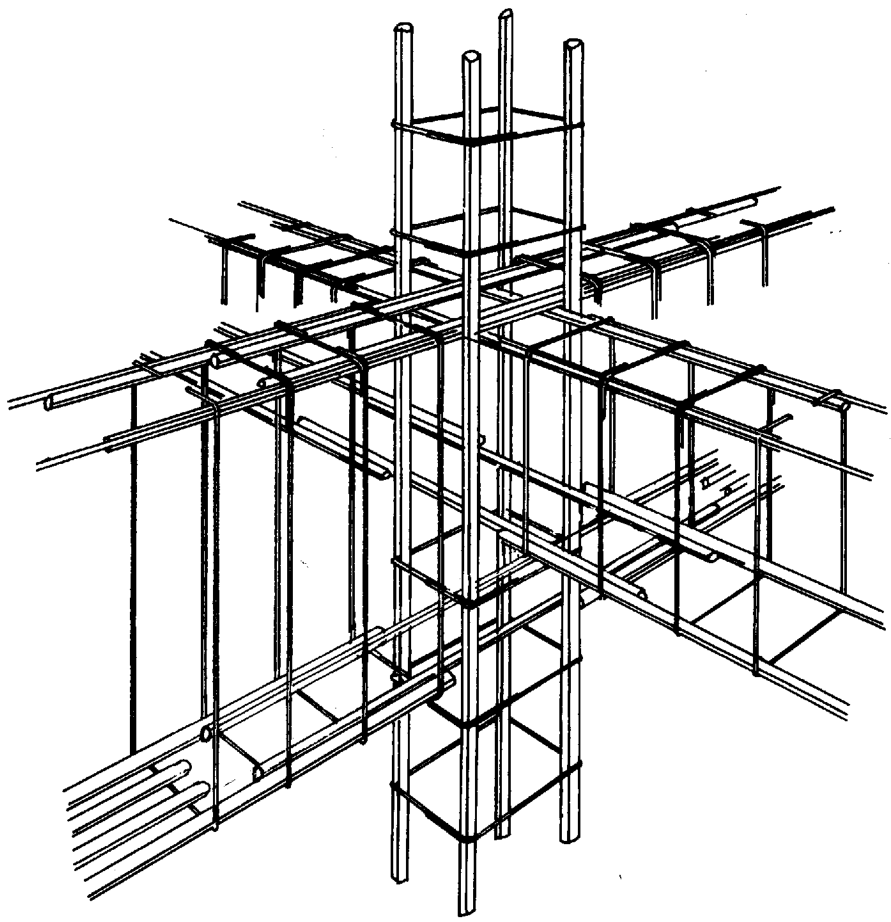
The Institution of Structural Engineers
The Concrete Society

AUGUST 1989

Standard method of detailing structural concrete



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11 UPPER BELGRAVE STREET, LONDON SW1X 8BH

Constitution of Joint Committee

Rex Lancaster, BSc(Eng), CEng, FIStructE, FICE, FCIArb, FACI *Chairman*
Peter Campbell, JP, DIC, CEng, FIStructE, FICE, FIMarE, ACIArb
***E. C. Chaplin,** BSc(Eng), CEng, FICE, FIHT
Colin Davies, BSc(Eng), MSc(Eng), CEng, FIStructE, FICE
D. K. Doran, BSc(Eng), DIC, CEng, FIStructE, FICE
†J. B. Higgins
M. R. Hollington, BSc(Eng), PhD, DIC, CEng, MIStructE, MICE
B. R. Rogers, MA, CEng, MICE
§R. A. Terry
J. R. Walmsley, CEng, FIStructE, MICE
Robin Whittle, MA, CEng, MICE
J. Willbourne, BSc(Eng), MSc(Eng), CEng, MIStructE
R. W. J. Milne, *Secretary to the Joint Committee*

*Chairman of a joint committee of the Concrete Society and the Institution of Structural Engineers responsible for preparing the section on prestressed concrete. Other members of that committee were:

A. E. Andrew, CEng, FIStructE
W. Thorpe, CEng, FIStructE
J. R. Walmsley, CEng, FIStructE, MICE
K. R. Wilson, MA, CEng, MICE

†Died December 1985
§Died 1988

Contents

Notes: 1. Words underlined are suitable for a tab index.
2. Yellow pages denote data sheets and model details.

Foreword

The metric version of the previous *Standard method of detailing reinforced concrete* was published in 1970 and this was followed in 1973 by the Concrete Society's publication on *Standard reinforced concrete details*. This version incorporates the two earlier publications, and as it now incorporates a section on prestressed concrete, the title has been amended to the *Standard method of detailing structural concrete*. As with the original *Standard method*, the Committee is a joint one between the Institution of Structural Engineers and the Concrete Society.

It is hoped that this document will become the standard reference work in structural design offices in conjunction with the *Manual for the design of reinforced concrete building structures* (1985) prepared jointly by the IStructE and the ICE.

The Joint Committee has relied entirely on BS 8110 for detailing principles and has not taken any decisions on matters of design. However, the distinction between the detailer's field and that of the designers' is not always clear, and some criticisms have been made that we have strayed too much into the design field. In practice, many decisions that are taken by the detailer are strictly in the province of the designer, and the detailer often makes up his own reference tables because they are not available elsewhere. We have attempted to provide such guidance in our document, and in so doing, we do not believe we have encroached on the design area.

We have also had criticisms from some designers on the length of the document. We have taken the views of detailers on this, in particular the comments from detailers attending training courses at the Cement & Concrete Association. As they have found the whole document useful and are quite happy to abstract key pages (principally the yellow pages) for everyday reference, we have been persuaded to retain almost the whole of the draft that was made available for comment. We are grateful for the many helpful comments we have received, all of which have been considered, and most of them accepted.

The original *Standard method* has been widely distributed and accepted both in the UK and abroad. When I have checked in design offices they invariably confirm that they are using the principles set out in the documents. Unfortunately, also invariably, they then qualify their statement by saying 'Well 90% of it anyway'. On investigation it always transpires that the 10% not being used is a different 10% in every office! This is not standardization. We hope this time to achieve 100% in every office!

The Joint Committee were saddened by the sudden deaths of Jim Higgins in December 1985 and Dick Terry in 1988 and would wish me to pay tribute to their great contribution to our work. Jim Higgins was particularly associated with Section 5 while Dick Terry was responsible for much of the artwork in other Sections.

R. I. Lancaster

R. I. Lancaster, *Chairman*

1 Introduction and scope

The objective of this manual is to provide a working document on structural concrete that can be used by the detailer in the design office to interpret the designer's instructions in the form of drawings and schedules for communication to the site. For prestressed concrete, the section is addressed more to the designer–detailer, since a general knowledge of prestressing terms and practice is necessary in this field. Large design offices may choose to incorporate the principles and the details in their own manuals. It is intended that the manual will be the standard reference work used on training courses and by design engineers. During the early stages of the development of this document Ove Arup & Partners made their detailing manual available to the Joint Committee, and this was a very useful base document.

A basic assumption in the preparation of this manual has been that it is the responsibility of the engineer to specify clear design requirements to the detailer and it is the responsibility of the detailer to implement these requirements in a consistent way that will be clear, complete and unambiguous to all users. In detailing structural concrete, the interests of all parties should be borne in mind; practices in the drawing office that lead to problems or extra costs on site cannot be termed good detailing.

It has not been the intention of the Joint Committee to decrease in any way the responsibility of the engineer, although it is recognized that certain details have design implications; therefore engineers should design with full knowledge of this manual. The words 'standard method' need clarification. It is not intended that any one detail should be copied slavishly for all situations, but it is intended that all the principles should be followed, both in general and in detail. Details can be prepared with different objectives in mind, e.g. to reduce labour on site by detailing to allow off-site prefabrication of the reinforcement into cages, or to utilize the materials most readily available on a particular site. It is believed that such different objectives can be achieved (but not necessarily all at the same time) within the principles covered in this manual.

Where another authoritative document exists, this manual refers to it rather than repeating it in full; it also excludes the sort of expertise associated with proprietary methods or materials. In general, the conventional use of materials covered by British Standards is assumed; where no standard or consensus of opinion exists no recommendation has been made.

The principles covered by BS 4466 and BS 1192 have been adopted. BS 4466 defines a standard method of scheduling and a set of bar shapes that, in suitable combination, are sufficient for any detailing situation; it is considered to be an essential companion document to the manual. The principles set out in this manual cover all forms of reinforced concrete construction; where relevant BS 8110, BS 8007 and BS 5400 have been used as a basis.

It is generally accepted that any division between civil and structural engineering is somewhat arbitrary, and it therefore follows that what is good practice in structural engineering will also be so in civil engineering. There are, however, a number of factors that occur in civil engineering and large-scale work of which account should be taken when detailing reinforcement. These include:

- the provision of access for men to place concrete in massive concrete sections such as raft foundations
- adjustments of reinforcement to take account of large pours of concrete. Attention is drawn to CIRA report 49, *Large concrete pours — a survey of current practice* (J. C. Birt)
- suitable reinforcement arrangements to suit long-strip methods of laying ground slabs
- recognition of the likely positioning of construction joints and their effect on reinforcement arrangements.

2 Drawings

2.1 General

Drawings are prepared so that the structural designer can communicate his requirements through the detailer to the contractor in a clear, concise and unambiguous manner. It is important to ensure that drawings are not unnecessarily congested or complicated.

Drawings used on construction sites will get dirty, wet and dog-eared. The clarity of the original drawing that will be reproduced is, therefore, most important, and this will usually be enhanced by the use of ink in the preparation of the original drawings.

It is recommended that A1 size drawings are generally used, larger sized drawings being used only when unavoidable. For each project, the chosen drawing size should be used consistently. The written descriptions on drawings should be as brief as possible, consistent with completeness, and the lettering should be clear. Any instructions on drawings should be positive; they should be written in the imperative.

Each drawing should give all the information (together with reference to associated drawings) necessary for the construction of the portion of the work shown, omitting other irrelevant detail. Details of materials to be used will normally be given in a separate specification, and reference to the concrete or other types of material on drawings will be in an abbreviated form.

Reference to any special items concerned with construction details should be made on the general arrangement drawings and not in a separate letter or document. Special requirements of the designer, e.g. details of cambers, chamfers, sequence of construction, position and type of joints, etc., should all be described on the general arrangement drawings.

2.2 Types of drawing

There are two principal types of drawing necessary for the preparation of reinforced concrete drawings and details. These are general-arrangement drawings and reinforcement drawings.

2.2.1 General-arrangement drawings

General-arrangement drawings for concrete structures consist of dimensional data necessary for the setting out and construction of the concrete formwork, e.g.:

- setting out of the concrete structure on site
- plans, sections and elevations where appropriate showing layout, dimensions and levels of all concrete members within the structure
- location of all holes, chases, pockets, fixings and items affecting the concrete work
- north point
- notes on specifications, finishes and cross-references of the construction.

All these matters should be considered at the outset of every drawing programme.

Detailed examples of structural layout drawings and guidance notes are illustrated at the beginning of Section 5.

2.2.2 Reinforcement drawings

Reinforcement drawings describe and locate the reinforcement in relation to the outline of the concrete work and to relevant holes and fixings.

Generally, circular holes up to 150mm diameter and rectangular holes up to 150 × 150mm in slabs or walls need need not be indicated on the reinforement drawings. Holes of larger size should be indicated on the reinforcement drawing and should be trimmed by suitable reinforcing bars.

Separate drawings or plans for top and bottom layers of reinforcement should be used only for fabric and in exceptional cases, e.g. hollow bridge decks with four layers of reinforcement.

Reinforcement drawings are primarily for the use of the steel fixers. It is preferable that general arrangement and reinforcement drawings be kept separate, but for simple structures a combined drawing will suffice.

2.2.3 Standard details

Standard details are those details that are used on a repetitive basis. Details used in this way must be carefully worked out, fully detailed and totally applicable to each location where they are to be specified.

Standard details may apply to concrete profiles or reinforcement arrangements, and they should be drawn to a large scale.

2.2.4 Diagrams

Diagrams may be used as a means of communicating design ideas during both pre-contract work and the post-contract period. Diagrams may be formally presented or sketched freehand providing they convey information clearly, neatly and in detail.

The information contained in diagrams should preferably be drawn to scale.

2.2.5 Record drawings

When the reinforced concrete structure has been constructed, the original drawings used for the construction process should be amended to indicate any changes in detail that were made during the construction process. A suffix reference should be added to the drawing number to indicate the drawing is a 'record drawing'. The amendments should be described in writing against the appropriate suffix reference. A register of drawings should be kept listing reference numbers, titles and recipients of drawings.

2.3 Photocopying and reduction

There are a number of considerations that must be made if photographically reduced drawings are to be fully intelligible in their reduced form. These include:

- the chosen range of line thickness
- the size and nature of the script used
- whether the drawing is produced in ink or pencil
- the arrangement of the information on the drawings, avoiding congestion
- the need to ensure that graphic and script information is, as far as possible, kept separate
- the possibility that solid black areas will not print properly.

Since many drawings will be reduced for archive storage on completion of the construction, all these matters should be considered at the outset of every drawing programme.

2.4 Abbreviations

The following standard abbreviations are recommended but, if there is any risk of confusion or ambiguity with the use of these abbreviations in any particular circumstances, then the words should be written in full. No other abbreviations should be used unless clearly defined on all the drawings on which they appear.

Particular attention is drawn to the use of lower-case and capital letters. All abbreviations are the same in the plural as in the singular.

2.4.1 General

reinforced concrete	RC
blockwork	blk
brickwork	brk
drawing	drg
full size	FS
not to scale	NTS
diameter	dia*
centres	crs
setting-out point	SOP
setting-out line	SOL
centre-line	℄
finished floor level	FFL
structural floor level	SFL
existing level	EL
horizontal	hor
vertical	ver

*For bar diameter use 'bar size' on drawings where necessary and ϕ in formulas.

2.4.2 Relating to reinforcement

far	(face)	F1	(outer layer)	F2	(second layer)
near	(face)	N1	(outer layer)	N2	(second layer)
bottom	(face)	B1	(outer layer)	B2	(second layer)
top	(face)	T1	(outer layer)	T2	(second layer)

Note: Since the contractor may not be familiar with this notation it should be illustrated by a sketch on the relevant drawings.

Additional abbreviations may be used but are not recommended for use without a clear description as they have been found to be ambiguous.

2.5 Drawing standards

It is the intention that BS 1192 *Recommendations for drawing practice* should be read in conjunction with this document, the two documents being mutually complementary. Parts 1 and 3 of BS 1192 are particularly relevant to the reinforced concrete detailer since they define the general principles of drawing practice and symbols. In Part 2 of BS 1192 are examples of reinforced concrete drawings, which also comply with the *Standard method.*

2.6 Dimensions of drawing sheets

The recommended dimensions of drawing sheets are given below; Fig. 1 shows the relative sizes.

Size of drawing sheets

BS reference	dimensions mm × mm
A0	841 × 1189
A1	594 × 841
A2	420 × 594
A3	297 × 420
A4	210 × 297

Note: Margins and information panels are within these dimensions

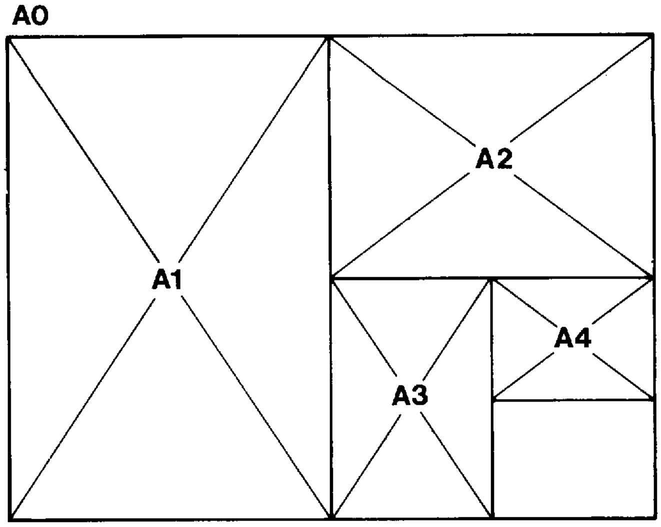


Fig. 1

2.7 Borders

All drawings should have a 20mm filing border on the left-hand side. Elsewhere the border should be 20mm (minimum) for A0 and A1 and 10mm (minimum) for A2, A3 and A4. The border margin line should be at least 0.5mm thick.

2.8 Title and information panels

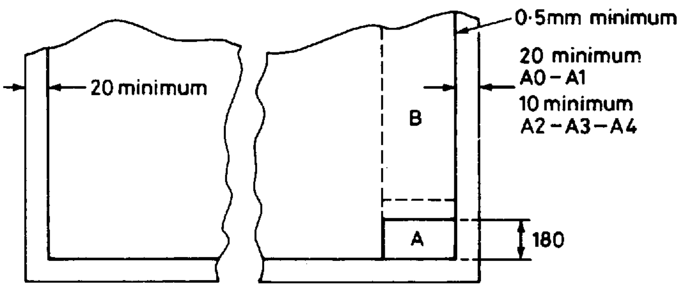


Fig. 2

Key information relating to the job and drawings should be placed in the bottom right-hand corner of the drawing sheet (Fig. 2, panel A). Panel A should include at least the following information:

- office project number
- project title
- drawing number with provision for revision suffix
- drawing title
- office of origin
- scales (a drawn scale is necessary when the drawing is to be microfilmed – see also BS 5536)
- drawn by (name)
- checked by (name)
- date of drawing.

Immediately above panel A a box should be provided to contain the necessary reference to relevant bar and fabric-schedule page numbers.

Panel B may be developed vertically from panel A to include such information as revisions working up from panel A and notes (working down from the top of panel B).

Notes on reinforcement drawings should include cross-references to general-arrangement drawings, a list of abbreviations, specified covers and the relevant 'schedule refs'.

2.9 Key

On jobs where a portion of the work has to be divided into several drawings, it is useful to have a small diagrammatic key on each drawing, with the portion covered by that drawing clearly defined, and adjacent panels identified with a given drawing number.

2.10 Orientation

2.10.1 Site plans

The direction of the north point should be clearly shown.

2.10.2 All other drawings

All other drawings relating to particular buildings or major subdivision of a job should have consistent orientation, which should preferably be as close as possible to the site-plan orientation.

2.11 Thickness of lines

The objective of using varying line thicknesses is to improve clarity by differentiation. The scale of drawing and the need for clear prints to be taken from the original should be borne in mind The following suggested line thicknesses are considered suitable for reinforced concrete drawings:

concrete outlines generally and general arrangement drawings	0.35mm
concrete outlines on reinforcement drawings	0.35mm
main reinforcing bar	0.7mm
links	0.35mm–0.7mm
dimension lines and centre-lines	0.25mm

Cross-sections of reinforcement should be drawn approximately to scale.

2.12 Lettering

Distinct and uniform letters and figures ensure the production of good, legible prints; the style should be simple. Capital letters should be used for all titles and sub-titles and should preferably be mechanically produced. Lower-case letters may be used in notes.

2.13 Spelling

The spelling of all words should be in accordance with BS 2787 or otherwise the Little Oxford Dictionary, e.g. asphalt, kerb, lintel, etc.

2.14 Dimensions

The general-arrangement drawing should show all setting-out dimensions and sizes of members. The reinforcement drawings should contain only those dimensions that are necessary for the correct location of the reinforcement. The points to which the dimension lines relate should be as shown in Fig. 3.

Dimensions should be written in such a way that they may be read when viewed from the bottom or the right-hand side of the drawing. They should, where possible, be kept clear of structural detail and placed near to and above the line, not through the line.

For site layouts and levels, the recommended unit is the metre. For detailing reinforcement and the specification of small sections, the recommended unit is the millimetre. It is not necessary to write mm. Dimensions should normally be to the nearest whole millimetre. Thus:

4.250
114.200
6 210m

5
15
1 725

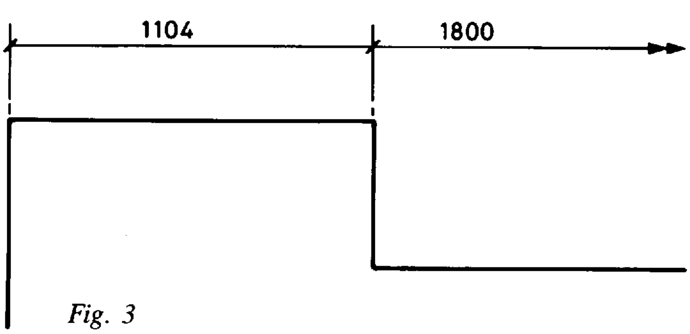


Fig. 3

2.15 Levels

2.15.1 Datum

On civil-engineering and major building works it is usually necessary to relate the job datum (a TBM or transferred OS benchmark) to the Ordnance Survey datum. On other works, a suitable fixed point should be taken as job datum such that all other levels are positive. This datum should be clearly indicated or described on the drawings, and all levels and vertical dimensions should be related to it. Levels should be expressed in metres.

2.15.2 Levels on plan

It is important to differentiate on site layout drawings between existing levels and intended levels.

Finished floor levels or structural floor levels should be indicated thus:

FFL
12.335

SFL
12.000

Existing levels should be indicated thus:

EL
11.445

2.15.3 Levels on section and elevation

The same method should be used as for levels on plan, except that the level should be projected beyond the drawing with a closed arrowhead indicating the appropriate line.

When constructing a structure it is the level of the structure that is important. If it is necessary to refer to the finished floor level, this should be a reference in addition to the structural floor level, as shown in Fig. 4.

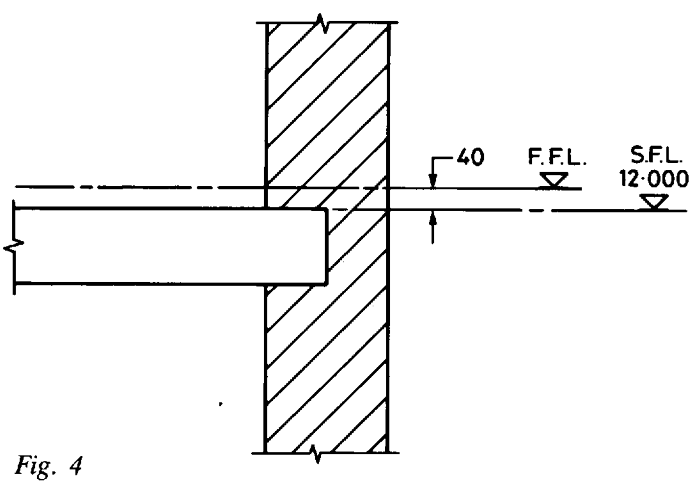


Fig. 4

2.16 Scales

Scales should be expressed as, for example, 1:10 (one to ten). The following scales are recommended as a suitable for concrete work:

general arrangements	1:100
wall and slab detail	1:50
beam and column elevations	1:50
beam and column sections	1:20

Where larger scales are required, the preferred scales specified in BS 1192 are: 1:20, 1:10, 1:5, 1:2 or full size.

2.17 Plans

Plans should be drawn in such a way as to illustrate the method of support below, which should be shown as broken lines. This is achieved if one assumes a horizontal section drawn immediately above the surface of the structural arrangement or component. Dimension lines should be kept clear of the structural details and information.

2.18 Elevations

An elevation on a portion of a structure will normally be taken as a vertical cut immediately adjacent to the element under consideration. Structural members cut by the section should be shown in full lines. Other connecting members behind the member being detailed should be shown by broken lines.

2.19 Sections

Where sections are taken through structural elements, only the material in the cutting plane is shown on a section; in general a cut showing features beyond should not be used. For clarity, the cut member may be shaded. The directions of sections should be taken looking consistently in the same direction, looking towards the left for beams and downwards for columns. A section should be drawn as near as possible to the detail to which it relates.

2.20 Grid lines and a recommended reference system

A grid system provides a convenient datum for locating and referencing members, since columns are usually placed at or near the intersection of grid lines.

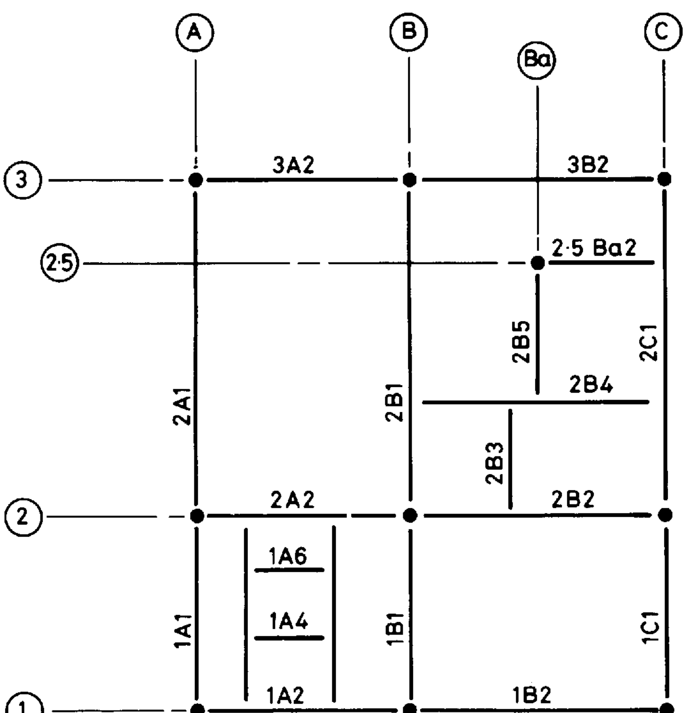


Fig. 5 Framing plan sketch

Grid notation should be agreed with the architect and would normally be numbered 1, 2, 3, etc. in one direction, and lettered A, B, C, ... X, Y, Z, AA, AB, etc. (omitting I and O) in the other direction. These sequences should start at the lower left corner of the grid system. Supplementary grids, if required, can be incorporated within the system and identified as follows: Aa, Ab, Ac, Ba, 2.5, 4.2, etc.*

Referring to the framing plan sketch Fig. 5:

all beams within a floor panel are referenced from the column situated in the lower left corner of that panel, e.g. *column* reference 2B occurs at the intersection of grids 2 and B.

each *beam* reference includes the column reference plus a suffix number, e.g. 2B1, 2B3, etc. for beams spanning up the panel, and 2B2, 2B4, etc. for beams across the panel.

Similarly for supplementary column 2.5 Ba.

This format is similar to the system used successfully for structural steelwork. Beams should be labelled on the general arrangement drawing, particularly off-grid members. Beams on grid lines may have their labels omitted, in which case strings of beams are described as follows:

e.g. beams along grid line 2/A to C

2.21 Procedure for checking drawings and schedules

All drawings and bar and fabric schedules must be checked by a competent person other than the detailer. The checking of drawings falls into 3 stages:

Stage 1: Design check

That the drawing correctly interprets the design as described as described in and supported by the checked calculations.

Stage 2: Detailing check

That the drawing has been prepared in accordance with current standards and meets the requirements of that particular job. That the information agrees with the general arrangement and other associated drawings and bar and fabric schedules, with particular reference to dimensions, termination of reinforcement, construction details, notes, etc., and that the details shown can, in practice, be constructed.

Where drawings are traced they must be checked to ensure they have been traced correctly, and where the layout of the drawing has been rearranged on the tracing, that the traced drawing continues to convey the intentions of the originator to the user.

Stage 3: Overall check

That the checks under stages 1 and 2 have been carried out. That the drawing is in all respects suitable for its purpose and truly reflects the requirements of the project.

Each drawing should have a 'box' containing the name of the draughtsman and checker.

Standard checking lists may be a useful aid but must not be considered a complete check, since no checklist can be totally comprehensive. Set out below are some items that could be used to form the basis for a checklist.

1. Is general presentation and orientation correct?
2. Are title, scales, drawing numbers correct?
3. Are revision letters correct and location of revisions shown?
4. Are sufficient sections and details given?
5. Are general notes complete and can they be understood?
6. Is spelling correct?

* After completion of the sketch above and then all the other sketches BS 1192 was published and it required the use of letters vertically and numbers horizontally.

7. Have all standards and codes of practice been complied with?
8. Are setting out dimensions correct?
9. Check dimensions?
10. Do running dimensions agree with overall dimensions?
11. Can materials specified be obtained?
12. Do number, sizes and reinforcement agree with the relevant calculations and other drawings?
13. Has cross-referencing to other drawings and bar and fabric schedules been provided?
14. Where applicable is 'no. off' correct?
15. Are chamfers, fillets and drips and similar features shown?
16. Are all projections reinforced?
17. Is the cover specified and correct?
18. Are splices and laps in correct position?
19. Do splices suit construction joints?
20. Is there congestion of reinforcement?
21. Are large-scale details required?
22. Are cranks required where bars cross?
23. Is layering of reinforcement correct both on plan and section?
24. Is reinforcement required for anti-crack or fire resistance?
25. Do hooks foul other reinforcement?
26. Are schedules correct?
27. Have drawings been signed by the detailer and checker?

Method of checking

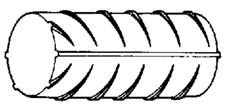
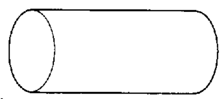
It is useful to adopt a standard checking system using different coloured pencils. A suggested colour system would be:

blue — correct
red — additions and corrections.

When the amendments have been completed the finished drawing must be checked against the check print.

3 Data for detailers

3.1 Bar reinforcement
Two main types of bar are available:

Appearance	yield strength (grade) N/mm^2	BS	abbreviated reference letter
 (Transverse ribs with or without two longitudinal ribs)	460	4449 (deformed type 2)	T
Plain round  (Plain round)	250	4449	R

Other types are as defined in job specification; the abbreviated reference letter is X

Note 1: Square twisted bars and chamfered square twisted bars to BS 4461 (deformed type 1) are obsolete.

Note 2: BS 8110 states:
'Different types of reinforcement, each complying with the British Standard, may be used in the same structural member.'

3.2 Sizes of reinforcing bars
Preferred sizes of high-yield (grade 460) reinforcing bars are 8, 10, 16, 20, 25, 32 and 40mm. Size 6 is not freely available owing to low demand and infrequent rollings. Size 50 is not generally stocked by fabricators but can be available to order and is dependent on rolling programmes. Since off-cuts of 50mm are useless, the size tends to be ordered cut to length from the mill and requires careful planning. Consideration should be given to using the freely available size 40 in bundles where size 50 would otherwise be used. Grade 250 (mild steel) bars are available in sizes 8, 10, 12 and 16mm.

