Concrete Society Technical Report No. 6

Standard reinforced concrete details

Report of a Concrete Society Working Party

The Concrete Society

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Constitution of the Working Party on Standard reinforced concrete details

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Foreword

Introduction

During the last decade there have been many proposals for standardization. Standard bar schedules, and a standard method of presenting calculations, have been discussed and adopted.

This development has been encouraged by the changing circumstances of working life: the shortage of experienced staff, ever-increasing salaries, the complexity of many designs, metrication and, not least, the advent of computers. The production of standards of various kinds has often exposed areas where so-called experience has in the past provided a solution to a technical problem or detail. On close examination, the 'solution' can often be seen to be an excuse for lack of thought, or lack of application of existing knowledge. If these misty areas can be illuminated and the fog cleared away, then designers may concentrate their attention on the areas where true judgement is required.

Objectives

Detailing is the process by which the intentions of the designer can be conveyed to the contractor. Reinforced concrete details are prepared for the steel fixer, who needs to be able, correctly and quickly, to identify and fix the steel.

The *Standard method of detailing reinforced concrete*[1] recommends methods of detailing. It describes the manner in which bars should be written up and the drawing layouts and drawing techniques that are appropriate. It only touches lightly on the details themselves.

If standard details are to be adopted, some thought must be given to the reasons for adopting particular details and to the likely benefits. Traditionally, designers tend to work to minimum quantities of materials. Is this always correct? How do we cost the saving in time which results from simple design? Simplification usually reduces the possibility of error. How can this be costed? Is it desirable for a designer to simplify his own work if the contractor's task is thereby rendered more difficult? These are only some of the questions that arise.

Working Party proposals

After an introductory chapter on the selection and specification of reinforcement, this booklet gives the Working Party's recommendations for five frequently occurring details:

(1) Shear reinforcement
(2) Column splices
(3) Beam-column intersection
(4) Wall details
(5) Holes in slabs

The reasons for suggesting particular solutions are discussed briefly and illustrations are given of the arrangements of bars in typical details.

The proposed details were put forward in a preliminary report by the Working Party to the members of The Concrete Society, which was announced in the September and October 1971 issues of *Concrete* and discussed in detail at the Society's Fourth Annual Convention at Bristol in September 1971. The Working Party met on three occasions to consider all comments on the preliminary report. The present document incorporates most of the suggestions that were received and is put forward as a report which is acceptable to members of the Society.

The recommendations have been arrived at with the requirements of both the old (CP 114[2]) and the new (CP 110[3]) Codes of Practice in mind. Specific requirements of the new Code are indicated by a vertical black line at the left-hand margin.

R. D. Anchor
Chairman

Selection and specification of reinforcement

Type of bar

The cost of steel reinforcement is about one-third or one-quarter of the total cost of normal reinforced concrete construction. The choice of the particular type and grade of steel to be used therefore has important economic consequences.

Bars are available in two fundamental grades:

(a) Mild steel to BS 4449
(b) High-yield steel to BS 4449 (Hot-rolled bars)
or BS 4461 (Cold-worked bars)

The percentage difference between the total cost per tonne of mild steel and that of high-yield steel has been reduced considerably over the last 10 years as successive price rises have increased the price of both products almost equally. The average cost of mild steel (including cutting, bending and fixing in position) is currently (at the end of 1972) about £115/tonne. The equivalent cost of high-yield steel is £118/tonne.

It is apparent that, where there is a stress advantage of at least 3%, high-yield steel is more economical. In almost all structural work this will be the case. The exception, according to the specified stresses in the current codes of practice, is for water-retaining structures but, if the saving in bond lengths due to the use of high-bond bars is credited, high-yield high-bond bars must be at least as economical as mild steel even under CP 114. Mild steel is clearly obsolescent as a general reinforcing material.

Two types of high-yield steel are available:

(a) Hot-rolled bars with a ribbed surface, to BS 4449
The specified characteristic yield stress is 410 N/mm^2.
(b) Cold-worked bars to BS 4461, either with a ribbed surface or in the form of a twisted square
The specified characteristic proof stress is:
Up to and including size 16 460 N/mm^2
Over size 16 425 N/mm^2

For designs to CP 114, where the maximum permissible tensile stress is limited to 230 N/mm^2 and where bars are classified for bond into two types, there is no difference in use between hot-rolled and cold-worked high-yield bars. The choice can therefore be left to the contractor, who can obtain the most advantageous quotation in relation to his requirements. For designs to CP 110, the designer will generally be able to take advantage of the actual specified characteristic strength for each type of steel. He has to decide according to the likely supply position at the time of construction whether to use bars with a slightly higher characteristic stress, or to restrict the design stress so that either type of steel may be used. He must further consider whether to use type 1 or type 2 bars (as defined in CP 110). For the majority of structural designs, there will be little saving in weight of steel to be obtained by using type 2 bars. In circumstances where anchorage bond stresses are very high, or where there is more than the usual number of fully stressed laps, type 2 bars with their improved bond properties will show some saving in steel weight.

Very-high-strength bars

Several types of bar reinforcement are now available which are not included in any British Standard Specification but are generally sold in accordance with the provisions of an Agrément Certificate. The economics of these bars should be considered for the particular application.

Size of bar

For a given cross-sectional area of steel, a small number of large bars will generally be cheaper than a large number of small bars. Typical prices (£/tonne at the end of 1972) for high-yield steel are:

	6 mm dia.	32 mm dia.
Steel	110	70
Fixing	70	15
Total	180	85

The prices of other sizes lie between these extremes.

On the other hand, the use of small sizes allows a closer approximation to the required steel area. Moreover, where bars over 25 mm dia. are used, the concrete cover may have to be increased. Anchorage bond considerations may force the designer to use the smaller sizes.

Bars for slabs will normally be chosen from sizes 10 to 16. Bars for beams and columns will normally be chosen from sizes 12 to 32. For stirrups in a beam, one size of bar should be chosen and the pitch varied as necessary.

Bar detailing and scheduling

Bars should be straight wherever possible. It is not normally necessary to use hooks on high-bond bars. Where bars are bent, the 'preferred shape. or 'other shape' given in BS 4466 should be used.

Bars should be written up as described in *Standard method of detailing reinforced concrete*. Bar schedules should be prepared in accordance with BS 4466. The preferred form of schedule, without bar shape diagrams, should be used. Pads of this standard form of bar schedule have been issued by the Society as publication 53.026.

The standard abbreviations for bar types must be used:

R Round mild-steel bars (BS 4449)
Y High-yield bars having a high bond strength (BS 4449 and BS 4461)
X Any other type, to be specified

Fabric reinforcement

Welded fabric reinforcement is a factory-made sheet material suitable for reinforcing slabs and walls. Bent fabric also may be used for supporting dowel-bars and other reinforcement, and for replacing stirrups and links in beams and columns. The use of fabric reinforcement may result in:

(a) a reduction in the site labour cost of receiving, sorting, hoisting and fixing—the number of separate items to be handled is very much reduced;
(b) a reduction in detailing and scheduling costs.

Standard meshes

Standard types of fabric are listed in BS 4483, and are available in sheets of the standard size 4·8 x 2·4 m, and also in sheets of other sizes within manufacturing and transport limits. Fabric may be obtained with plain wires, indented wires, ribbed bars or square twisted bars.

Where the anticipated shrinkage or other stresses are approximately equal in each direction, as in ground slabs and structural toppings, square-mesh fabric is more suitable than long-mesh fabric. Long-mesh fabric is used in roads and strip footings.

Structural mesh fabrics may be used in suspended slabs where the minimum quantity of steel as specified by the Code of Practice is required.

Non-standard meshes

Special meshes may be manufactured in accordance with the designer's requirements, but enough of one type and size must be specified to enable the manufacturers to quote an attractive price. Mesh sizes of 100, 200 and 400 mm are preferred, but sheets of special fabric may have varying spacings of wire or gaps in the sheet. The wire and bar sizes preferred for use in fabric reinforcement are 6, 8, 10, 12 and, for bars only, 16, 20, 25.

Scheduling fabrics

Standard fabrics should be scheduled as described in Section 16 of *Standard method of detailing reinforced concrete*. Non-standard fabrics and non-rectangular sheets should be scheduled with a sketch to show the necessary dimensions, with sizes and spacings.

Shear reinforcement

Shape of stirrups

Stirrups should be chosen from the standard shapes given in BS 4466, "Bending dimensions and scheduling of bars for the reinforcement of concrete". All dimensions should be internal unless clearly indicated otherwise on the drawings.

The minimum internal radius (*r*) of bend should be two diameters for mild steel and three diameters for high-yield steel. The stirrup should be continued for at least eight diameters beyond the end of a 90° curve or four diameters beyond the end of the curved section of a hook.

Shape Codes 60, 73 and 81 (Figures 1 to 3) are commonly used but Shape Code 73 is particularly useful because it allows the main reinforcement to be fixed easily. This type of stirrup should have a size not less than 10 mm and cannot be used in narrow sections where there would be insufficient space between the bar ends.

The effect of the radius of bend should be considered when positioning the longitudinal bars since the bar tends to be fixed inwards, as shown in Figure 4. This displacement can cause difficulties in very narrow sections.

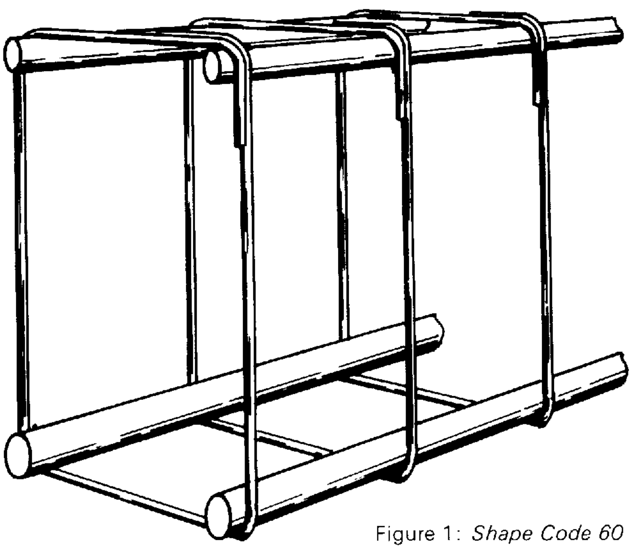


Figure 1: *Shape Code 60*

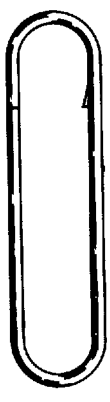


Figure 2: *Shape Code 81*

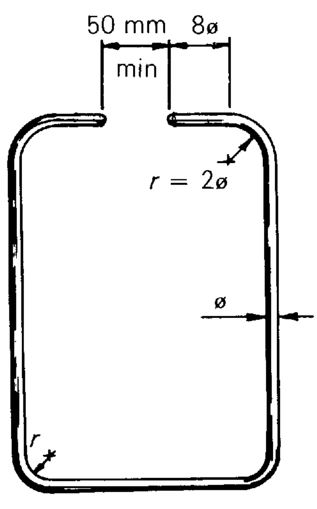


Figure 3: *Shape Code 73*

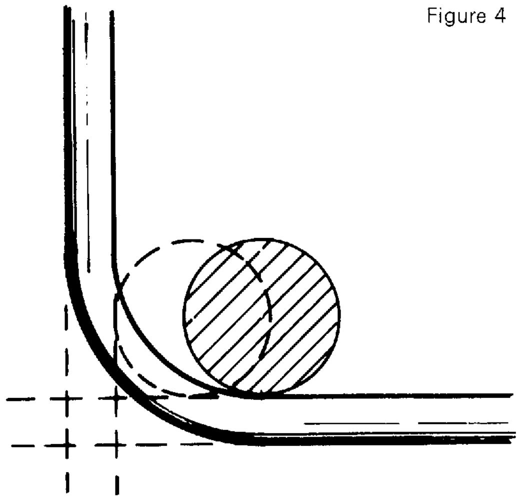


Figure 4

Size and type of bar for stirrups

Bars of 6, 8, 10 or 12 mm are normally specified for stirrups. Larger bars are more difficult to bend accurately, particularly if the dimensions are small.

