JAMES COOK CYCLONE STRUCTURAL TESTING STATION

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PRACTICAL BRICKWORK AND MASONRY

TECHNICAL REPORT NO. 9

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W.A. Tapiolas

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PRACTICAL BRICKWORK AND MASONRY

W.A. Tapiolas *

SUMMARY

The integrety and performance of masonry construction is somewhat dependent upon satisfactory foundations. The footings should be designed to suit the soil conditions and should be constructed to the same degree of care as any other structural member. The methods of providing wall reinforcing for both concrete masonry and calcium silicate brick construction are discussed in this paper and recommendations are made regarding the size and spacing of such reinforcement. Methods of constructing bond beams and lintels for window openings are outlined, and the need for proper damp-proofing is emphasized. An example of some current construction is given. The paper concludes by recommending three features that if properly implemented would lead to safer construction to resist high wind forces.

* General Manager, Tropical Homes Townsville Pty. Ltd.

This Report is a reprint of a paper presented by the author as part of the Cyclone Building Construction Seminar organized during November 1980 in Townsville by the Cyclone Building Research Committee. Other papers presented at the seminar are listed below -

- Introduction to Wind Loads
- Roof and Wall Cladding
- Bracing
- Wall and Roof Framing
- Connections and Fastenings
- Windows and Doors
- Brickwork and Blockwork Theory
- Building Regulations

A bound set of all papers may be purchased from the Secretary, Cyclone Building Research Committee, P.O. Box 707, Townsville, 4810.

1. INTRODUCTION

This paper deals with several practical aspects of masonry construction in the northern cyclonic area. Some problems which are encountered in the foundations and footings of domestic buildings, and how these can affect the performance of the building under high wind loading, will be considered at first.

Although the term masonry is usually related to concrete masonry blocks and clay bricks, the use of calcium silicate bricks and blocks has increased considerably during the last few years. There are several areas which need careful consideration in the use of calcium silicate blocks. Problems encountered in reinforced concrete masonry will also be considered, together with some new developments in the construction of concrete masonry houses which have been designed in accordance with current engineering practice.

Throughout this paper, where the general term "masonry" is used, it includes concrete masonry, calcium silicate bricks and blocks and clay bricks.

2. FOUNDATIONS

Although this seminar is concerned with the design and performance of buildings and components during a cyclone, it is not possible to consider masonry construction without firstly considering the foundations. If poorly designed or constructed foundations cause failure in certain sections of a building under normal conditions, then the forces acting on that building during a cyclone may cause a behaviour different from that predicted by the designer, and could in fact result in a failure which would not normally occur had the foundations been correctly constructed. Everyone has seen cases of cracking in masonry walls caused by subsidance of the foundations.

It is possible to imagine the problems which will be encountered in such a wall should it be subjected to severe cyclonic wind loading. Generally in Commercial/Industrial constructions, the design of a building has been carried out by a structural engineer who has soil tests taken on the site, and who then designs the foundations accordingly. Unfortunately, this is not always the case in domestic construction. Soil testing is rarely done, and the greater proportion of foundation failures occur in dwellings.

The foundations for masonry walls generally fall into one of two classes:-

(i) strip footings, as in figure 1

or (ii) slab-on-ground footings, as in figure 2

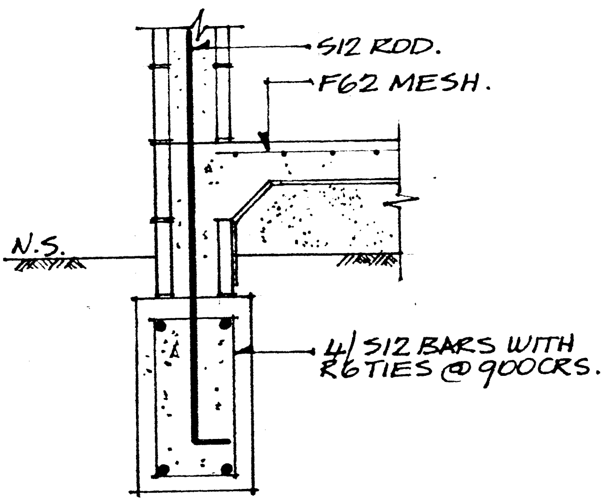


FIG. 1. STRIP FOOTING.

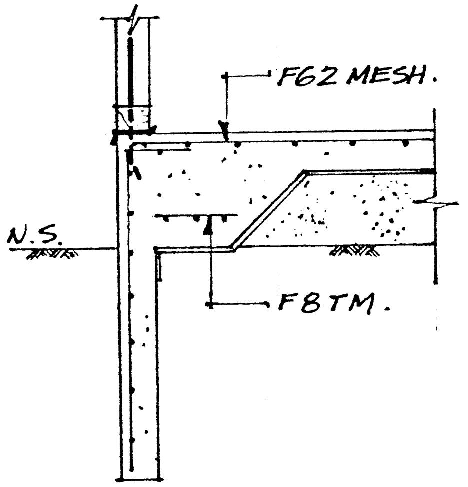


FIG. 2. SLAB-ON GROUND FOOTING.

The choice and design of a particular footing for a building is influenced by the following:-

(i) building type and design

(ii) the site conditions - sloping sites in particular require special attention

and (iii) the soil type

The ideal foundation is one of compacted sand, rock, or soil containing a high percentage of sand or silt and a small percentage of clay. Such soils are suitable for any foundation type. However, for soils which have a low bearing strength, or which exhibit gross moisture movement characteristics, a more selective choice of foundation type is required. Soils such as clay and fine silt, commonly referred to as plastic soils, have adequate bearing strength, but may be subject to considerable volume change with change in moisture content. The moisture content of the soil under a slab will vary seasonally, and from the perimeter to the cente, with consequent variations in the forces applied to various parts of the building (see figure 3).