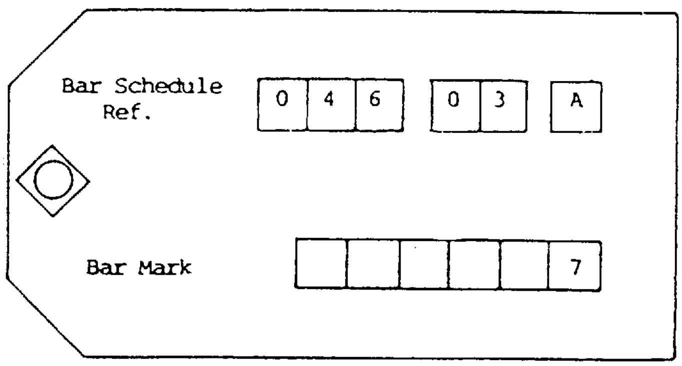
(For weights and cross-sectional areas see Tables 6 to 10 at the end of this Section.)

3.3 Overall dimensions of reinforcing bars
Standard length of bars available from stock is 12m (12mm and above) or for smaller sizes (8, 10mm) 8, 9 or 10m. The maximum length of bar available and transportable is 18m, but extra costs and delays may be involved if 12m lengths are exceeded.

For a bent bar to be transportable the shape should be contained by an imaginary rectangle where the shortest side does not exceed 2.75m.

The word 'size' rather than 'diameter' is used to describe the nominal size of a bar. For example, on a size 20 deformed bar no cross-dimension measures 20mm because of the surface deformations. Most deformed bars can be contained in a circumscribing circle 10% more than the nominal size of the bar, however, because of variations in rib size individual sections can measure 13% or 14% more than the nominal size at the largest cross-dimension (see p. 19).

3.4 Shop practice
For schedules and scheduling, see Section 4. Labels attached to bundles of bars by the fabricator and BS 4466 requires that the following information is contained on them:



3.5 Properties of reinforcing bars
The cross-sectional areas, weights and perimeter tabulated are basically for plain round bars. For bars to BS 4449 having projected transverse rib areas of less than 3% by mass, the same areas, weights and perimeters apply.

The effective perimeter of a bar may be taken as 3.14 times its nominal size.

3.6 Rebending bars
Rebending grade 460 bars on site should not be permitted. Grade 250 bars not exceeding 12mm in size may be used for this purpose (e.g. for connecting stairs of half-landing to walls) provided that care is taken not to reduce the radius of bend below twice the bar size. It is impractical to bend larger sizes of higher grades without the possibility of reducing the strength of the bars at some point (usually where cast-in bars emerge from the concrete).

3.7 Fabric reinforcement
For detailing and scheduling, see Section 4. For British Standard fabrics, see Table 10 at the end of this Section.

3.8 Large radius bends (BS 8110, clause 3.12.8.26)
The designer will normally be responsible for the calculation of large radius bends, but the detailer should be aware of their existence and should be able to recognize the difference between the occasion when a large radius bend is required and when a standard bend is required. For further guidance on large radius bends see Appendix 3A.

3.9 Cover

3.9.1 Nominal cover reinforcement

Cover should be specified on the drawings as 'nominal cover to all steel'. Nominal cover to all steel reinforcement (including links) should be determined by considerations of fire resistance and durability in envisaged conditions of exposure. The actual minimum cover to all reinforcement may be up to 5mm less than the nominal cover.

The nominal cover to a link should be such that the resulting cover to the main bar is at least equal to the size of the main bar (or to a bar of equivalent size in the case of pairs or bundles of three or more bars). Where no links are present, the nominal cover should be at least equal to the size of the bar.

Where special surface treatments are used (e.g. bush hammering), the expected depth of treatment should be added to the nominal cover.

Sufaces subject to moisture, washing down, etc. should be considered as subject to moderate exposure.

Nominal cover as specified in BS 8110 is given in Tables 1 to 5; for equivalent data on bridges see BS 5400.

Nominal covers should not be less than the maximum (nominal) aggregate size.

The categories of exposure in the durability tables in BS 8110 are defined as:

mild: concrete surfaces protected against weather or aggressive conditions

moderate: concrete surfaces sheltered from severe rain or freezing while wet; concrete subject to condensation; concrete surfaces continuously under water; concrete in contact with non-aggressive soil

severe: concrete surfaces exposed to severe rain, alternate wetting and drying and occasional freezing, or severe condensation

very severe: concrete surfaces exposed to sea-water spray or de-icing salts directly or indirectly or corrosive fumes or severe freezing conditions while wet

extreme: concrete surfaces exposed to abrasive action, e.g. sea water carrying solids, or flowing water with pH $\leq$ 4.5, or machinery or vehicles.

Tables 1 to 5 give the nominal covers required for durability and fire protection. For further guidance on fire protection see BS 8110. Although it is not the responsibility of the detailer, Table 3 sets out, for information, the minimum dimensions of members for fire resistance.

3.9.2 Example of determining nominal cover

For a simply supported beam with mild exposure using grade 30 concrete and requiring 1½ hour fire resistance.

requirement for	BS 8110 ref.	nominal cover
main bar size 32mm link size 8mm	clause 3.3.1.2	(32-8) mm = 24mm
mild exposure	Table 3.4	25mm
1½ hour fire resistance	Table 3.5	20mm
20mm aggregate	clause 3.3.1.3	20mm

Adopt 25mm nominal cover
Specify 25mm as nominal size of spacers

3.9.3 Tolerance on cover

Cover to reinforcement is liable to variation on account of the cumulative effect of inevitable small errors in the dimensions of formwork and the cutting, bending and fixing of the reinforcement.

All reinforcement should be fixed to the nominal cover specified on the drawings. The permissible tolerance should be as follows:

- the actual concrete cover should be not less than the specified cover minus 5mm (Note: the expressions 'nominal cover', 'cover' and 'specified cover' are used interchangeably, but they all mean 'absolute minimum cover +5mm).
- where reinforcement is located in relation to only one face of a member (e.g. a straight bar in a slab) the actual concrete cover should not be more than the required nominal cover plus:

5mm on bars up to and including 12mm size
10mm on bars over 12mm up to and including 25mm size
15mm on bars over 25mm size.

3.9.4 Achieving the required cover

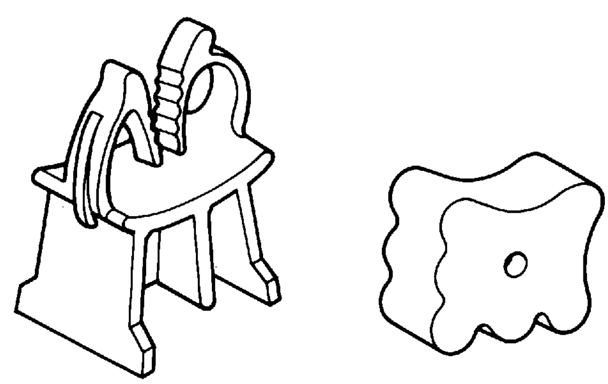
Non-structural connections for the positioning of reinforcement should be made with steel wire, tying devices or by welding. It is not necessary to tie or weld every bar intersection provided that rigidity of the cage or mat can be obtained while the concrete is being placed and vibrated.

Layers of bars in beams can be separated by means of short lengths of bar. The spacing along the beam should be specified on the drawings (usually 1m), and the bar spacers should be detailed on the schedules.

There are two main views among designers on how spacers and chairs should be dealt with. Some believe that the method of achieving cover and position should be left entirely to the contractor, while others specify spacers and detail chairs. In practice, insufficient attention is paid to the importance of achieving cover. If bent reinforcing bars (e.g. shape code 83) are specified as chairs, they should be shown on the relevant bar schedules. It should be noted, however, that BS 4466: 1981 allows hard drawn wire chairs to be substituted with the designer's agreement.

Where the designer specifies the method of achieving the cover and positioning of the spacers, the following types of spacers and chairs are examples and the detailer should establish what the designer's requirements are and use the guidance below if appropriate.

The main way of maintaining cover is by the use of spacer blocks. A wide range of plastic and concrete spacers is available. Some are designed to provide two different nominal covers, and it is desirable for the nominal covers to be provided to be marked on the spacer. Examples of spacers to achieve bottom cover are shown below:



In the case of concrete spacers, the concrete should be comparable in strength, durability, porosity and appearance with the surrounding concrete, they should retain their strength when wet and should not contain anything harmful to concrete, steel or hands. Site-manufactured concrete or mortar spacers should not be used.

The type of formwork to be used and the finished face required may also influence the choice of spacer. Trials may be necessary if a particularly high grade of finish is required. The spacing is usually a matter of trial and will

Table 1 Nominal cover (in mm) to all reinforcement (including links) to meet durability requirements (see note)

conditions of exposure	*nominal cover*				
	mm	mm	mm	mm	mm
mild	25	20	20*	20*	20*
moderate	—	35	30	25	20
severe	—	—	40	30	25
very severe	—	—	50	40†	30
extreme	—	—	—	60†	50
maximum free water/cement ratio	0.65	0.60	0.55	0.50	0.45
minimum cement content, kg/m^3	275	300	325	350	400
lowest grade of concrete	C30	C35	C40	C45	C50

* These covers may be reduced to 15mm provided that the nominal maximum size of aggregate does not exceed 15mm.
† Where concrete is subject to freezing while wet, air-entrainment should be used.

Note: This Table relates to normal-weight aggregate of 20mm nominal maximum size.

Table 2 Nominal cover (in mm) to all reinforcement (including links) to meet specified periods of fire resistance for reinforced concrete (see notes 1 and 2)

fire resistance period h	*beams* simply supported	continuous	*floors* simply supported	continuous	*ribs* simply supported	continuous	*columns*
½	20**	20**	20**	20**	20**	20**	20**
1	20**	20**	20	20	20	20	20**
1½	20	20**	25	20	35	20	20
2	40	30	35	25	45	35	25
3	60	40	45	35	55	45	25
4	70	50	55	45	65	55	25

** These covers may be reduced to 15mm provided that the nominal maximum size of aggregate does not exceed 15mm.

Note: 1: The nominal covers given relate specifically to the minimum member dimensions given in Table 3. Guidance on increased covers necessary if smaller members are used is given in BS 8100: Part 2.
Note 2: Cases that that are stippled require additional measures necessary to reduce the risks of spalling (see BS 8110: Part 2: Section 4).

Table 3 Minimum dimensions (in mm) of reinforced concrete members for fire resistance

fire resistance h	*beams* min. width b	*ribs* b	*floors* min h (for open soffit) b	*columns* (dimension b) fully exposed	50% exposed	one side exposed	*walls* (minimum thickness) p<0.4%	p<1%	p>1%
½	80	125	75	150	125	100	150	100	75
1	120	125	95	200	160	120	150	120	75
1½	150	125	110	250	200	140	175	140	100
2	200	125	125	300	200	160	200	160	100
3	240	150	150	400	300	200	—	200	150
4	280	175	170	450	350	240	—	240	180

Note: p is the cross-sectional area of the steel relative to that of concrete

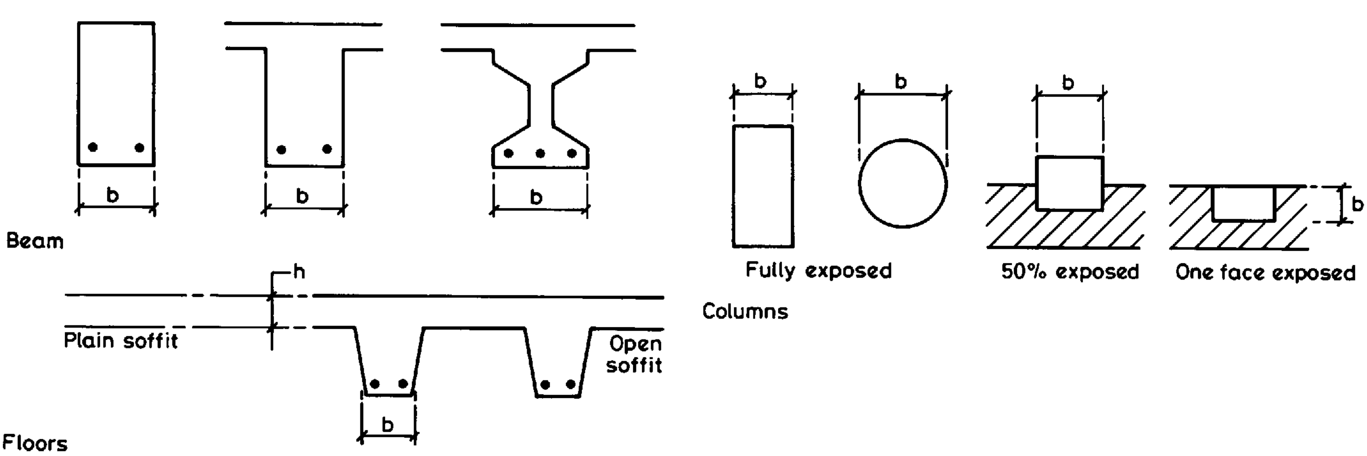


Table 4 Nominal cover (in mm) to all steel (including links) to meet durability requirements for prestressed concrete

conditions of exposure	*nominal cover*			
	mm	mm	mm	mm
mild	20	20*	20*	20*
moderate	—	30	25	20
severe	—	40	30	25
very severe	—	50†	40†	30
extreme	—	—	60†	50
maximum free water/cement ratio	0.60	0.55	0.50	0.45
minimum cement content, kg/m^3	300	325	350	400
lowest grade of concrete	C35	C40	C45	C50

* These covers may be reduced to 15mm provided that the nominal maximum size of aggregate does not exceed 15mm.
† Where concrete is subject to freezing while wet, air-entrainment should be used.

Note: This table relates to normal-weight aggregate of 20mm nominal maximum size.

Table 5 Nominal cover (in mm) to all steel to meet specified periods of fire resistance for prestressed concrete (see Notes 1 and 2)

fire resistance h	*beams* simply supported	continuous	*floors* simply supported	continuous	*ribs* simply supported	continuous
½	20**	20**	20	20	20	20
1	20	20**	25	20	35	20
1½	35	20	30	25	45	35
2	60	35	40	35	55	45
3	70	60	55	45	65	55
4	80	70	65	55	75	65

** These covers may be reduced to 15mm provided that the nominal maximum size of aggregate not exceed 15mm.

Note: The nominal covers given relate specifically to the minimum member dimensions given in table 3. Guidance on increased covers necessary if smaller members are used is given in BS 8110: Part 2.
Note 2: Cases that are stippled require attention to the additional measures necessary to reduce the risks of spalling (see BS 8110: Part 2).

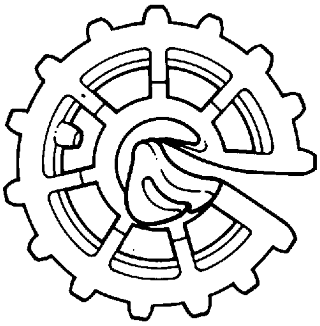
** For the purposes of assessing a nominal cover for beams and columns, the cover to main bars, which would have been obtained from the tables in BS 8110: Part 2, have been reduced by a notional allowance.

Tendon in ducts. The cover to any duct should be not less than 50mm. Precautions should be taken to ensure a dense concrete cover, particularly with large or wide ducts.

External tendons. Where these are to be protected by dense concrete of at least grade C40, added subsequently, the thickness of this cover should not be less than that required for tendons inside the structural concrete in similar conditions. The concrete cover should be anchored by reinforcement to the prestressed member and should be checked for crack control in accordance with Section 3 of BS 8110.

depend on the strength of the spacer, the size and centres of the reinforcement and the loadings applied to it, the bearing area and the type of formwork. Spacers will not usually be further apart than 1m each way or closer than, say, 0.5m each way.

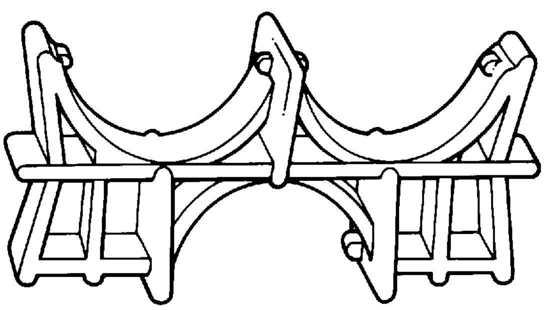
An example of a spacer for vertical application is shown below:



The Concrete Society will be publishing a document on spacers, which will represent the latest views.

3.9.5 Achieving the correct position

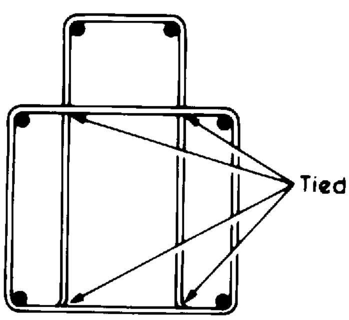
Provided that the correct cover is achieved, the lateral location of the steel in horizontal and vertical members is not usually critical. A different situation arises, however, in a ribbed floor, and here it is desirable to indicate the use of a spacer that will both locate the steel and provide cover. An example is shown below:



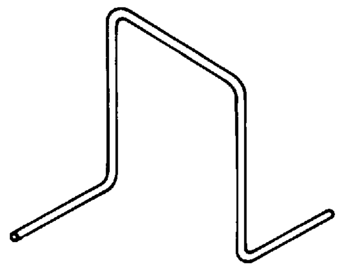
Where 2 bars are used in a rib, links should be provided to locate the reinforcement.

The correct positioning of top steel (particularly important in cantilevers) can be achieved by one of the following five basic methods:

1. with specially shaped reinforcement, which may be tied or welded to other reinforcement

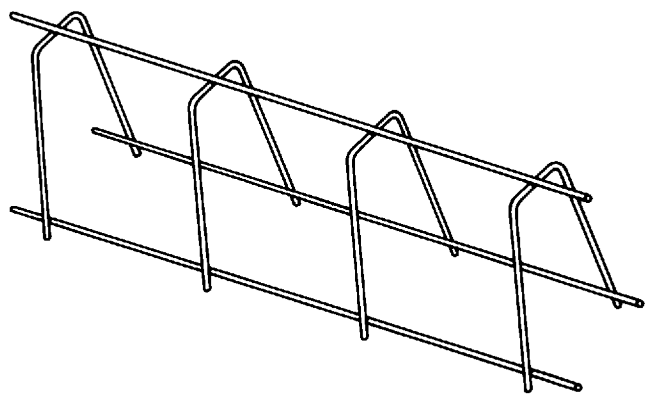


2. by the use of 'goalposts' at specified centres (if specified they should be fully detailed on the bar schedule)

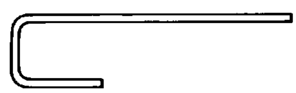


3. by the use of high wire chairs

4. by the use of continuous high wire chairs



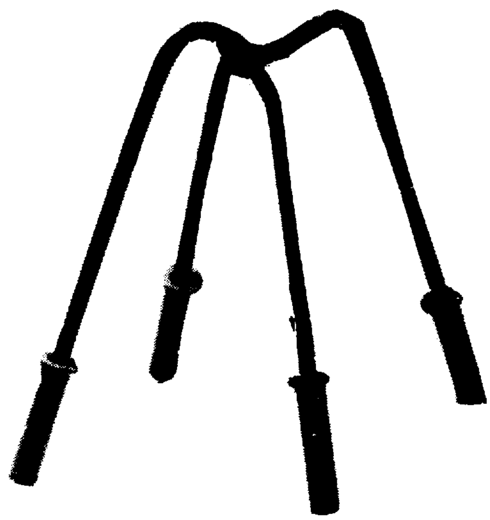
5. by the use of 'trombone' shapes. (shape code 38).



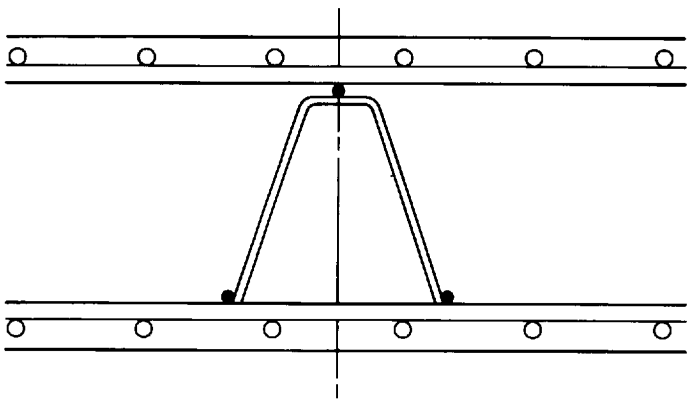
For methods 1, 2 and 5 the bars are usually supplied by the reinforcement fabricator, and if they are shown on the drawings they must also be included in the bar schedules

Chairs should be designed to support the main steel and the weight of workmen walking on it during construction. It need not, normally, be designed to take other construction loads, since other loading ought not to occur. The size of bar used and the centres of the chairs will vary with the height of chair required and the weight to be supported. A minimum size of R10 is recommended for slabs, but this may have to be increased substantially for heavy reinforcements. The centres of chairs should be specified on the reinforcement detail drawings and should not normally exceed about 1m in two directions at right-angles. A sufficient number of chairs should be included on the bar schedules to allow some flexibility in sequence of construction.

For method 3 (high wire chairs) similar considerations apply, but 4 or 5mm hard drawn wire is usually used to manufacture such high chairs and a typical design looks like this:



Method 4 (continuous high chairs) is growing in the UK because of the saving in steel fixing time. Such continuous chairs are used to space two layers of steel. Typical designs look like this. The chairs are designed using 4 or 5mm hard drawn wire and are available in 1m lengths; they are usually fixed at about 1m centres.



Vertical steel can be spaced using horizontal U-bars (not less than R6), but if they are specified they should be included on the bar schedules. Two layers of vertical steel in walls should be kept apart by horizontal U-type spacers of suitable size (not less than R6). Sufficient spacers should be used to ensure the rigidity of the reinforcement. The size of reinforcement will not only determine the length of the vertical bars but will, in conjunction with the height of the lift, determine the number and size of spacers. At least one horizontal line of spacers should be employed in each lift of concrete, and the spacers should be included on the bar schedules.

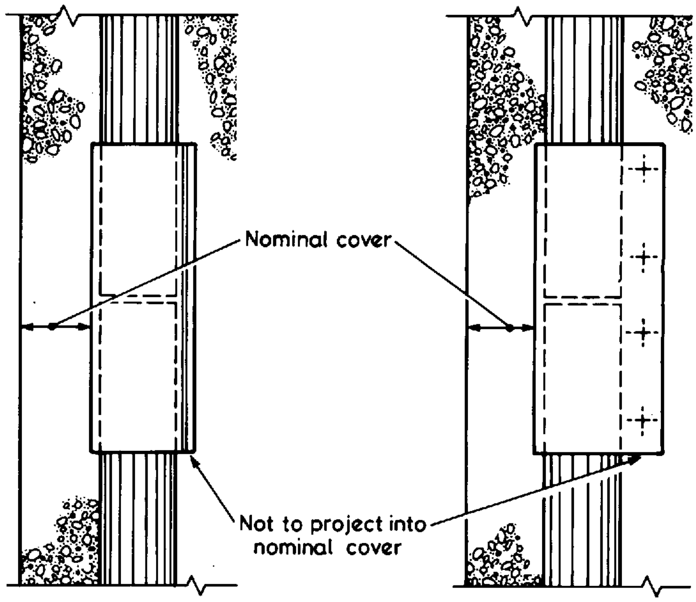
3.10 Anchorage lap lengths and shear reinforcement

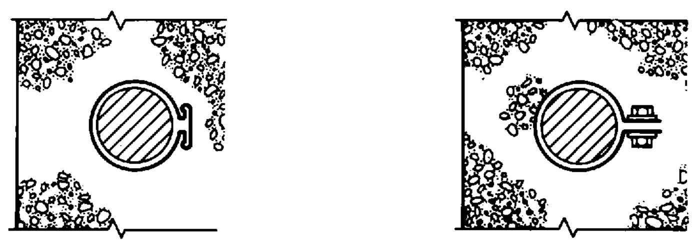
These should be determined by the designer, Appendix 3B gives equivalent straight anchorage lengths, hooks and bends, and minimum overall depths of various U-bars.

3.11 Full-strength joints in reinforcing bars (BS 8110, clause 3.12.8.8.)

3.11.1 Compression

For joints entirely in compression the two types of sleeves illustrated below are available.





It is necessary to square saw-cut the bar ends so that any gap after butting the bars does not exceed 3°. Sleeves for 20mm size bars and larger are available. To cater for the possibility of some tensile forces it is desirable to stagger compression joints or provide a small size bar (say, T10) as a splice lapping across the joint.

The normal cover requirements for durability and for fire should apply from the outside face of the coupler and not from the reinforcement bar. Normally the cover specified to the links or stirrups will ensure adequate cover to the coupler.

3.11.2 Tension

1. tapered threaded couplers (10mm and above)
2. swaged couplers (16mm rubbed and above)
3. sleeves filled with molten metal (12mm rubbed and above)
4. welding (butt, lap or splice joints)

Method 1 is essentially a factory-based operation with the threads being tightened on site; however the threading can be carried out on site for larger projects. Methods 2, 3 and 4 are site operations in their basic form. However, by introducing an intermediate stud, method 2 can be swaged in the factory and tightened on site.

Methods 3 and 4 are applicable to both straight and bent bars, but with the basic threaded (1) and basic swaged (2) methods, the second bar to be fixed must be straight. Modified versions of both methods are available where the

Table 6 Cross-sectional areas of bars at specific spacings in mm² per m width:

bar size mm	bar spacing, mm 50	75	100	125	150	175	200	250	300
6*	566	377	283	226	188	162	141	113	94
8	1 066	670	503	402	335	287	251	201	168
10	1 570	1 047	786	628	524	449	393	314	262
12	2 262	1 508	1 131	905	754	646	565	452	377
16	4 022	2 681	2 011	1 608	1 340	1 149	1 005	801	670
20	—	4 189	3 142	2 513	2 094	1 795	1 571	1 257	1 047
25	—	6 545	4 909	3 927	3 272	2 805	2 454	1 963	1 636
32	—	—	8 042	6 434	6 362	4 596	4 021	3 217	2 681
40	—	—	—	10 053	8 378	7 181	6 283	5 027	4 189
50*	—	—	—	—	13 090	11 220	9 617	7 854	6 545

* non-prefered sizes, but given for sake of completeness

Table 7 Cross-sectional areas in square millimetres of specific numbers of bars (and perimeters)

size mm	number of bars 1	2	3	4	5	6	7	8	9	10	perimeter mm
6*	28.3	56.5	84.8	113	141	170	198	226	255	283	18.85
8	50.3	100	151	201	251	302	352	402	452	503	25.13
10	78.5	157	236	314	393	471	550	628	707	785	34.12
12	113.1	226	339	452	566	679	792	905	1 018	1 131	37.70
16	201.1	402	603	804	1 005	1 206	1 407	1 608	1 810	2 011	50.27
20	314.2	628	942	1 257	1 571	1 885	2 199	2 513	2 827	3 142	62.83
25	490.9	982	1 473	1 963	2 454	2 945	3 436	3 927	4 418	4 909	78.54
32	804.2	1 608	2 413	3 217	4 021	4 825	5 630	6 434	7 238	8 042	100.5
40	1 257	2 513	3 770	5 026	6 283	7 540	8 790	10 053	11 310	12 566	125.7
50*	1 963.5	3 927	5 890	7 854	9 812	11 781	13 744	15 708	17 671	18 635	157.1

* non-preferred sizes, but given for sake of completeness

Table 8 Actual size of deformed bars

nominal bar size	6	8	10	12	16	20	25	32	40
maximum bar size 'a'	8	11	13	14	19	23	29	37	46

Table 9 Weights of bars in kilogrammes per square metre (reinforcement in one direction only)

bar size mm	weight per metre kg	length per tonne m	spacing of bars in millimetres 50	75	100	125	150	175	200	250	300
6*	0.222	4 605	4.440	2.960	2.220	1.776	1.480	1.269	1.110	0.888	0.740
8	0.395	2 532	7.900	5.267	3.950	3.160	2.633	2.257	1.975	1.580	1.317
10	0.616	1 823	12.320	8.213	6.160	4.928	4.107	3.520	3.080	2.464	2.053
12	0.888	1 126	17.760	11.84	8.880	7.104	5.920	5.074	4.440	3.552	2.960
16	1.579	633	31.580	21.05	15.79	12.63	10.53	9.023	7.895	6.316	5.263
20	2.466	406	—	32.88	24.66	19.73	16.44	14.09	12.33	9.864	8.220
25	2.854	259	—	51.39	38.54	30.83	25.69	22.02	19.27	15.42	12.85
32	6.313	158	—	—	63.13	50.50	42.09	36.07	31.57	25.25	21.04
40	9.864	101	—	—	—	78.91	65.76	56.37	49.32	39.46	32.88
50*	15.413	65	—	—	—	—	102.75	88.07	77.06	61.65	51.38

* non-preferred sizes

Table 10 Equivalent bar sizes

size mm	2 bars total area mm^2	2 bars equivalent size mm	3 bars total area mm^2	3 bars equivalent size mm	4 bars total area mm^2	4 bars equivalent size mm
16	402	23	603	28	804	32
20	628	28	943	35	1260	40
25	982	35	1470	43	1960	50
32	1610	45	2410	55	3220	64
40	2510	57	3770	69	5030	80
50	3927	71	5890	87	7854	100

Table 11 Designated fabric (BS 4483)

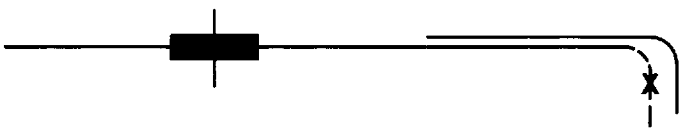
type of fabric	size of mesh mm × mm	BS ref. no.	weight kg/m^3	size mm	cross-sectional area mm^2/m	size mm	cross-sectional area mm^2/m	notes
		A98	1.54	5	98	5	98	fabric made in either hard-drawn wire (BS 4482) or bars (BS 4449)
		A142	2.22	6	142	6	142	
square mesh	200 × 200	A193	3.02	7	193	7	193	
		A252	3.95	8	252	8	252	
		A393	6.16	10	393	10	393	exceptions: A98 and all long-mesh fabrics and main wires of B196, plain hard drawn wire only.
		B196	3.05	5	196			
		B283	3.73	6	283	7	193	
		B385	4.53	7	385			
structural mesh	100 × 200							stock sheets 2.4m wide 4.8m long
		B503	5.93	8	503			
		B785	8.14	10	785	8	252	
		B1131	10.90	12	1131			
		C283	2.61	6	283			
		C385	3.41	7	385	5	49	
		C503	4.34	8	503			
long mesh	100 × 400							
		C636*	5.55	9	636	6	71	
		C785	6.72	10	785			
wrapping	100 × 100	D31	0.49	2	31	2	31	stock sheets 2.4m × 1.2m
		D49	0.77	2.5	49	2.5	49	
	200 × 200	D98	1.54	5.0	98	5.0	98	

The BS reference number is the area of the main wires in mm^2 per metre width rounded to the nearest mm^2.