Where only a nominal arrangement of stirrups is required from structural design considerations, it is often advisable to provide additional face bars and ties in order to prevent buckling of the stirrups under the construction loads (Figure 5). In beams more than 1 m deep, stirrups made from bar sizes below 12 mm are particularly susceptible to buckling. On the other hand, sizes over 16 mm should only be used in exceptional

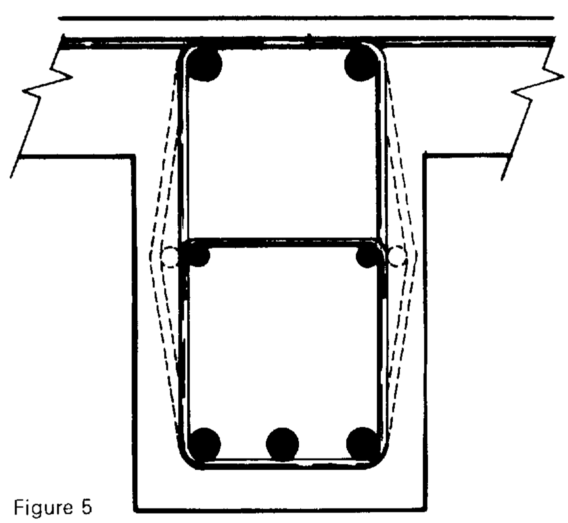


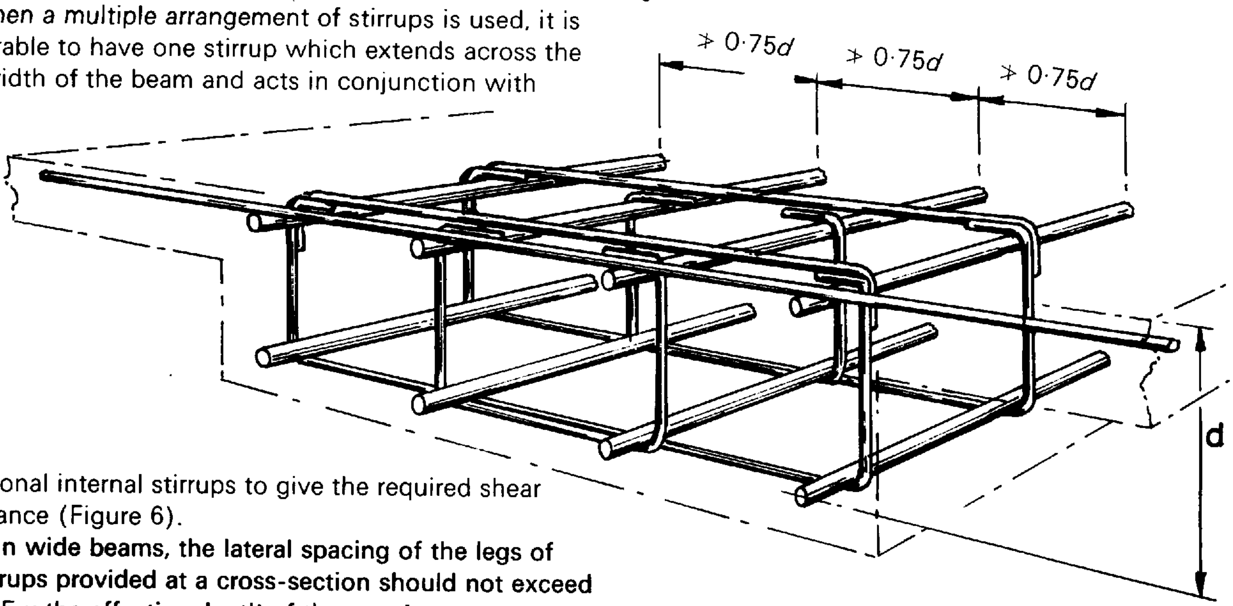
Figure 5

circumstances such as deep beams with heavy top steel.

With the exception of nominal arrangements of stirrups, it is more economical to use high-yield steel than mild steel for stirrups, owing to the substantial stress advantage and the low cost differential.

When a multiple arrangement of stirrups is used, it is preferable to have one stirrup which extends across the full width of the beam and acts in conjunction with additional internal stirrups to give the required shear resistance (Figure 6).

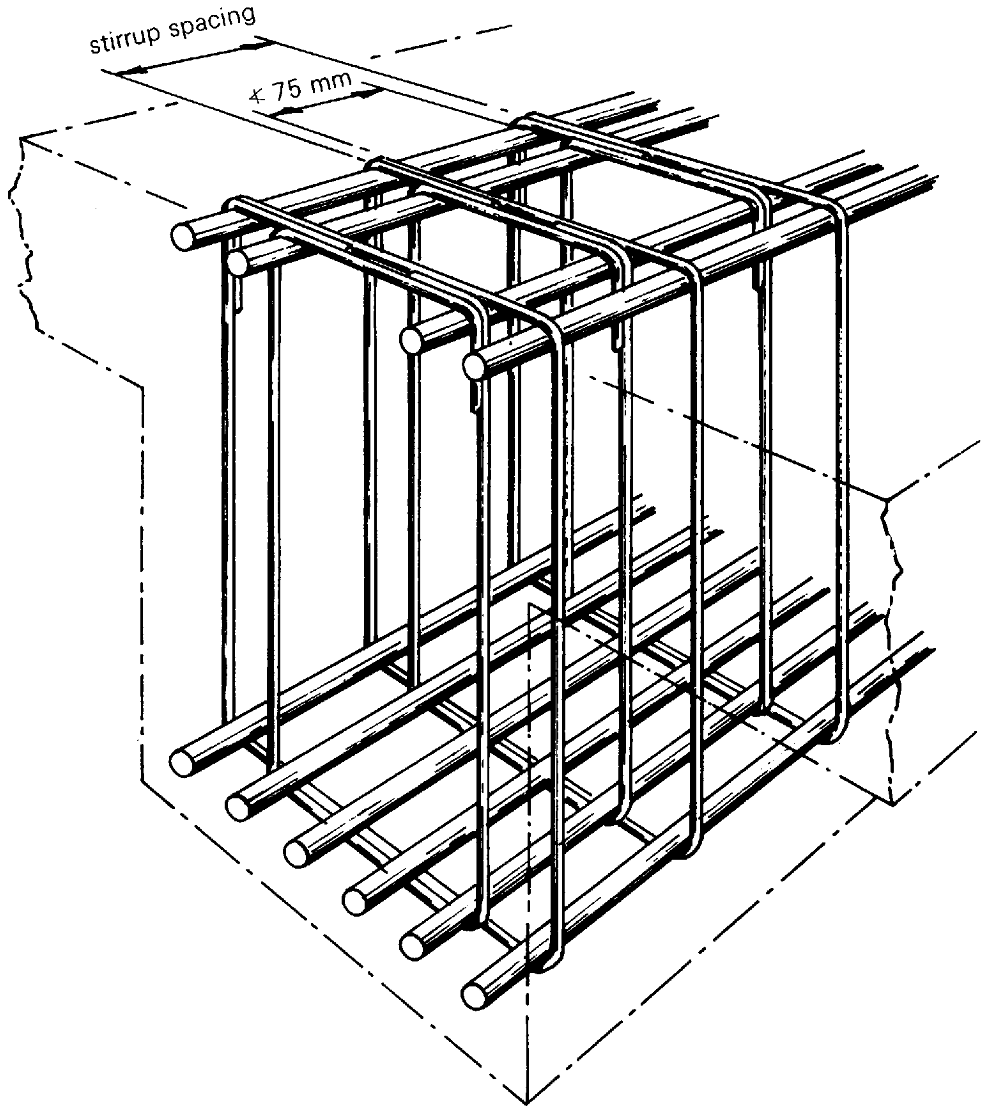
Figure 6



In wide beams, the lateral spacing of the legs of stirrups provided at a cross-section should not exceed 0·75 x the effective depth of the member.

The minimum clear space between stirrups should be 75 mm, to enable a vibrator to be inserted (Figure 7). The arrangement of any internal stirrup legs should also allow the concrete to be placed and compacted without difficulty.

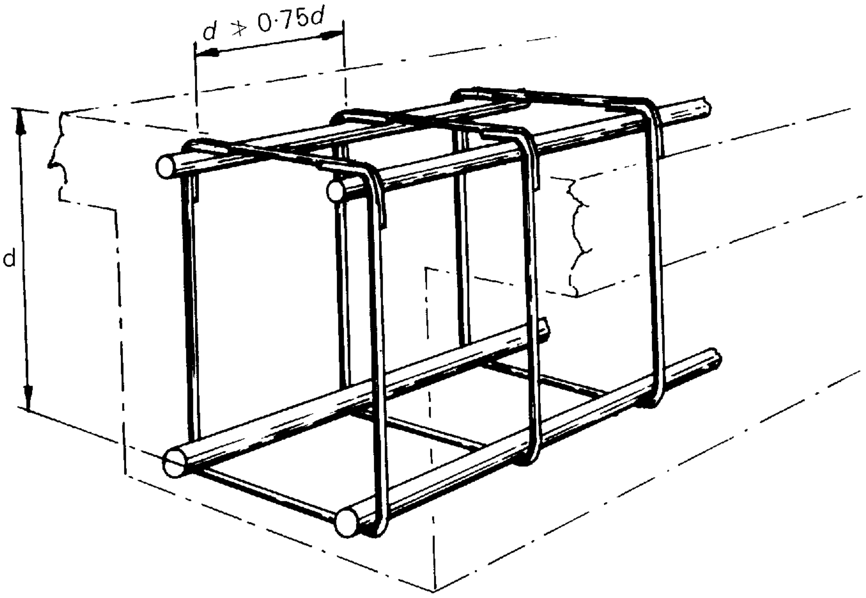
Figure 7



Arrangement of stirrups

In lightly loaded beams where the shear stress is less than the permissible stress in the concrete, the spacing of the stirrups should not exceed 0·75 x the effective depth of the member and the stirrups themselves should have a cross-sectional area complying with Code requirements (Figure 8). Stirrups should enclose all tension reinforcement.

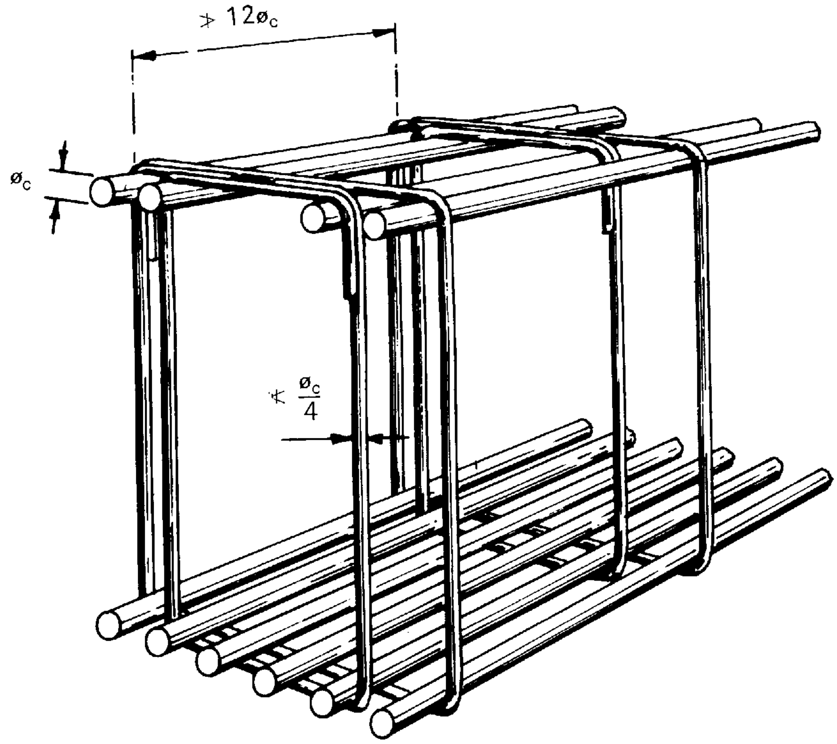
Figure 8



In more heavily loaded beams where compression reinforcement is required, the stirrups should be at least one-quarter the size of the largest compression bar and should be provided at a maximum spacing of twelve times the size of the smallest compression bar (Figure 9).

The arrangement of stirrups should not be changed abruptly and the transition from a design to a nominal spacing should occur over a beam length of two or three times the effective depth of the member.

Figure 9



Bent-up bars

Bent-up bars are normally used to carry heavy shear forces. The resistance to shear of a beam reinforced with bent-up bars is based on the assumption that the inclined bars form the tension members and the concrete the compression members of a lattice girder system. The inclination of the bent-up bars should be between 30° and 60° but the local bearing stress inside the bend in the bar may be the limiting condition (Figure 10).

By choosing a suitable arrangement of stirrups and bent-up bars, it is possible to avoid congestion of reinforcement. Bent-up bars are most effective in deep beams with low span/depth ratios where the straight inclined portions of the bars extend over a considerable length of beam.