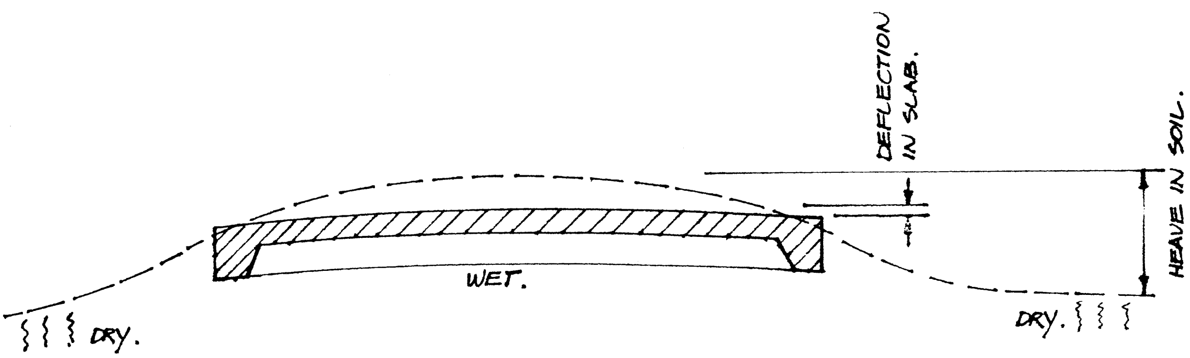


FIG. 3. SEASONAL VARIATION IN SOIL MOISTURE CONTENT.

These localised changes in moisture result in differential movements which may result in localised failures in the structure. The type of foundation which should be used in the various soil types can be related to the extent of the movement likely to be experienced.

The Domestic Construction Manual (Smith and Adams 1980) sets out recommendations regarding foundations which are suitable for various soil types. Should there be any doubt about the nature of the site, this publication provides very valuable information for the designer and builder.

Because of the very competitive nature of domestic construction, builders will not adopt a conservative design of their own accord, and will generally use the lightest design as allowed and accepted as common building practice. The reason is simple, the customer! Very few of our clients (less than 10%) would or could be prepared to pay for a more conservative design. They are only interested in the price, not the fact that one builder may have larger footings with more reinforcing. This is particularly so in the lower end of the market, and for project design homes. The customer generally selects his builder after shopping around for the best price. Builders can only keep prices to a minimum by using minimum designs, and this applies from the foundations to the roof.

Consequently, the Building Authorities must be careful to ensure the design is suitable for the site. An increasing number now insist on a certificate from a structural engineer regarding the suitability of the foundations before approval is granted. It is doubtful if some designs currently in use in the Townsville area would meet with the Engineer's requirements. For this reason, the supervision of footings in plastic soils is most critical, to ensure that construction follows the plan. The greatest single cause for concern is in the correct placing of reinforcement. Where reinforcement is required to be continuous, laps are required to transfer full loads from one length to the next. Laps should be as set out below:-

Round bars:	45 times diameter
Deformed bars:	23 times diameter
Mesh:	spacing of mesh bars + 25 mm.

Cover of reinforcement is also important, to avoid penetration of moisture, rusting of reinforcement, and spalling of concrete. The tieing and placing of reinforcement is another area where poor workmanship can result in failure. For suspended slabs and beams, the exact location of the reinforcement is important as a variation of location of only 15 mm. in such structures may result in a loss of strength of 40%, resulting in excessive deflections and cracking.

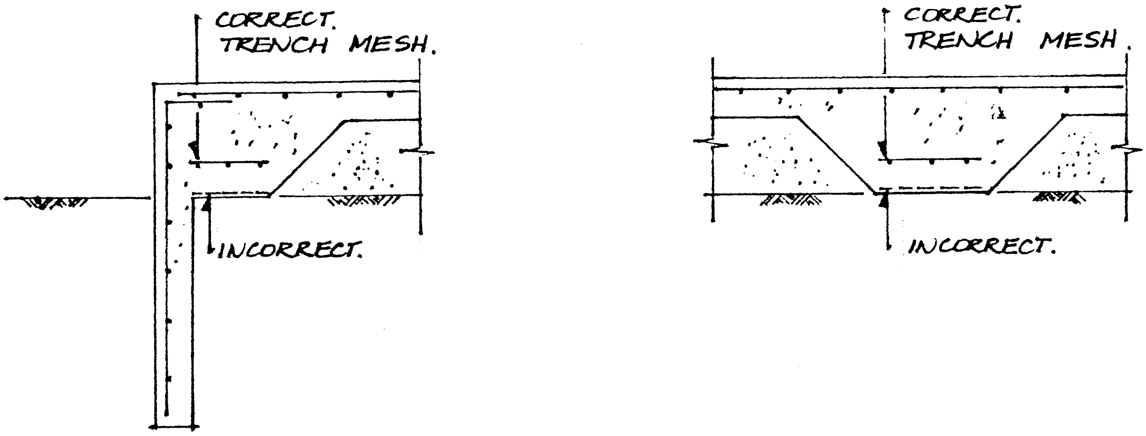


FIG. 4. CARELESS PLACING OF REINFORCEMENT.

The placing of services in slab-on-ground foundations requires care. It is not unusual to see plumbers placing water pipes and other service conduits across beams or slab thickenings, without any thought being given to the likely effect on the footing.

Compacting and placing of concrete should be done to avoid segregation and porosity. Compaction also assists the concrete strength and poorly compacted concrete will result in water penetration and rusting of reinforcement. Particular attention must be given to compacting concrete around the edges of slabs exposed to the weather.

3. CALCIUM SILICATE BRICKWORK

Lime-sand or calcium silicate bricks are now being used in place of the traditional clay bricks in a brick veneer or cavity brick situation and in place of concrete masonry blocks, both reinforced and unreinforced.

These bricks and blocks have tremendous customer appeal because of the range of light colours, surface finish, the elimination of the need for painting blocks, and for their competitive price. The 200 mm. block construction in particular has become popular recently, and it is with this method of construction that most problems occur.