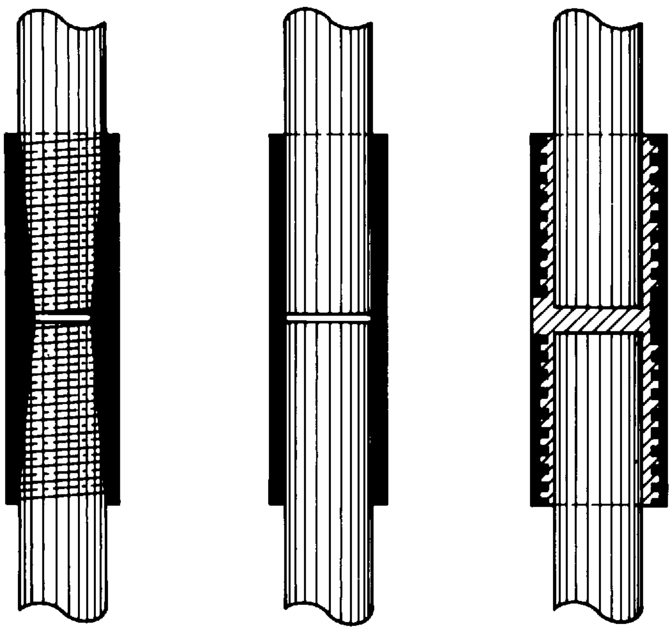
The prefix letter indicates:

- A square mesh
- B structural mesh (cross wires to comply with BS 8110)
- C long mesh (light cross wires)
- D wrapping fabric
- X other fabrics

second bar is bent and cannot therefore be rotated, but by careful detailing it is usually possible to use the second bar in a straight form, e.g. where the second bar would have been bent to provide a nominal end anchorage it is often possible to lap a small size bar instead. A slim version of method 1 is available with approximately the same overall diameter as a ribbed bar.



Where a bent second bar is completely unavoidable it may be possible to join it to the first bar before the first bar is concreted into position.



1 2 3

Grade 250 and grade 460 bars are defined as readily weldable in BS 4449.

Full-strength welds can be obtained with both grades of bars. It is a common fallacy that cold-worked bars revert to mild steel, but this is not true for the time/temperature input associated with welding. Care needs to be taken to ensure that properly qualified welders carry out all welding of full strength joints in reinforcement.

Metal-arc butt weld with double-V preparation

15 × bar size with two metallic-arc fillet welds 5 × bar size in length

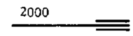
Butt weld with fillet weld 10 × bar size in length

For more information on 1 to 4, refer to CIRIA report 92 and to coupler and reinforcement suppliers.

3.11.3 Detailing joints

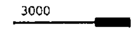
Compression joints should be detailed like this:

 (shape code 99)

and scheduled like this: 

Tension joints should be detailed like this:

 (shape code 99)

and scheduled like this: 

Since couplers do not appear in BS 4466 an explanation of the signs should be given in the general notes on each drawing and bar schedule.

Note: In all cases the detailer should assume that the bar terminates at the centre of coupler (i.e. allow for no gap). The necessary adjustments to length can then be made according the system chosen. For long runs of coupled bars (e.g. multi-storey columns), small amounts of dimensional 'creep' may occur because of the accumulative effect of tolerances, and the desired length of the final bar should be checked *in situ* before end preparation.

Appendix 3A Large-radius bends

The radius of bend is required to be greater than the standard where bars are stressed beyond a distance of four times the bar size past the end of the bend (BS 8110, clause 3.12.8.25).

Examples of where large radius bends may be required:

- end column and wall connections to beam or slab
- cantilever retaining walls
- corbels
- bottom bars for simple pile caps.

In circumstances where triaxial compressive stresses exist or where a bar is placed inside and perpendicular to the bend, it is possible to reduce the large radius of bend. In this instance the engineer should be consulted.

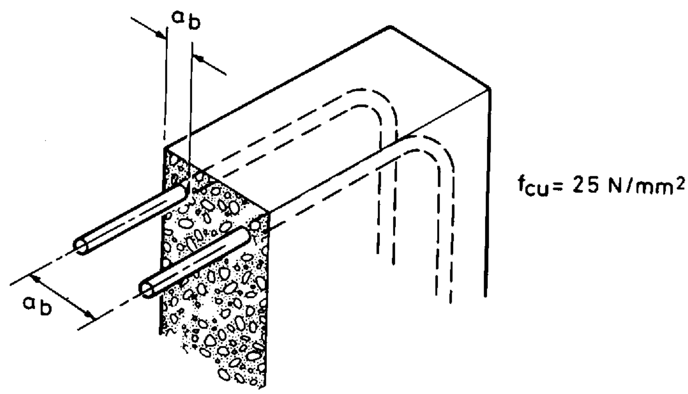


Table A1 Large-radius bends: internal radius of bend, mm

a_b mm	*design stress in bar at ultimate load* N/mm²	*bar size,* mm 10	12	16	20	25	32	40
25	100	30	35					
	150	45	55					
	200	55	75					
	250	70	90					
	300	85	110					
	350	100	130					
	400	115	150					
50	100	20	30	40	55	80		
	150	35	40	60	85	120		
	200	45	55	80	115	155		
	250	55	70	105	140	195		
	300	65	85	125	170	235		
	350	75	100	145	200	275		
	400	90	110	165	225	315		
75	100	20	25	35	50	65	95	
	150	30	35	55	70	100	140	
	200	40	50	70	95	130	185	
	250	50	60	90	120	165	235	
	300	60	75	110	145	195	280	
	350	70	85	125	170	230	325	
	400	80	100	145	195	260	375	
100	100	20	25	35	45	60	80	115
	150	30	35	50	65	90	125	170
	200	40	45	65	85	120	165	225
	250	45	60	85	110	145	205	285
	300	55	70	100	130	175	245	340
	350	65	80	115	155	205	290	395
	400	75	95	135	175	235	330	450
150 and over	100	20	25	30	40	50	70	95
	150	25	35	45	60	80	110	145
	200	35	45	60	80	105	145	195
	250	45	55	75	100	130	180	240
	300	55	65	90	120	155	215	290
	350	60	75	105	140	185	250	335
	400	70	85	120	160	210	285	385

Notes:

1. Maximum design stress = characteristic stress/1.15
   grade 250 217.4 N/mm²
   grade 460 400 N/mm²
2. Minimum radius may govern
   grade 250 2 × bar size
   grade 460 3 × bar size (≤ 20 mm)
   grade 460 4 × bar size (≥ 25 mm)

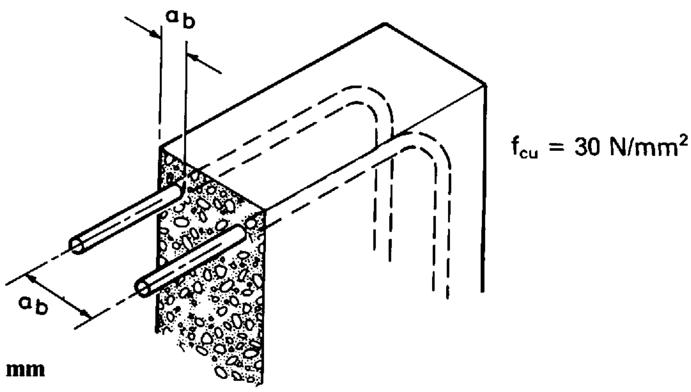


Table A2 Large-radius bends: internal radius of bend, mm

a_b mm	*design stress in bar at ultimate load* N/mm²	*bar size,* mm 10	12	16	20	25	32	40
25	100	25	30					
	150	35	45					
	200	45	60					
	250	60	75					
	300	70	90					
	350	80	110					
	400	95	125					
50	100	20	25	35	45	65		
	150	25	35	50	70	100		
	200	35	45	70	95	130		
	250	45	60	85	120	165		
	300	55	70	105	140	195		
	350	65	80	120	165	230		
	400	75	95	135	190	260		
75	100	20	25	30	40	55	80	
	150	25	30	45	60	80	115	
	200	35	40	60	80	110	155	
	250	40	50	75	100	135	195	
	300	50	60	90	120	165	235	
	350	60	75	105	140	190	270	
	400	65	85	120	160	220	310	
100	100	20	20	30	40	50	70	95
	150	25	30	40	55	75	105	140
	200	30	40	55	75	100	135	190
	250	40	50	70	90	125	170	235
	300	45	60	85	110	145	205	285
	350	55	70	95	130	170	240	330
	400	65	80	110	145	195	275	375
150 and over	100	20	20	30	40	50	65	80
	150	20	25	40	50	65	90	120
	200	30	35	50	65	85	120	160
	250	35	45	65	85	110	150	200
	300	45	55	75	100	130	180	240
	350	50	65	90	115	155	210	280
	400	60	75	100	135	175	240	320

Notes:

1. Maximum design stress = characteristic stress/1.15
   grade 250 217.4 N/mm²
   grade 460 400 N/mm²
2. Minimum radius may govern
   grade 250 2 × bar size
   grade 460 3 × bar size (≤ 20 mm)
   grade 460 4 × bar size (≥ 25 mm)

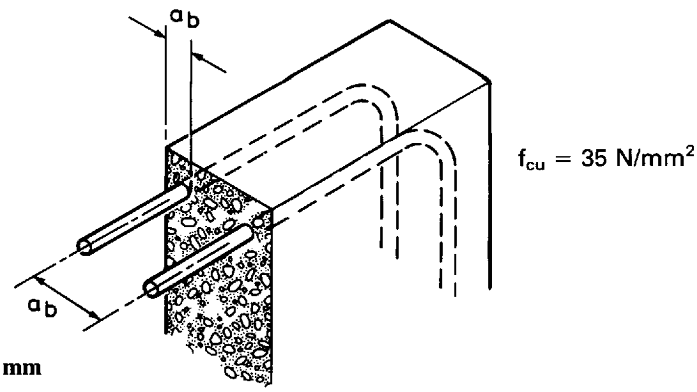


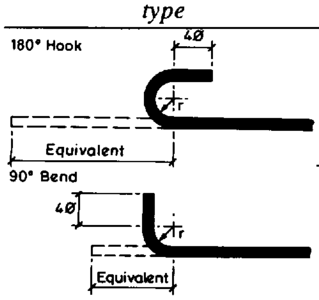
Table A3 Large-radius bends: internal radius of bend, mm

a_b mm	*design stress in bar at ultimate load* N/mm^2	*bar size,* mm 10	12	16	20	25	32	40
25	100	20	25					
	150	30	40					
	200	40	55					
	250	50	65					
	300	60	80					
	350	70	90					
	400	80	105					
50	100	20	25	30	40	55		
	150	25	30	45	60	85		
	200	30	40	60	80	110		
	250	40	50	75	100	140		
	300	45	60	90	120	170		
	350	55	70	105	140	195		
	400	65	80	120	160	225		
75	100	20	25	30	40	50	65	
	150	20	25	40	50	70	100	
	200	30	35	50	70	95	135	
	250	35	45	65	85	115	165	
	300	45	55	75	105	140	200	
	350	50	60	90	120	165	235	
	400	55	70	100	140	185	265	
100	100	20	25	30	40	50	65	80
	150	20	25	35	45	65	90	120
	200	25	35	45	65	85	120	160
	250	35	40	60	80	105	145	200
	300	40	50	70	95	125	175	240
	350	45	60	85	110	145	205	285
	400	55	65	95	125	170	235	325
150 and over	100	20	25	30	40	50	65	80
	150	20	25	35	45	55	75	105
	200	25	30	45	55	75	100	140
	250	30	40	55	70	95	130	170
	300	40	45	65	85	110	155	205
	350	45	55	75	100	130	180	240
	400	50	60	85	115	150	205	275

Notes:
1. Maximum design stress = characteristic stress/1.15
   grade 250 217.4 N/mm^2
   grade 460 400 N/mm^2
2. Minimum radius may govern
   grade 250 2 × bar size
   grade 460 3 × bar size (≤ 20 mm)
   grade 460 4 × bar size (≥ 25 mm)

Appendix 3B Anchorage and lap lengths
(BS 8110, clause 3.12.8)

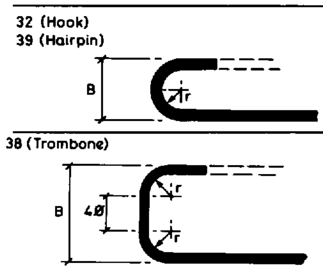
Table B1 Equivalent straight anchorage lengths of standard hooks & bends, mm



anchorage type	*value*	f_y N/mm^2	*bar size,* mm 8	10	12	16	20	25	32	40
180° Hook	16Ø	250	128	160	192	256	320	400	512	640
	24Ø	460	192	240	288	384	480	600	768	960
90° Bend	8Ø	250	64	80	96	128	160	200	256	320
	12Ø	460	96	120	144	192	240	300	384	480

Note: These values are *not* hook allowances for forming 180° hooks, or bend allowances for forming 90° bends.
Ø = bar size, mm

Table B2 Minimum overall depth of various U-bars, mm



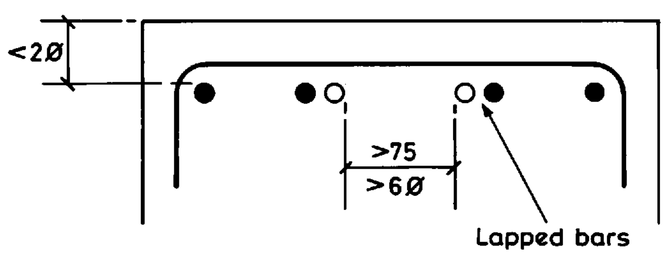
shape code	*B*	*r*	f_y N/mm^2	*bar size,* mm 8	10	12	16	20	25	32	40
32 (Hook) 39 (Hairpin)	6Ø	2Ø	250	50	60	75	100	120	150	195	240
	8Ø	3Ø	460	65	80	100	130	160	–	–	–
	10Ø	4Ø	460	–	–	–	–	–	250	320	400
38 (Trombone)	10Ø	2Ø	250	80	100	120	160	200	250	320	400
	12Ø	3Ø	460	100	120	145	195	240	–	–	–
	14Ø	4Ø	460	–	–	–	–	–	350	450	560

Tension laps (BS 8110, clause 3.12.8.13)

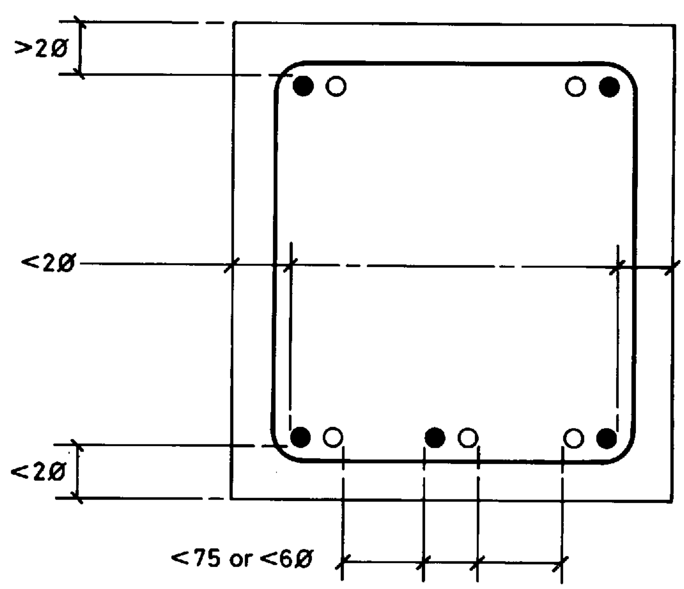
Tension laps should be at least equal in length to the anchorage length necessary to develop the design stress in the bars. If the lapped bars are of unequal size, then the lap length is based on the size of the smaller bar. Furthermore:

(a) The lap length is increased to 1.4 × anchorage length (see Tables B4 to B7) if:

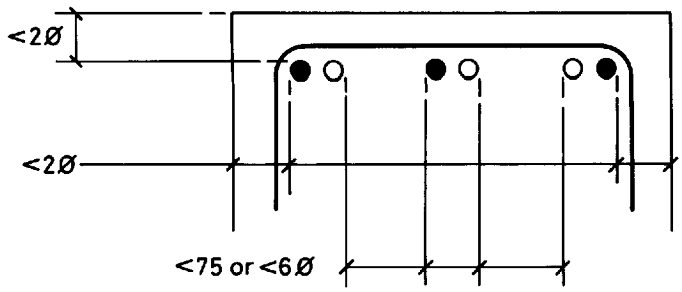
(i) the minimum cover to lapped bars in the top of a section as cast is less than 2 × bar size, or



(ii) the minimum cover to lapped corner bars (not in top) of a section is less than 2 × bar size, or



(iii) the clear distance between adjacent laps is less than 75 mm or 6 × bar size, whichever is greater.



(b) The lap length is increased to 2.0 × anchorage length (see Tables B4 to B8) if conditions *(a)* (i) and (ii) above apply.

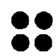
Compression laps (BS 8110, clause 3.12.8.15)

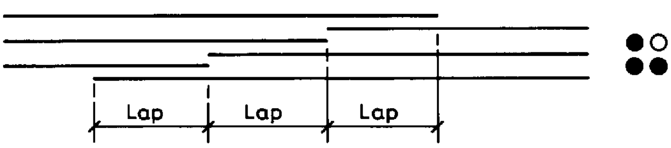
The length of the compression lap should be 1.25 × the compression anchorage length necessary to develop the design stress in the bars (see Tables B4 to B7).

Lapping of bundled bars

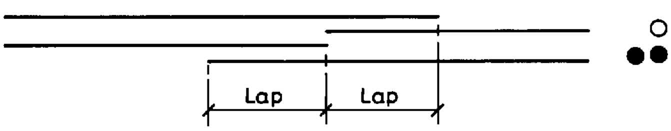
(BS 8110, clause 3.12.4.1)

At laps no more than four bars may be in contact.

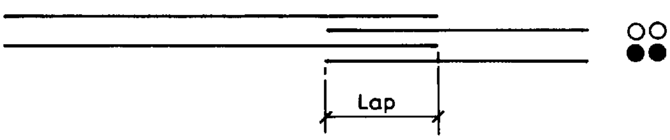




For bundles of three bars, laps should be staggered.



For bundles of two bars (pairs), laps are preferably staggered.



Where bundles of two barss are lapped but not staggered, then the lap length will be based on the equivalent diameter of the two bars. Otherwise the lap length is based on the value of the single bar.

Anchorage and lap lengths (BS 8110, clause 3.12.8)

(For lap lengths in accordance with BS 8007: 1987, see Section 9).

Grade 250 (mild-steel plain bar to BS 4449)

Design ultimate stress in tension or compression = $0.87f_y$ = 217.5 N/mm^2
Design ultimate anchorage bond stress f_{bu}

f_{cu}, N/mm^2	25	30	35	40
tension	1.4	1.53	1.66	1.77
compression	1.75	1.92	2.07	2.21

Table B3

size of bar, mm		8	10	12	16	20	25	32	40
tension anchorage = $0.87f_y \times \varnothing/4f_{bu}$, mm									
f_{cu}	25	310	390	465	620	775	975	1245	1555
	30	285	355	425	570	710	885	1135	1420
	35	265	330	395	525	655	820	1050	1315
	40	245	310	370	490	615	770	985	1230
compression anchorage = $0.87f_y \times \varnothing/4f_{bu}$, mm									
f_{cu}	25	250	310	375	500	620	775	995	1245
	30	225	285	340	455	565	710	910	1135
	35	210	265	315	420	525	655	840	1050
	40	195	245	295	395	490	615	785	985
tension lap = tension anchorage, 15$\varnothing$ or 300 mm, whichever is greatest									
f_{cu}	25	310	390	465	620	775	970	1245	1555
	30	300	355	425	570	710	885	1135	1420
	35	300	330	395	525	655	820	1050	1315
	40	300	305	370	490	615	770	985	1230
tension lap × 1.4 (BS 8110, clause 3.12.8.13)									
f_{cu}	25	435	545	650	870	1085	1360	1740	2175
	30	395	495	595	795	995	1240	1590	1985
	35	370	460	550	735	920	1150	1470	1840
	40	345	430	515	690	860	1075	1375	1720
tension lap × 2.0 (BS 8110, clause 3.12.8.13)									
f_{cu}	25	620	780	930	1240	1550	1940	2490	3110
	30	570	710	850	1140	1420	1770	2270	2840
	35	530	660	790	1050	1310	1640	2100	2630
	40	490	620	740	980	1230	1540	1970	2460
compression lap = compression anchorage × 1.25, 15$\varnothing$ or 300 mm, whichever is the greatest									
f_{cu}	25	310	390	465	620	775	970	1245	1555
	30	300	355	425	570	710	885	1135	1420
	35	300	330	395	525	655	820	1050	1315
	40	300	305	370	490	615	770	985	1230

Anchorage and lap lengths (BS 8110, clause 3.12.8)

(For lap lengths in accordance with BS 8007: 1987, see Section 9).

Grade 460 (high yield deformed bar type 2 to BS 4449 and BS 4461)

Design ultimate stress in tension or compression = $0.87f_y$ = 400.2 N/mm^2
Design ultimate anchorage bond stress f_{bu}

f_{cu}, N/mm^2	25	30	35	40
tension	2.5	2.74	2.96	3.16
compression	3.15	3.45	2.73	3.98

Table B4

size of bar, mm		8	10	12	16	20	25	32	40
tension anchorage = $0.87f_y \times \varnothing/4f_{bu}$, mm									
f_{cu}	25	320	400	480	640	800	1000	1280	1600
	30	290	365	440	585	730	915	1170	1460
	35	270	340	405	540	675	845	1080	1355
	40	255	315	380	505	635	790	1010	1265
compression anchorage = $0.87f_y \times \varnothing/4f_{bu}$, mm									
f_{cu}	25	255	320	380	510	635	795	1015	1270
	30	230	290	350	465	580	725	930	1160
	35	210	270	320	430	535	670	860	1075
	40	200	250	300	400	500	630	805	1005
tension lap = tension anchorage, 15∅ or 300 mm, whichever is greatest									
f_{cu}	25	320	400	480	640	800	1000	1280	1600
	30	300	365	440	585	730	915	1170	1460
	35	300	340	405	540	675	845	1080	1355
	40	300	315	380	505	635	790	1010	1270
tension lap × 1.4 (BS 8110, clause 3.12.8.13)									
f_{cu}	25	450	560	670	895	1120	1400	1795	2240
	30	410	510	615	820	1025	1280	1635	2045
	35	380	475	570	760	945	1185	1515	1895
	40	355	445	530	710	885	1105	1415	1770
tension lap × 2.0 (BS 8110, clause 3.12.8.13)									
f_{cu}	25	640	800	960	1280	1600	2000	2560	3200
	30	585	730	875	1170	1460	1825	2340	2925
	35	540	675	810	1080	1355	1690	2165	2705
	40	505	635	760	1010	1265	1580	2025	2530
compression lap = compression anchorage × 1.25, 15∅ or 300 mm, whichever is the greatest									
f_{cu}	25	320	390	475	635	795	995	1270	1590
	30	300	360	435	580	725	905	1160	1450
	35	300	335	405	535	670	840	1075	1340
	40	300	315	375	500	630	785	1005	1255

Anchorage and lap lengths (BS 8110, clause 3.12.8)

(For lap lengths in accordance with BS 8007: 1987, see Section 9).

Grade 460 (plain wire to BS 4482)

Design ultimate stress in tension or compression = $0.87 f_y$ = 400.2 N/mm^2
Design ultimate anchorage bond stress f_{bu}

f_{cu}, N/mm^2	25	30	35	40
tension	1.4	1.53	1.66	1.77
compression	1.75	1.92	2.07	2.21

Table B5

size of bar, mm		5	6	7	8	9	10	12
tension anchorage = $0.87 f_y \times \varnothing / 4 f_{bu}$, mm								
f_{cu}	25	355	430	500	570	645	715	860
	30	325	390	455	585	650	785	
	35	300	360	425	485	545	605	725
	40	280	340	395	450	510	565	680
compression anchorage = $0.87 f_y \times \varnothing / 4 f_{bu}$, mm								
f_{cu}	25	285	345	400	455	515	570	685
	30	260	315	365	420	470	520	625
	35	240	290	340	385	435	485	580
	40	225	270	315	360	405	450	540
tension lap = tension anchorage, 15∅ or 300 mm whichever is greatest								
f_{cu}	25	355	430	500	570	645	715	860
	30	325	390	455	520	585	650	785
	35	300	360	425	485	545	605	725
	40	300	340	395	450	510	565	680
tension lap × 1.4 (BS 8110, clause 3.12.8.13)								
f_{cu}	25	500	600	700	800	900	1000	1200
	30	455	550	640	730	1820	1915	1095
	35	425	505	590	675	760	845	1015
	40	395	475	555	635	710	790	950
tension lap × 2.0 (BS 8110, clause 3.12.8.13)								
f_{cu}	25	715	860	1000	1145	1285	1430	1715
	30	650	785	915	1045	1175	1305	1565
	35	605	725	845	965	1085	1210	1450
	40	565	680	790	905	1015	1130	1355
compression lap = compression anchorage × 1.25, 15∅ or 300 mm, whichever is the greatest								
f_{cu}	25	355	430	500	570	645	715	860
	30	325	390	455	520	585	650	785
	35	300	360	425	485	545	605	725
	40	300	340	395	450	510	565	680

Anchorage and lap lengths (BS 8110, clause 3.12.8)

(For lap lengths in accordance with BS 8007: 1987, see Section 9).

Grade 460 (deformed type 2 wire to BS 4482)

Design ultimate stress in tension or compression = $0.87f_y$ = 400.2 N/mm^2
Design ultimate anchorage bond stress f_{bu}

f_{cu}, N/mm^2	25	30	35	40
tension	2.5	2.74	2.96	3.16
compression	3.15	3.45	3.73	3.98

Table B6

size of bar, mm		5	6	7	8	9	10	12
tension anchorage = $0.87f_y \times \varnothing/4f_{bu}$, mm								
f_{cu}	25	200	240	280	320	360	400	480
	30	185	220	255	290	330	365	440
	35	170	205	235	270	305	340	405
	40	160	190	220	255	285	315	380
compression anchorage = $0.87f_y \times \varnothing/4f_{bu}$, mm								
f_{cu}	25	160	190	220	255	285	320	380
	30	145	175	205	230	260	290	350
	35	135	160	190	215	240	270	320
	40	125	150	175	200	225	250	300
tension lap = tension anchorage, 15∅ or 300 mm whichever is greatest								
f_{cu}	25	300	300	300	320	360	400	480
	30	300	300	300	300	330	365	440
	35	300	300	300	300	305	340	405
	40	300	300	300	300	300	315	380
tension lap × 1.4 (BS 8110, clause 3.12.8.13)								
f_{cu}	25	300	335	390	450	505	560	670
	30	300	305	360	410	460	510	615
	35	300	300	330	380	425	475	570
	40	300	300	310	355	400	445	530
tension lap × 2.0 (BS 8110, clause 3.12.8.13)								
f_{cu}	25	400	480	560	640	720	800	960
	30	365	440	510	585	660	730	875
	35	340	405	475	540	610	675	810
	40	315	380	445	505	570	635	760
compression lap = compression anchorage × 1.25, 15∅ or 300 mm, whichever is the greatest								
f_{cu}	25	300	300	300	320	355	395	475
	30	300	300	300	300	325	360	435
	35	300	300	300	300	300	335	405
	40	300	300	300	300	300	315	375

Anchorage and lap lengths (BS 8110, clause 3.12.8)

(For lap lengths in accordance with BS 8007: 1987, see Section 9).