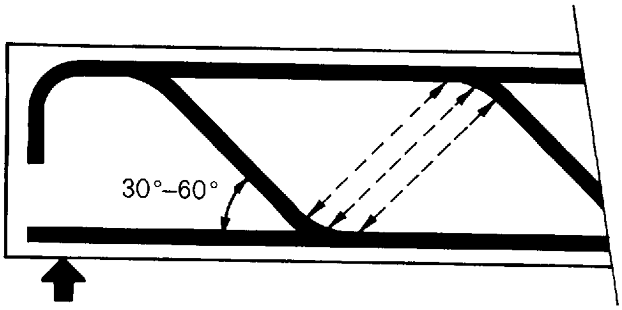


Figure 10

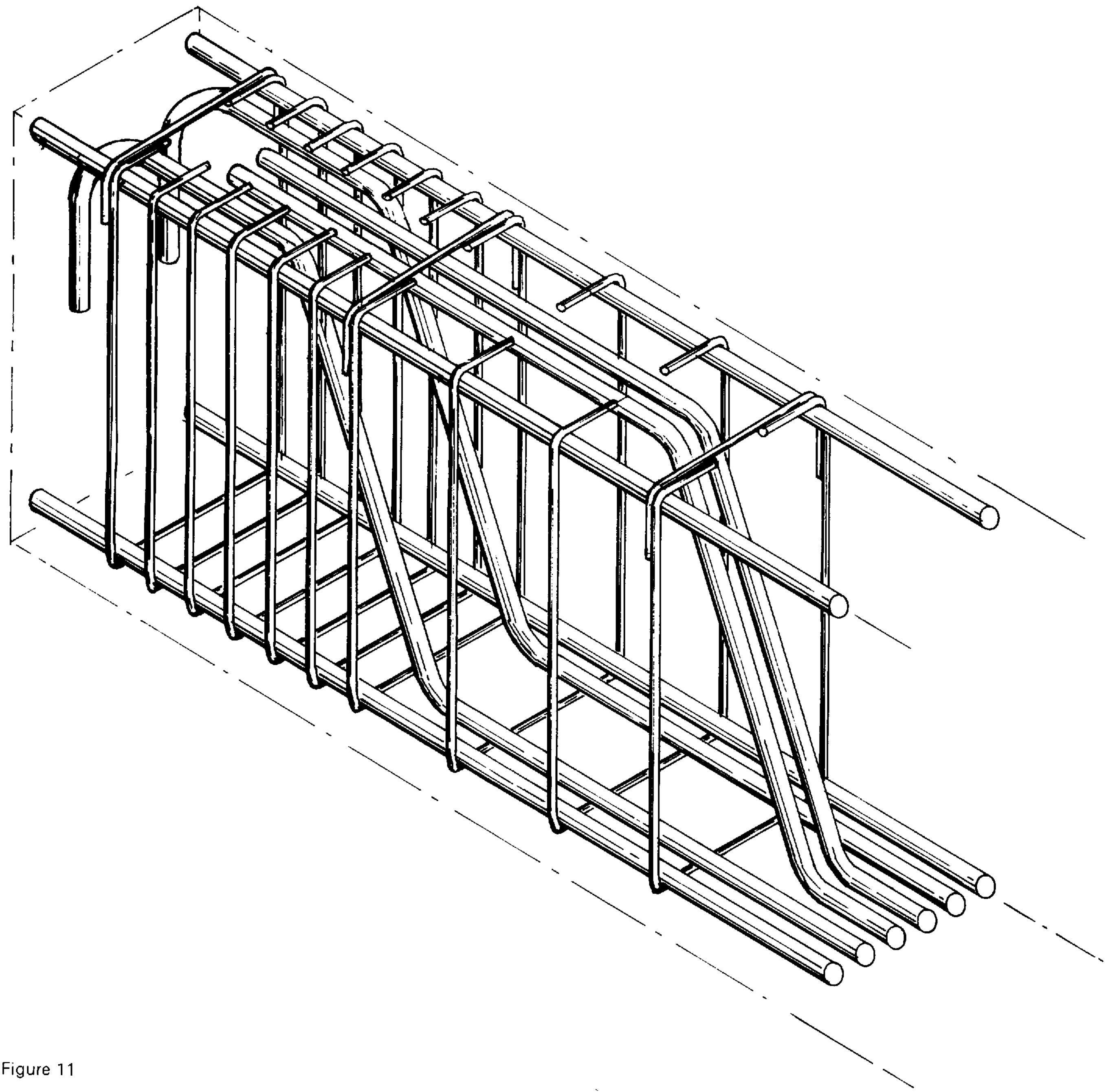


Figure 11

Column splices

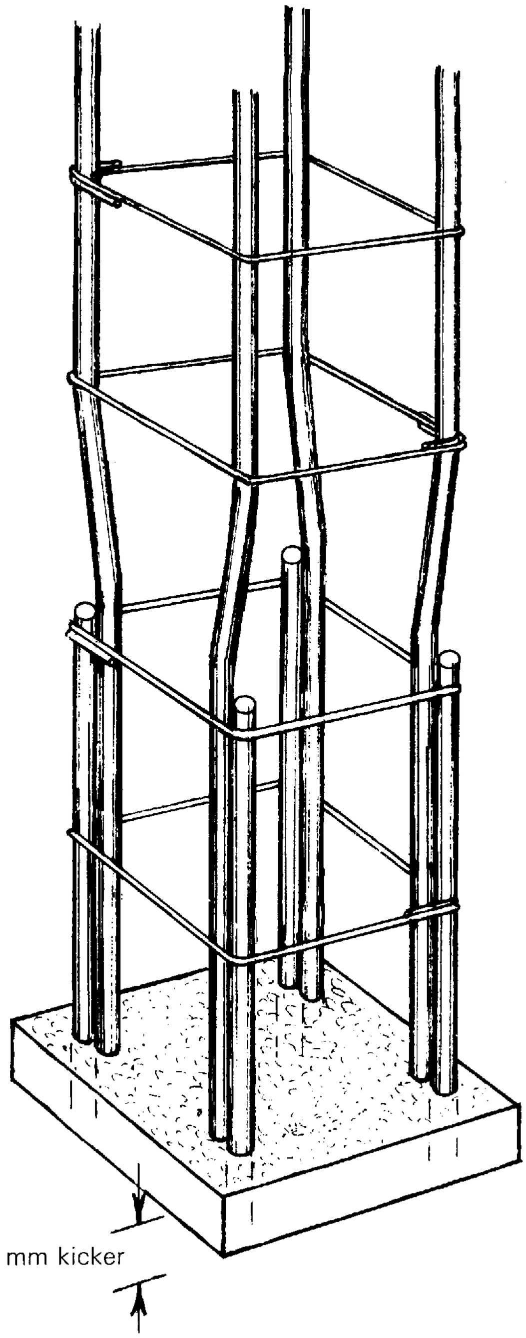


Figure 12

Positioning of splice

Continuity of column reinforcement can be achieved by extending the lower bars and cranking the upper bars to form a lap (Figure 12). In this way, the reinforcement is in the best position to withstand any bending stresses at the ends of the column.

Positioning of bars

The amount of reinforcement at laps must not exceed 10% of the cross-sectional area of the column, but even this amount may cause practical problems. The cranked bars can be placed in two planes relative to the lower column reinforcement (Figure 13). In this way, it is possible to simplify the assembly of the reinforcement cage and to provide maximum structural stiffness about the minor axis and facilitate the concreting operation in the case of small columns. A minimum 10 mm tolerance between the reinforcement cages should be provided at a splice.

All bars or groups of bars in a column should be within 150 mm of a restrained bar (Figure 14).

The over-all dimension of a ribbed or square twisted bar can be taken as 1·1 x nominal bar size.

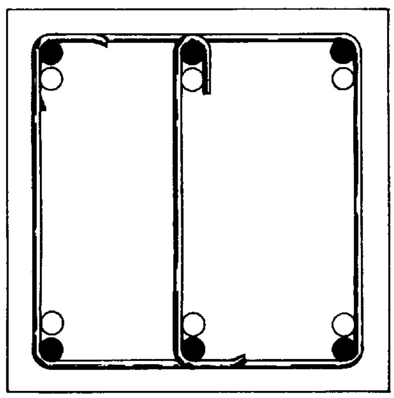


Figure 13

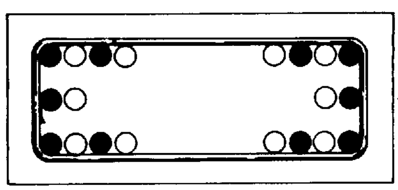


Figure 14

Arrangement of links

An adequate link must be provided at the upper offset point in the cranked bar in order to resist the horizontal component of the force in the inclined portion of the bar. A similar link at the lower offset point will resist any bursting stresses due to bending.

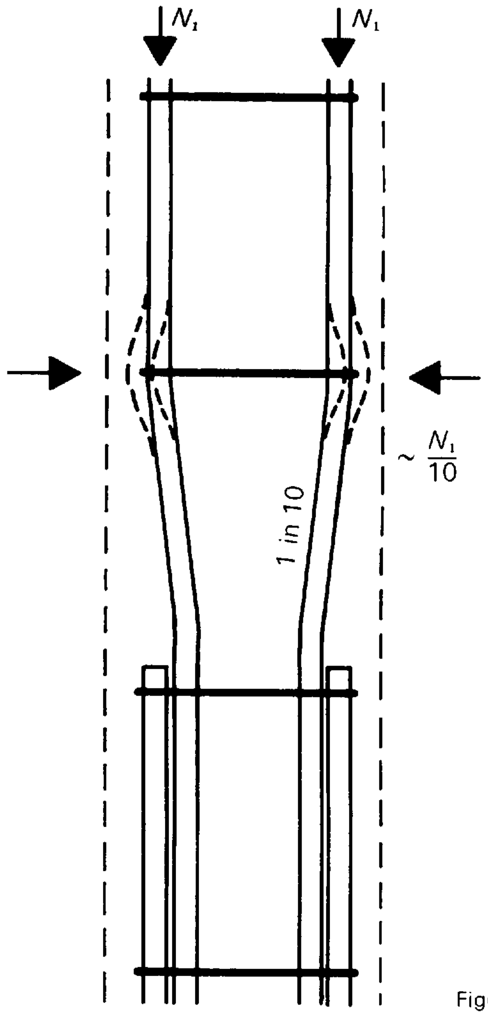


Figure 15

Offset cranked bar

The slope of the inclined portion of a cranked bar should be 1 in 10. The portions of the bar above and below the offset points should be parallel to the column axis.

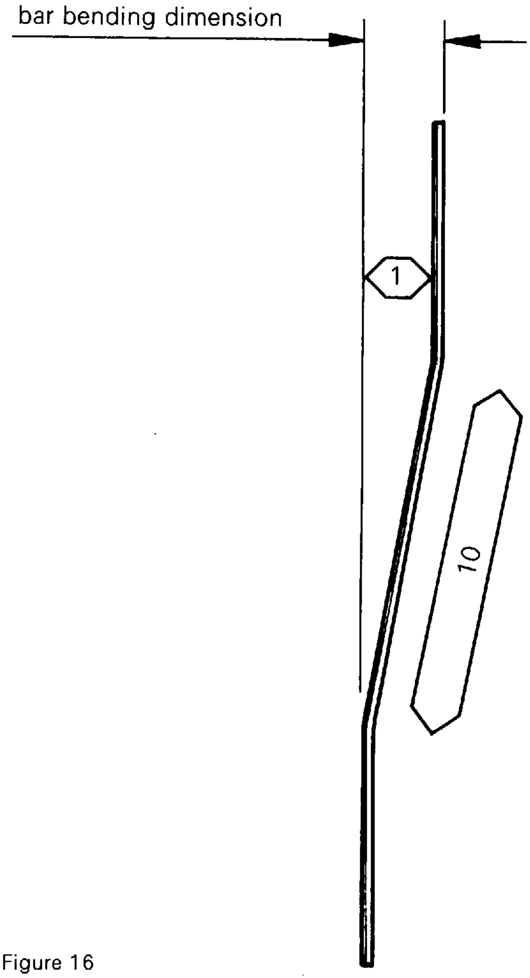


Figure 16

Dowelled splices

Where column faces are offset, a separate dowelled splice should be provided (Figure 17). The dowels are located by special links wired to the lower reinforcement cage. This detail avoids cranking column bars at both ends.

Mechanical splices

As an alternative to lapping at a splice, the compression force in the reinforcement may be transmitted by end bearing of square-cut bars held in concentric contact by a suitably welded sleeve or mechanical device (Figure 18). This type of detail may be more expensive than a straightforward lap, but is useful in areas of congested reinforcement or in the case of bundled bars where the splices can be staggered conveniently to achieve greater structural continuity. A mechanical splice does not normally take tension or provide torsional resistance.