The calcium silicate block has a bed area approximately 60% greater than a concrete masonry block, providing for a much greater bond area. The mortar mix used is critical with these blocks and it is important that the additive as recommended by the manufacturer be used strictly as directed. This additive prevents dehydration of the mortar mix. The mix should be as sloppy and sticky as practicable. As the bricks are laid dry, they tend to suck the water out of the mortar, thus preventing a proper cure. This causes the mortar to be soft and crumbly, and also causes the bond to break at the slightest movement in the foundations. The recommended mortar mix is 1 cement + 1 lime + 6 sand and the additive should be used at the rate of 225 grams per bag of cement.

External joints should be rolled or ironed and not raked. The raking of external joints tends to accelerate moisture loss from the mortar and cause strength loss due to improper curing. As the cores of these blocks are not large, it is not possible to fill them with concrete as for concrete masonry. The manufacturer recommends that the reinforced cores be filled with mortar as the blocks are being laid. When using these blocks, the bricklayer must take greater care that the blocks are laid strictly as per the manufacturers recommendation.

3.1 Wall Reinforcing

There are two recommended methods of providing wall reinforcing in calcium silicate blockwork. The first uses a RHS steel top plate, which is continuous all round the building (see figure 5).

Top plate joints should be welded on three sides and should be within 100 mm. of a bolt. Vertical reinforcing can be either joined with a rod connector or welded.

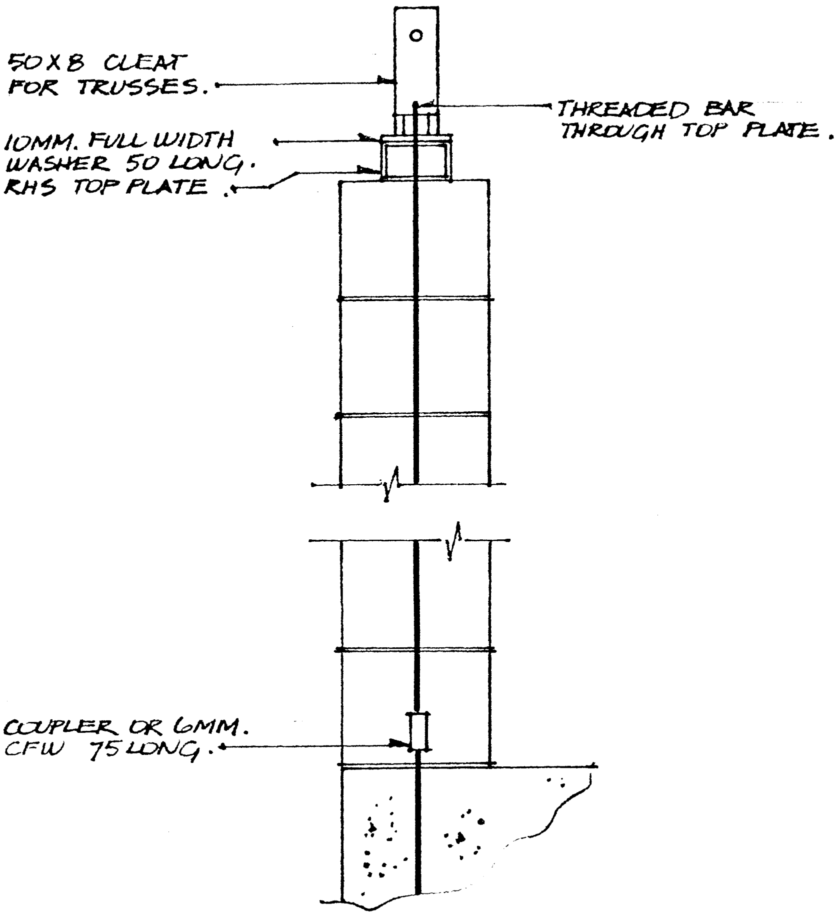


FIG. 5. STEEL TOP PLATE DETAIL.

Table 1 provides information on the vertical wall reinforcing and Table 2 lists top plate sizes.

TABLE 1

VERTICAL REINFORCEMENT

Terrain category	Wall height	Reinforcing required
1	2400	S16 @ 800
	2700	S16 @ 600
	3000	S16 @ 500
2	2400	S16 @ 1000
	2700	S16 @ 800
	3000	S16 @ 700
3	2400	S12 @ 1200
	2700	S12 @ 1000
	3000	S12 @ 800

TABLE 2

TOP PLATES

Terrain category	Max. bolt spacing	Top plates Grade 250 mild steel
1	800	102 x 76 c 3.6
2	1000	102 x 70 x 3.6
3	1200	76 x 51 x 3.2
		89 x 38 x 3.2

For terrain category 3, there is an alternative method to the steel top plate method. This method uses a bond beam block similar to that used in concrete masonry. As the cross sectional area is smaller than that of a concrete masonry block, this method is only suitable for terrain category 3 areas (see figure 6).

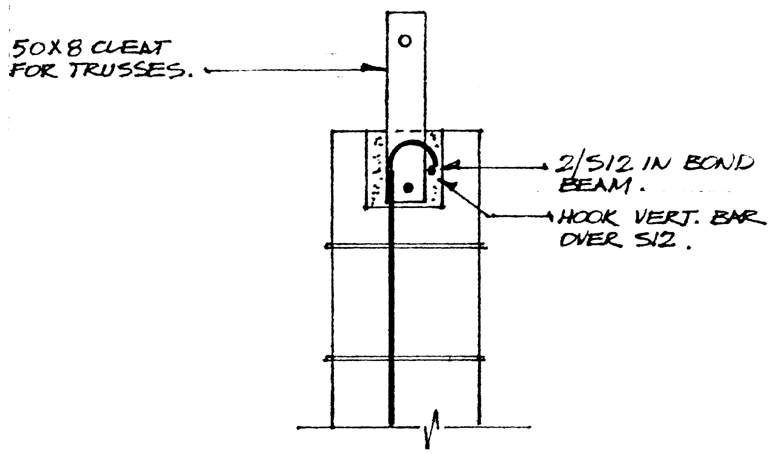


FIG. 6. BONDBEAM ALTERNATIVE TO TOP PLATE.

