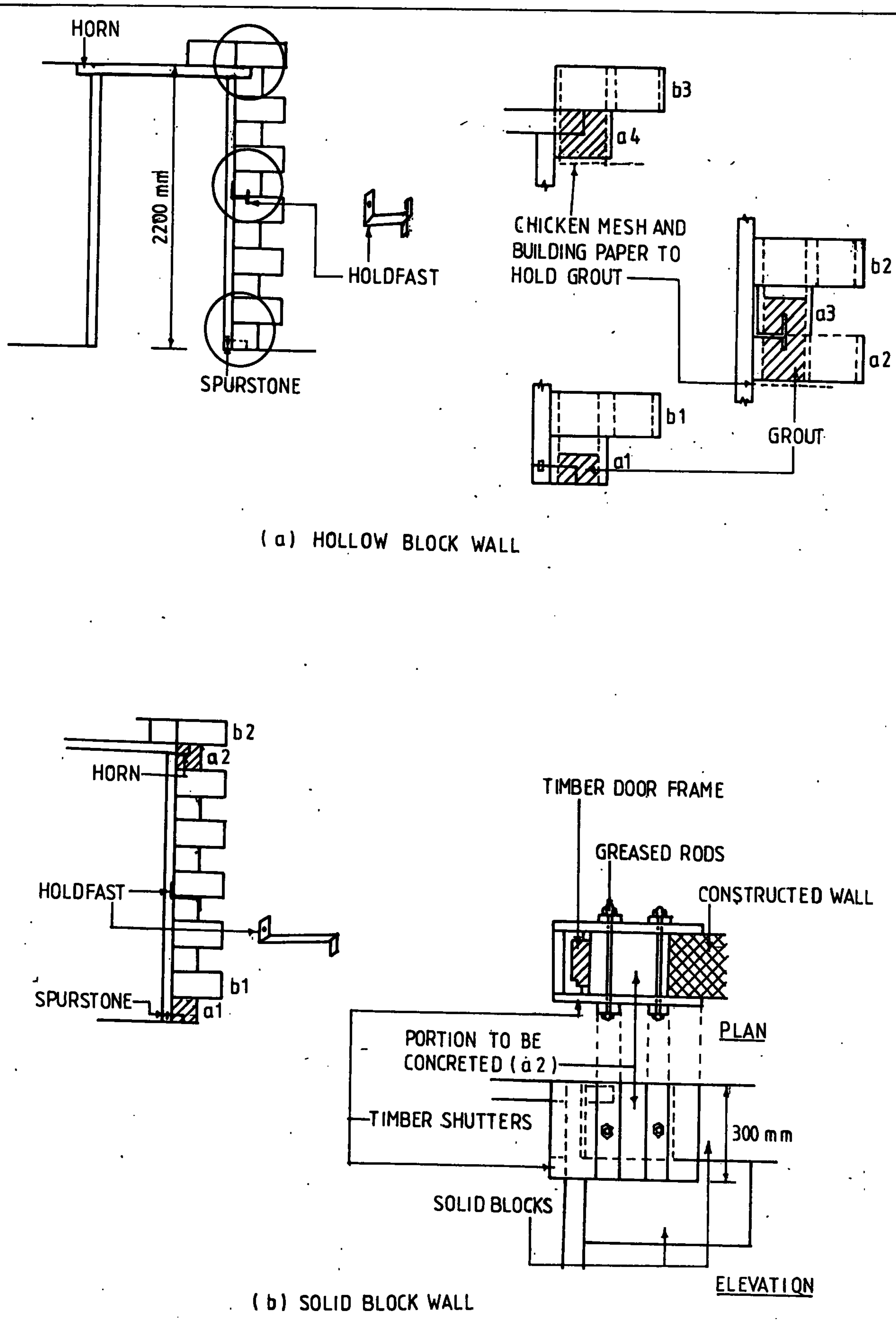


FIGURE 11 - DOOR DETAIL

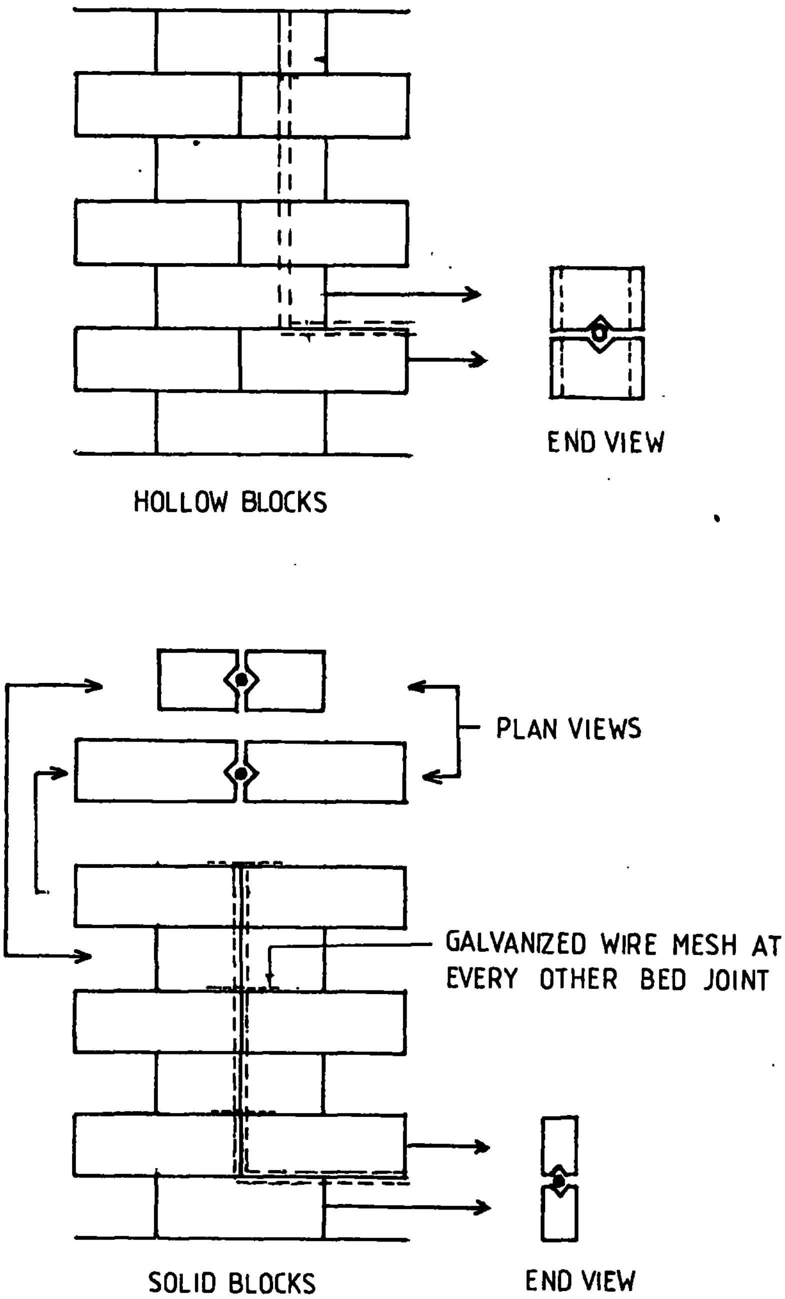


FIGURE 12 - PROVISION OF ELECTRICAL CONDUITS