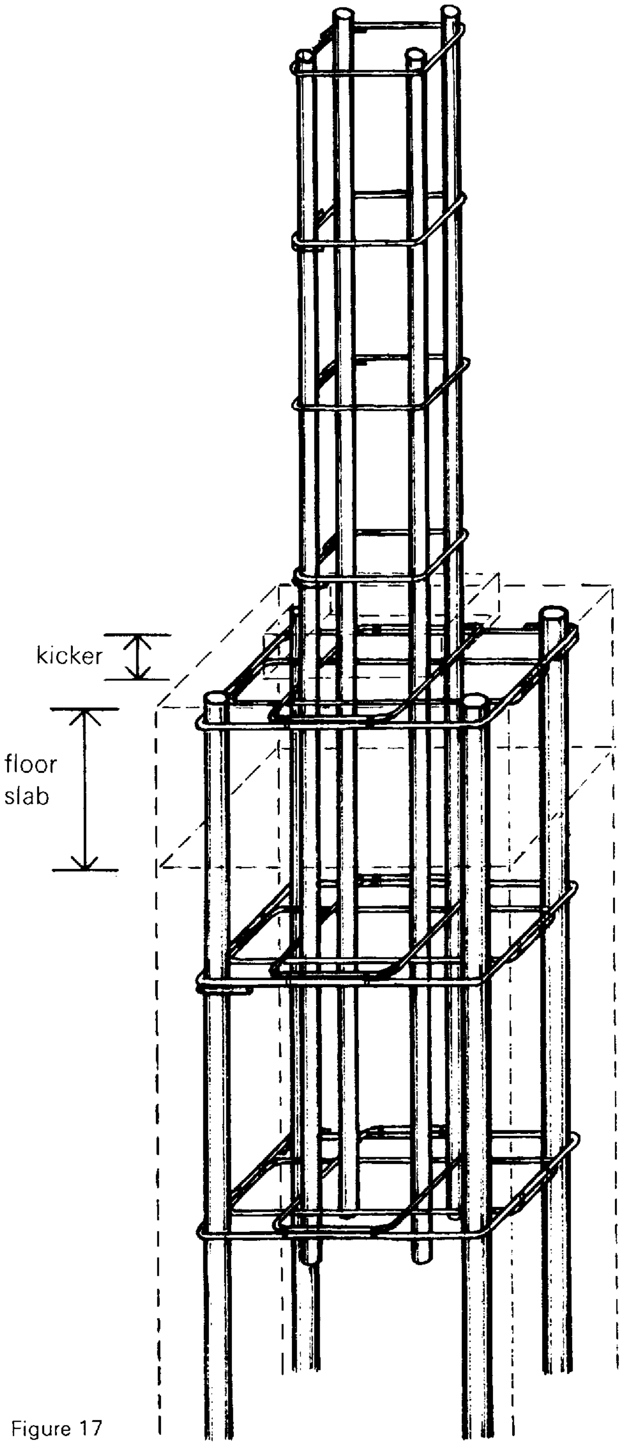


Figure 17

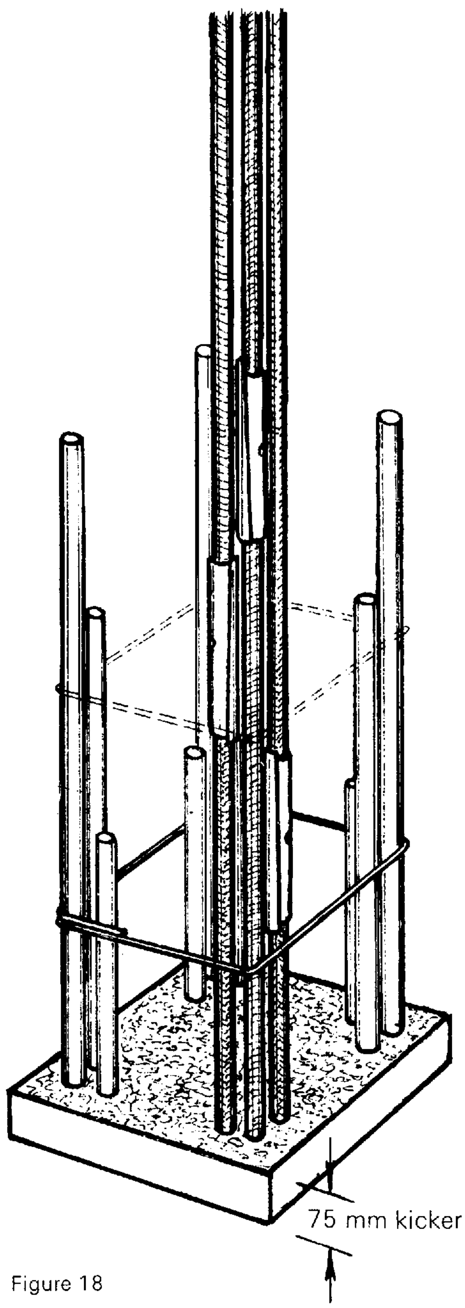


Figure 18

Beam-column intersections

Beam and column arrangements

There are three basic types of beam-to-column intersection as shown in Figure 19:

(a) beam and column of same width;
(b) beam wider than column;
(c) column wider than beam.

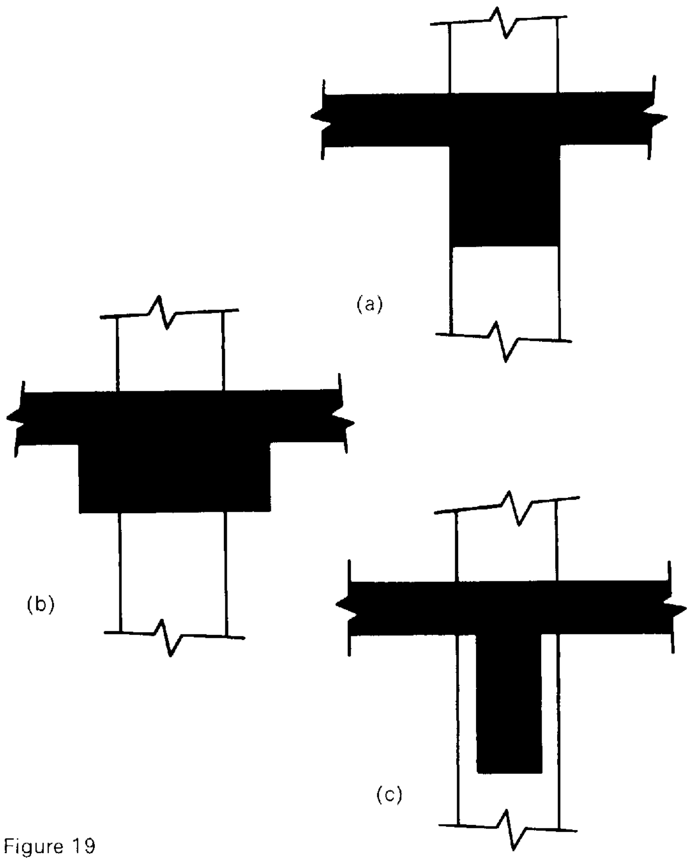


Figure 19

The detailing problems associated with other types of intersection, e.g. where one side of a beam is flush with the face of an external column, can normally be treated in the same way as one of the basic arrangements.

At each type of intersection, there can be various arrangements of main and secondary beams (Figure 20).

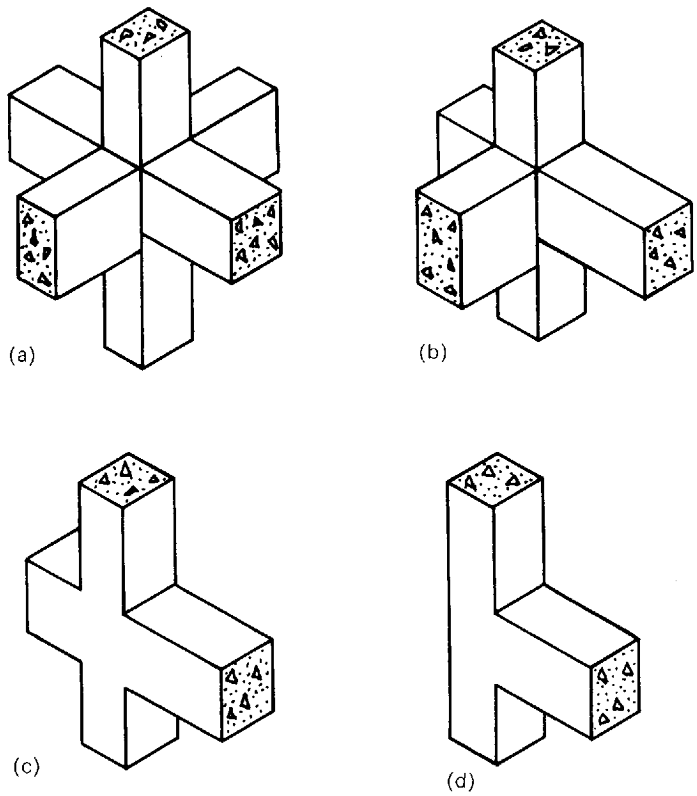


Figure 20

Arrangement of reinforcement

At an early stage in the design, it is essential to establish a system of detailing so that the arrangements of reinforcement in the different members do not obstruct one another at the beam-to-column intersections. The more complex problems occur when the beam and column have the same width. Similar difficulties can arise, however, when the beam and column have slightly different widths and the amount of concrete cover varies.

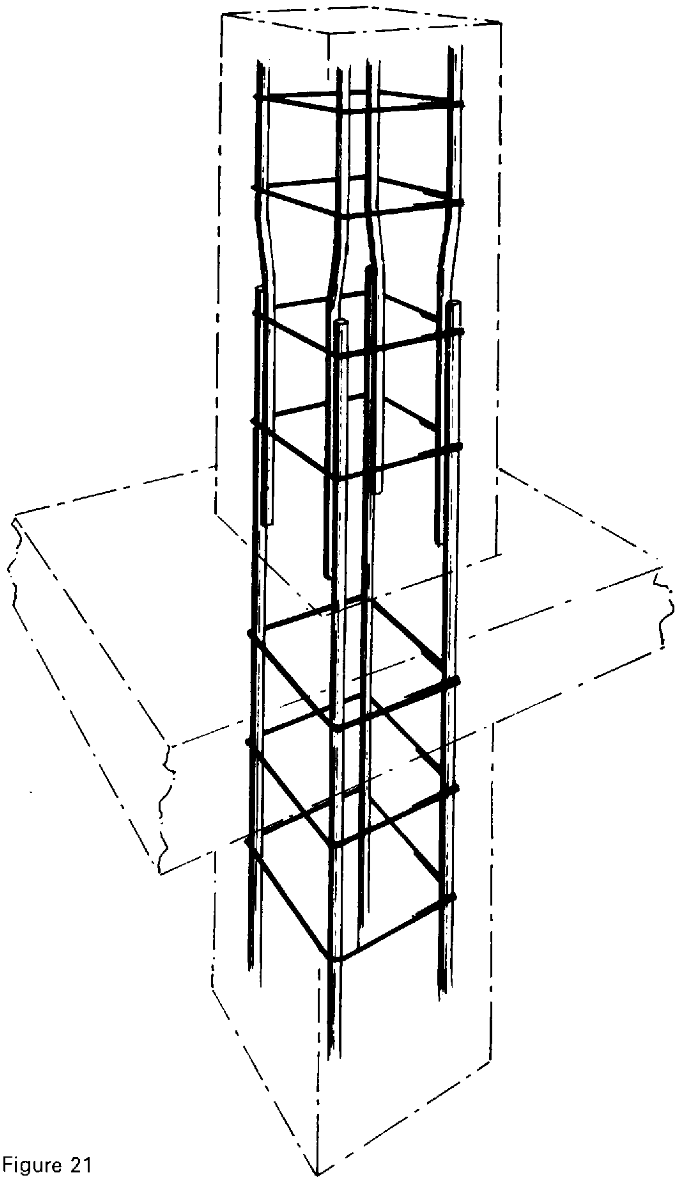


Figure 21

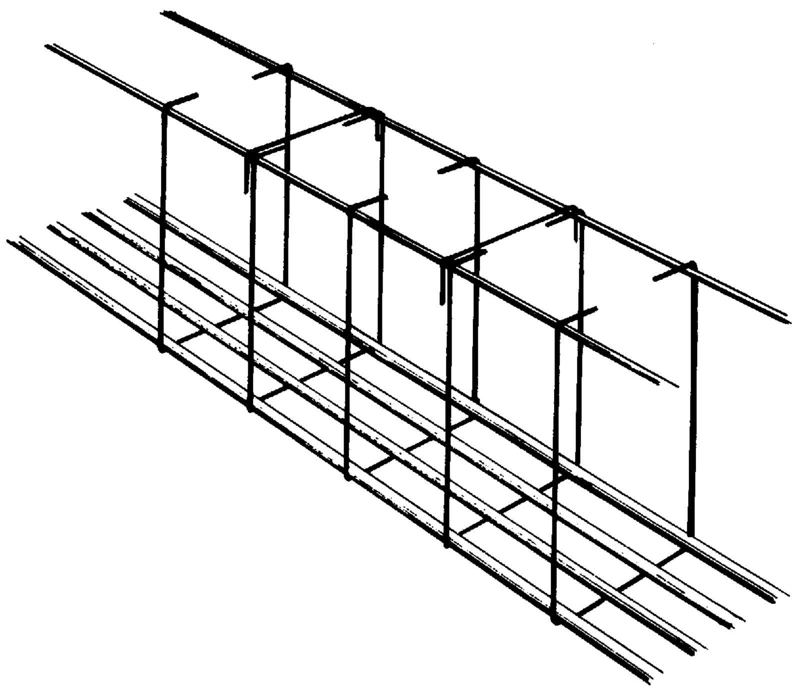
The method of detailing for beam-to-column intersections should take account of the following factors wherever possible:

(a) The reinforcement of the lower column should continue through the beam without cracking as shown in Figure 21. (See recommendations for column splices.)