3.2 Lintels to Openings

The original method used to support lintels was to use two steel plates 50 mm x 10 mm with welded 12 mm bolts to every second core (see figure 7). In practice, this method proved unsatisfactory as it was not possible to stop excessive deflections and this caused the bond between brick and mortar to fail. In some cases, the resulting deflections caused windows to jam. In an endeavour to overcome this problem, some builders used timber window heads with infill panels (see figure 8).

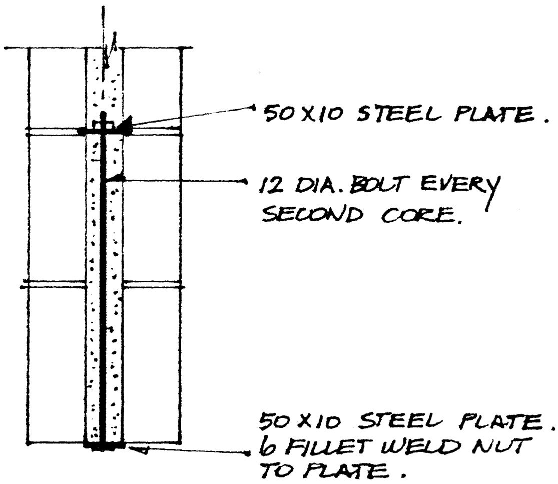


FIG. 7.

The manufacturer now recommends the use of a double steel angle lintel, and provides for this by manufacturing a block suitably grooved for the course immediately above window. (see figure 9).

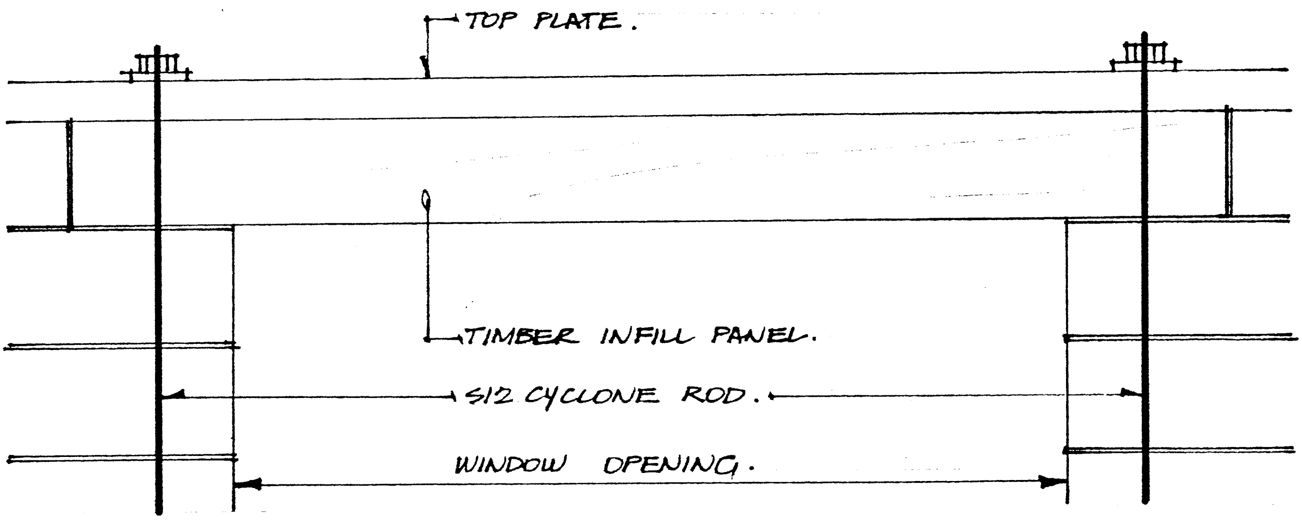


FIG. 8. TIMBER HEAD INFILL PANEL.

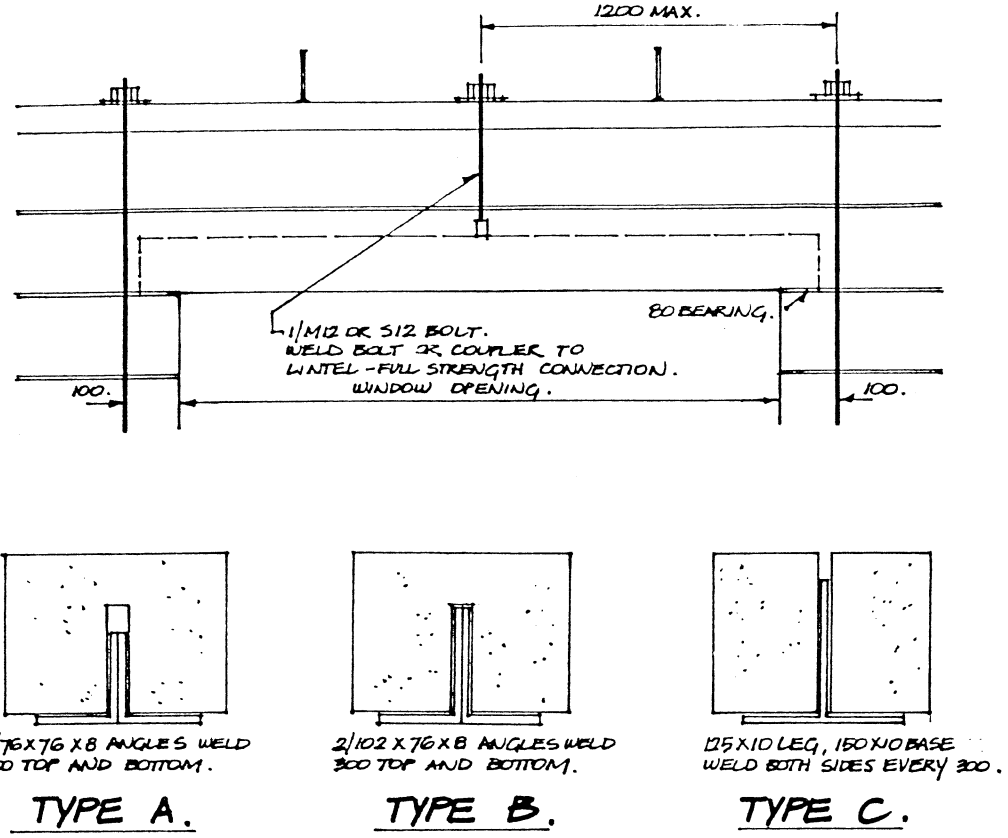


FIG. 9. WINDOW OPENINGS - LINTEL DETAILS.