Grade 460 (welded wire fabric to BS 4483)

Design ultimate stress in tension or compression = $0.87f_y$ = 400.2 N/mm^2
Design ultimate anchorage bond stress f_{bu}

f_{cu}, N/mm^2	25	30	35	40
tension	3.25	3.56	3.85	4.11
compression	4.05	4.44	4.79	5.12

Table B7

size of bar, mm		5	6	7	8	9	10	12
tension anchorage = $0.87f_y \times \varnothing/4f_{bu}$, mm								
f_{cu}	25	155	185	215	245	275	310	370
	30	140	170	195	225	255	280	335
	35	130	155	180	210	235	260	310
	40	120	145	170	195	220	245	290
compression anchorage = $0.87f_y \times \varnothing/4f_{bu}$, mm								
f_{cu}	25	125	150	175	200	220	245	295
	30	115	135	160	180	205	225	270
	35	105	125	145	165	190	210	250
	40	100	115	135	155	175	195	235
tension lap = tension anchorage, but not less than 250 mm								
f_{cu}	25	250	250	250	250	275	310	370
	30	250	250	250	250	255	280	335
	35	250	250	250	250	250	260	310
	40	250	250	250	250	250	250	290
tension lap × 1.4 (BS 8110, clause 3.12.8.13) but not less than 250 mm								
f_{cu}	25	250	260	300	345	390	430	515
	30	250	250	275	315	355	395	470
	35	250	250	255	290	330	365	435
	40	250	250	250	275	305	340	410
tension lap × 2.0 (BS 8110, clause 3.12.8.13) but not less than 250 mm								
f_{cu}	25	310	370	430	495	555	615	740
	30	280	335	395	450	505	560	675
	35	260	310	365	415	470	520	625
	40	250	290	340	390	440	485	585
compression lap = compression anchorage × 1.25, but not less than 250 mm								
f_{cu}	25	250	250	250	250	380	310	370
	30	250	250	250	250	255	280	340
	35	250	250	250	250	250	260	315
	40	250	250	250	250	250	250	295

Appendix 3C Shear resistance of beams
(BS 8110, clause 3.4.5)

Table C1 Ultimate shearing resistance provided by a single system of links

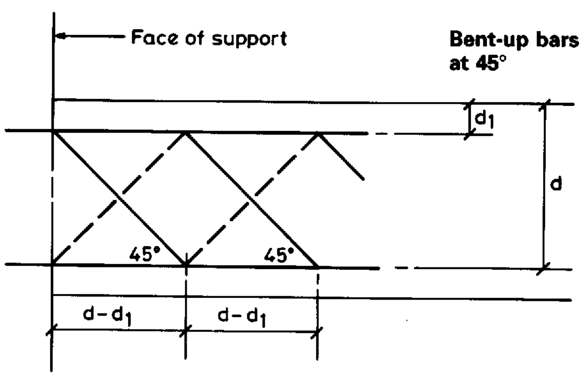
type of reinforced cement	*bar size* mm	*factor*	*spacing of links (single system) (s_v), mm* 50	75	100	125	150	175	200	225	250	275	300
grade 250 f_{yv} = 250 N/mm^2	6	K_{sv}	246	164	123	98	82	70	61	54	49	44	41
		b_{vmax}	615	410	307	246	205	175	153	136	123	111	102
	8	K_{sv}	437	291	218	175	145	125	109	97	87	79	73
		b_{vmax}	1093	729	546	437	364	312	273	243	281	198	182
	10	K_{sv}	683	455	341	273	227	195	170	151	136	124	114
		b_{vmax}	1708	1139	854	683	569	488	427	379	341	310	284
	12	K_{sv}	984	656	492	393	328	281	246	218	196	179	164
		b_{vmax}	2460	1640	1230	984	820	703	615	546	492	447	410
grade 460 f_{yv} = 460 N/mm^2	6	K_{sv}	452	301	226	181	150	129	113	100	90	82	75
		b_{vmax}	1131	754	565	452	377	323	283	251	226	205	188
	8	K_{sv}	804	536	402	322	268	230	201	178	161	146	134
		b_{vmax}	2011	1341	1006	804	670	574	503	447	402	365	335
	10	K_{sv}	1257	838	628	503	419	359	314	279	251	228	209
		b_{vmax}	3143	2095	1571	1257	1047	898	785	698	628	571	524
	12	K_{sv}	1810	1207	905	724	603	517	452	402	362	329	301
		b_{vmax}	4526	3017	2263	1810	1509	1293	1131	1006	905	823	754

$K_{sv} = \dfrac{0.87 f_{yv} A_{sv}}{s_v}$ = ultimate shearing resistance provided by single system in N/mm of effective depth

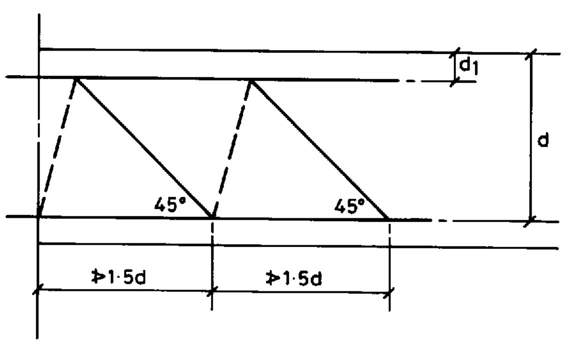
b_{vmax} = maximum permissible width of section with nominal links (single system), mm

Table C2 Ultimate shearing resistance in kN by bars inclined at 45°

bar size	*ultimate resistance when Ø = 45°* f_y = 250 N/mm^2 single system	double system	f_y = 460 N/mm^2 single system	double system
16	30.9	61.8	56.9	113.8
20	48.3	96.6	88.9	177.8
25	75.5	151.0	138.9	277.8
32	123.7	247.4	227.6	455.2
40	193.3	386.5	355.6	711.2



Double system



Single system

4 Detailing and scheduling

4.1 Detailing techniques

The majority of detailing examples contained in this report are based on a manual detailing system, detailing fully all aspects of each element. This method, being the 'traditional' method of detailing in the UK, tends to be simpler to plan and operate than the other methods listed below, but in certain circumstances takes longer to produce.

4.2 Tabular method of detailing

The tabular method may be adopted where a number of concrete elements have similar profile and reinforcement arrangement but have differing dimensions and quantity of reinforcement.. A typical element is drawn, usually not to scale, but visually representative of its shape, with the dimensions and reinforcement given as code letters. A table is given to show the actual values of these code letters for each individual element (see Table 12).

Advantages

A large number of similar elements may be detailed on a few drawings
Quicker to produce therefore saving detailing time.

Disadvantages

Elements are not drawn to scale
Checking of drawings and schedules tends to take longer and is more prone to error
Once alterations or additions are made, special details may be required to which the initial tables have to refer: this complicates the system and leads to errors
Visual checks of drawings may be misleading.

4.3 Preprinted drawings

These are used where a library of drawings are kept for typical elements or details that may be required on other contracts. Examples of this may be:

standard notes
pile caps with schedules
concrete box culverts
construction expansion joint details.

Copy negatives are taken of the original, and the title box is completed to suit a particular contract. The advantages of these drawings is obvious but care must be taken to ensure that the details given do, in fact, apply to the condition required. A check should also be made to ensure that the preprinted drawing complies with current standards.

4.4 Overlay drawings

These are parts of drawings produced on clear acetate negatives so that various parts may be brought together, laid on top of each other, and printed to form a single negative. These drawings are, by their nature, not to scale and have similar advantages and disadvantages as the tabular method of detailing.

4.5 Computer-aided detailing and scheduling

It has been estimated that the manual detailing and scheduling of a reinforced concrete structure takes twice as long as the design stage. Therefore it follows that any automatic method of detailing and scheduling should have significant effect on design office procedures.

At present detailing and scheduling programs fall into four main categories:

- *Scheduling programs with no detailing capability*
  This type of program was the first to be developed and removed the arithmetic drudgery and the inevitable errors from the preparation of schedules and cutting lists.
- *Scheduling programs with detailing capability based on line printer diagrams and preprinted sheets*
  The output from some of the more sophisticated types of scheduling programs contain line printer diagrams and are intended to be used as reinforcement details when read in conjunction with printed schedules or detail sheets.
- *Detailing and scheduling programs with visual display and limitations on plotter output*
  The capability of these programs can include full interactive input of data and drawn-to-scale details produced by the plotter. These programs are normally limited to structures based on a rectangular grid.
- *Detailing and scheduling system with virtually no restriction on plotter output with all drawing activities carried out on a graphics display*
  In systems of this type the detailer uses a high-resolution graphics display at every stage to produce and check his drawings. The results are passed to a plotter for drawing production. The schedule is automatically produced on a printer, as a direct result of the computerized draughting process.

Most of the scheduling programs were developed 10–15 years ago when computer graphics equipment was very expensive, but although this type of hardware is now more readily available, it must be remembered the cost of producing or buying the software for a sophisticated detailing program is a significant item. The ideal program is one that requires the minimum input for the maximum output, and experience has shown that a combination of handwork and computer graphics is probably the most economic method of detailing and scheduling

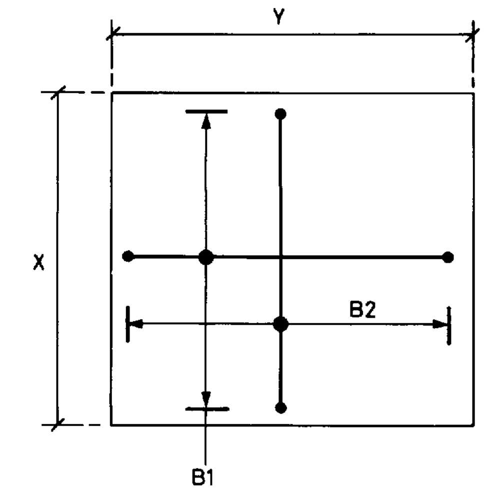
The relative advantages of different computer-aided methods will vary from office to office depending on the hardware, software and staff that are available, but it is important to bear in mind that a computer-based detailing and scheduling system is only a useful tool that has to be used in a responsible way by a suitably experienced person.

4.6 Detailing reinforcement

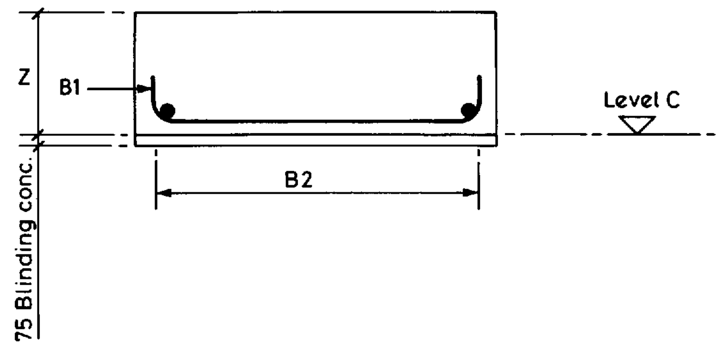
Reinforcement detailing should be kept as simple as possible consistent with showing its shape and exact location. The standard sequence of description on drawing is as follows:

Number, type and grade, size, mark, bar centres, location or comment. For example, in a slab 20T16-63-150B1 describes 20 no. deformed type 2 bars of 16mm nominal size at a pitch of 150mm in the bottom outer layer. The bar mark is –63–.

Table 12 Examples of tabular method of detailing



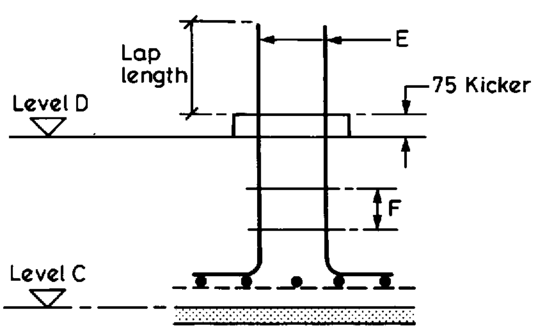
Plan



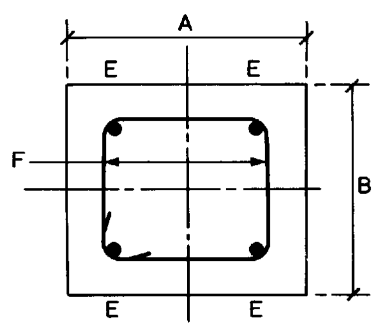
Elevation

column bases

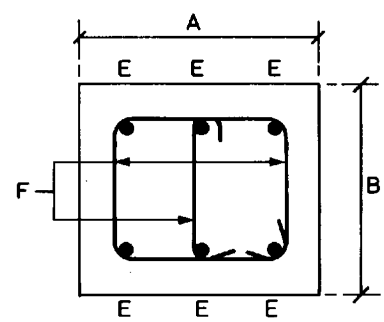
base	*no. off*	X	Y	Z	*reinforcement*		*level*
					B1	B2	C
7A, 7B, 7C	3	1800	1800	400	12 T20-1-150	12 T20-1-150	19.00
8A, 8B, 8C	3	1800	1350	400	9 T16-2-150	12 T20-1-150	19.000



A-A



1-1



2-2

column starters

col	*no. off*	*level*		*reinforcement*		*sect*	*elev*	*column dims*	
		C	D	E	F			A	B
7A, 7B 7C, 7D	5	19.000	19.400	4 T32-3	3 T10-4-150	1-1	A-A	350	550
8C	4	19.500	19.950	6 T25-5	6 T10-6-150 + 6 T10-7-150	2-2	A-A	575	575

Previous page is blank

Note that bar centres, location or comment, are not usually required for beams and columns (see Section 5). To avoid confusion when totalling quantities for entry on the schedule, the number of bars in a group or the number of sheets of fabric in a set should be stated only one on the drawing.

The position of reinforcement should be established by dimensions to the faces of the concrete or the formwork.

All reinforcement that needs to be fixed in a certain part before it can be concreted should be detailed with that part, e.g. starters from a tank floor into the walls must be detailed with the floor.

Although the elements of a structure, such as beams, slabs and columns, are detailed separately, the designer and the detailer should always consider each element as a part of the entire structure. Frequently the arrangement of reinforcement in an element will affect the arrangement in the adjacent elements, and the following cases often arise:

- at beam-to-column intersections where the beam reinforcement must avoid the column reinforcement
- at beam-to-beam intersections where the levels of the several layers of reinforcement in each beam must be such that they will pass over each other and give the correct cover to the upper and lower layers
- at slab-to-beam intersections the cover over the top reinforcement in the beam must be sufficient for the top steel in the slab to pass over the beam with the correct cover.

Generally it is advisable early in the design to establish a system for achieving the above, particularly in projects on which several detailers may be working simultaneously on adjacent elements of the structure.

It can be useful to detail to a large scale a typical beam–column junction to determine reinforcement locations. Subsection 4.9 gives some guidelines and points to consider when producing this drawing.

Detailing should be carried out so that fabrication of reinforcement units off-site is facilitated. Sketches of details to achieve this are shown in subsection 4.10 onwards. The decision to preassemble the reinforcement will normally be taken by the contractor: however the detailer should bear the possibility in mind.

4.7 Spacing of reinforcement

Minimum distances between bars (BS 8110, clause 3.12.11.1)

Horizontal distance

The horizontal distance between bars should not be less than (h_{agg} + 5mm), where h_{agg} is the maximum size of the coarse aggregate.

Vertical distance

The vertical distance between bars should not be less than ⅔ h_{agg} (see Fig. 16).

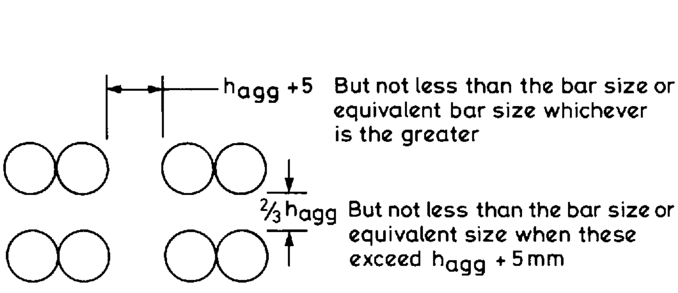


Fig. 16

When the bar size or equivalent bar size is greater than h_{agg} + 5mm, both the vertical and horizontal distances should be not less than the bar size or equivalent bar size.

Using 20mm maximum size aggregate, the minimum horizontal distance will be 25mm and the vertical distance will be 16mm. These spacings will be satisfactory for single bars up to 25mm diameter and for bundles using smaller bars, e.g. 2T12. Generally the minimum spacing for bundled bars will be determined from the equivalent diameter.

4.8 Bundled bars (BS 8110, clause 3.12.4.1)

A bundle is defined as a group of parallel bars in contact to act as a single unit and, for the purpose of design, is treated as a single bar of equivalent area. The equivalent size of a bundle is the size of a single round bar having an area equal to the area of the bundle.

It is sometimes advantageous to bundle tensile or compressive reinforcement with two, three or four bars in contact to provide for better placing of concrete around and between the reinforcement in heavily reinforced members. Not more than four bars may be grouped into one bundle even at laps.

No more than two bars should be bundled in one plane. Typical bundle shapes are triangular, square, or L-shaped patterns.

4.9 Points to consider before detailing

Points to consider before detailing are shown in Figs. 17, 18 and 19 used in conjunction with the general guidelines given below.

General guidelines

(*a*) study and be familiar with what is to be detailed, check that calculations, setting-out details, concrete profiles, services, concrete covers, type of reinforcement, concrete grade required are known
(*b*) decide which scales to be used
(*c*) plan drawings for content and therefore number of drawings required
(*d*) determine which are secondary and which are main beams from calculations and general-arrangement drawings; check direction of slab spans and layering of slab reinforcement
(*e*) determine setting out of column reinforcement
(*f*) consider any difficult junctions and draw sketch details to a scale of 1:10 or larger to clarify
(*g*) check that beam reinforcement will pass column reinforcement
(*h*) check beam-to-beam connections and ensure layers of reinforcement do not clash
(*i*) check location of laps remembering maximum lengths of bar available
(*j*) detail all beams in one direction, then beams in other direction
(*k*) draw sufficient sections or details to show reinforcement arrangement not only in simple areas but particularly in congested areas of reinforcement
(*l*) check wording required for title boxes, notes, job number and drawing number
(*m*) produce bar or fabric schedules, using a print of the drawing and mark off bars as they are listed; update drawing with errors found during scheduling
(*n*) provide check prints of both drawing and schedules for checking by another competent person.

Notes relating to Figs. 17, 18 and 19

1. every column bar must be retained by a link except where the distance between column bars is 150mm or less
2. check that where column reinforcement is bent out, e.g. top lift of column, the concrete cover will be maintained and there is clearance for slab and beam reinforcement
3. secondary-beam reinforcement to have increased top cover (check with designer that this reduction in lever arm is satisfactory)

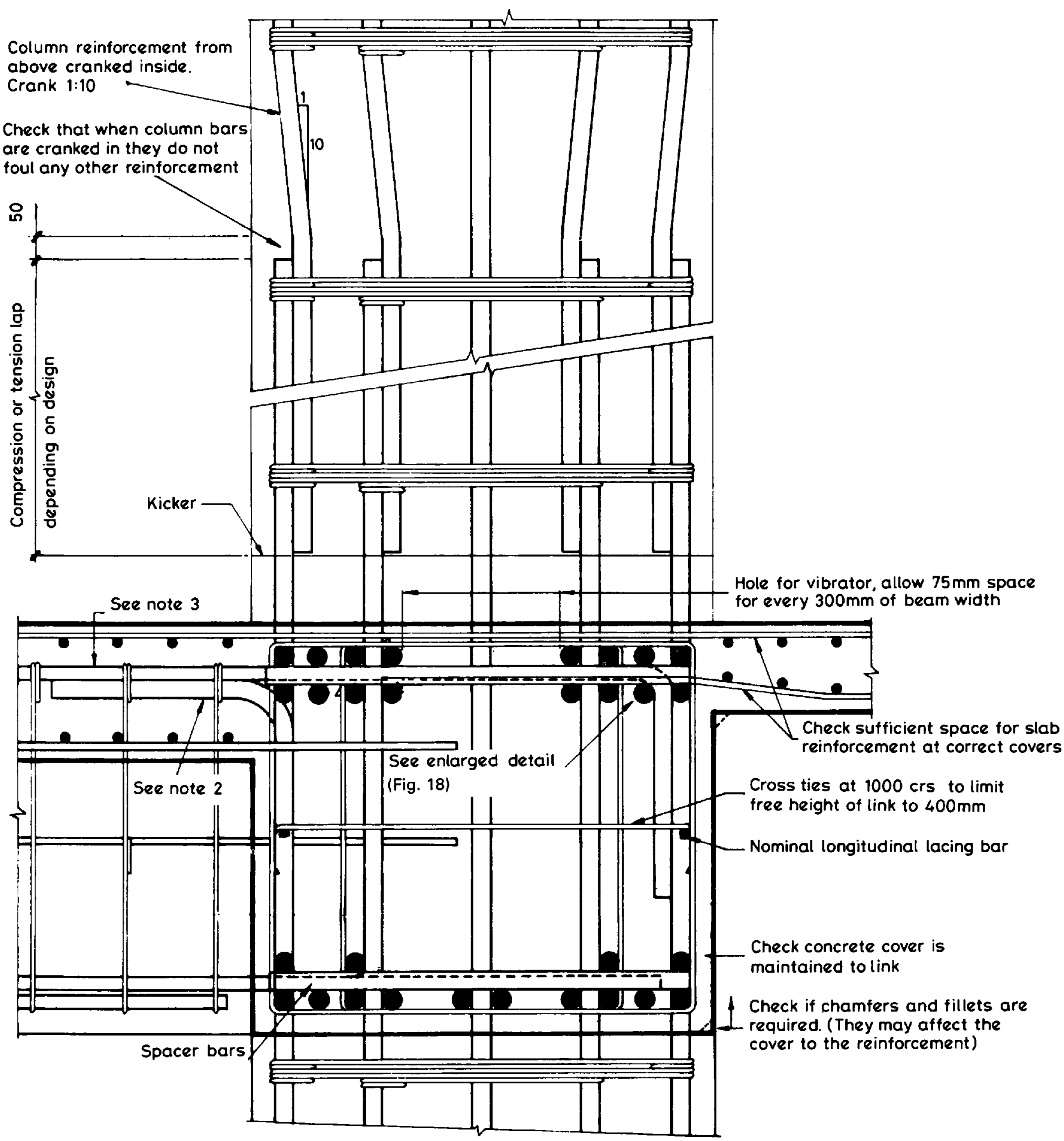
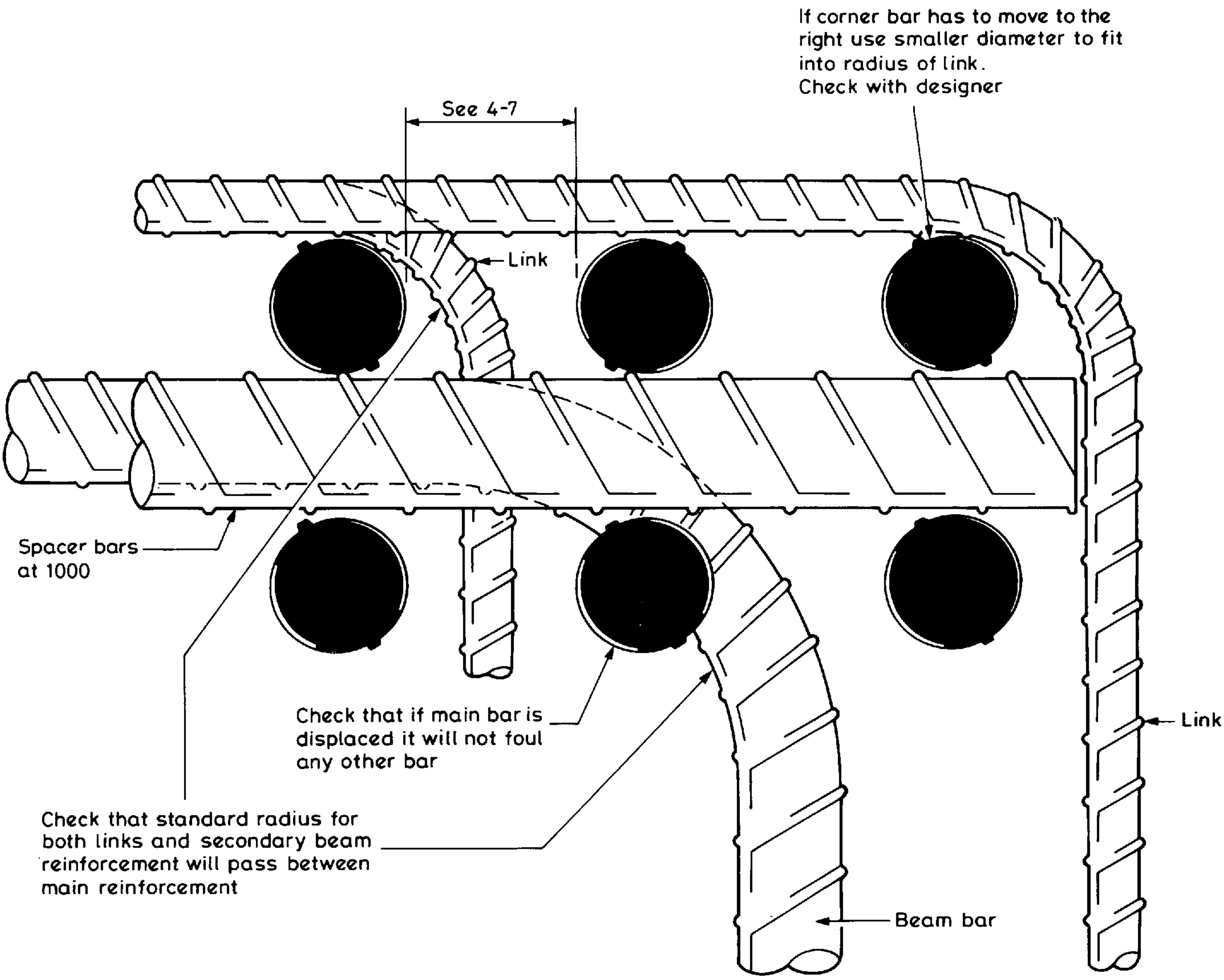
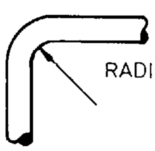


Fig. 17 Typical section through main beam



Enlarged corner detail



ACTUAL SIZE OF DEFORMED BARS.									
NOMINAL BAR SIZE	6	8	10	12	16	20	25	32	40
MAXIMUM BAR SIZE 'a'	8	11	13	14	19	23	29	37	46

Fig. 18

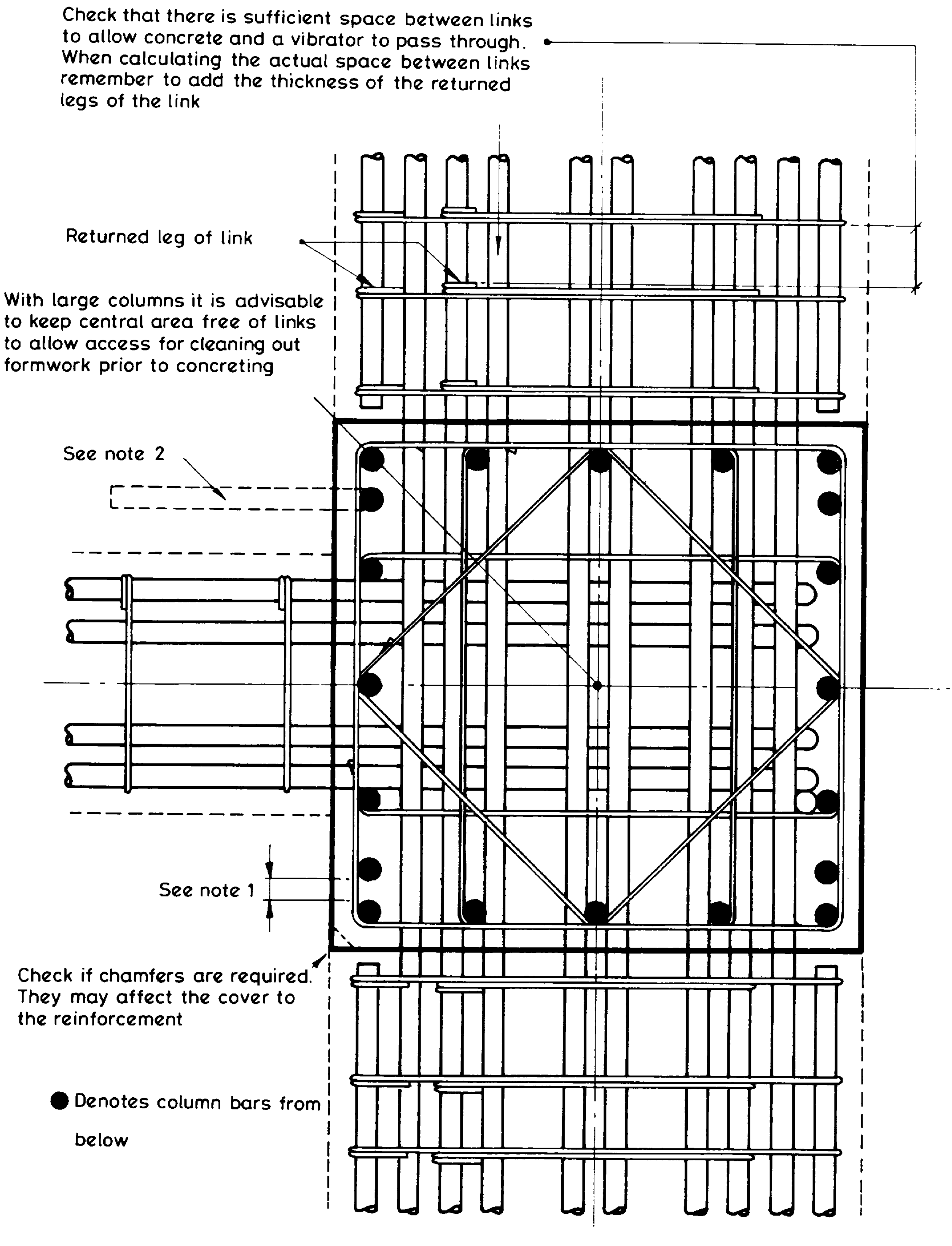

Check that there is sufficient space between links to allow concrete and a vibrator to pass through. When calculating the actual space between links remember to add the thickness of the returned legs of the link
Returned leg of link
With large columns it is advisable to keep central area free of links to allow access for cleaning out formwork prior to concreting
See note 2
See note 1
Check if chamfers are required. They may affect the cover to the reinforcement
● Denotes column bars from below

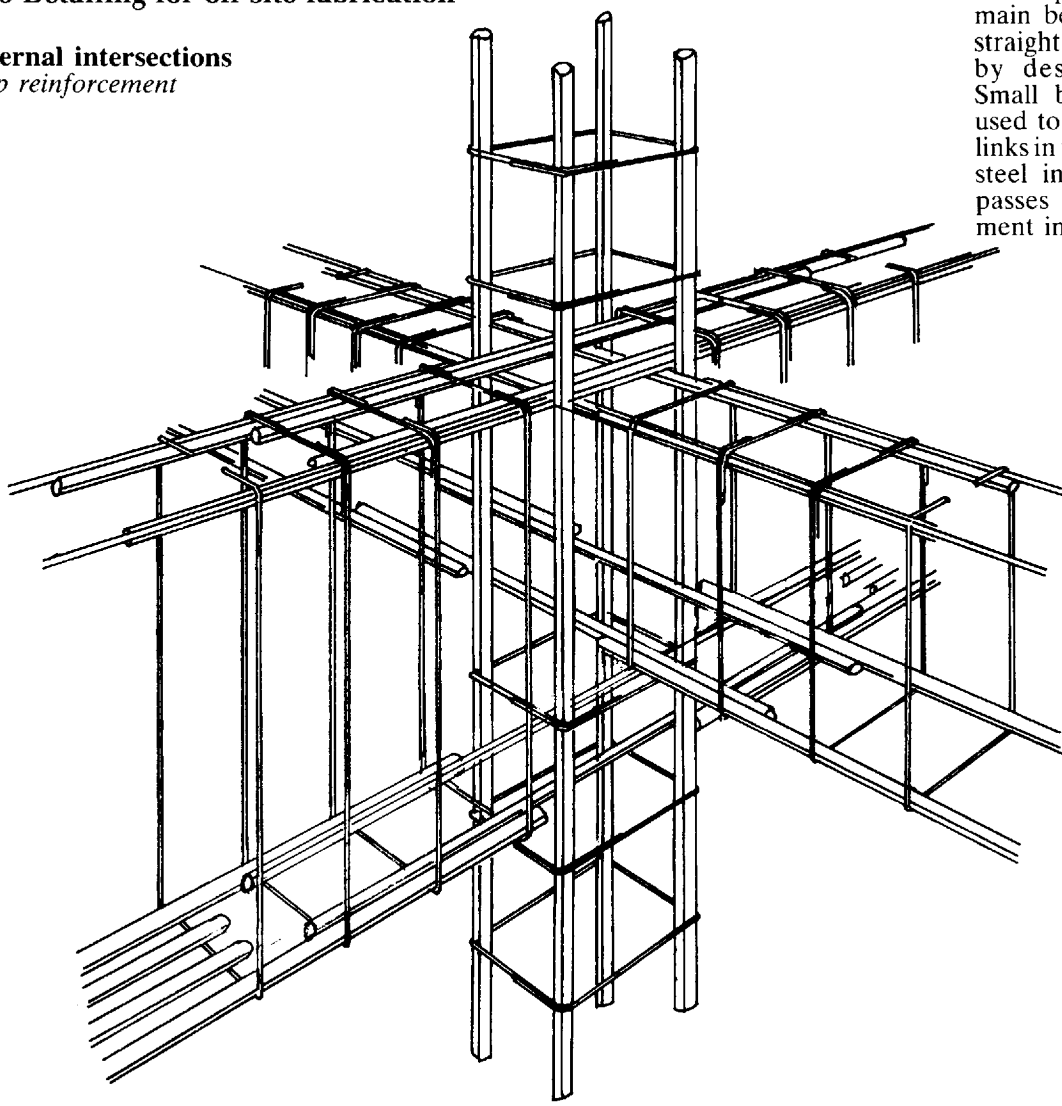
Fig. 19

4.10 Detailing for off-site fabrication

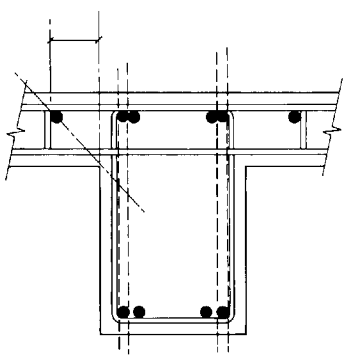
Internal intersections

Top reinforcement

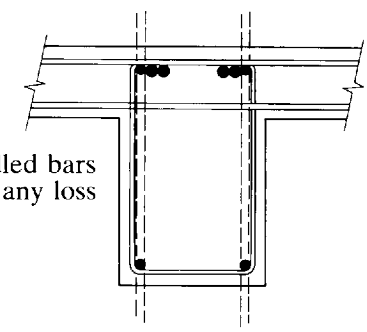
The top reinforcement in the main beam is in the form of straight bars that are curtailed by design considerations. Small bars (12mm, say) are used to locate the tops of the links in the beam cage. The top steel in the secondary beam passes under the reinforcement in the main beam.