(b) A standard arrangement of main reinforcement should be used for each type of member in a particular structure. The arrangement of reinforcement which is used, e.g. four bars per layer in the beam with three bars in the face of the column, will depend upon the nature of the job.

(c) The detail should facilitate the prefabrication of the reinforcement cages (Figure 22).

Figure 22

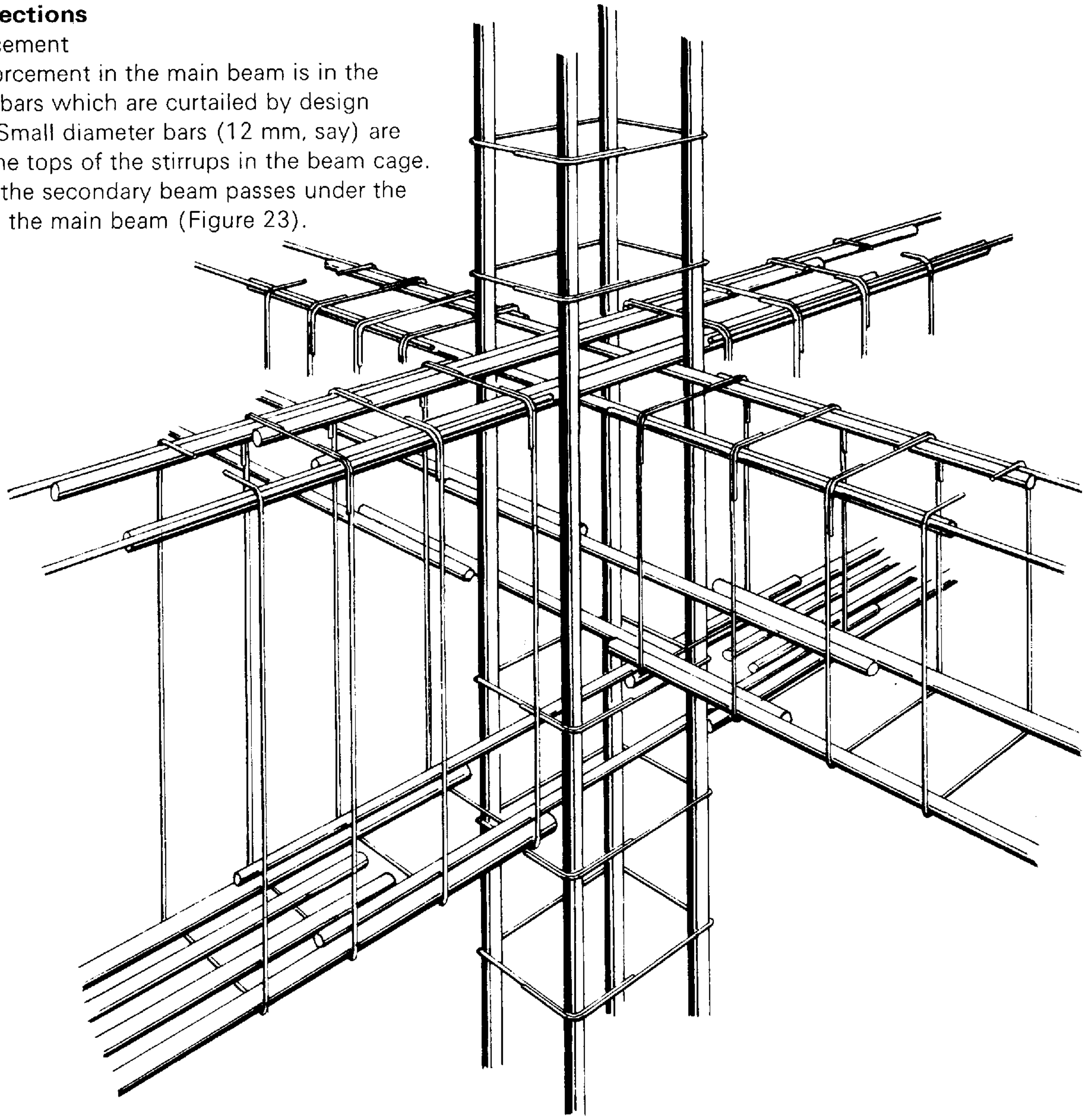


Internal intersections

(a) Top reinforcement

The top reinforcement in the main beam is in the form of straight bars which are curtailed by design considerations. Small diameter bars (12 mm, say) are used to locate the tops of the stirrups in the beam cage. The top steel in the secondary beam passes under the reinforcement in the main beam (Figure 23).

Figure 23



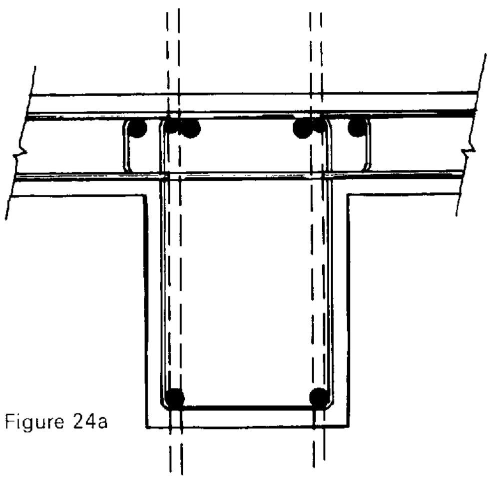


Figure 24a

In narrow beam sections, it may be advantageous to position some bars within the slab outside the limits of the beam (Figure 24a) in order to leave openings wide enough for the insertion of a vibrator.

An additional stirrup may be required since CP 110 requires all tension reinforcement to be enclosed.

Alternatively bundled bars may be used without any loss of lever arm (Figure 24b).

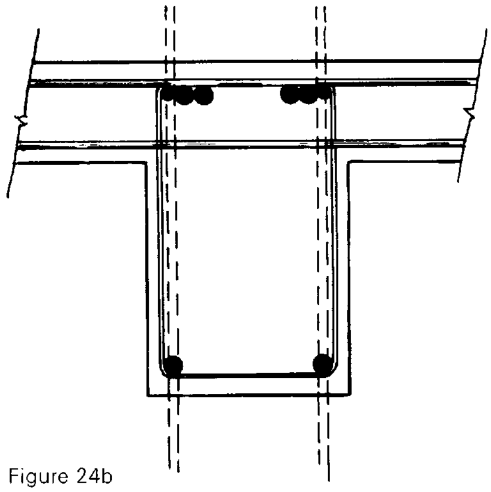


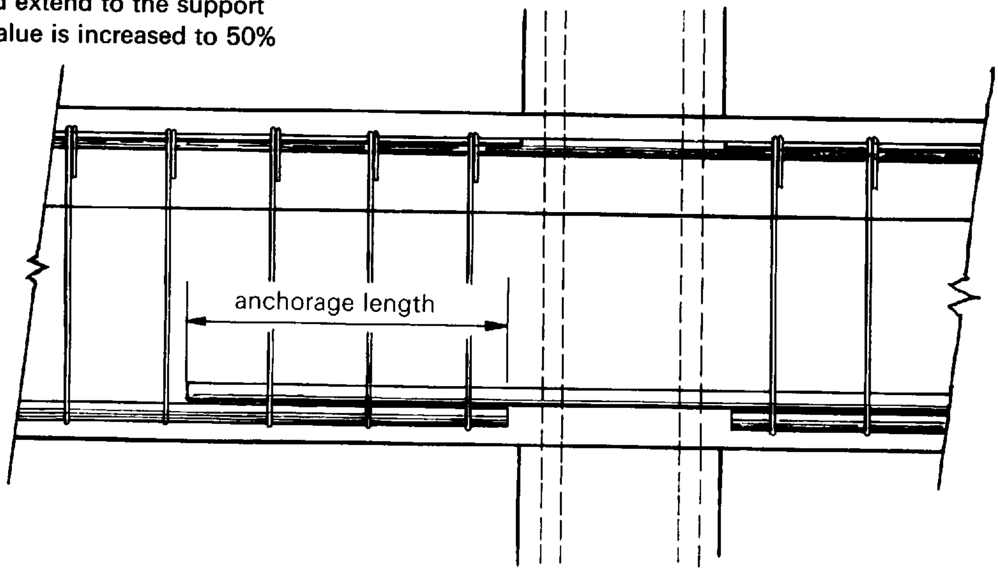
Figure 24b

(b) Bottom reinforcement

The bottom reinforcement in the beam does not extend into the column and structural continuity is provided by lacing bars of similar size (Figure 25).

CP 110 requires that at least 30% of the mid-span tension reinforcement should extend to the support at an interior column. This value is increased to 50% at an exterior column.