For terrain category 3, type A consisting of 2/76 x 76 x 8 angles welded together is suitable for spans up to 2.0m for a tiled roof and 2.2m for sheet roofing. Type B is suitable for spans up to 2.6m for tiled roofs and 3.0m for sheet roofing and type C is suitable for spans up to 2.8m for tiled roofs and 3.2m for sheet roofing. The above figures are for a truss span not exceeding 10m. Since this method of lintel support has been adopted, the problem of cracking mortar joints and deflections over openings appears to have been cured.

4. CONCRETE MASONRY

The largest usage of masonry in cottage construction in the Townsville area is reinforced concrete masonry. The popularity of this method of construction over brick-veneer and timber framed construction is increasing rapidly. This is particularly so with the ever increasing number of owner-builders appearing in domestic construction.

The concrete masonry industry has responded by providing detailed structural information for builders and designers who use their product (Christie and Isaacs, 1976, 1977). This has caught some of the other building material manufacturers unaware, and has resulted in an even larger share of the cottage market going to concrete masonry.

With the 200 mm single leaf construction method, there are several areas which require particular care. These are:-

(i) the proper placement of reinforcing and filling of cores
(ii) water penetration at ground floor level, and
(iii) the tieing of intersecting walls, particularly bracing walls.

Generally the compressive strength of mortar for concrete masonry is not as important as bond strength. Bond strength has an important effect on the tensile and transverse strength of walls, and affects the integrity of a masonry wall under lateral loading. As for the calcium silicate blocks, bond depends to a marked degree on the balance between the initial rate of absorption of the block and the water retention properties of the mortar. Bed joint thickness also has a vital relationship to the strength of walls. Flexural tests on small walls (Anon.1964) have shown a marked reduction in strength as the joint thickness was increased from 6 mm to 18 mm. A close control on joint thickness to the standard 10 mm is therefore essential.

4.1 Reinforcement in Concrete Masonry

Assuming that the building has been designed correctly, there are certain areas which require care in the reinforcing of concrete masonry. Figure 10 shows a typical external reinforced concrete block wall.

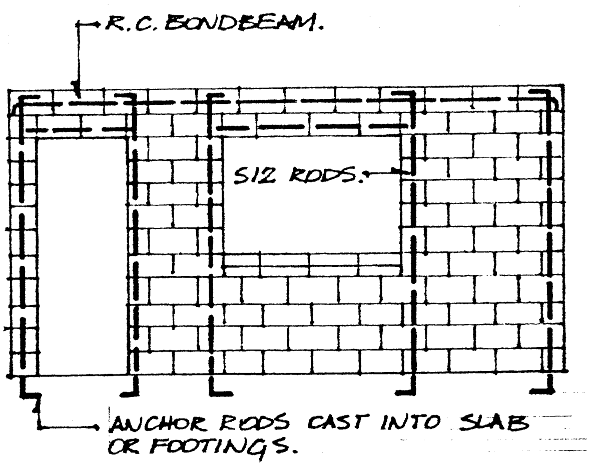


FIG. 10. EXTERNAL WALL REINFORCING.

When the first course above floor level is laid, a cleanout block should be used whenever there is a starter bar, this is generally not done in cottage work. Quite a considerable amount of mortar droppings accumulates at floor level and these should be removed to allow the concrete core fill to flow to slab level. An accumulation of mortar droppings will prevent this, causing a reduction in strength at floor level and the possible introduction of moisture which could cause corrosion of the reinforcing rod. Vertical cores should also have mortar protrusions cleaned out with a rod, to allow the core fill to flow to the bottom. These accumulations have to be removed. If you do not think it is necessary to clean out mortar droppings from cores, you have never taken the trouble to look down a core. Even with a concrete pump, voids and porous concrete will occur in cores which are supposed to be completely filled. Wetting down of the cores and bond beams with a hose before filling is advisable to allow the conrete to flow freely and avoid voids. It is important that the correct laps are used in bond beam and lintel reinforcement. This is particularly so at corners. Reinforcing rods should also be tied together at laps. It is also desirable to use lintel blocks under window openings more than 1500 mm wide. The various methods of fixing the roof framing to the bond beam block appear to be adequate.

The most favoured method is the use of a 30 mm x 6 mm plate with 16 mm hole top and bottom. This plate is then threaded over one of the reinforcing bars in the top lintel block (see figure 11).