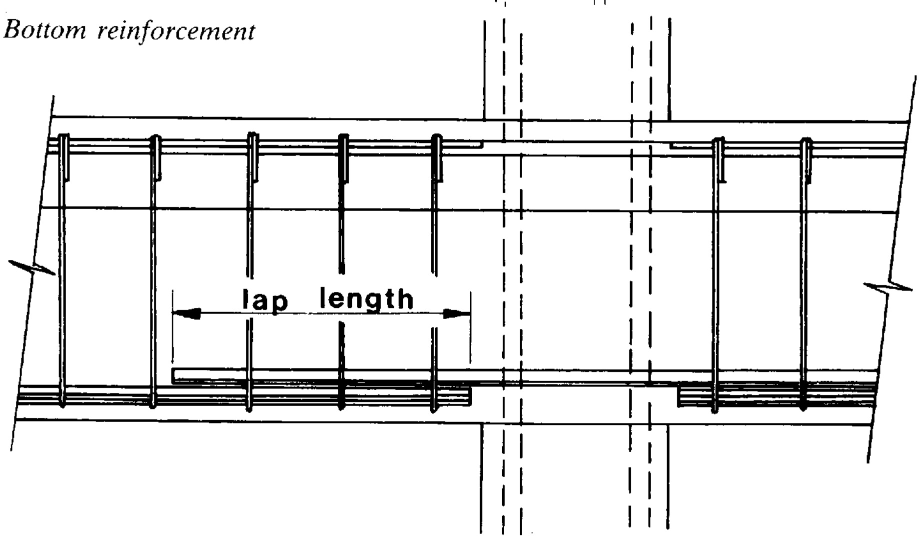
In narrow beam sections, it may be advantageous to position some bars within the slab outside the limits of the beam in order to leave openings wide enough for the insertion of a vibrator. An additional stirrup may be required since BS 8110 requires all tension reinforcement to be enclosed.



Alternatively, bundled bars may be used without any loss of lever arm.

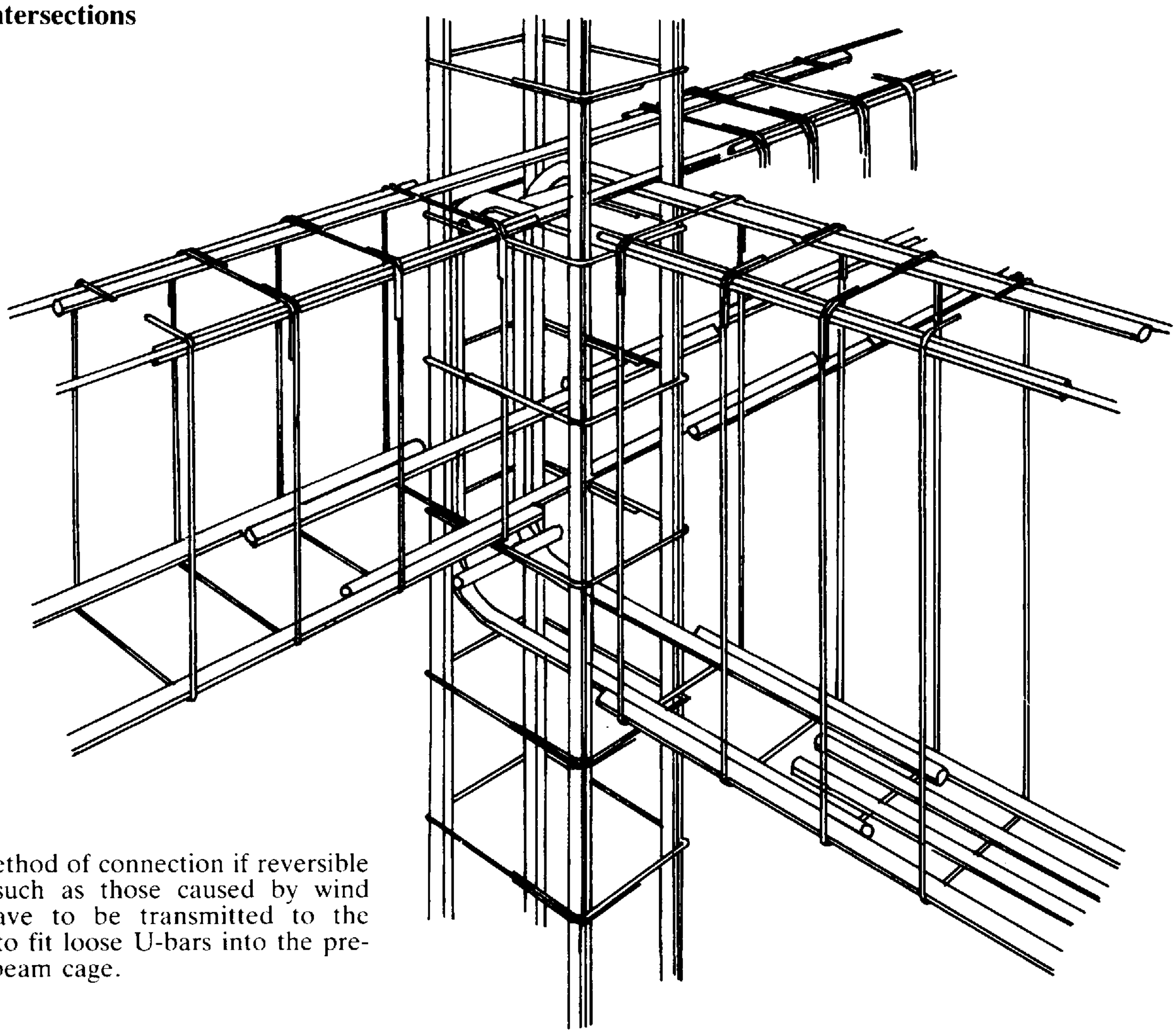


Bottom reinforcement

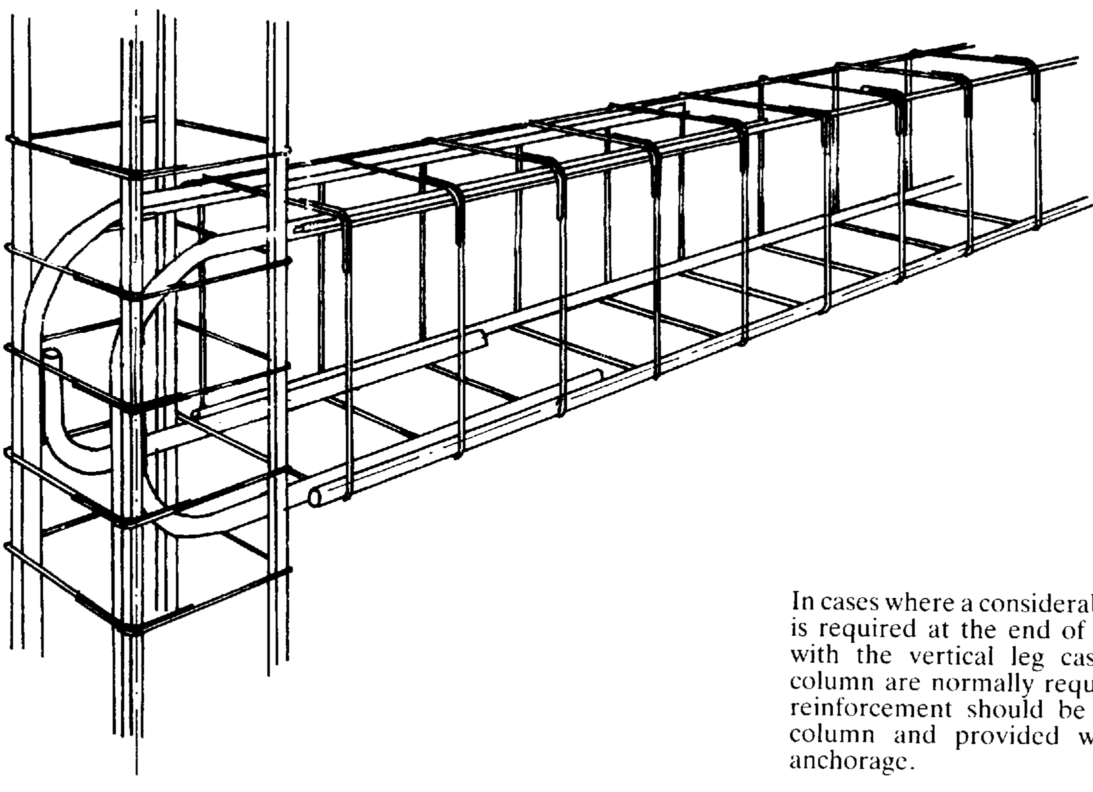


The bottom reinforcement in the beam does not extend into the column, and the structural continuity is provided by lacing bars of a suitable size.

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.



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 are normally required. The bottom reinforcement should be taken across the column and provided with an adequate anchorage.

4.11 Schedules and scheduling

Scheduling is the operation of listing the location, mark, type and size, number off, length and bending details of each bar or sheet of fabric. When dealing with bars the completed lists are called 'bar schedules' (see pages 49 and 50). The bars should be grouped together for each structural unit, e.g. beam, column, etc. In a building, the bars should be listed floor by floor.

Separate schedules should be prepared for fabric reinforcement using the form of fabric schedule shown (see page 00). Fabrics should be grouped together according to their BS reference number and the size of sheet.

For cutting and bending purposes schedules should be provided as separate A4 sheets and not as part of the detailed reinforcement drawings. Each schedule should be a document complete in itself, and reference to earlier schedules by the use of such terms 'as before' or 'repeat as 1st floor' should not be allowed.

Schedules are used by:

- the detailer
- the person checking the drawing
- the contractor who orders the reinforcement
- the organization responsible for fabricating the reinforcement
- the steel fixer
- the clerk of works or other inspector
- the quantity surveyor.

The schedules should have simple consecutive reference numbers not exceeding six characters, and should be cross-referenced to the relevant drawing number. Such terms as page number, sheet number, etc., can be confusing and are not recommended. A convenient way of achieving this is to use the first three characters to refer to the drawing number (implying that the project will be divided into units with a maximum number of 999 drawings per unit), to use the next two characters to describe the schedule number (starting at 01 and not exceeding 99 schedules per drawing), and to reserve the last character for revision letters. If an internal job number or other internal reference number is used, it is suggested that this should be incorporated in the site reference – rather than extending the reinforcement schedule reference.

The form of bar and fabric schedule and the shapes of bar used should be in accordance with BS 4466. The preferred shapes in this Standard account for more than 95% of the reinforcement that is used. It is preferable that bars should be listed in the schedule in numerical order.

It is quite common for a reinforcement supplier to prepare separate lists using the schedule as a basis. These lists are referred to as 'cutting and bending lists', and on these, the bars are usually sorted into delivery batches by sequence of type, size and length.

It is essential that the bar mark reference on the label attached to a bundle of bars refers uniquely to a particular group or set of bars of defined length, size, shape and type used on the job. This unique reference is achieved by a combination of the bar schedule reference number and the bar mark number (to comply with BS 4466, both the schedule reference number and the bar mark must appear on the label attached to the bundle of bars).

Thus the bar-schedule reference number (046 02A in the example that follows, (note the importance of the zeros) and the bar mark are associated, and the bar-marking system that follows is based on the assumption that the bar-schedule reference numbering system set out in BS 4466 is used precisely as described with no variations. Each schedule must have a different reference number and must refer only to one drawing. Such terms as sheet number, page number, 1 of 8, 2 of 8, etc. and such practices as including the date, the year, the draughtsman's initials, the job number or other internal reference as part of the reference number must not be used with this combined systems of bar marking and schedule numbering. Each of these practices may have intrinsic merits, but they should be abandoned in favour of a system that is universally applicable and universally understood.

Correct scheduling is not possible without a thorough knowledge of BS 4466.

The bar size is not part of the bar mark, and prefixes or suffixes of letters or other characters to describe the location of the bars should not be included in the bar mark. The exception to this rule is when bars of varying shape or length are used and are described on the drawing thus:

8T20–1(a to h)–150

The bar mark given on the schedule is therefore 1a, 1b, 1c....

On a small job with only a few drawings it may be convenient to start at bar mark 1 and carry on through the whole job in a consecutive sequence. On larger jobs it may be more convenient to start scheduling each drawing with bar mark 1, relying on the site to distinguish between mark 1 on drawing 1 and mark 1 on drawing 2.

When top and bottom reinforcement are detailed on separate drawings it is advantageous to allocate a group of bar marks for each drawing, e.g. bottom reinforcement bar marks 1–99, top reinforcement bar marks 100–199.

When it becomes necessary to revise a bar item on the schedule the schedule number should be given a revision letter (not a number). The same letter should be written in the right-hand margin of the schedule in line with the bar marks affected. The bar-schedule reference number would then become 1201A but the bar mark would remain 63 as before. The revision letter to the schedule is unrelated to a revision letter on the drawing, the schedule may be revised but without a revision to the related drawing.

Allowances for tolerances

Cover to reinforcement is liable to variation on account of the cumulative effect of inevitable small errors in the dimensions of formwork and the cutting, bending and fixing of the reinforcement.

All reinforcement should be fixed to the nominal cover shown on the drawings, using spacers of the same nominal size as the nominal cover. The term 'nominal cover' implies a permissible negative tolerance of 5mm, i.e. the actual cover could be 5mm less than the nominal cover.

Where a reinforcing bar is to fit between two concrete faces (e.g. a single rectangular link in a beam), the dimensions on the schedule should be determined as the nominal dimension of the concrete less the nominal cover on each face and less an allowance for all other errors as in Table 12.

Deducation for tolerances in position of bent steel (BS 8110, clause 3.12.1.3)

	overall concrete dimension (measured in direction of tolerance) mm	deduction to determine bending dimension mm
(i)	0–1000	10
(ii)	1000–2000	15
(iii)	over 2000	20
	Deduction for tolerances at ends of straight bars	
(iv)	any length	40

These deducations apply to most reinforced concrete construction, but where tolerances on member size is greater than 5, 5, 10 and 10mm for the four categories, respectively, larger deductions should be made or the nominal cover increased (see Fig. 26).

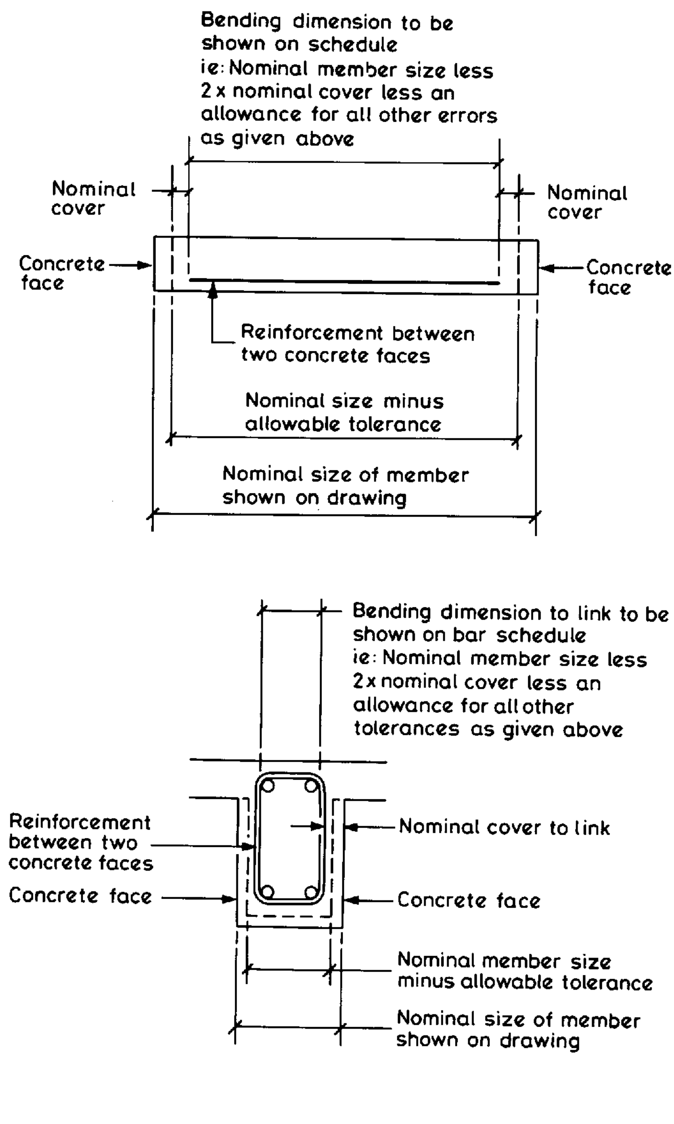


Fig. 26

Paper width 210

15 | 25 | 15 | 12 | 10 | 12 | 12 | 15 | 10 | 15 | 15 | 15 | 15 | 15 | 9

40

5 5 5 5 5 5 5 5

30 · 20 · 10 · 23 x 10 = 230 · Paper length 297 · 5 · 5

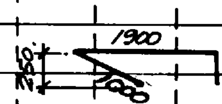
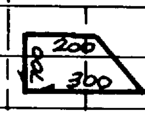
XY and partners

Site ref: *Job No: 1234. Physics Block, Eastford.*

Bar schedule ref : 046 02 A

Date prepared : *9.6.83* Date revised: *12.6.83.*

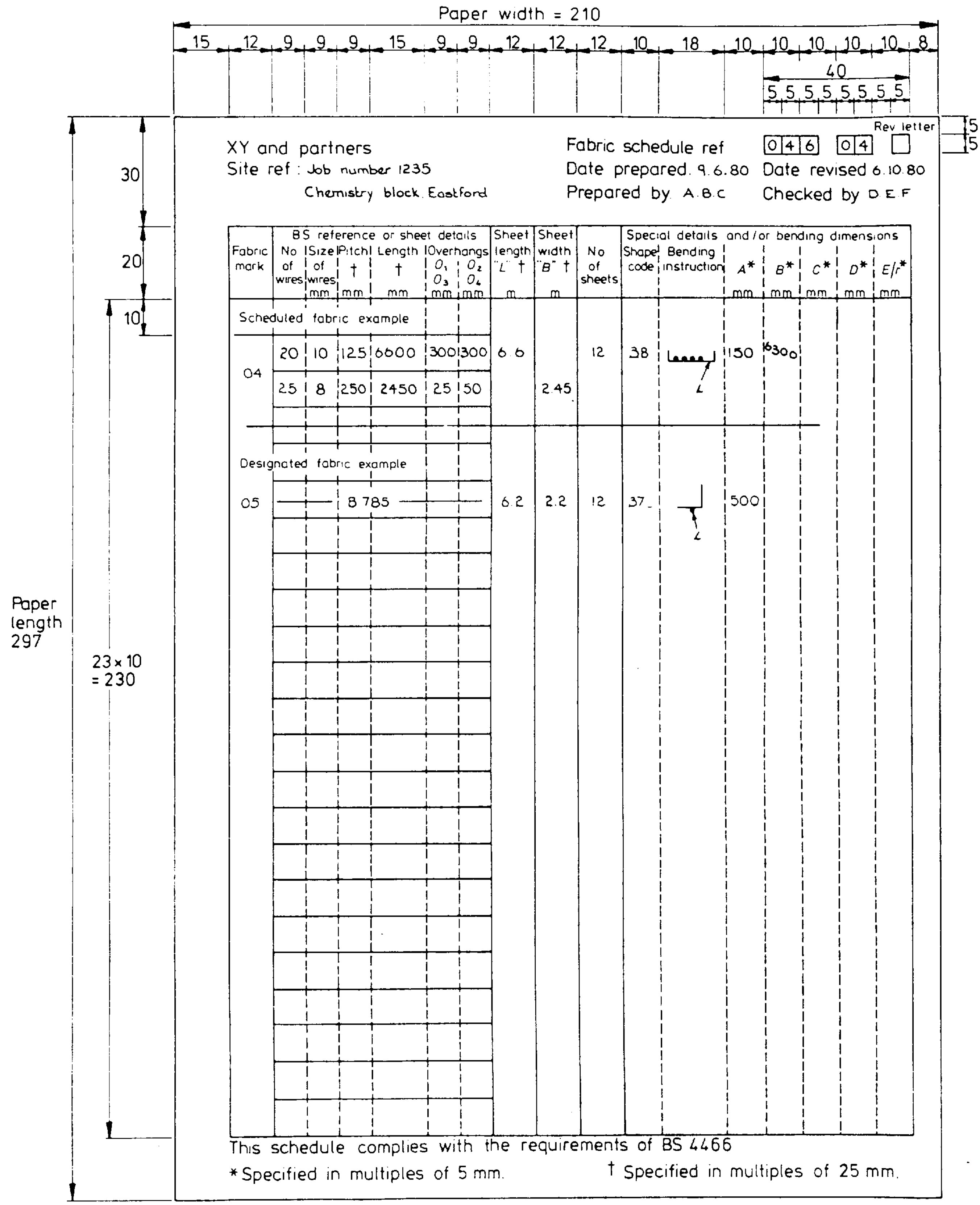
Prepared by : *RAT* Checked by : *ABC.*

Member	Bar mark	Type and size	No of mbrs	No of bars in each	Total no	Length of each bar † mm	Shape code	A* mm	B* mm	C* mm	D* mm	E/r* mm
Wall AB.	*5*	*T16*	*4*	*2*	*8*	*1825*	*20*	*STRAIGHT.*				
	6a.	*T20*	*2*	*4*	*8*	*1300*	*37*	*300*				
	6b	*T20*	*2*	*4*	*8*	*1500*	*37*	*300*				
	6c	*T20*	*2*	*4*	*8*	*1700*	*37*	*300*				
	6d	*T20*	*2*	*4*	*8*	*1900*	*37*	*300*				
	7	*T20*	*5*	*5*	*25*	*3400*	*99*					
								(Give dimensions for setting out not angles).				
	8	*T12 T16*	*5*	*10*	*50*	*2100*	*99*					

A

This schedule complies with the requirements of BS 4466

✱ Specified in multiples of 5mm † Specified in multiples of 25mm



Paper width = 210
15 12 9 9 9 15 9 9 12 12 12 10 18 10 10 10 10 10 8
40
5 5 5 5 5 5 5 5
Rev letter
5
5
30
20
10
Paper length 297
23 × 10 = 230
XY and partners
Site ref : Job number 1235
Chemistry block, Eastford
Fabric schedule ref 046 04
Date prepared 9.6.80
Date revised 6.10.80
Prepared by A.B.C
Checked by D.E.F
Fabric mark
BS reference or sheet details
No of wires
Size of wires mm
Pitch † mm
Length † mm
Overhangs O1 O3 mm O2 O4 mm
Sheet length "L" † m
Sheet width "B" † m
No of sheets
Special details and/or bending dimensions
Shape code
Bending instruction
A* mm
B* mm
C* mm
D* mm
E/r* mm
Scheduled fabric example
04
20 10 125 6600 300 300 6.6 12 38 150 16300
25 8 250 2450 25 50 2.45
L
Designated fabric example
05 B 785 6.2 2.2 12 37 500
L
This schedule complies with the requirements of BS 4466
* Specified in multiples of 5 mm.
† Specified in multiples of 25 mm.

5 Structural elements

General guidance for the preparation of drawings is provided in Section 2; more detailed guidance is provided in this Section.*

Each element described for detailing is divided into three parts:

1. design information that the detailer needs to and his understanding of the requirements (for clarity cross-references are given to the relevant clause in BS 8110 although equivalent requirements may appear in other design codes)
2. detailing methods
3. examples of detailing (yellow pages).

*Note 1 Throughout this Section † denotes reference to clause number in BS 8110.
Note 2 See BS 1192 for preferred method of showing sections and dimensions.

5.1 LAYOUTS

Layout drawings, commonly known as general arrange ment drawings (or GAs) are developed over a period of time and coordinated from dimensional information pro vided by the architect, engineer and specialists. The dimensions should be checked and approved before commencing the detailing of reinforcement.

5.1.10 Methods of preparing general arrange ment drawings for concrete structures

Projects vary in size and complexity. It is important to select a scale that will enable the final drawing to be read with clarity. Large floor areas can be spread over several drawings and linked and referenced by means of key plans. Local complexities, such as staircases, can be isolated and referenced to a larger-scale drawing.

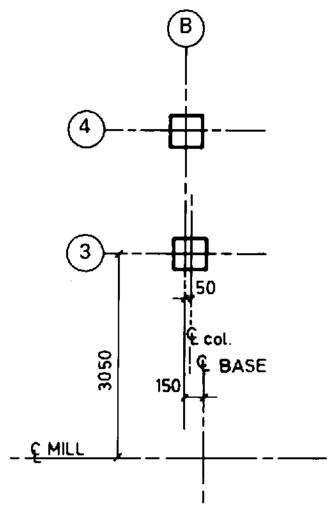
5.1.11 Information shown on general arrange-ment drawings for concrete structures

5.1.11.1 On plan

(a) Grid lines

These form a network across the job and provide a convenient datum for dimensioning and referencing elements (see subsection 2.20).

Grids usually coincide with the centre-lines of columns; clarify if they do not.



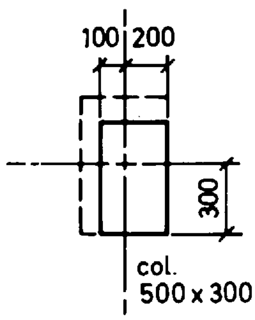
(b) Centre-lines

These often coincide with grid lines. Otherwise notate and locate by offset dimensions from nearest grid. It is useful to locate groups of holes, pockets, isolated bases, plinths, machinery, plant, etc.

(c) Columns

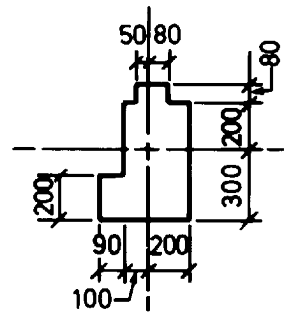
State overall concrete size (largest dimension first) and locate relative to the nearest grid lines. If the size of the column is greater below floor, show the lower profile dotted; its size will be indicated on the lower floor plan.

Where repetition occurs it may be convenient to add an explanatory note, e.g. all columns 300 × 300 and centred on grid lines unless noted.

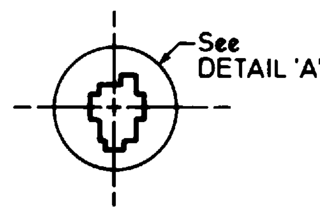


(d) Nibs on columns

Dimension on plan.

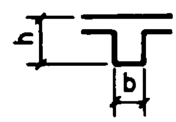


Where the profile becomes more complex it may be necessary to refer to an enlarged detail for dimensions. Elevations will be required if the vertical extent of the nibs is not obvious from the plan.

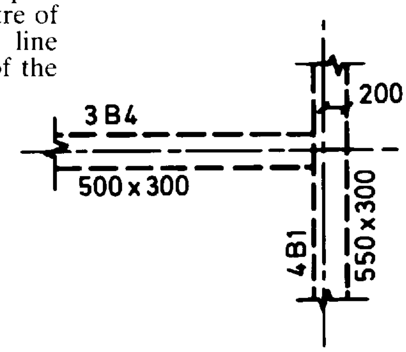


(e) Downstand beams

State beam reference (see subsection 2.20) and overall concrete size ($h \times b$), both preferably at the centre of span. The dotted line plots the profile of the lowest beam soffit.

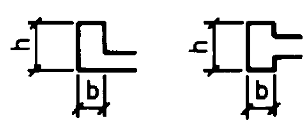


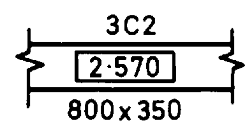
Where repetition occurs it may be convenient to add an explanatory note, e.g. all internal beams 600 × 300 unless noted.



(f) Upstand beams

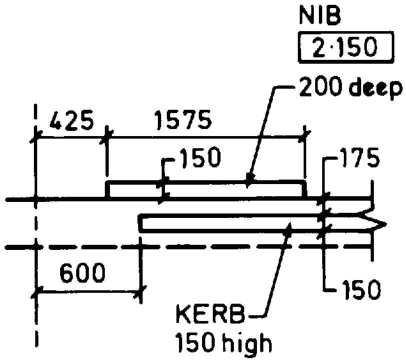
State beam reference and overall concrete size ($h \times b$). Add level to top of beam and/or draw section to clarify.





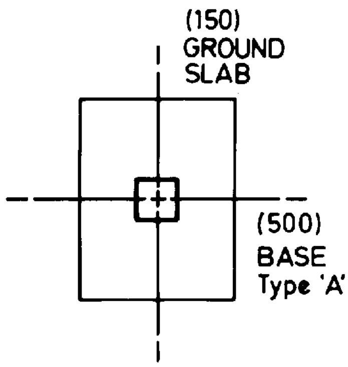
(g) Nibs and kerbs on beams

Locate extent of projection on plan and notate, indicating depth. Clarify with section and/or add levels to top.