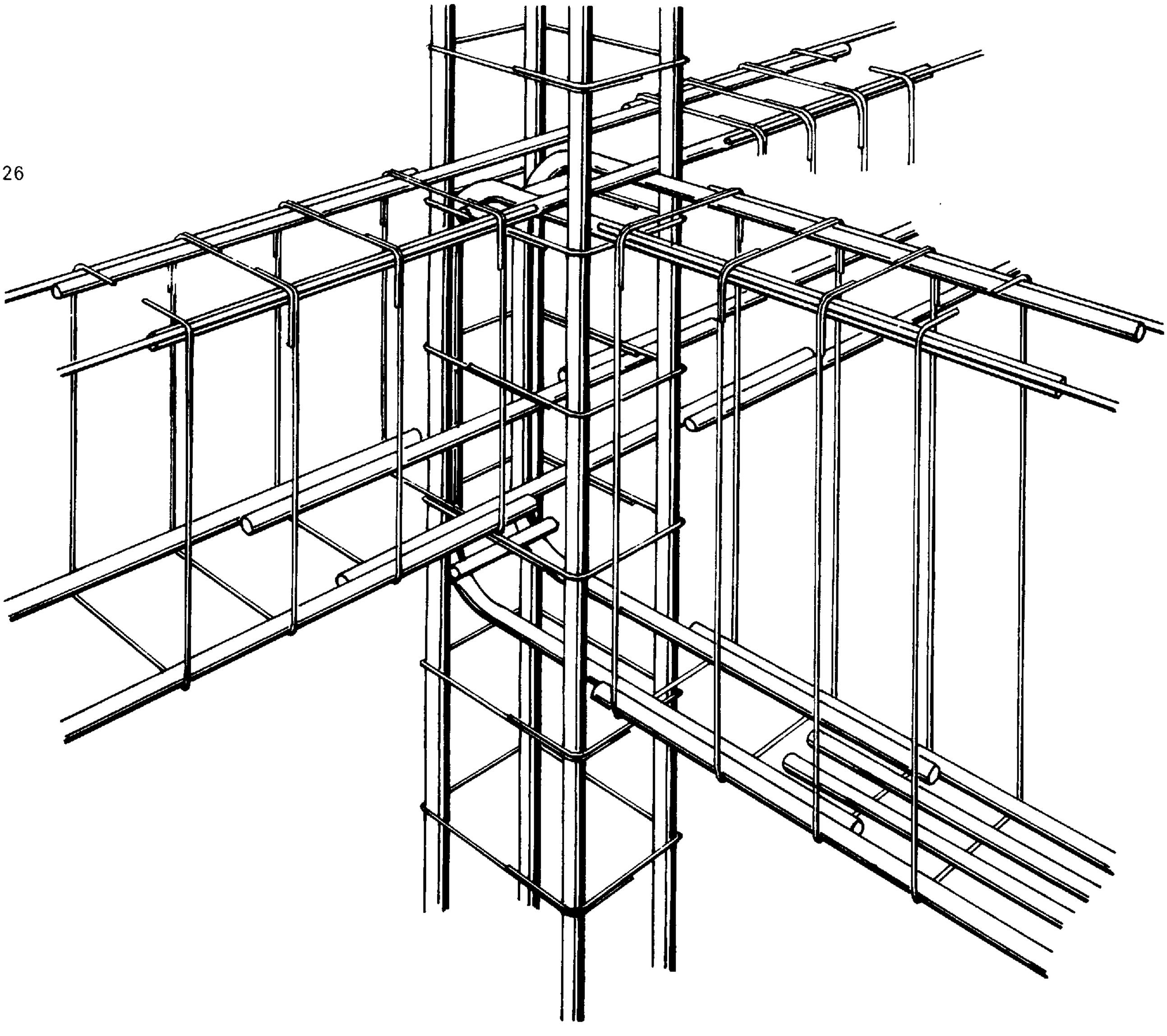
Figure 25



External intersections

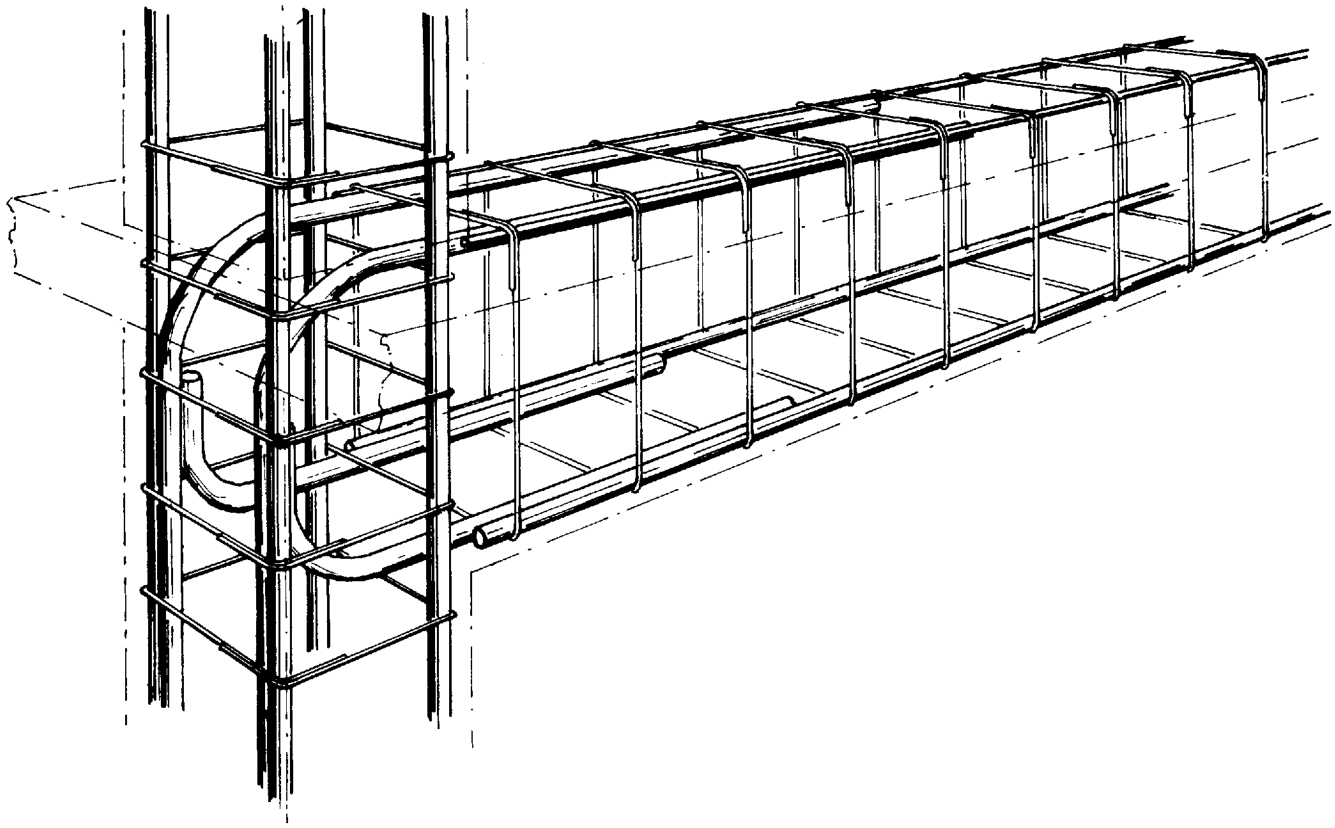
A useful method of connection if reversible moments, such as those caused by wind loading, have to be transmitted to the column, is to fit loose U-bars into the prefabricated beam cage (Figure 26).

Figure 26



In cases where a considerable degree of fixity is required at the end of the beam, L-bars with the vertical leg cast into the lower column (Figure 27) are normally required. The bottom reinforcement should be taken across the column and provided with an adequate anchorage to resist stress caused by reversed moments.

Figure 27



Wall details

Arrangement of reinforcement

In most instances it is necessary to provide reinforcement to distribute the cracking caused by shrinkage and thermal effects.

In the case of an external wall directly exposed to the weather, the distribution reinforcement should be not less than 0·25% for high yield steel or 0·3% for mild steel of the concrete volume.

The distribution steel is most effective when it is placed at relatively close centres outside the main vertical reinforcement, although in some instances the stresses will require that the vertical bars are in the outside layer.

Wall reinforcement should be detailed to permit a storey height to be cast in one operation (Figure 28). Therefore, the vertical steel should be not less than 12 mm bars at 300 mm centres in order to ensure adequate rigidity of the reinforcement cage. Alternatively, small bars in the form of a welded fabric can be used. It is suggested that a maximum pitch of 200 mm is adopted for horizontal distribution steel. U-bars or similar spacers to Shape Code 38 should be provided to maintain the correct separation between the layers of reinforcement in each face of the wall. Normally the U-bars will be the same diameter as the horizontal bars. Nominal diagonal reinforcement should be provided in both faces around all openings in a wall (Figure 29). In walls less than 200 mm thick it is difficult to compact the concrete and it is normal practice to provide a single layer of reinforcement in the exposed face.

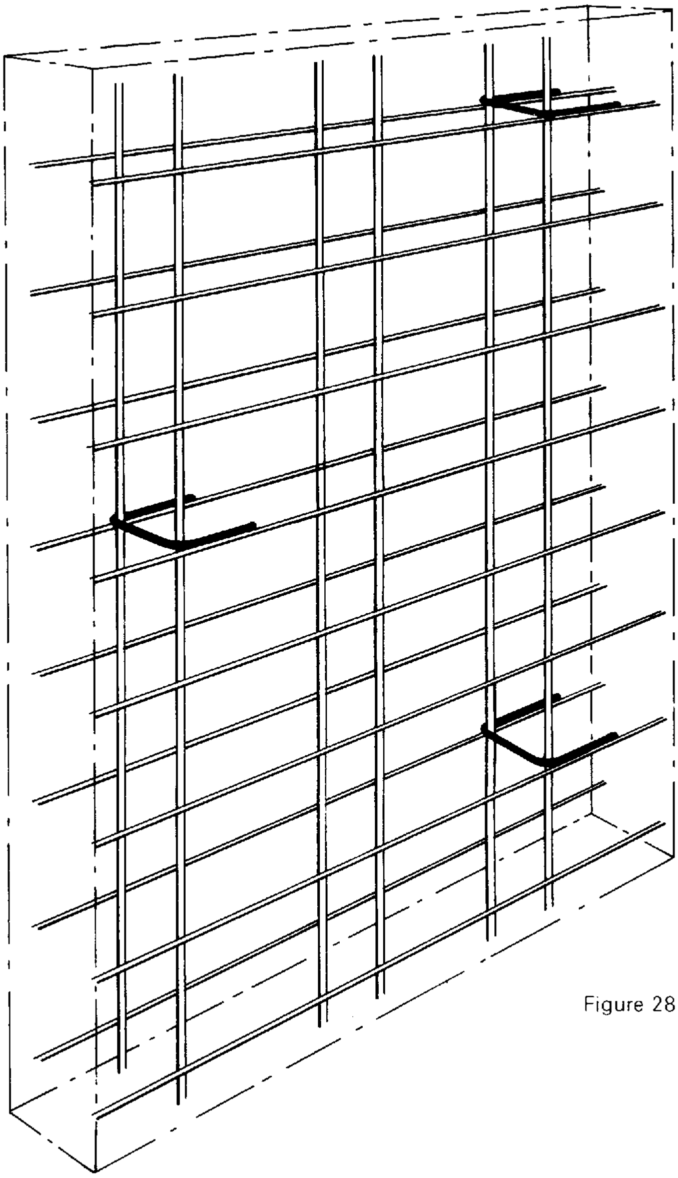


Figure 28

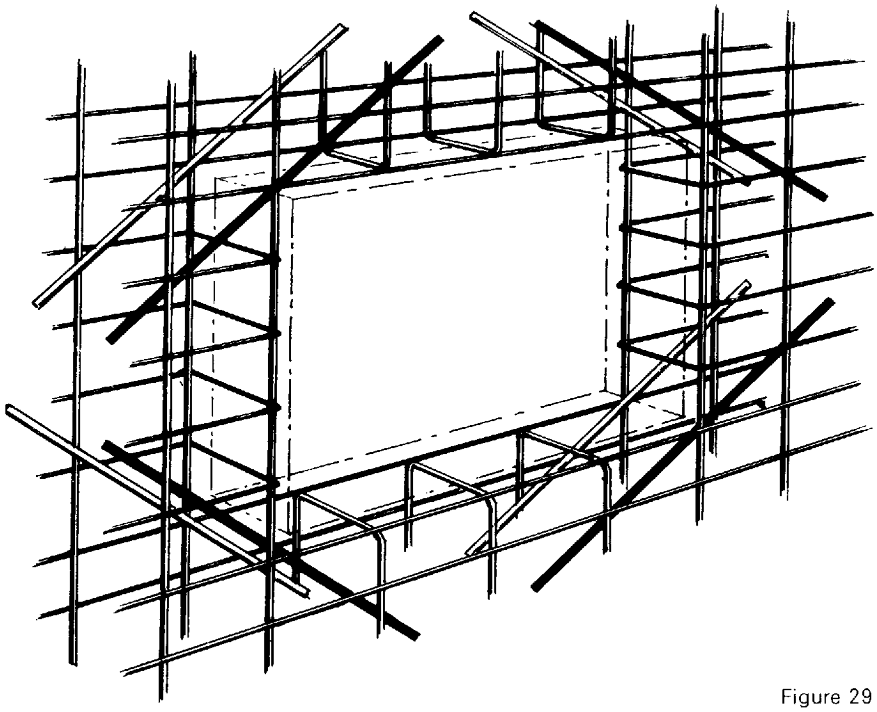


Figure 29

External wall details

In most cases it is unnecessary to joggle the wall reinforcement where laps occur since the bars can be slightly displaced over a short length of wall. If the reduction in wall thickness at any point requires the vertical reinforcement to be offset by more than 75 mm, separate splice bars should be detailed.

Kickers, not less than 75 mm high, should be used wherever possible to ensure correct alignment of the formwork.

The wall-slab intersection is normally reinforced with U-bars (Figure 30a), which can be scheduled with the slab reinforcement. Where there is no designed top steel, nominal U-bars should be used. The upper leg of these U-bars should extend at least 600 mm beyond the face of the wall.

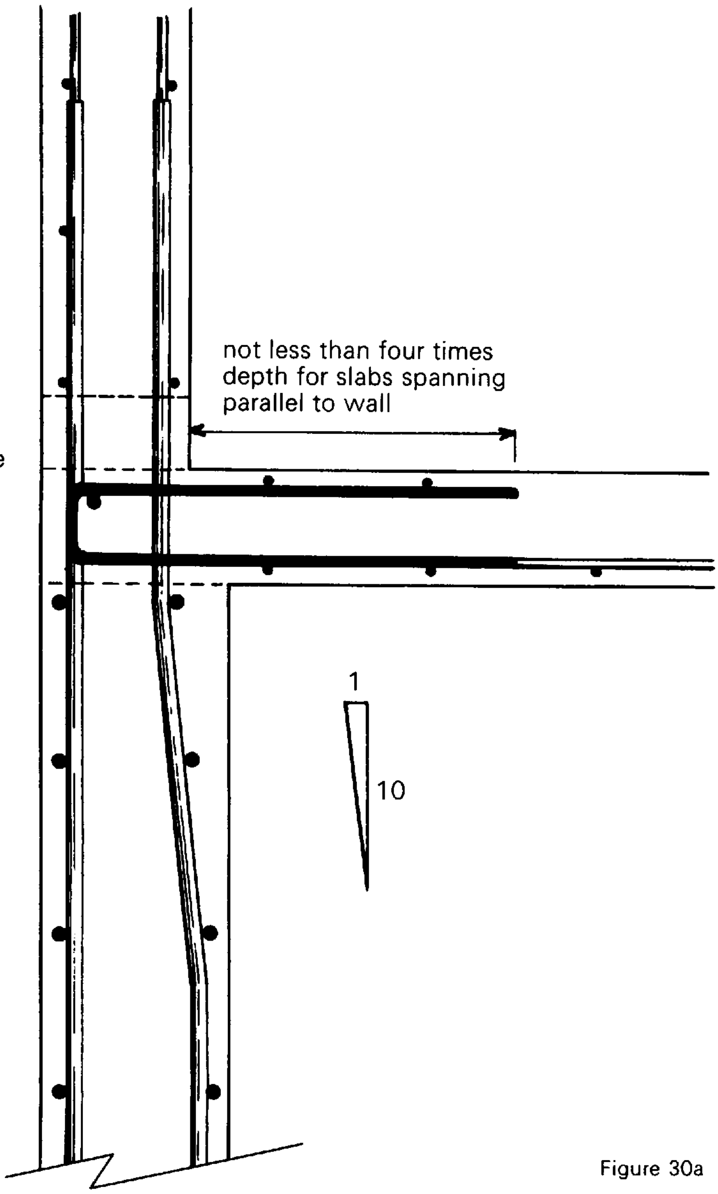


Figure 30a

In the case of an intersection where a significant bending moment is transmitted into the wall from the slab, it is necessary to use an L-shaped bar in order to satisfy bond requirements (Figure 30b). In this instance the continuity steel is cast into the wall and should be scheduled with the wall reinforcement.