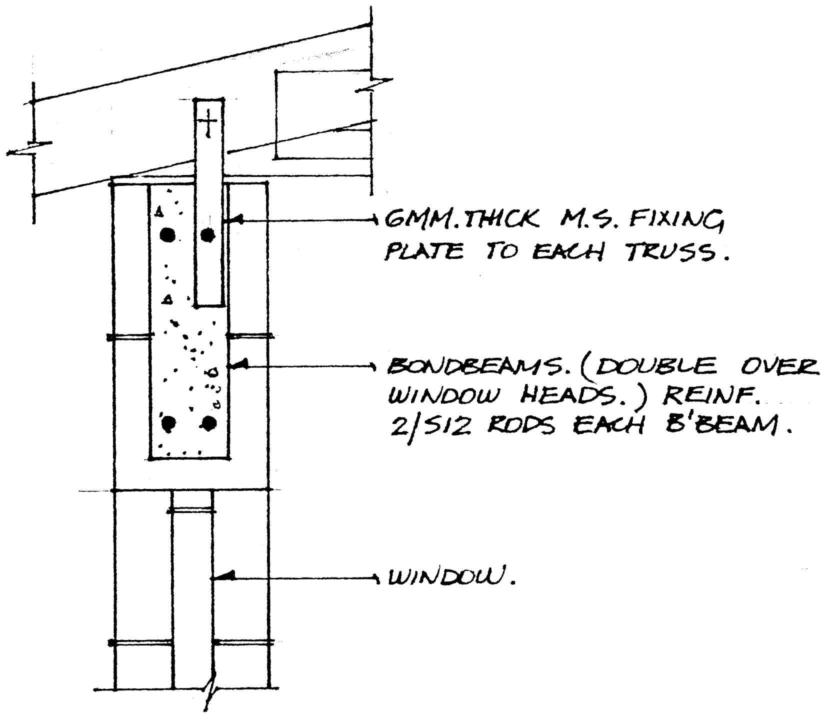


FIG. 11. TRUSS TO BONDBEAM CONNECTION.

With prefabricated roof trusses, the traditional timber top plate bolted to the lintel block is preferred as some truss manufacturers will not allow bolts through the heel of the truss.

4.2 Waterproofing at slab level

Whether the slab-on-ground method or strip footing method is used, the prevention of moisture penetration at ground slab level causes problems to builders. This is particularly so where poorly aligned formwork or careless laying of the first course causes the slab to protrude past the bottom edge of the block.

Mechanical trowel machines tend to cause a peak at the edge of the ground floor slab, causing a slight fall from outside to inside as indicated in figure 12 (a).

Current building practice favours the deletion of damp course in single leaf construction. If this is done, it is advisable to provide some fall to the outer edge of the slab, under the masonry wall (see figure 12b).

This will assist in preventing outer edge fall moisture entering from the outside, but may not prevent moisture which enters the hollow cores through minute fractures of the mortar bond, and then falls to the slab, from entering at floor slab level.

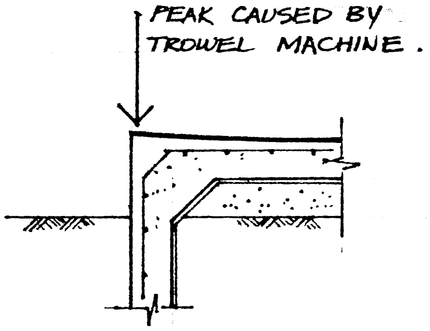


FIG. 12 (a).

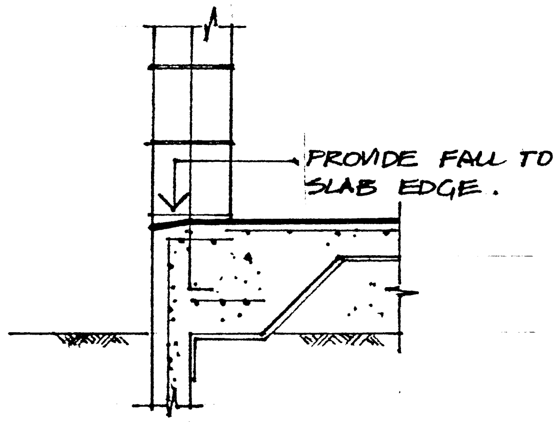


FIG. 12 (b). FALL TO EDGE.

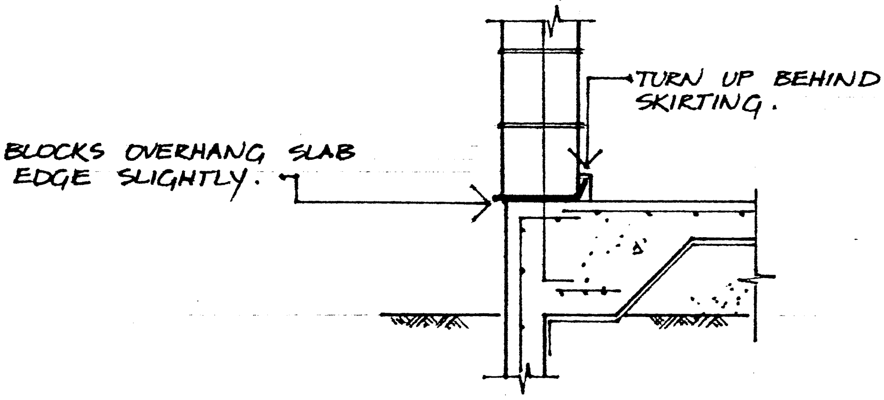


FIG. 13. USE OF DAMPCOURSE.

Where damp course has been specified, the use of bituminous coated aluminium core dampcourse could help to overcome this problem, provided it is turned up behind the skirting board (figure 13). Even if a fall at the edge of the slab or dampcourse has been provided, in high rainfall areas, or if the slab edge is subjected to constant wetting from sprinklers, moisture will enter due to capilliary action through the slab edge and up under the external wall, causing damage to floor coverings. The slab edge should be treated with a waterproof render or a silicone water repellent or good quality paint. This problem generally does not occur in the Townsville area, but is common in other areas of the North. The only really effective method of preventing moisture entering at floor slab level is to provide a recess 200 mm wide and 100 mm deep under the external walls (see figure 14).

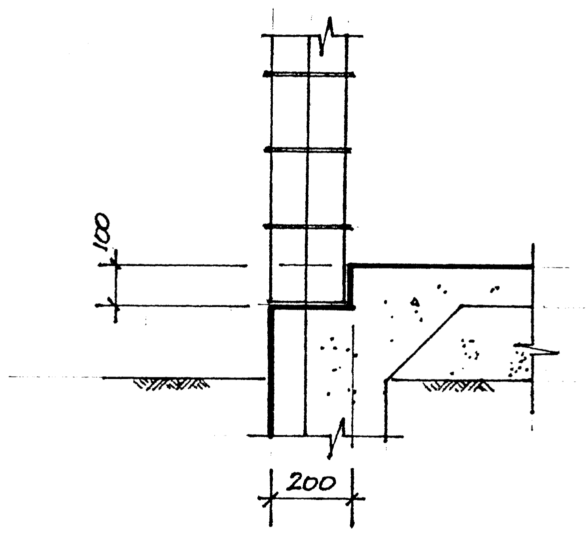


FIG. 14. SLAB RECESS.