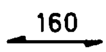
(h) Bases and ground slabs

Notate and indicate thickness.

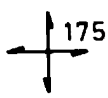


(j) Suspended slabs

Show direction of span and indicate thickness of slab, preferably near the centre of the panel.



one-way spanning

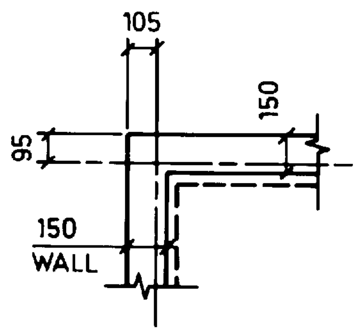


two-way spanning cantilever — 150 CANTILEVER

tapered cantilever (add section) — 150 to 200 CANTILEVER

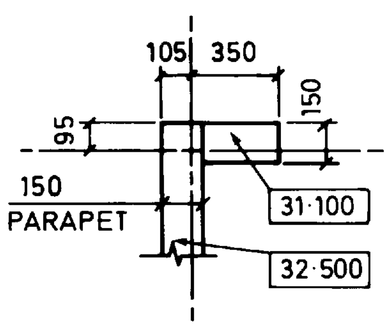
(k) Walls

State wall thickness and its location relative to the nearest datum. If the wall size under is different then show its profile dotted; its thickness will be indicated on the lower floor plan.



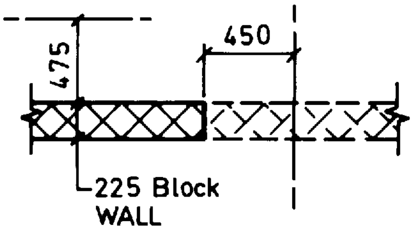
(l) Dwarf walls and parapets

These walls are viewed just above their top and not ated. Sections and/or levels are added for clarity.

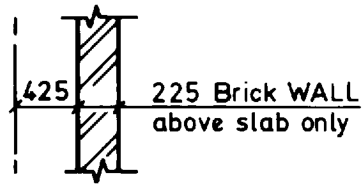


(m) Loadbearing walls

(i) Indicate wall material and thickness and its location relative to the nearest datum. Supporting walls under to be shown dotted and notated on the lower floor plan.



(ii) Locate and identify walls above floors that are not continuously supported by walls below.



Generally non-loadbearing partitions are not shown on structural drawings.

(n) Levels

These provide a vertical datum and should be displayed prominently at each level as appropriate, thus:

(i) top level of concrete, e.g. foundation base — 125·000

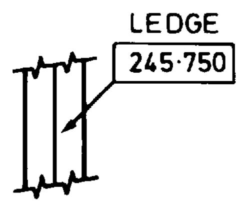
(ii) top of structural floor level — SFL 150·050

(iii) top of finished floor level — FFL 150·075

(iv) top of existing level — EL 150·075

(v) arrow indicates direction of down slopes and falls and up slopes — 50 FALL →, UP →

(vi) arrow indicates level to top surface as noted.



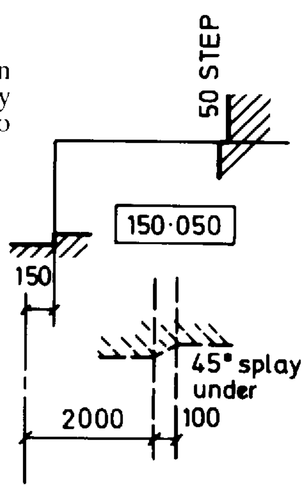
(p) Steps in level

Lines at a change in level can be quickly identified by adding sectional hatching to the plan as follows:

step on top surface

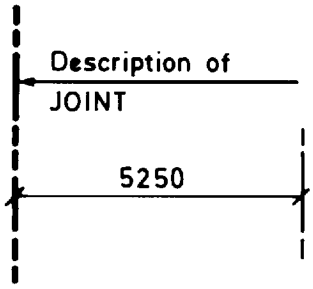
splay on slab soffit shown dotted

locate steps to the nearest datum appropriate.



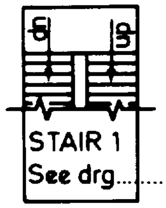
(q) *Joints*

Any special joint required by the engineer should be located and notated on plan with a bold chain-dotted line and supported by a section if required for clarification.



(r) *Stairwells*

On floor plans, complicated areas such as stairwells are often referred to an enlarged layout drawing. The direction of stair flights should be indicated as though standing on the subject floor. The area referred to is crossed.



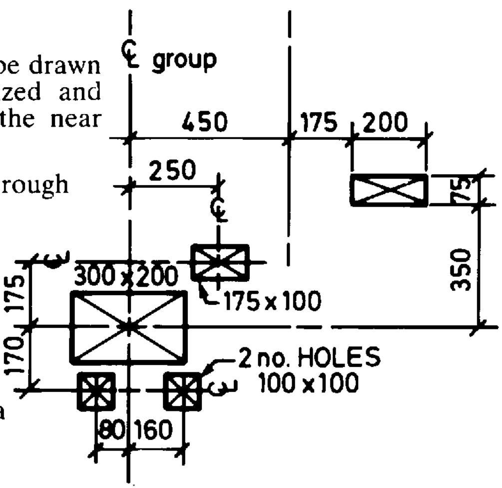
(s) *Holes*

All should be drawn to scale, sized and located to the nearest datum:

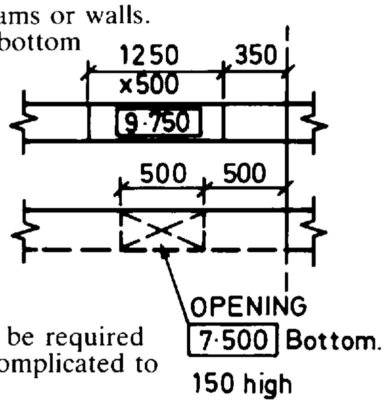
(i) hole through slab

(ii) groups of holes.

Identify holes with a cross.



(iii) holes through beams or walls. Indicate level to bottom of hole, e.g. window sill. Show cross dotted if below the section, e.g. downstand beam.

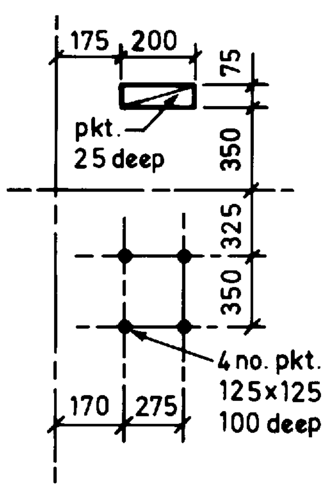


An elevation will be required if holes are too complicated to show on plan.

(t) *Pockets and recesses*

(i) similar to holes but identify area with diagonal only and notate

(ii) small pockets such as those used for anchor bolts are usually identified by a large dot and notated.



5.1.11.2 On section

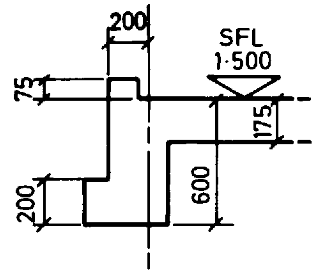
Sections are drawn to clarify the plan and provide mainly vertical information:

(a) *General cross-sections*

These provide a general impression of the entire vertical structure. Major dimensions and levels are shown. Complicated profiles etc. can remain undimensioned — these will be shown by local section prepared with the floor layouts. The elevation of background walls and columns are often included to increase the impression.

(b) *Local sections*

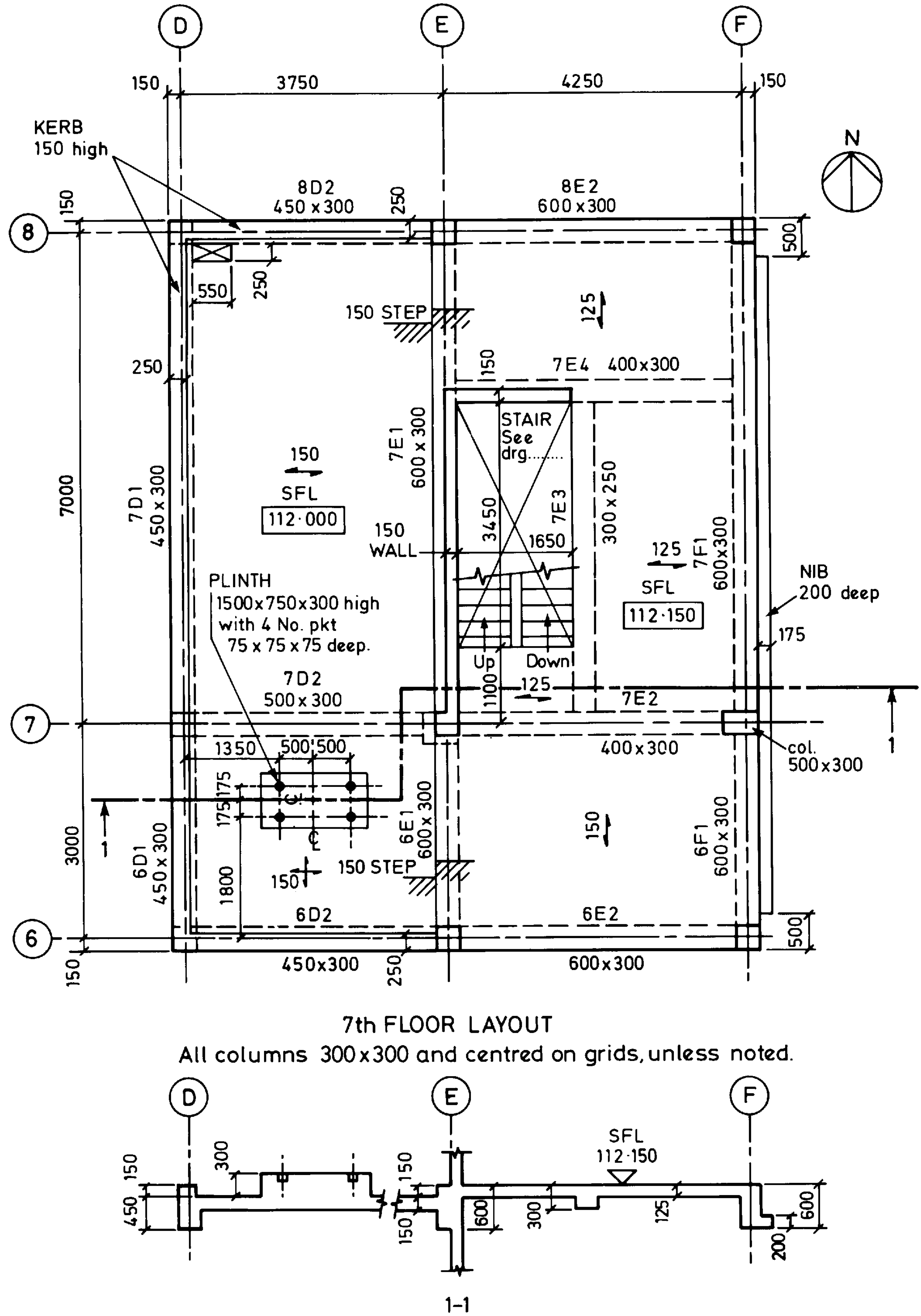
Show all vertical dimensions and levels. Some horizontal dimensions added will help to tie in with the plan. Local sections are preferably placed alongside the plan.



5.1.11.3 Fixing in concrete

Where ancilliary fixings are likely to affect the proper location of the reinforcement they should be located on the drawings. Where extensive, these fixings may be indicated only and referred to other drawings for location etc. Consideration shoud also be given to any extra reinforcement required.

5.1.20 Example of general-arrangement drawing for concrete structures



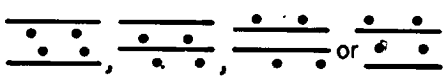
5.2 SLABS

5.2.10 Design information

These data are output from the approved calculations for each span which should indicate:

(a) For slabs designed and detailed in accordance with BS 8110 simplified rules (for bar curtailment rules etc, see clause 5.2.11.1)

(i) concrete grade to determine laps, durability, etc.
(ii) design method assumed, i.e. 1-way, 2-way, flat slab, etc.
(iii) type of support assumed, i.e. simple, restrained, cantilever, etc.
(iv) cover for top T1 and bottom B1 bars (see clause 5.2.22.1a)
(v) orientation for layering bars, e.g.



(vi) type of reinforcement and any size restrictions
(vii) area of main steel for bottom and top bars (required) A_s(mm^2/m) or, preferred type/size and pitch (actual)
(viii) special requirements, i.e. data for tie, torsion, shear bars, trimming of holes, internal radius of bends if non-standard, etc. Provide sketches where appropriate.

(b) For other slabs, in addition to above:

(ix) location of bar curtailments, if non-standard (for BS 8110 bar curtailment general rules see clause 5.2.11.2)
(x) location of compression bars if required A'_s(mm^2/m)
(xi) width of non-standard width column strips in flat slabs
(xii) lap lengths required if non-standard
(xiii) any special requirements, i.e. data for column drops

(c) Summary of slab calculations
For convenience it is often possible to rationalize main reinforcement areas/type, size and pitch. These can be summarized for the detailer by marking up a copy of the relevant general, arrangement drawing, using coloured pencils to differentiate top from bottom bars, or using the abbreviations B1, T1, etc. (see clause 5.2.22.1a), i.e.
locate A_s bottom on panel thus:

B1 / 1000 mm^2/m   B1 / T16 @ 200

locate A_s top on panel thus: or

T1 / 1300 mm^2/m   T1 / T16 @150

The additional data outlined in (*a*) or (*b*) above can be noted in the margins or sketched on plan to suit.

(d) Minimum reinforcement
These data are not always provided in the calculations, but are based on minimum or nominal percentages of reinforcement related to the slab thickness and reinforcement type (see Table 15)
Minimum reinforcement is generally provided as:

(i) distribution bars in B2 layer for 1-way slabs
(ii) lacer bars to top main bars.

5.2.11 Design code requirements

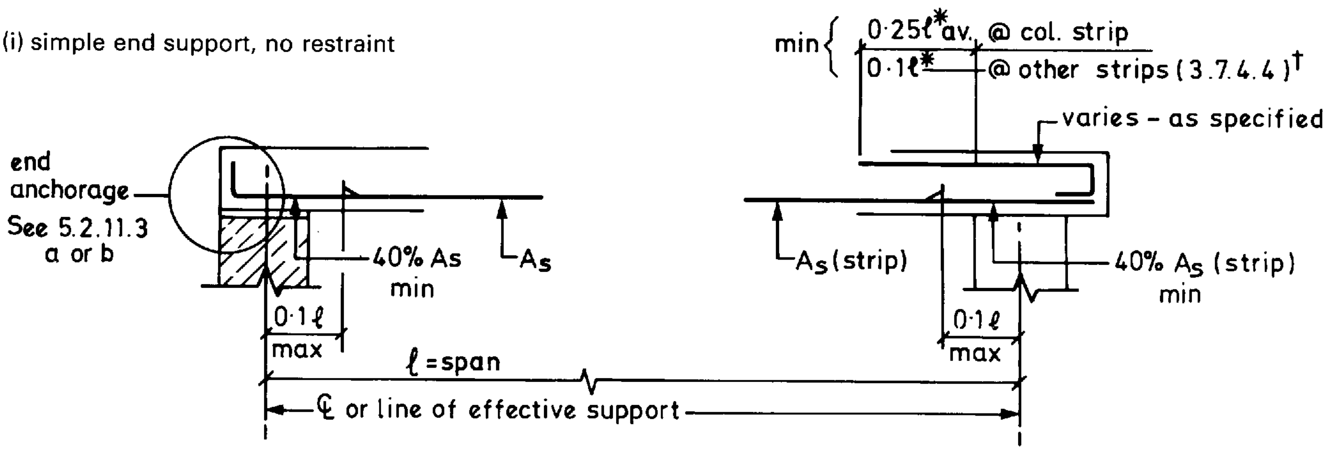
5.2.11.1 Simplified rules for bar curtailments in slabs (BS 8110, clause 3.12.10, Fig. 3.25)

Assumptions:

a. Slabs are of approximately equal span (within 15%)
b. Slabs support substantially uniformly distributed loads
c. Check that top slab reinforcement satisfies beam flange requirements (3.4.1.5†)
d. Tie force requirements should also be considered (3.12.3†)
e. Consider torsional effects in 2-way slabs where corners are prevented from lifting (3.5.3†).

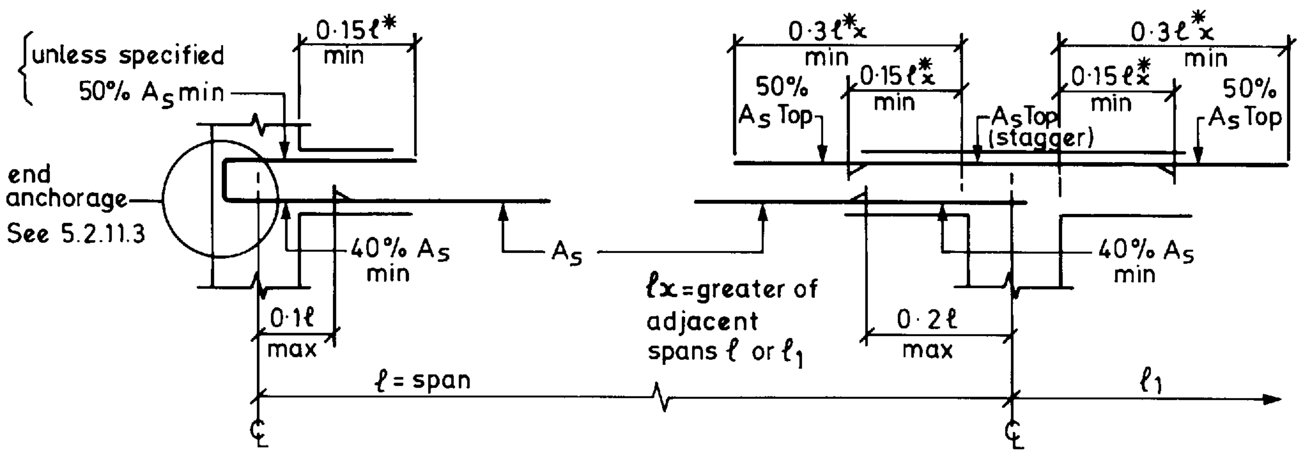
(i) simple end support, no restraint

(ii) discontinuous edge (flat slab)

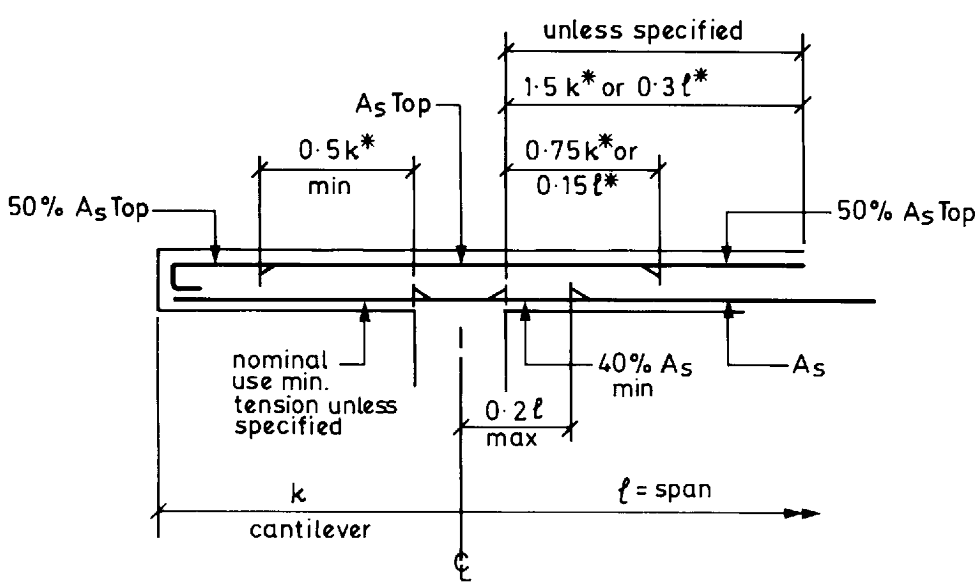


(iii) restrained end support

(iv) continuous internal support

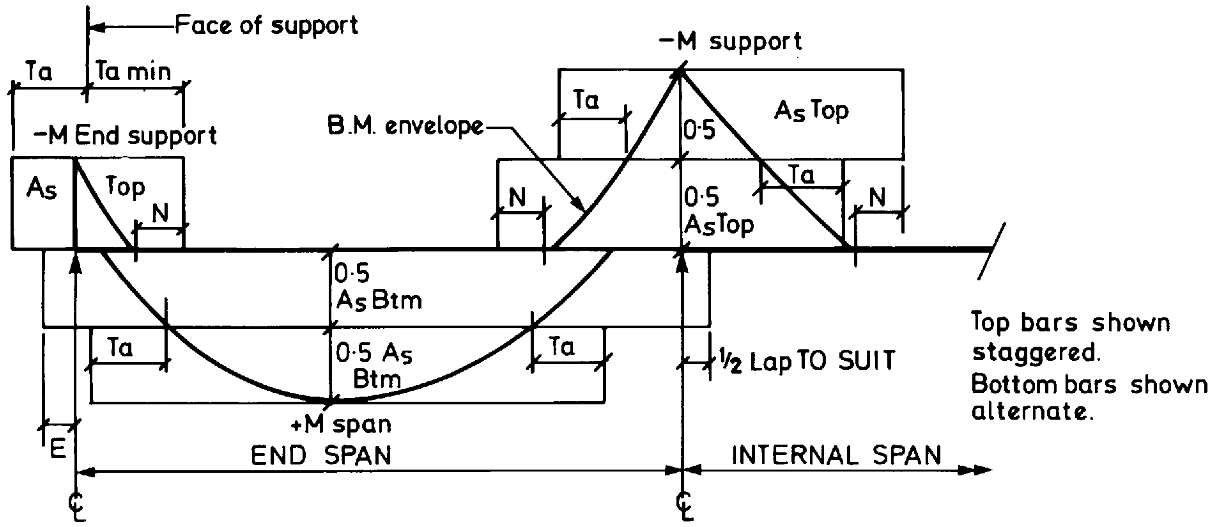


(v) cantilever



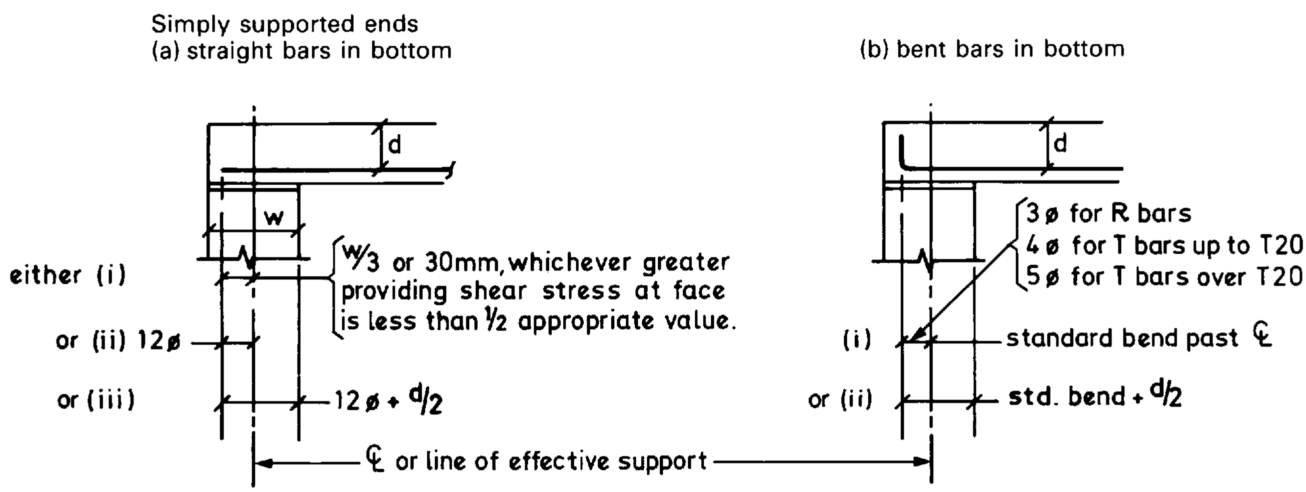
* or 45 ø whichever is greater

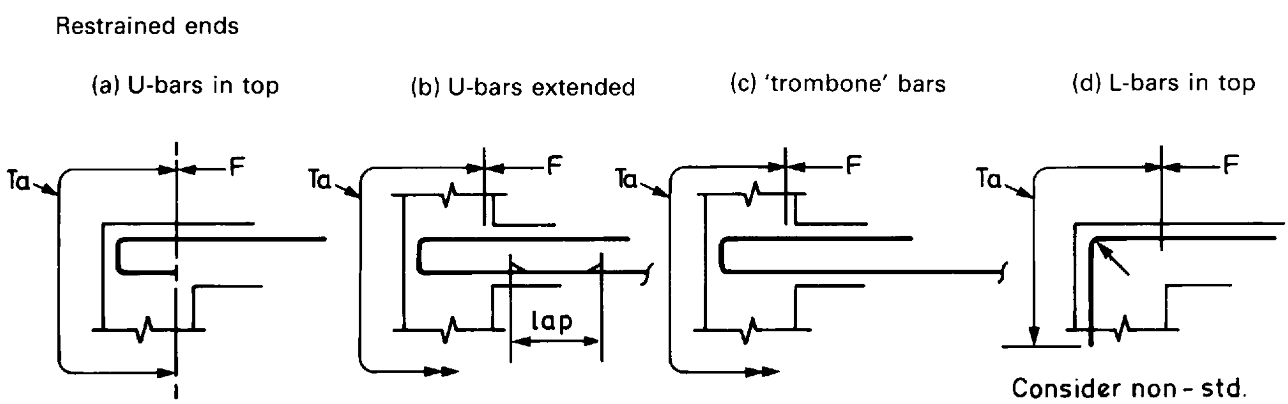
5.2.11.2 General recommendations for bar curtailments in slabs (clause 3.12.9.1†)



Key Ta = Tension Anchorage Length
N = Nominal 12ø or d (effective depth) whichever is the greater
E = Effective End Anchorage required if simple support
ø = Bar nominal size

5.2.11.3 End anchorage alternatives based on BS 8110: general recommendations (3.12.9.4†)





Key F = Face of vertical bar in restraining member
Ta = Tension Anchorage Length

5.2.11.4 Tie provision (internal and/or peripheral) (3.12.3†)

Ensure that any reinforcement specified for stability ties is effectively continuous by lapping and/or anchoring as necessary.

Table 15 Minimum tension reinforcement in slabs (3.12.5.2.)† Table 3.27

Spacing of minimum tension reinforcement

$F_y = 460\text{N/mm}^2$ 0.13% bh (both directions)				$b = 1000$	$F_y = 250\text{N/mm}^2$ 0.24% bh (both directions)				$b = 1000$	0.15% $fl.h$ (across flanged beams)			
bar nominal size, mm				slab depth	bar nominal size, mm				slab depth	bar nominal size, mm			
8	10	12	16		8	10	12	16		8	10	12	16
pitch, mm				mm	pitch, mm				mm	pitch, mm			
200	200			100	200	200			100	200	200		
300	300			125	150	250	300		125	275	300		
250	375	375		150	125	200	300	375	150	225	350		
200	300	450		175	100	175	250	450	175	175	300	400	
175	300	400		200		150	225	400	200	150	250	350	
150	250	350		225		125	200	350	225	150	225	300	
150	200	300		250		125	175	300	250	125	200	300	
125	200	250	500	300		100	150	250	300	100	175	250	400
100	150	250	400	350			125	225	350		150	200	350
	150	200	375	400			100	200	400		125	175	300
	100	175	300	500				150	500		100	150	250

Note: The above chart is not applicable to water-retaining structures.

Table 16 Maximum spacing of tension bars in slabs (3.12.11.2.7†)

(a) In all cases, maximum spacing not to exceed the lesser of $3d$ or 750mm
Normal cracking controlled using following rules:
(b) F_y = 250, maximum slab depth = 250mm
(c) F_y = 460, maximum slab depth = 200mm
(d) $A_s < 0.3\%\ bd$
(e) When $A_s = 0.3 \rightarrow 1.0\%\ bd$ limit bar spacing to $\frac{\text{value from Table below}}{\%\ \text{reinforcement}}$
(f) When $A_s > 1\%\ bh$ use appropriate spacing (mm) from Table below

Spacing of bars according to % redistribution

f_y	%moment to or from section considered											
	−30	−25	−20	−15	−10	0	+10	+15	+20	+25	+30	
250	210	225	240	255	270	300	300	300	300	300	300	c o
460	115	120	130	135	145	160	180	185	195	200	210	mm

Note: If %moment redistribution unknown assume (−15) at supports, (0) for span (3.12.11.2.8)

5.2.20 Detailing

5.2.21 Methods of detailing slabs

There are several techniques possible for detailing slabs — choice perhaps depending on the size of the project, its complexity and the degree of panel repetition. Normally the concrete profile dimensions are abstracted from the relevant general-arrangement drawings. These together with the calculations should be at their final stage before commencing the detailing stage.

5.2.21.1 Combined top and bottom reinforcement

(a) Multipanels
Prepare concrete profiles from the general-arrangement drawing to a suitable scale, usually 1:50. Identify similar panel types, and detail bottom then top reinforcement for each different panel type. Large floors may spread over several drawings linked by key plans.

(b) Unit panels
Similar to clause 5.2.21.1a, but different panel types are identified and drawn as single panels linked by key plan. Method particularly flexible when panel types repeat throughout a job. Adjacent panel reinforcement should be carefully coordinated.

5.2.21.2 Separate top and bottom reinforcement

Useful when detailing fabric or when the reinforcement is very complicated. Top and bottom reinforcement is separated for clarity and drawn onto two identical outlines, preferably on the same drawing. Suitable instructions should ensure that these separate layers are constructed together.

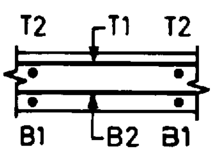
5.2.21.3 Tabular method
Combinations of information such as bar mark, bar type and size, bar pitch, etc. can be scheduled alongside the detail. This will tend to reduce congestion on the drawing and improve checking procedures, computer methods and the work of the quantity surveyor Each typical bar should be identified on the drawing by its bar mark and bar layer (see clauses 5.2.22.1 and 5.2.34 example.)

bar mark	type/ size	etc.
63	T10	
etc	etc	

5.2.21.4 Computer methods
Where drawings are produced fully or partly by computer graphics the method of preparation and presentation should follow standard principles wherever possible.