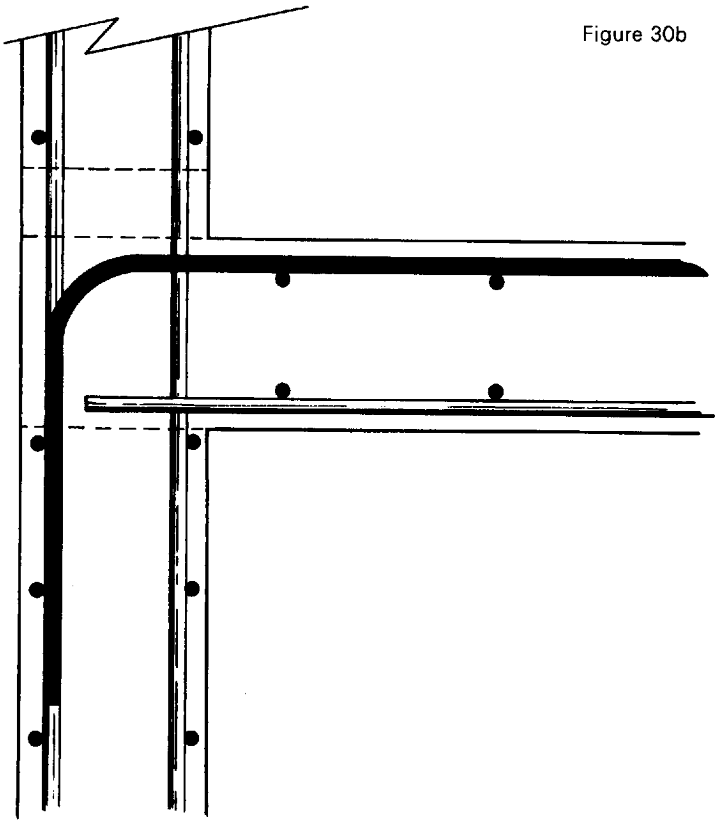


Figure 30b

Internal wall and half-landing details

The tensile reinforcement in the top of the slab at the intersection with an internal wall will be determined by design considerations.

At least 50% of the mid-span tension reinforcement in the bottom of the slab should extend across the wall-slab joint.

Alternatively, if the bottom reinforcement is in the form of prefabricated mats, an equivalent area of steel should be provided in the form of continuity bars with adequate anchorage lengths.

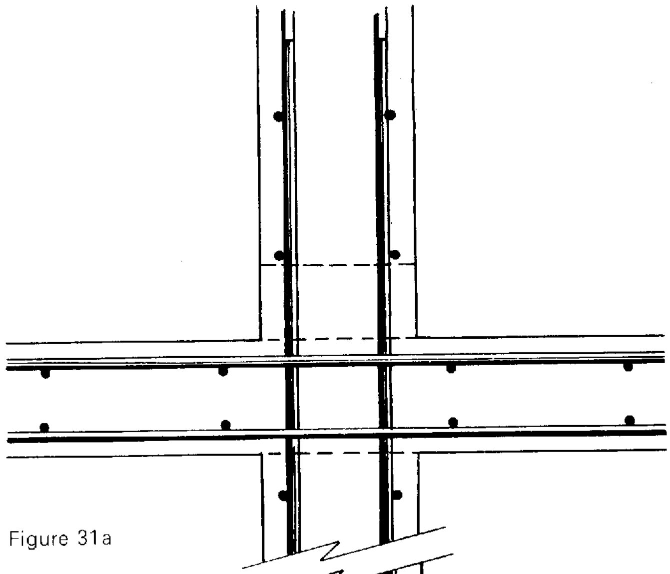


Figure 31a

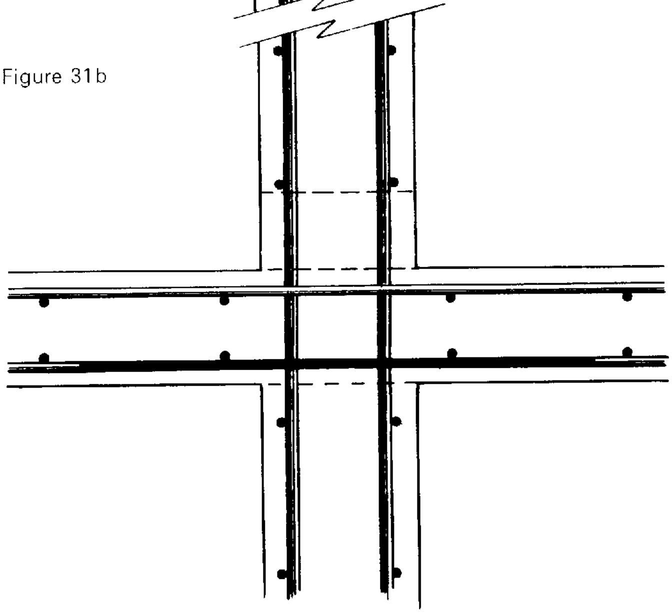
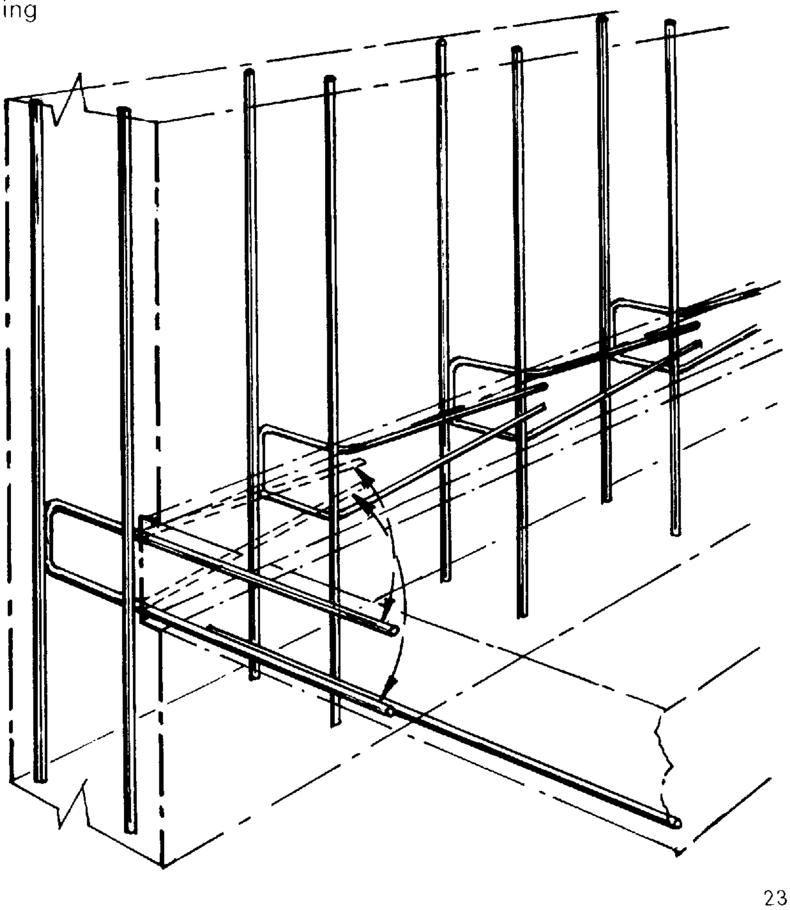


Figure 31b

Slabs or half-landings which occur between main floor levels should be cast into 20 mm deep preformed rebates in the supporting wall (Figure 32). The connecting U-bars should normally be in mild steel with a diameter not greater than 12 mm so that they can be bent out of the rebate into the correct position after the wall shutter has been removed. This type of detail is also used in conjunction with various sliding formwork techniques.

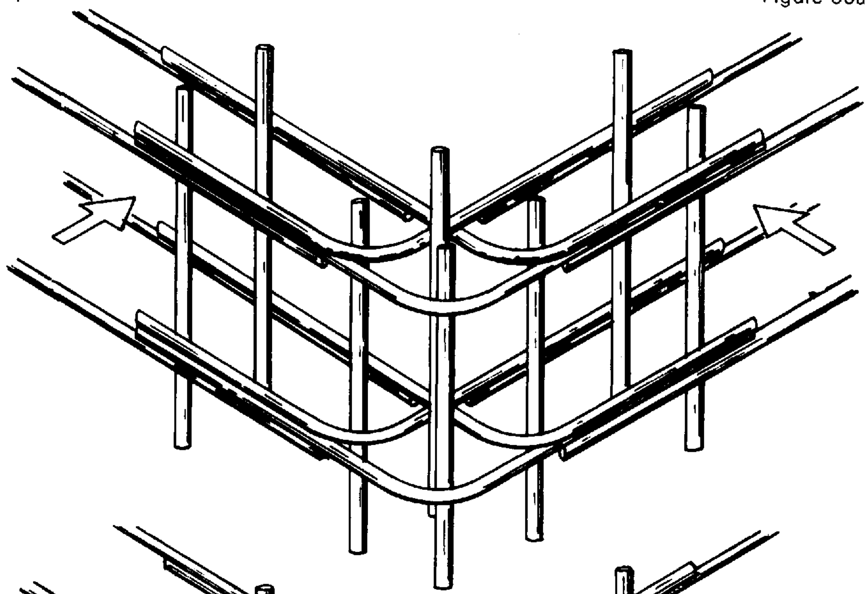
Figure 32

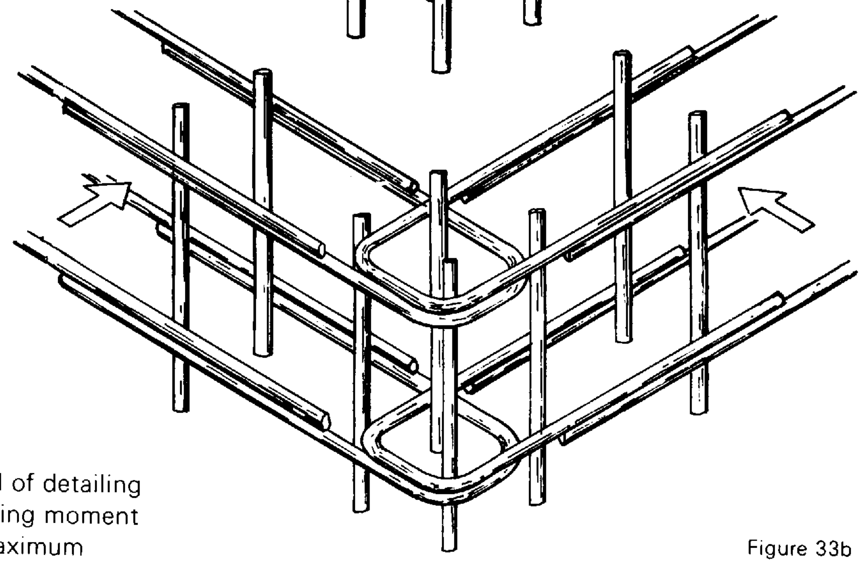


Corner details

Simplicity of construction is a most important consideration when detailing the corner connection between two walls. For corners that are closing, the normal details using bars with an adequate anchorage (Figure 33a) or pairs of U-bars (Figure 33b) are satisfactory.