4.3 Tieing of Intersecting Walls

With masonry internal walls, it is not possible to provide a bond to all intersecting walls. Where 200 mm walls intersect, the use of 19 mm x 4 mm steel straps is recommended. These straps are Z shaped as in figure 15, and are used at each alternate course. The cores into which the straps protrude should then be concrete filled.

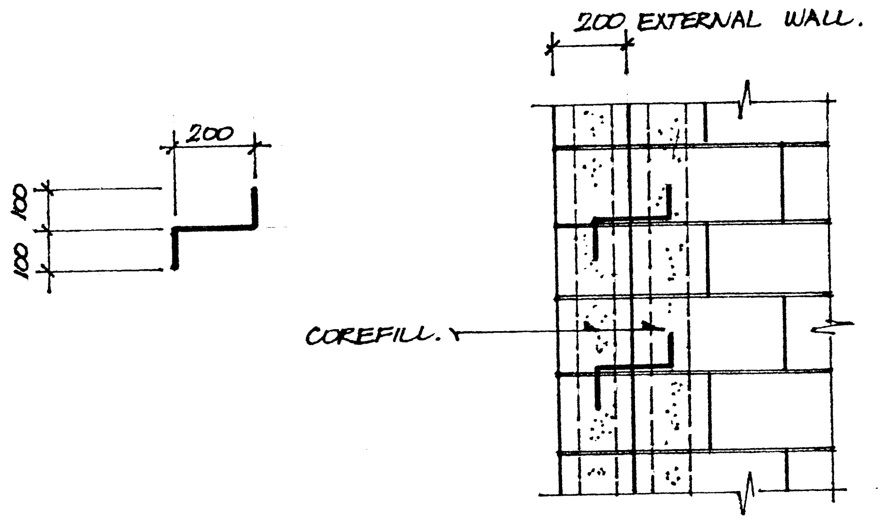


FIG. 15. TIEING INTERSECTING 200 MM. WALLS.

For 100 mm masonry, the use of wall ties to each alternate course should be used.

Now that dwellings are being designed to resist racking, and shear walls are provided to certain locations along an external wall, the correct tieing of masonry walls is most important. If there is any uncertainty in the mind of the builder or designer, the Domestic Construction Manual should be consulted.

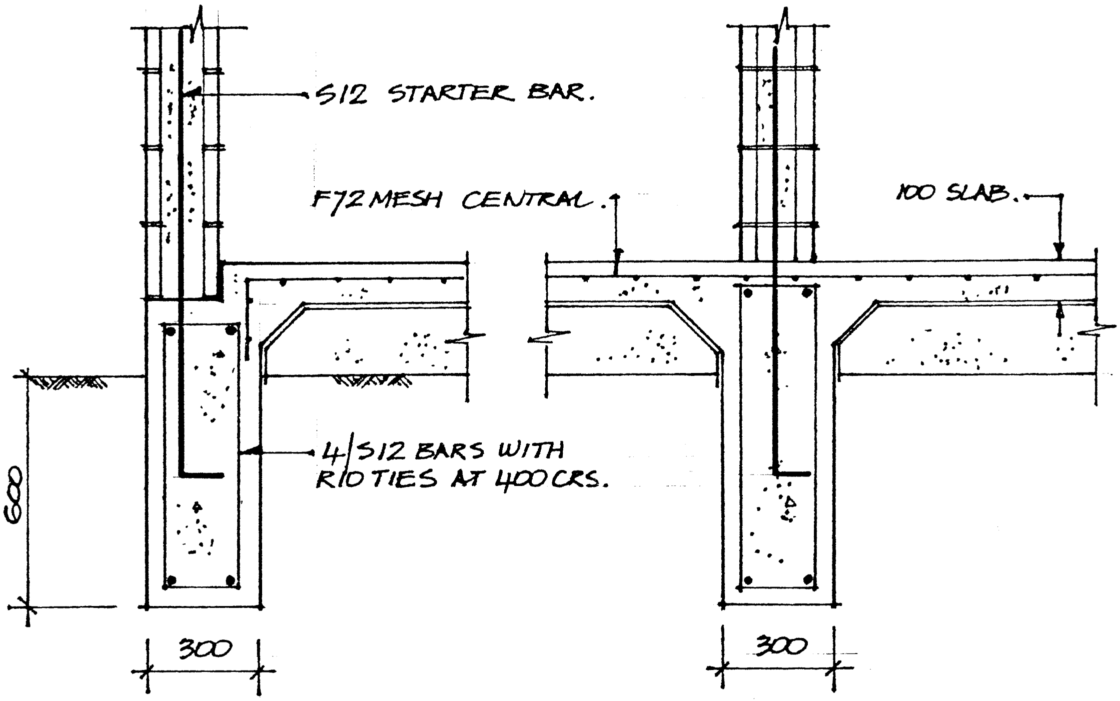
5. NEW TRENDS IN CONCRETE MASONRY

The Queensland Housing Commission is currently supervising the construction of a group of homes in Townsville and Cairns for the D.A.I.A. These homes are of single leaf masonry construction on slab-on-ground foundations. This venture into masonry construction is only a recent development for the Queensland Housing Commission. Some of the recommended practices previously mentioned are being carried out in this project. As some of them add quite consdierably to the cost of a dwelling, it is little wonder that they are being pioneered by a Government Department, whose budget extends further than that of the private individual.