5.2.22 Bar detailing on slabs
5.2.22.1 On plan
(a) Locating layers of reinforcement
Reinforcement is fixed in layers starting from the bottom of the slab upwards and bar marks should preferably follow a similar sequence of numbering. Notation is as follows:

(i) abbreviation for top outer layer T1
(ii) abbreviation for top second layer T2 e.g.
(iii) abbreviation for bottom second layer B2
(iv) abbreviation for bottom outer layer B1

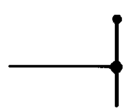


Note: Repeat this sketch on each relevant drawing for clarity and presentation.

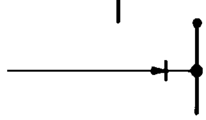
(b) Typical bar and indicator line
Generally each bar mark is represented on plan by a typical bar drawn to scale, using a thick line. The bar is positioned approximately midway along its indicator line, the junction highlighted by a large dot. The first and last bars in a zone of several bars are represented by short thick lines, their extent indicated by arrowheads.

Bends or hooks, when they occur at either end of the typical bar are represented by a medium dot or similar

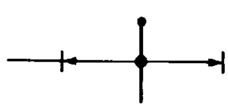
(i) one bar only 1T10-63-T1



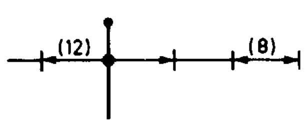
(ii) two bars 2T10-63-150T1



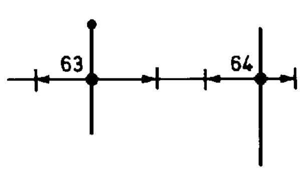
(iii) a zone of three or more bars 20T10-63-150T1



(iv) multiple zones, showing similar marks in each zone, with quantities indicated in brackets 20T10-63-150T1

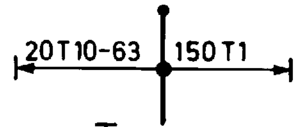


(v) multiple zones, showing dissimilar marks in each zone 12T10-63-150T1 8T20-64-200T1

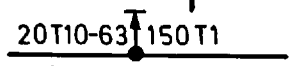


Generally the 'calling up' of bars is located at the periphery of the detail on an extension of the indicator line, as shown above.

(vi) when space is restricted 'calling up' can be written within the zone of the indicator line, or in extreme cases:

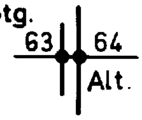


(vii) written along the bar itself



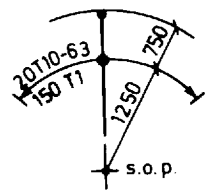
(viii) instructions to stagger bars of same mark

(ix) instructions to alternate bars of different mark

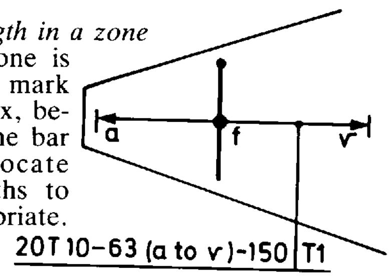


(c) Bars detailed 'elsewhere' are shown as a thick dashed line

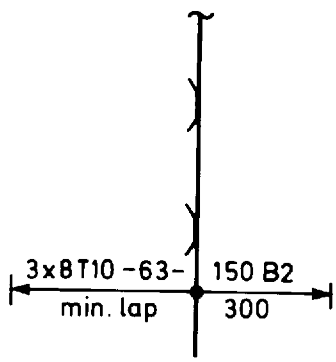
(d) Bars set out from a radius in a 'fan' zone
The indicator line can be located on a datum radius for measuring the pitch of the bars. Locate end of bars to datum.



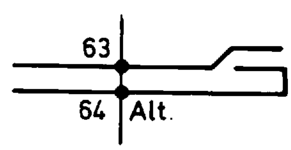
(e) Bars of varying length in a zone
Each bar in the zone is given the same bar mark but a different suffix, beginning with 'a'. The bar schedule will allocate different bar lengths to each suffix as appropriate.



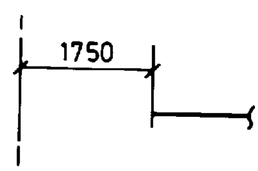
(f) Bars in long panels
To simplify the 'calling up' of strings of bars in very long panels, e.g. distribution bars in one-way slabs, identical bars of a convenient length can be lapped from end to end of the panel. State minimum lap. The use of random length bars is not recommended.



(g) Cranked and bent bars
These are sometimes, for convenience, drawn on plan as though laid flat. However, confusion on site can result if some of these bars are required to be fixed flat and some upright. Sections and notes should be provided to clarify this method if used.



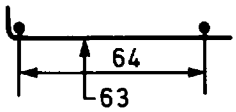
(h) Fixing dimensions
Dimensions (mm) are restricted to those required by the steel-fixer to locate bars not already controlled by end covers. Dimension lines are thin lines terminated by short obliques.



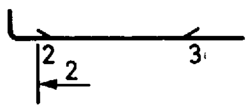
5.2.22.2 In section — drawn where required to clarify the fixing

(a) Bars in elevation are represented by thick line with mark indicator.

(b) First and last bars in a zone are indicated by a dot in section with appropriate mark.



(c) Curtailed bars are identified by short 30° obliques with appropriate mark. If congested clarify ends with pointers.



5.2.23 Other requirements for slabs

5.2.23.1 Special notes for slabs

In addition to standard notes for reinforcement drawings (see subsection 2.8) the following note should appear on all slab drawings:

(a) Cover to outer reinforcement: B1...T1...end...

(b) Bar layer notation:

Bar layer notation:	top outer layer	T1
	top second layer	T2
	bottom second layer	B2
	bottom outer	B1

5.2.23.2 Chairs and spacers

Chairs support the top reinforcement. Where specified, traditional bent chairs of shape code 83 should be scheduled using the following guidelines:

(a) bar size for slab less than 200mm thick — 10mm

(b) bar size for slab greater than 200mm thick — 12mm minimum.

(c) location within panel — along periphery of 0.1 span

(d) additional location for flat slab — along interior supports

(e) spacing of chairs (and spacers) — 1000mm.

The bottomlayer is generally supported from the deck by plastic or concrete-block spacers selected to provide the appropriate concrete cover. For more comprehensive information concerning chairs and spacers, see Section 6.

5.2.23.3 Trimming of holes in slabs

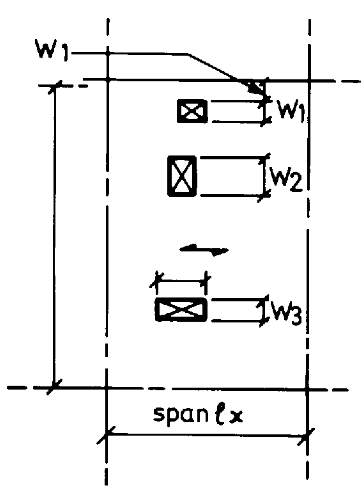
(a) Where holes, or groups of holes are considered to be of structural significance (i.e. in flat slabs, etc.), the design data should indicate any special reinforcement.

(b) Where holes, or groups of holes are considered to be structurally insignificant, then the following rules apply:

(i) minimum unsupported edge distance = width of hole w_1

(ii) maximum width of isolated opening measured at right-angles to span = 1000

(iii) maximum length of isolated opening measured parallel to span = 0.25 span l_x



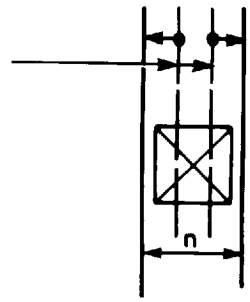
(iv) maximum total width ($w_1+w_2+w_3$) of multiple holes measured at right-angles to the span l_x = 0.25 span l_y

(v) small isolated holes with sides 150mm or less can generally be ignored structurally. Significant holes should be drawn to scale and shown on the reinforcement drawing.

(vi) larger isolated holes with sides 500mm or less either:

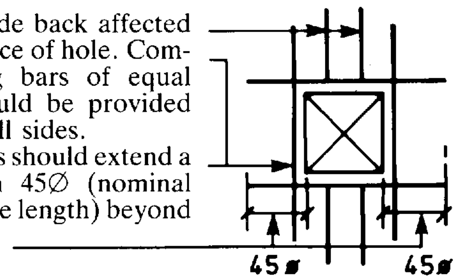
displace affected bars equally either side of hole, provided that resultant spacing does not exceed the values shown in Tables 15 and 16.

or:



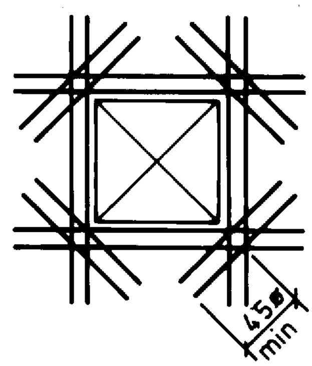
cut or slide back affected bars to face of hole. Compensating bars of equal area should be provided to trim all sides.

Trimmers should extend a minimum 45∅ (nominal anchorage length) beyond the hole.



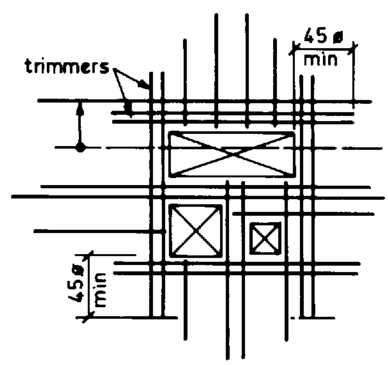
(vii) large isolated holes with sides (500-1000)mm

Treat as (vi) above, but in addition trim top of holes with similar bars. If depth of slab exceeds 250mm, provide diagonal reinforcement of similar area in top and bottom, but consideration should be given to the congestion of multiple layers.



(viii) groups of holes within boundary of 500mm or less

Trim as single hole using methods described in (vi) above. Bars should pass alongside holes where possible.



(ix) groups of holes within boundary of (500-1000)mm or less

Trim as single hole using methods described in (vi) and (vii) above.

5.2.24 Shear reinforcement in slabs (where minimum depth = 200mm) (3.5.5.3†) Table 3.17†

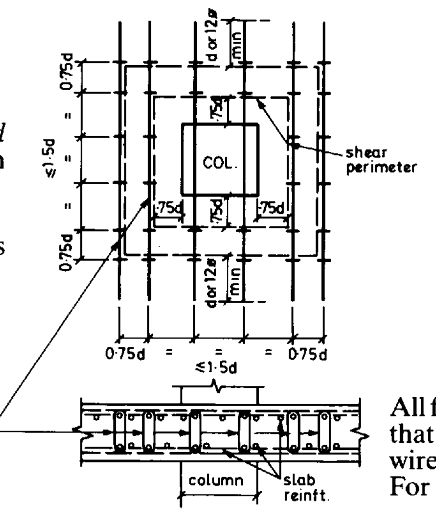
Generally provided by vertical links which also serve as chairs.

5.2.24.1 Flat slabs (3.7.6†)

(a) *Column shear heads* (3.7.7.5†)

(i) A minimum of 2 shear perimeters are spaced at 0.75d from face of column

(ii) Vertical shear legs are shape code 81 (2 legs) or shape code 85 (1 leg) spaced at a maximum of 1.5d around each perimeter



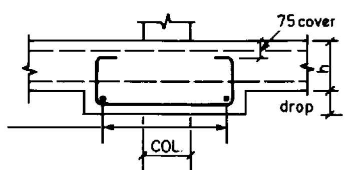
(iii) Links can be threaded onto say T12 lacer bars to form convenient 'ladders' which are fixed along side the B2 then T2 layers of slab reinforcement. This detail also ensures that adequate cover to links is achieved.

(b) *Column drops*

(i) Main slab reinforcement carries through

(ii) Nominal mat: T12 at 300 each way

Design data to specify other



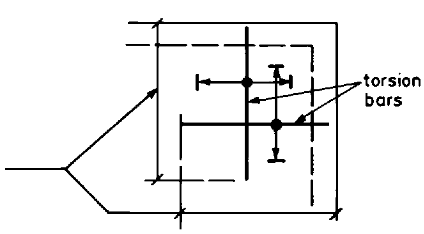
Alternatively, consider the use of fabric in these regions (see subsection 2.6)

5.2.25 Torsion reinforcement in restrained slabs (3.5.3.5†)

5.2.25.1 At corners (2 discontinuous edges, both simple supports)

(a) Torsion reinforcement required top and bottom.

(b) Gross area required = 0.75 × maximum A_s span bottom each way in both top and bottom.



(c) Extent of torsion bars = 0.2 × shorter span.

5.2.26 Fabric reinforcement in slabs

(a) *General*

Two-directional reinforcement can be factory welded and fabricated into sheets to help speed fixing and achieve economy in construction costs. BS 4466:1981 defines three types of fabric:

(i) Designated (standard mesh) fabric — see Tables, Section 3.
Stock sheet sizes are 4.8 × 2.4m; these can be reduced by cutting to suit. Wire sizes range up to 12mm with standard 100/200mm meshes. Peripheral wires are welded at ½ pitch from the edge of the sheet.

(ii) Scheduled (non-standard) fabric
Wire sizes (maximum 12mm) and sheet sizes can be varied. Wire pitches must remain constant but may be non-standard. Wire projections at edges may vary.

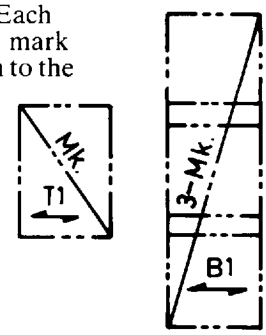
(iii) Detailed (purpose-made) fabric
These sheets can be specified using standard reinforcing bars. These bars can be set at varying pitches and edge projections. Sheet sizes can vary with due consideration given to handling and transportation.

All fabrics can be bent to most BS shapes. However, ensure that redundant cross-wires do not inhibit fixing. These wires can be eliminated by specifying purpose-made fabric. For further guidance consult the manufacturers of fabric.

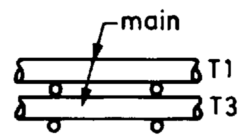
(b) *Suspended solid floor construction*

For clarity on plan it is recommended that the top sheets of fabric be drawn separately from the bottom sheets, preferably on the same drawing. Fabric is identified by a chain double-dashed line.

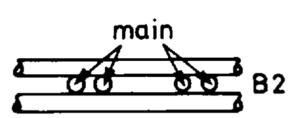
(i) Fabric detailing on plan. Each individual sheet is given a mark number and related on plan to the concrete outline.
Indicate the direction of the main reinforcement and its layer notation. Wherever multiple sheets of identical marks occur they can be combined as shown.



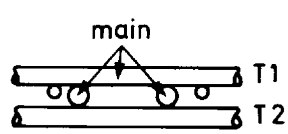
Areas of reinforcement can be increased by double 'layering'.



Also consider the possible advantages of 'nesting' the two sheets to maximize the lever arm.

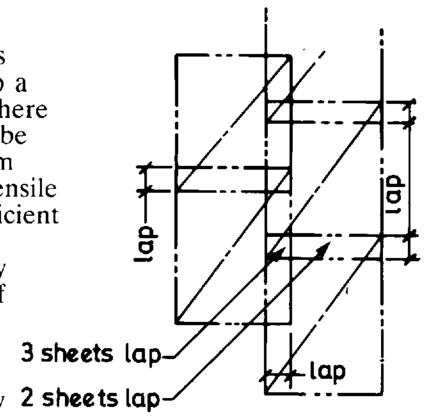


Similarly 'nesting' when main steel is required in two directions, crossing at 90°.



Structural mesh type 'B' is often specified for suspended slabs, possibly with the addition of loose bars. With reasonable production runs, consideration should be given to specifying 'purpose-made' fabric. For each fabric mark indicate its reinforcement in a table alongside the plan. Minimum reinforcement requirements are shown in Table 15.

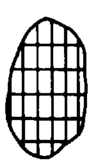
(ii) Laps in fabric
The need for laps should be kept to a minimum and, where required, should be located away from regions of high tensile force. Allow sufficient clearance to accommodate any 'multi-layering' of sheets at laps, reducing these occurrences where possible by 'staggering' sheets.



Show lap dimensions on plan and/or indicate minimum lap requirements in a note on the drawing. Minimum laps are required to prevent cracks caused by secondary stresses. Explanatory notes and Tables of lap lengths for welded fabric are given in Appendix 3B.

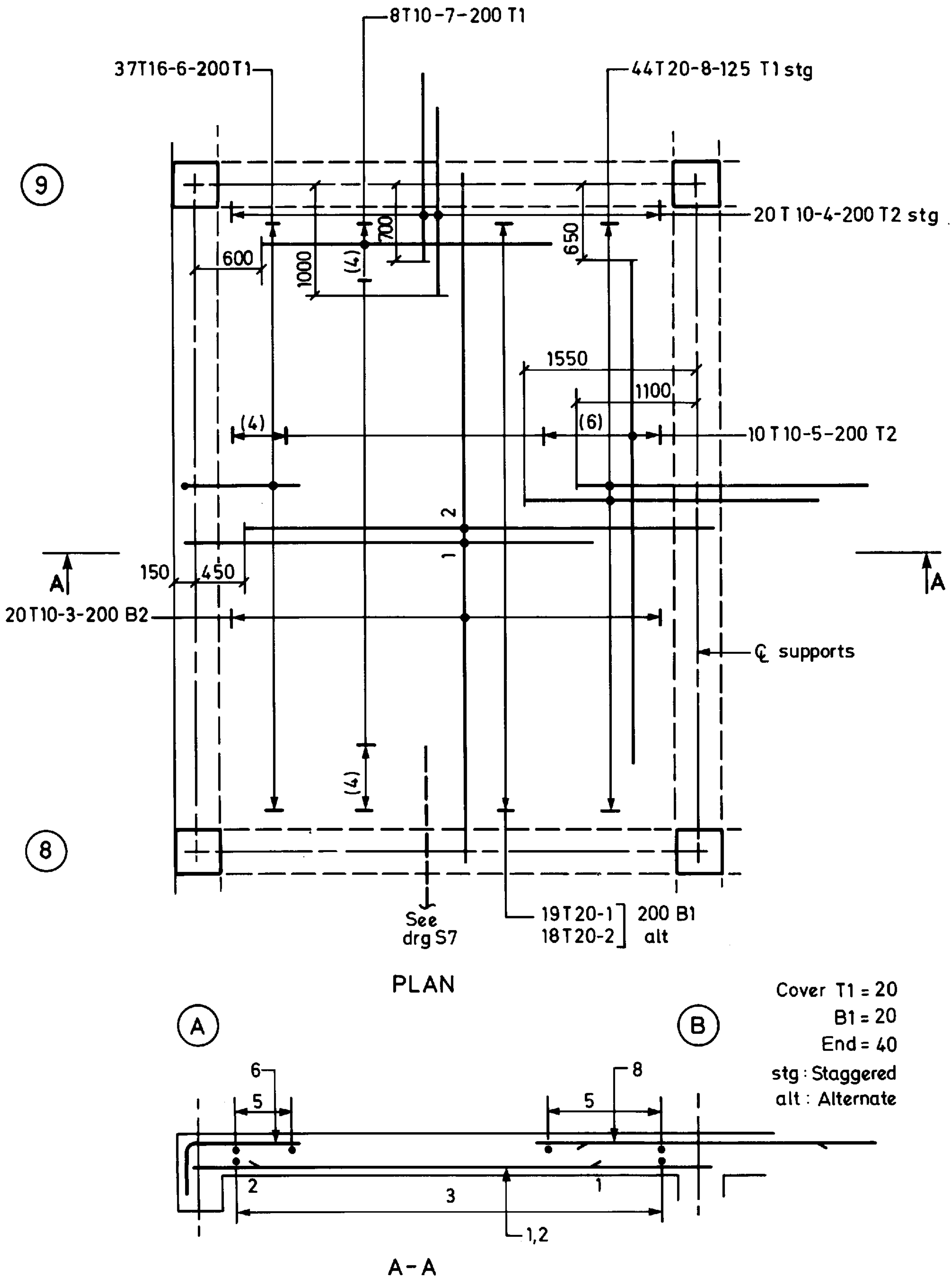
(c) *Voided-slab construction*
A nominal designated fabric is normally placed within the topping of trough and waffle-type floors. The extent of the fabric is shown by a diagonal on the plan of the reinforcement drawing and the fabric type scheduled as gross area in m^2 by adding a suitable percentage to the net area of the floor to allow for laps. For ordering purposes, the contractor should translate this gross area into the quantity of sheets required to suit his method of working. Where more comprehensive detailing of fabric sheets is required refer to clause 5.2.26a.

(d) *Ground-slab construction*
The presence of fabric reinforcement can be indicated by a sketch and a prominent note on the drawing. This can be the general-arrangement drawing (in straightforward cases.) The note should include type of fabric, location within the depth of slab and minimum lap requirements. A typical section to clarify this construction should be included. The fabric type is scheduled as a gross area by adding a suitable percentage to the net area of slab to allow for laps. For ordering purposes, the contractor should translate this gross area into the quantity of sheets required to suit his method of working. Where more comprehensive detailing of fabric sheet is required, refer to subclause 5.2.26(a).