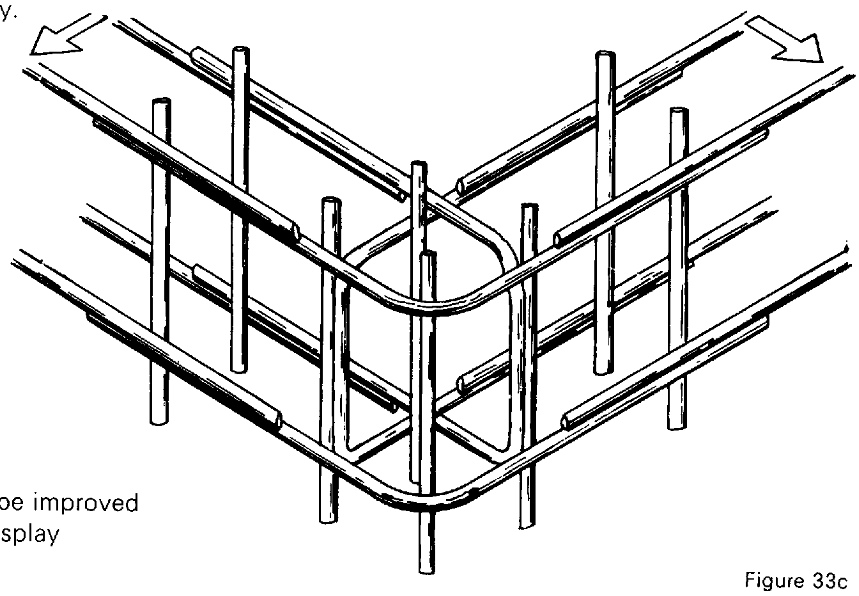
Figure 33a





For corners that are opening, the method of detailing is far more important, especially if the bending moment is significant. Tests have shown that the maximum opening bending moment that can be transmitted by the details shown for closing corners can be less than 25% of the flexural strength of the corresponding wall section. A looped bar is more efficient structurally, although it is difficult to bend and fix. The alternative intersecting 'hairpins' detail (Figure 33c) is more practical and has a high structural efficiency.

Figure 33b



In all cases, the structural efficiency will be improved considerably if it is practicable to provide a splay corner reinforced with diagonal bars.

Figure 33c

Holes in solid slabs

General

There are many instances where a hole can be made in a floor or roof without impairing the strength of the surrounding solid slab. The following methods of detailing reinforcement around holes of this type are recommended in order to prevent cracks developing at the corners of openings.

Structural limitations

Where the designer considers a hole will affect the structural behaviour of the slab a special analysis will be required, but in other cases it is possible to standardize the reinforcement details, provided the following limitations are observed.

(1) No hole should be closer than its width to an unsupported edge (Figure 34).

(2) The maximum width of hole measured transversely to the main reinforcement should not be greater than 1000 mm.

(3) In any 4 m width of slab measured at right-angles to the main reinforcement, not more than one-quarter of the slab should be removed (Figure 35). For slabs less than 4 m wide, the permissible width of holes should be reduced proportionately.

(4) The length of hole measured parallel to the main reinforcement should not be greater than one-quarter of the span.

(5) Where a single hole is adjacent to the column and its larger dimension is less than one-quarter of the column side or one-half the slab depth, whichever is the lesser, then its presence may be ignored.

(6) Where a hole in a solid slab is located at a clear distance of less than six times the thickness *(h)* of the slab from the edge of the column (Figure 36), the critical shear perimeter shall be reduced by the length between the radial projection of the hole.

Reinforcement details

A hole which has no structural significance may be trimmed by one of the following methods, depending upon the size of the opening.

Detail A: For holes with a width at right-angles to the span not greater than 200 mm, where the reinforcement in the slab is not cut.

Detail B: For holes with a width not greater than 500 mm, where the bars are cut and replacement reinforcement is provided.

Detail C: For holes with a width not greater than 1000 mm, where replacement reinforcement is provided and additional bars are placed in the top of the slab.

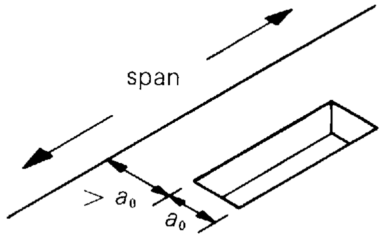
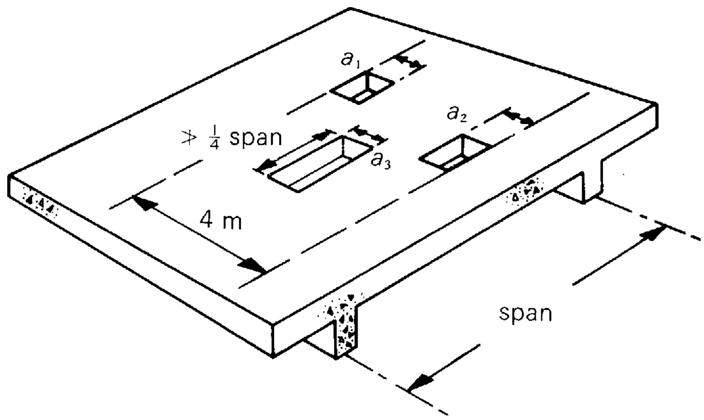


Figure 34



$a_1 + a_2 + a_3 \not> 1$ m

Figure 35

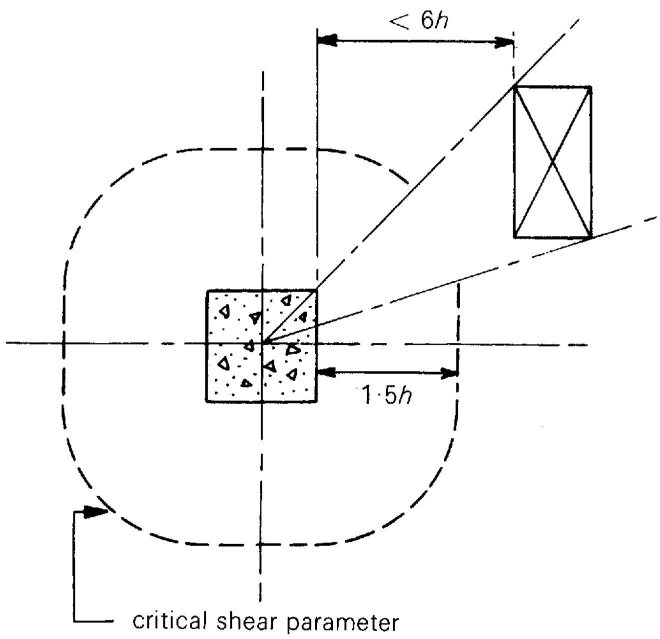


Figure 36

In all cases, the trimming reinforcement should be placed as close to the edge of the hole as is practical.

All diagrams relate to main reinforcement in the bottom of slabs. Top reinforcement should be treated in the same manner as the bottom steel.

Detail A: Width of hole not greater than 200 mm (Figure 37)

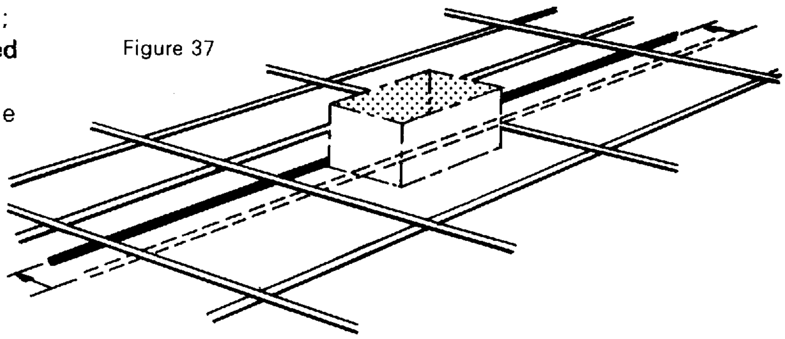
The reinforcement which interferes with the hole may be moved to one side provided that:

(1) the slab thickness is not more than 250 mm;

(2) **the resultant spacing of bars does not exceed three times the effective depth of the slab.**

If either of these conditions is not satisfied, the trimming reinforcement should be as Detail B.

Figure 37



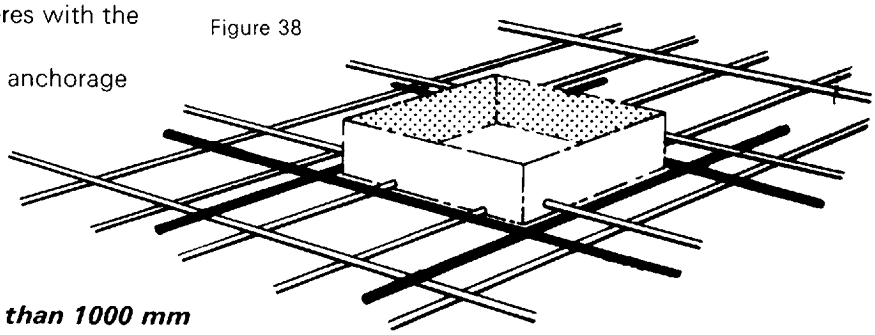
Detail B: Width of hole not greater than 500 mm (Figure 38)

The main reinforcement which interfers with the hole should be cut and replaced by bars of the same size placed evenly on all sides of the hole. Additional reinforcing bars will be required if an uneven number of bars are cut.

If the distribution reinforcement interferes with the hole, it should be cut.

All replacement bars should extend an anchorage length beyond the edges of the hole.

Figure 38

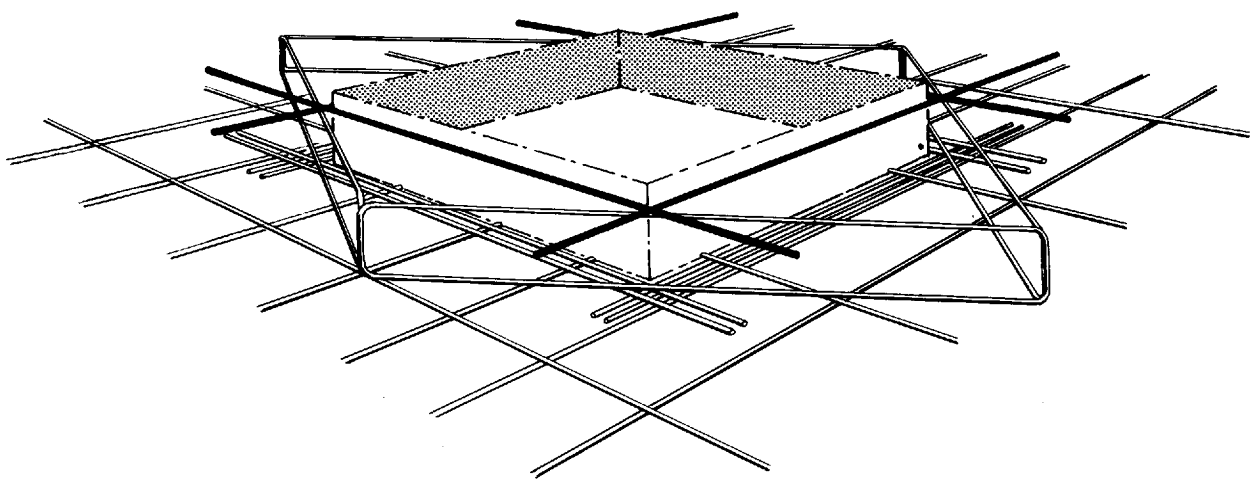


Detail C: Width of hole not greater than 1000 mm (Figure 39)

The main reinforcement should be treated in the same manner as Detail B, but with additional replacement bars of the same size placed on each side of the hole in the top of the slab.

Diagonal reinforcement in the form of links or straight bars supported by chairs, or links, of the same size as the replacement reinforcement should be placed at the corners of the hole. The effective length of the diagonal bars should be at least two anchorage lengths.

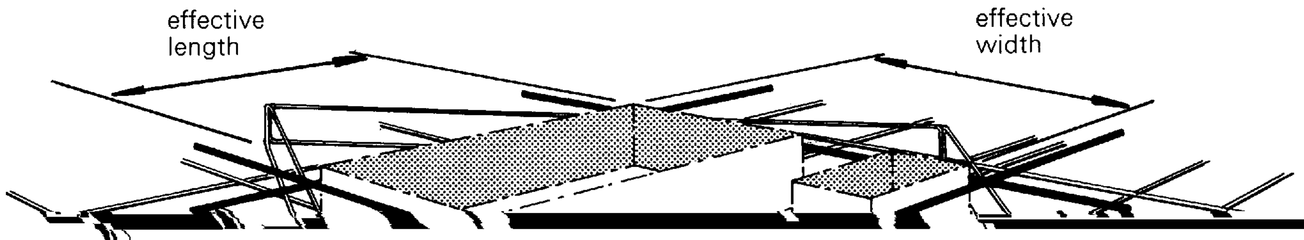
Figure 39



Groups of holes

When the distance between holes is less than 1·5 times the width of the largest opening, the group should be treated as a single hole with an effective width and length as indicated. The trimming reinforcement for groups of holes should be as Details B or C, depending upon the effective width. Wherever possible, bars should be moved to the sides of holes. In all cases, one additional replacement bar of the same size as the main reinforcement should be placed on each side of the group of holes.

Figure 40



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Report of a Concrete Society Working party