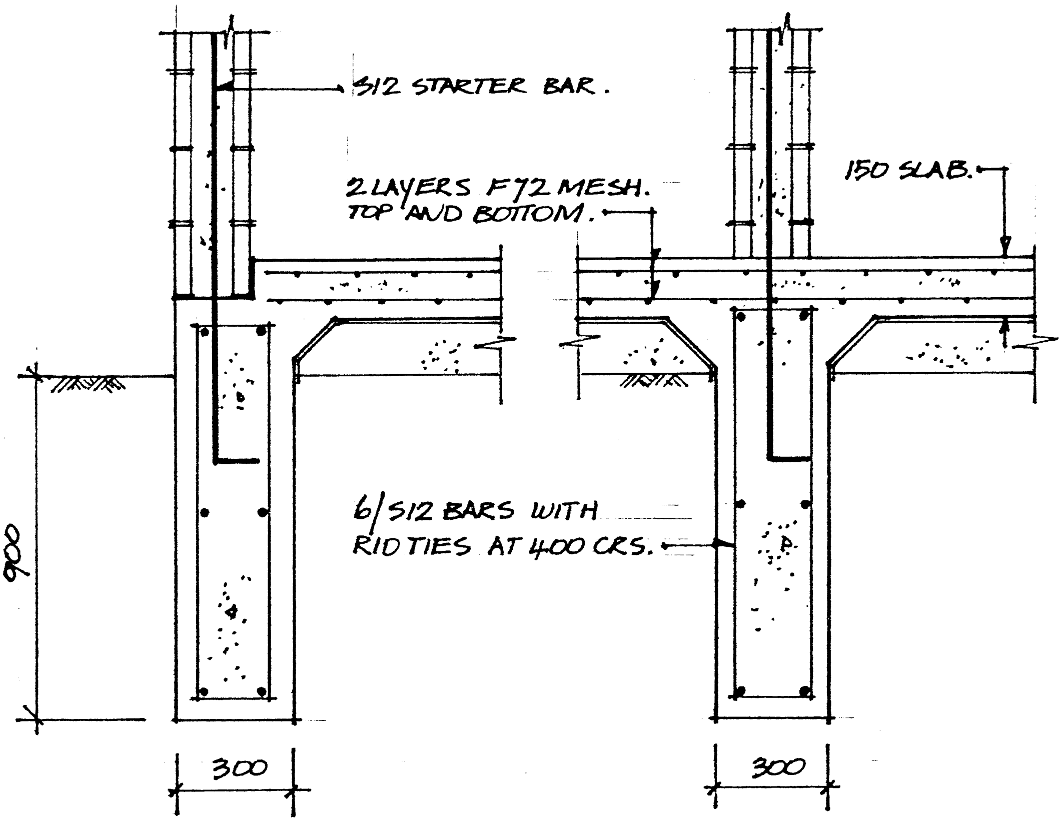
5.1 The Foundations

The soil type of the sites range from low and medium plasticity to high plasticity, and the foundations have been designed accordingly. Instead of the normal sand or cracker dust fill used under floor slabs, these houses, with slab-on-ground foundations, have a sub-grade which is compacted to 100% standard compaction. To achieve this kind of compaction, a select fill material having a moisture content of 15% should be rolled with a vibrator roller. Fifty millimetres of sand is then spread over the compacted sub-grade before the slab is poured. Edge beams to the slab perimeter are used. For the low plasticity soils, this beam is 825 mm x 300 mm reinforced with 4/S12 bars and R10 ties at 400 crs. (see figure 16). For the high plasticity soils, the edge beam is 1125 mm x 300 mm with 6/S12 rods and R10 ties at 400 crs. The low plasticity floor slab is 100 mm thick reinforced with F72 mesh. For the high plasticity floor, the design shows a 150 mm slab reinforced with two layers of F72 mesh.

As an illustration of the amount of concrete used with this method of construction, the average $90m^2$ slab-on-ground footing as presently constructed uses $18m^3$ of concrete. For the low plasticity soil design, for the same size $90m^2$ home, $28m^3$ of concrete is used on the slab. For the high plasticity design, which has a 150 mm slab, $41m^3$ of concrete is required.



LOW TO MEDIUM PLASTICITY SITE.



HIGH PLASTICITY SITE.

FIG. 16.

5.2 The Blockwork

The masonry external walls have been laid in a recess set down 100 mm to the slab perimeter (see figure 16). Clean out blocks are used at all starter bars, both internally and externally. All external walls and 200 mm nominal internal walls have vertical reinforcement from slab beams to lintel beams at both sides of all openings, and at a maximum of 1200 mm spacings. Two courses of lintels/bond beams are provided continuously around the top of all external walls and 200mm internal walls. Both courses have 2/S12 rods at the bottom. To all window openings greater than 1500 mm wide, a 200 mm nominal bond beam with 2/S12 bars is used to the course immediately below the sills.

6. CONCLUSIONS

Generally in the cottage industry, not enough attention is paid to the design of foundations to suit the soil type. This is particularly so for medium to high plasticity soils. It is recommended that builders have their standard designs checked by a Structural Engineer. Professional advice should also be sought where it is suspected that the soil type is plastic.

With calcium silicate blockwork, the use of the recommended mortar mix is vital. Joints should be ironed and not raked, and blocks laid dry. Use of a steel top plate is advisable, with the correct vertical reinforcing as recommended by the manufacturer. All external walls should be silicone treated on completion.

To construct the average $100m^2$ concrete masonry home to the requirement of the Queensland Housing Commission, as discussed above, would add in excess of $4,000 to the price of the home at November 1980 prices. The designs used are ultra conservative and it is doubtful whether the average home buyer could afford this extra burden to the cost of his home. There are, however, several features which can and should be adopted in the cottage industry for single leaf masonry construction.

These features are:-

(i) the use of a recess at the outer edge of the floor slab
(ii) the use of clean out blocks to all vertically reinforced cores
and (ii) the provision of a bond beam to the course below the sill to all window openings greater than 1500 mm.

Although the inclusion of these recommendations would add approximately \$500 to \$600 to the price of the average 100 square metre masonry home, they could save many times this amount at a later date.

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