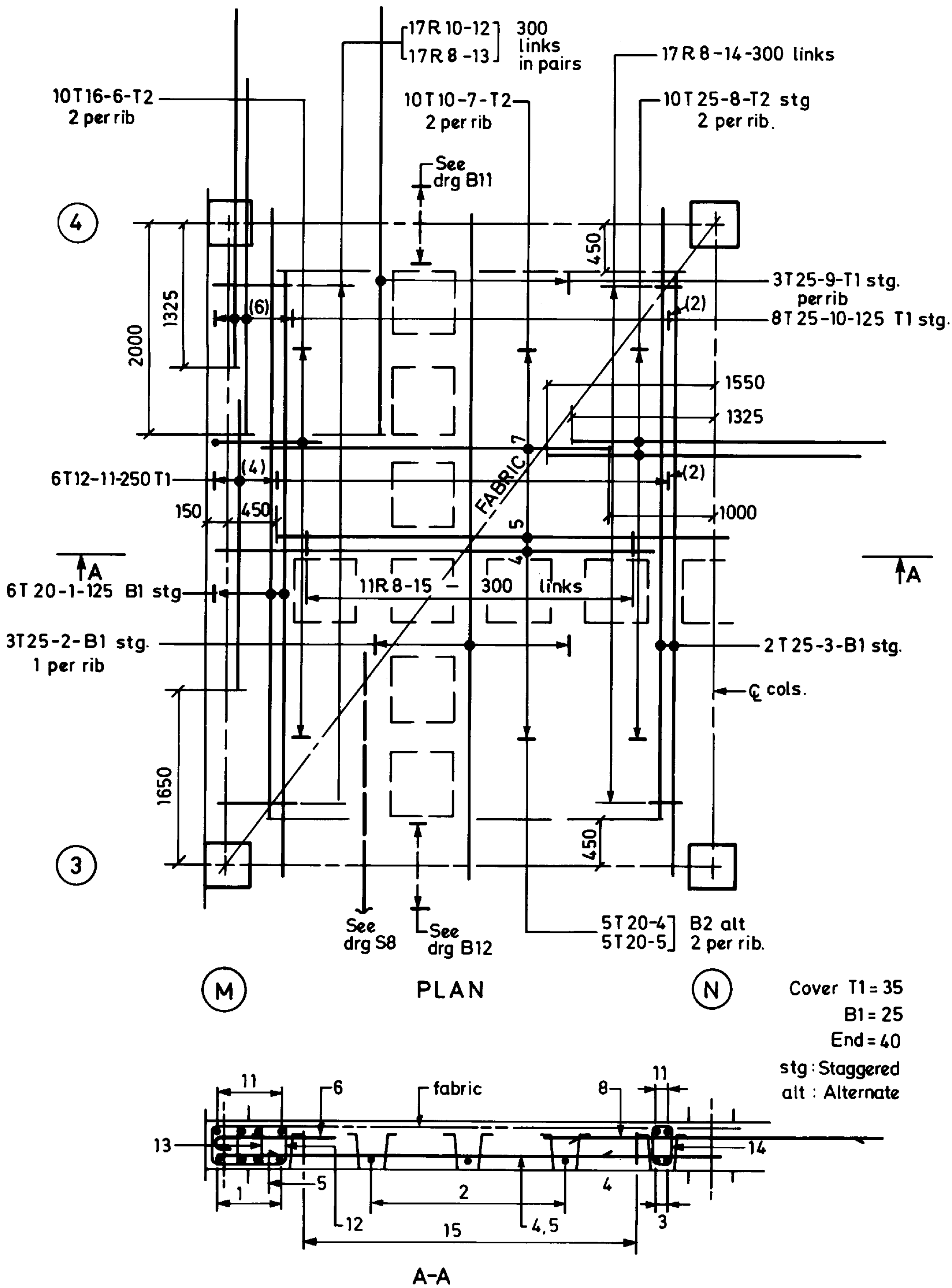


5.2.30 Examples of detailing

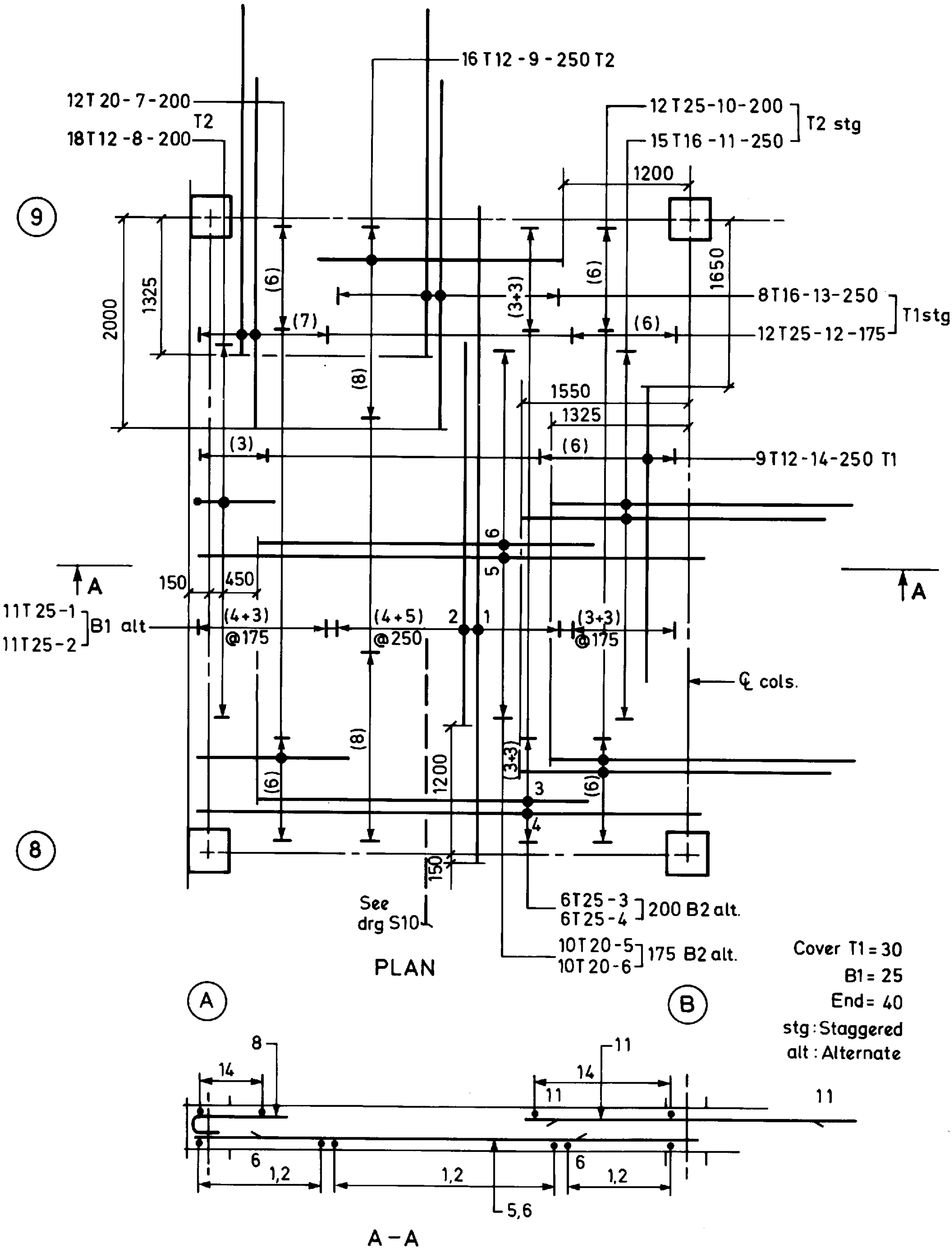
5.2.31 Typical one-way spanning slab



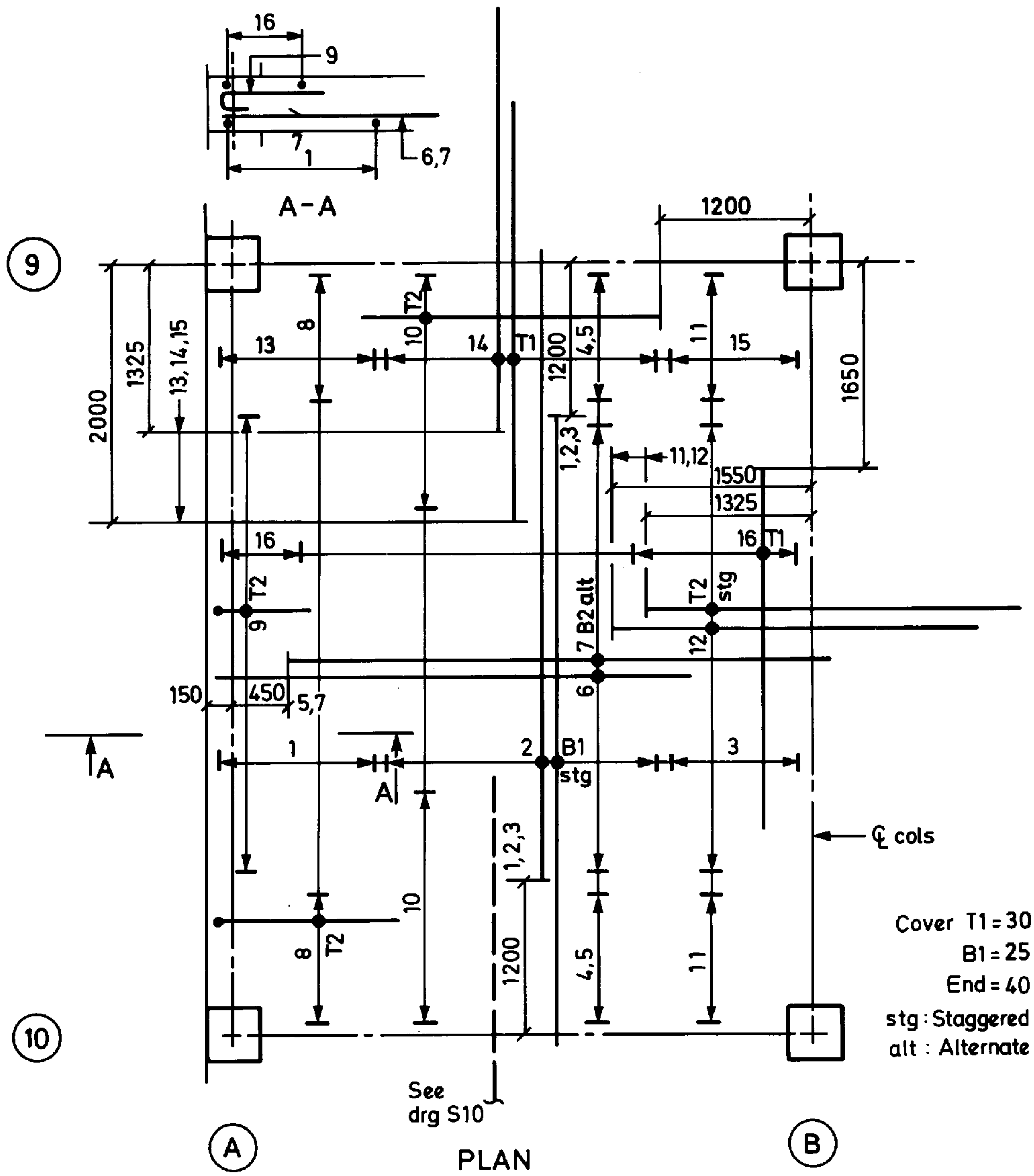
5.2.32 Typical ribbed-slab panel



5.2.33 Typical flat-slab panel

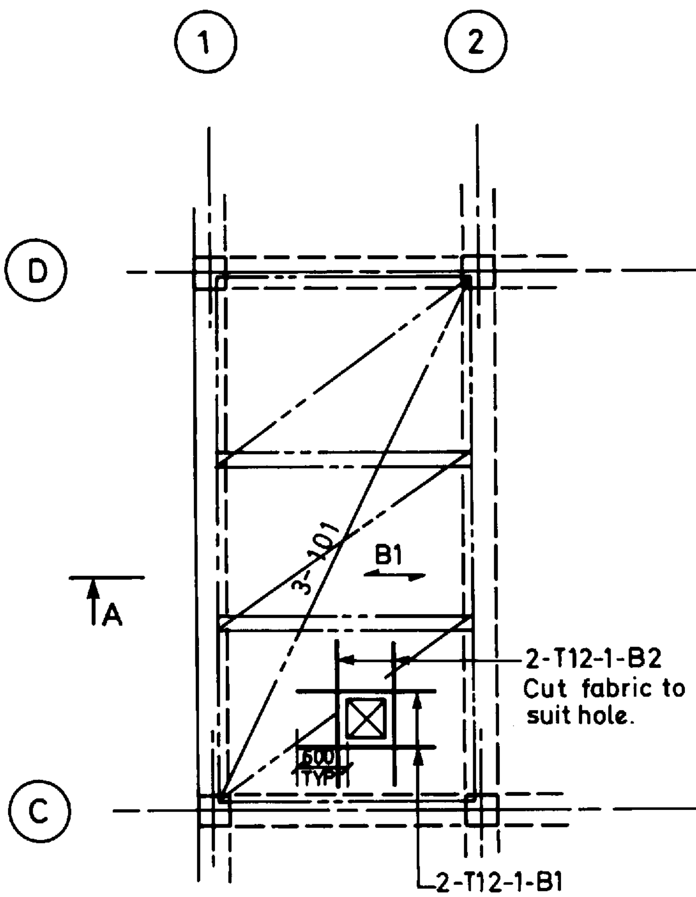


5.2.34 Typical flat-slab panel (tabular method)

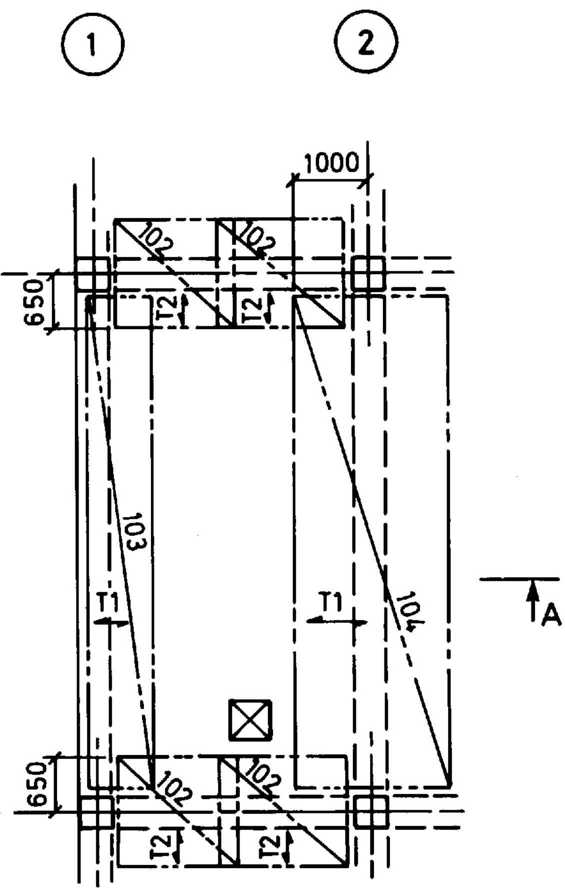


Fixing information								
Layer	Pitch (mm)	MK	Type/size	No. bars	Layer	Pitch (mm)	MK	Type/size	No. bars
B1	175	-1-	T25	7	T2	200	-9-	T12	18
	250	-2-	T25	9		250	-10-	T12	8+8
	175	-3-	T25	6		200	-11-	T25	6+6
B2	200	-4-	T25	3+3		250	-12-	T16	15
	200	-5-	T25	3+3	T1	175	-13-	T25	7
	175	-6-	T20	10		250	-14-	T16	8
	175	-7-	T20	10		175	-15-	T25	6
T2	200	-8-	T20	6+6		250	-16-	T12	3+6

5.2.35 Typical flat-slab panel showing fabric reinforcement

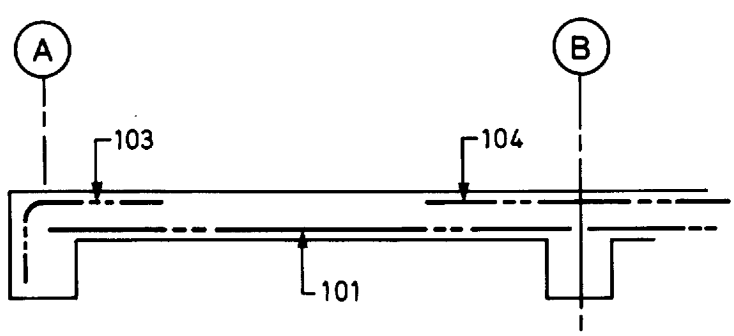


PART PLAN -
BOTTOM FABRIC
+BARS



PART PLAN -
TOP FABRIC

Fabric			
MK	Type	Main	Secondary
101	B1131	T12 e 100	T8 e 200
102	A252	T8 e 200	T8 e 200
103	Detailed	T12 e 150	T8 e 200
104	Detailed	T16 e 150	T8 e 200



A-A

Cover : T1 = 20
B1 = 15
End = 40
Min lap = 250

5.3 COLUMNS

5.3.10 Design information

These data are output from the approved calculations for each column type and should indicate:

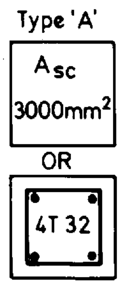
(a) General

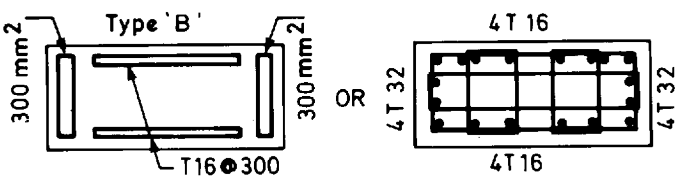
(i) concrete grade to determine laps, durability, etc.
(ii) cover requirements to vertical bars or links
(iii) type of reinforcement and any size restrictions
(iv) required area and distribution of main vertical bars A_{sc}(mm^2) or preferred actual type/size, and location
(v) kicker height, otherwise assumed as 75mm
(vi) state lap length requirements at column splices and whether tension or compression
(vii) state link type/size and pitch otherwise assumed to be as code requirements, see below, also Table 17
(viii) any special requirements.

Summary of column calculations

For convenience and simplicity it is often possible to rationalize similar reinforcement areas/ type, size and location:

For example, these can be summarized at the end of the calculations as columns – reinforcement types A, B, etc. Mark their location on copy of the relevant general-arrangement drawings.

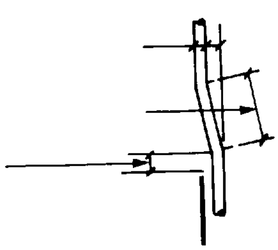




5.3.11 Design code requirements

(a) Main vertical reinforcement

(i) Minimum area —— 0.4% of cross section (3.12.5.3†) Table 3.27†
(ii) Minimum size of bars — 12mm
(iii) Minimum number of bars — no. in rectangular columns
(iv) Minimum number of bars — 6 no. in circular columns
(v) Maximum area if vertically cast — 6% of cross-section (3.12.6.2†)
(vi) Maximum area if horizontally precast — 8% of cross-section (3.12.6.2†)
(vii) Maximum area at laps — 10% of cross-section (3.12.6.2†)
(viii) Minimum overall joggle offset = 2 ∅ + 10% tolerance
(ix) Minimum joggle length = 10 × centre-line ofset or 300mm minimum
(x) Allow 75 clearance above lower bar to start of joggle for tolerance



(b) Horizontal links

(i) Minimum size — ¼ size of largest vertical bar (3.12.7.1†)
(ii) maximum pitch — 12 × size of smallest compression bar (see Table 17).
(iii) all vertical corner bars or groups to be tied by links at minimum 135°. (3.12.7.2†)
(iv) alternate outer vertical bars or groups should be tied by links 3.12.7.2†)
(v) however, outer vertical bars or groups, should be tied if spacing between them exceeds 150mm. (3.12.7.2†)
(vi) circular links or spiral reinforcement provides adequate restraint in circular columns. (3.12.7.3†)

(c) In section, the length of the longer side should not exceed 4 × length of the shorter side. (3.8.1†)

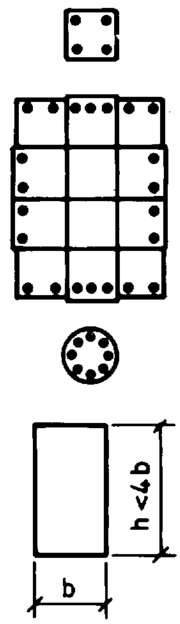


Table 17 Column link data

nominal size of vertical bars mm	*minimum size of links* mm	*maximum pitch of links* mm
12	6 (8 preferred)	125
16	6 (8 preferred)	175
20	6 (8 preferred)	225
25	8	300
32	8	* 375 often reduced to 300
40	10	475 often reduced to 300
50	16	600 often reduced to 300

* Reduce pitch of links to 200 at *laps* when cover is less than 1½ × largest vertical bar size (3.12.8.12†)

5.3.20 Detailing

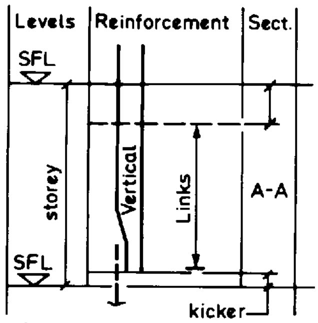
5.3.21 Methods of detailing columns

Most columns with straightforward profiles are prepared in tabular form, especially for the larger jobs. Alternatively, columns can be shown in full elevation. Normally the concrete profile dimensions are abstracted from the relevant general-arrangement drawings. These, together with the calculations, should be at their final stage before commencing the detailing stage.

5.3.21.1 Column schedules

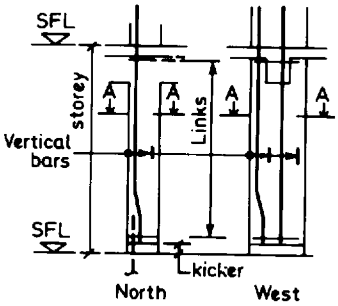
The elevation is prepared in economical tabular form, the concrete profile appearing only in the section.

Each column type is scheduled, indicating storey height, floor levels, kicker heights and depth of horizontal member. The vertical reinforcement and links are added to the schedule and bar mark location identified from a mid-storey height section. Additional sections may be added for special features. Column starter bars cast with and projecting from other members, e.g. bases, should be detailed with those members.



5.3.21.2 Column elevations

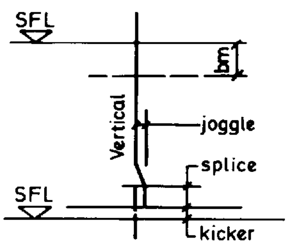
Concrete profiles are elevated from at least one side depending on their complexity and preferably drawn looking from a consistent direction. Main vertical and link reinforcement is added, with sections to clarify the fixing.



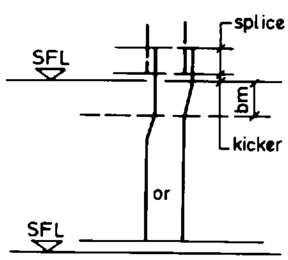
5.3.21.3 Column/beam intersections

Often the most critical details on a job will be the column–beam junctions. Careful thought should be given at an early stage to the arrangement of bars. Preferably one detail solution should be consistently followed throughout the job.

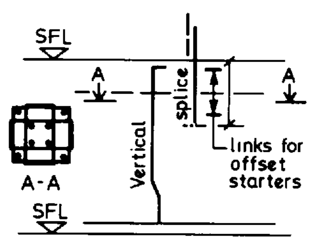
(*a*) The simplest solution is to allow the column bars to run through the beam at constant cover. The transverse beam reinforcement is detailed to avoid these bars. The lower end of the vertical bar is joggled to accommodate the splice with the lower member.



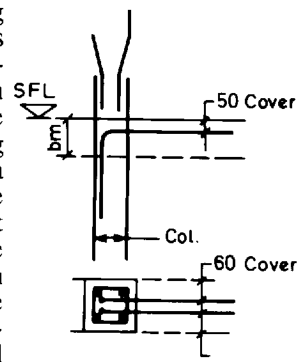
(*b*) Alternatively, the top end of the vertical bar is joggled to avoid beam bars and/or to accommodate the splice above. However, this reduces the moment capacity of the column at the kicker. This detail is also useful when the column above decreases in size by up to 75mm, say.



(*c*) When there are large reductions in size of the column above, the step between faces can become excessive for a bar to joggle. Usually the vertical bar is terminated within the beam and a separate starter bar provided. These starter bars are provided with links tied into the lower column bars to align them to lap with bars in the offset column above. For bars with top bend, allow top clearance for beam reinforcement (say, 100mm cover).



(*d*) Where large bending moments occur at ends, it is sometimes necessary to provide separate bars fixed with the column to carry these moments from the framing beam. They often require a large radius bend (see Appendix A) and are difficult to place accurately. These bars should be detailed with the column, *not* with the beam, and referenced extremely carefully to avoid clashes with other beam reinforcement. If structurally feasible a U-bar placed and detailed with the beam is a preferred detail.



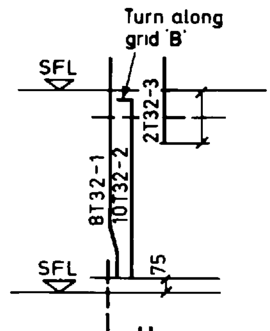
5.3.22 Bar detailing on columns

5.3.22.1 On elevation

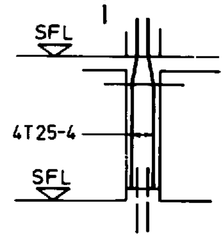
(*a*) *Vertical bars*

Generally each bar mark is illustrated by a typical bar drawn as a thick line in elevation. Bars detailed 'elsewhere' are shown as a thick dashed line.

(i) In the tabular form joggles and bends are drawn in their correct relative position. 'Calling-up' of bars can be written along the bar. Loose bars should be located from a floor datum. Note any special orientation of bends required.



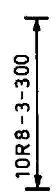
(ii) In the elevated form bars are related to the concrete profiles. Bars are generally 'called-up' on indicator lines.



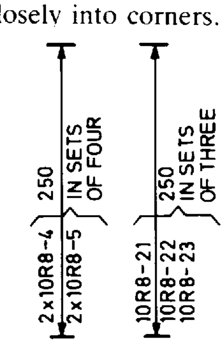
(*b*) *Links*

Generally the spread of links is indicated by an indicator line terminated by arrowheads. The links are provided to restrain the vertical bars from buckling. Generally the top link terminates at the soffit of the slab for peripheral columns, or at the soffit of the shallowest beam for internal columns. Mild steel links with their standard 2d internal bend radius allow vertical corner bars to fit more closely into corners.

(i) single links

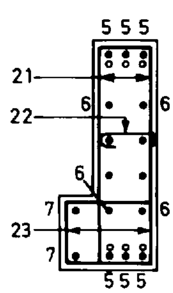


(ii) multiple links



5.3.22.2 On section

Generally sections are drawn at mid-storey height looking down. Sections are preferably drawn to a suitable scale to clarify the fixing of the links and to locate the vertical bars. Reinforcement in nibs and projections should also be indicated. Bars cut in section appear as black dots with appropriate mark. Any starter bars beyond appear as open circles. Links are drawn with a thick line.



5.3.23 Other requirements for columns

5.3.23.1 Special notes for columns

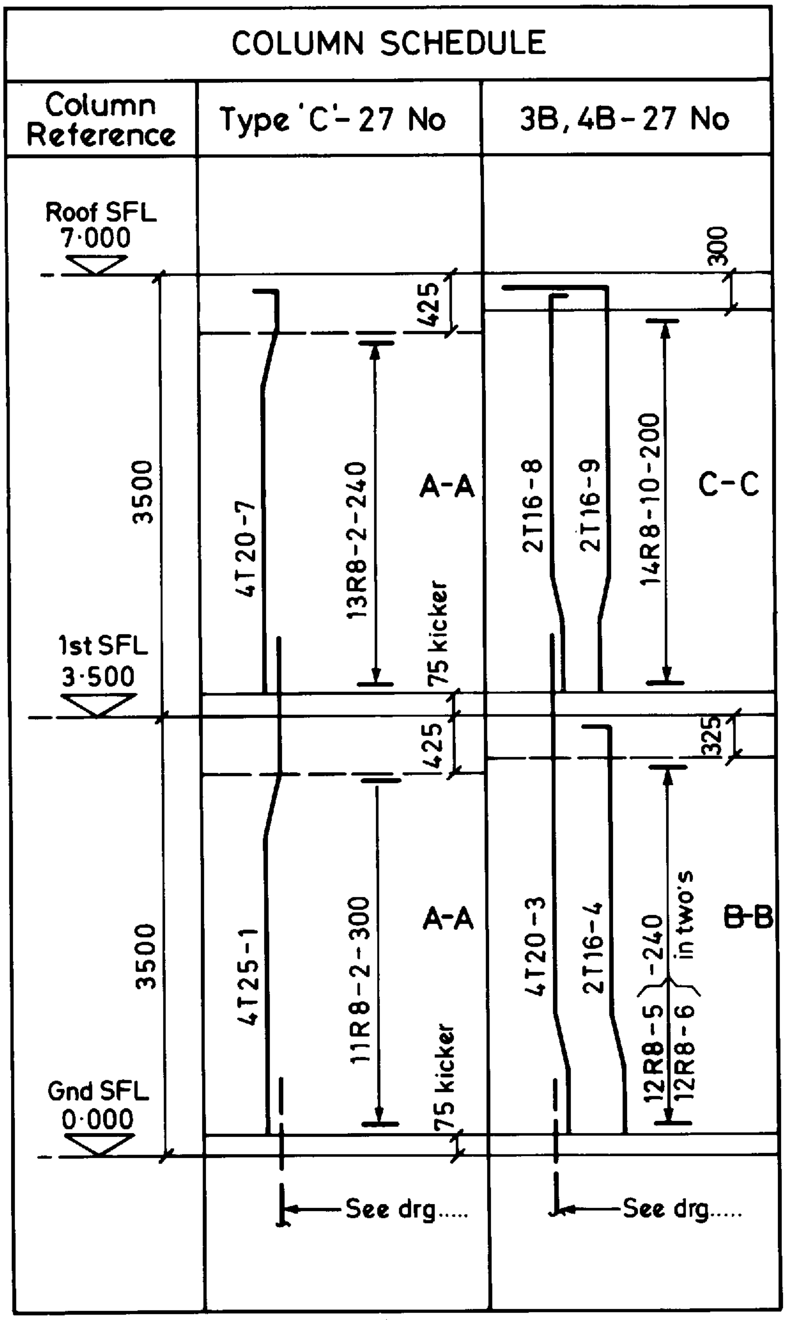
In addition to standard notes for reinforcement drawings (see subsection 2.8) the following note should appear on all column drawings:

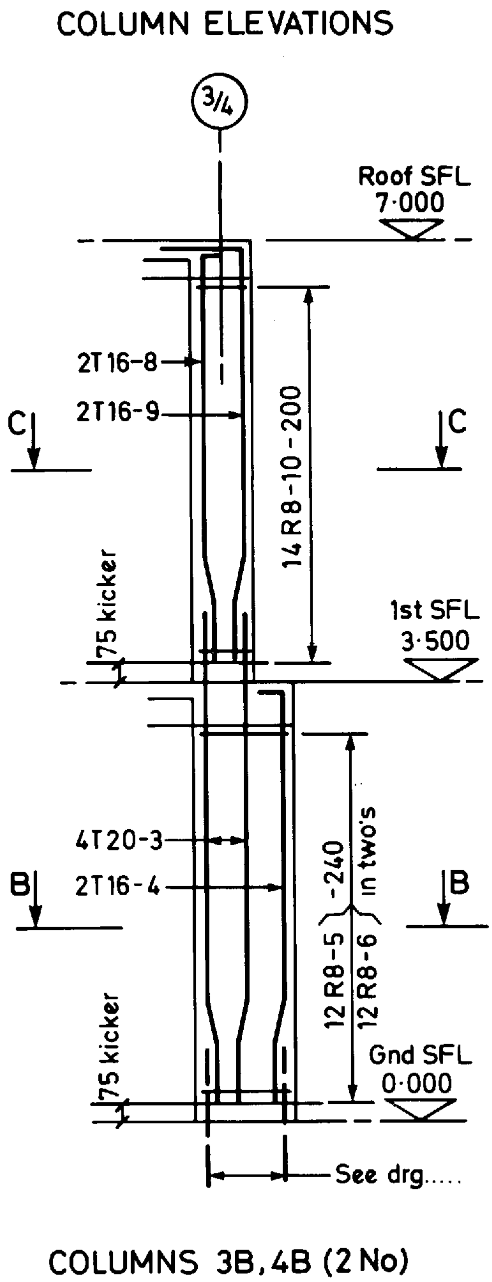
Nominal cover to links.....mm, unless noted.

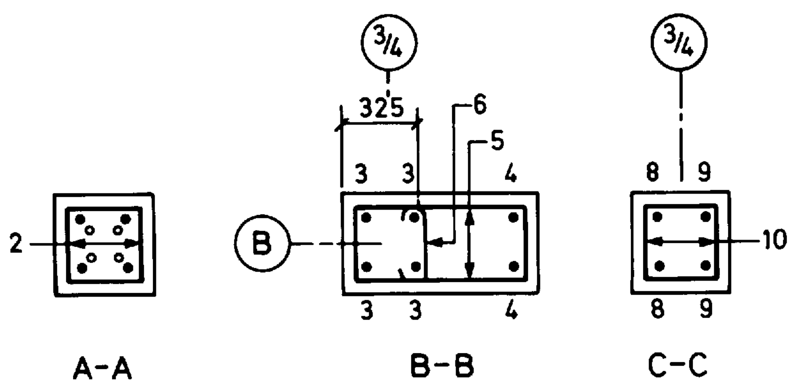
5.3.23.2 Column heads

Column head shear reinforcement is a special requirement specified by the designer. This can be incorporated with the column reinforcement or referenced and detailed as a separate item or with the slab.

5.3.30 Examples of detailing







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5.4.10 Design information

These data are output from the calculations for each span and the designer should indicate:

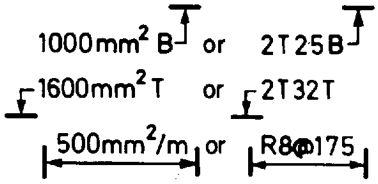
(a) *For beams designed and detailed in accordance with BS 8110 simplified rules* (for bar curtailment rules etc. see subclause 5.4.11.1)
  - (i) concrete grade to determine laps, durability, etc.
  - (ii) type of support assumed, i.e. simple restrained, cantilever, etc.
  - (iii) nominal cover requirements to links/longitudinal bars with proper regard for durability and fire resistance (see clause 3.3.9). Clearance should be allowed for the layering of slab reinforcement (see clause 5.2.22.1) and for beam bars at the beam/column intersection (see clause 5.4.21)
  - (iv) type of reinforcement and any size restrictions
  - (v) area of main longitudinal tension bars (required) A_s(mm^2) or, preferred type/size, with sketch (actual)
  - (vi) location of shear zones with dimensions from centre-line of supports
  - (vii) area of shear reinforcement in each shear zone (required) A_{sv}(mm^2) or, preferred type/size and pitch of link legs both in elevation and section, with sketch (actual)
  - (viii) any special requirements, e.g. location of compression bars, torsion bars, bent-up shear bars, trim for slots and holes, tie bars, laps and critical stresses, radius of bend, etc.

(b) *For other beams,* e.g. those with point loads, in addition to above:
  - (ix) location of bar curtailments, if non-standard (for BS 8110 general bar curtailment rules see clause 5.4.11.2). Provide bending moment diagrams if available.

(c) *Summary of beam calculations*
When large areas of simple floor beams occur it is possible to rationalize main reinforcement areas/type, size including shear links. For example, these can be summarized and presented to the detailer by marking up two copies of the relevant general arrangement drawing — one copy for east/west beams, the second copy for north/south beams. Top from bottom data can be differentiated by using coloured pencils, or the abbreviations B and T.
i.e. locate A_s bottom midspan thus:

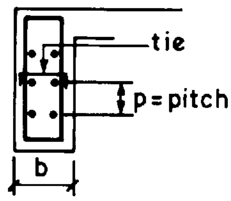
locate A_s top support

locate A_{sv} links and extent



Additional data required can be sketched or noted on the print etc.

(d) *Minimum reinforcement*
  - (i) For minimum link reinforcement see Table 19.
  - (ii) For min tension reinforcement under various conditions see Tables 21 and 22.



Beams whose depth exceeds 750mm should be provided with side lacers (3.12.11.2.6†) maximum pitch 250mm

$$\text{minimum bar size} = \sqrt{\frac{s_b \times b}{f_y}} \text{ mm. } (3.12.5.4\dagger)$$

where s_b is the bar spacing
b is the breadth of section at the point considered (or 500mm if less).

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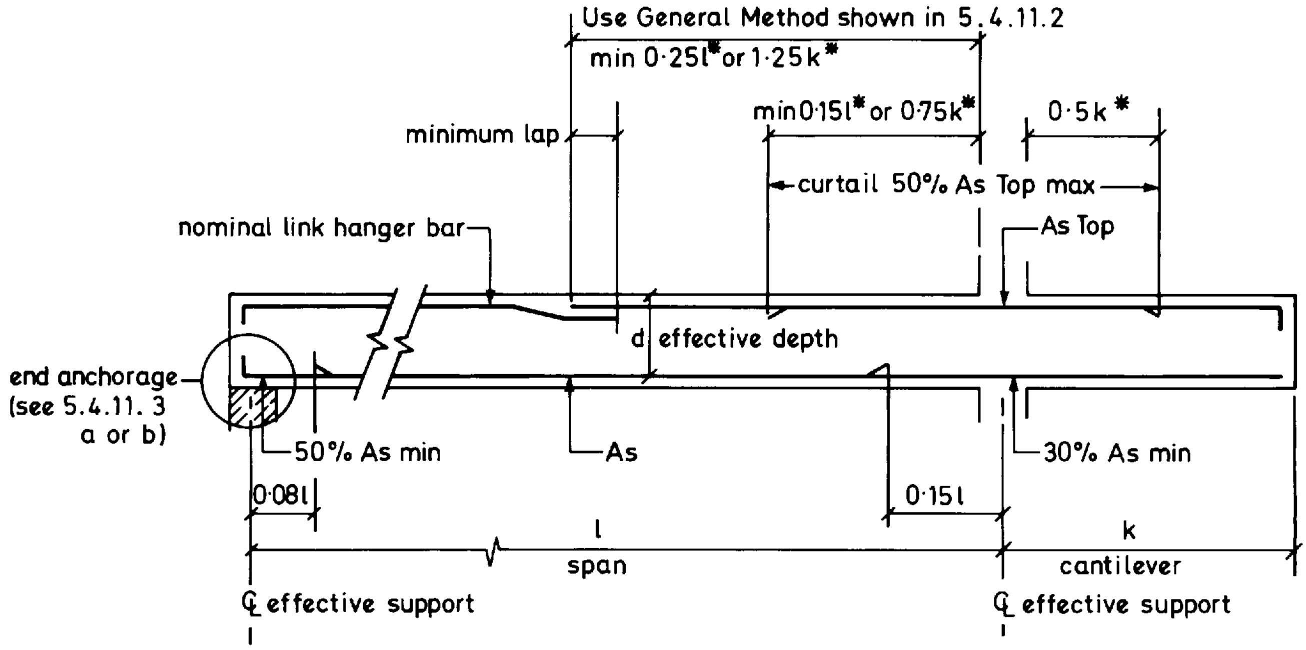
5.4.11 Code requirements for beams

5.4.11.1 Curtailment and areas of bars based on BS 8110 simplified rules (Fig 3.24, 3.12.10†)

Assumptions:

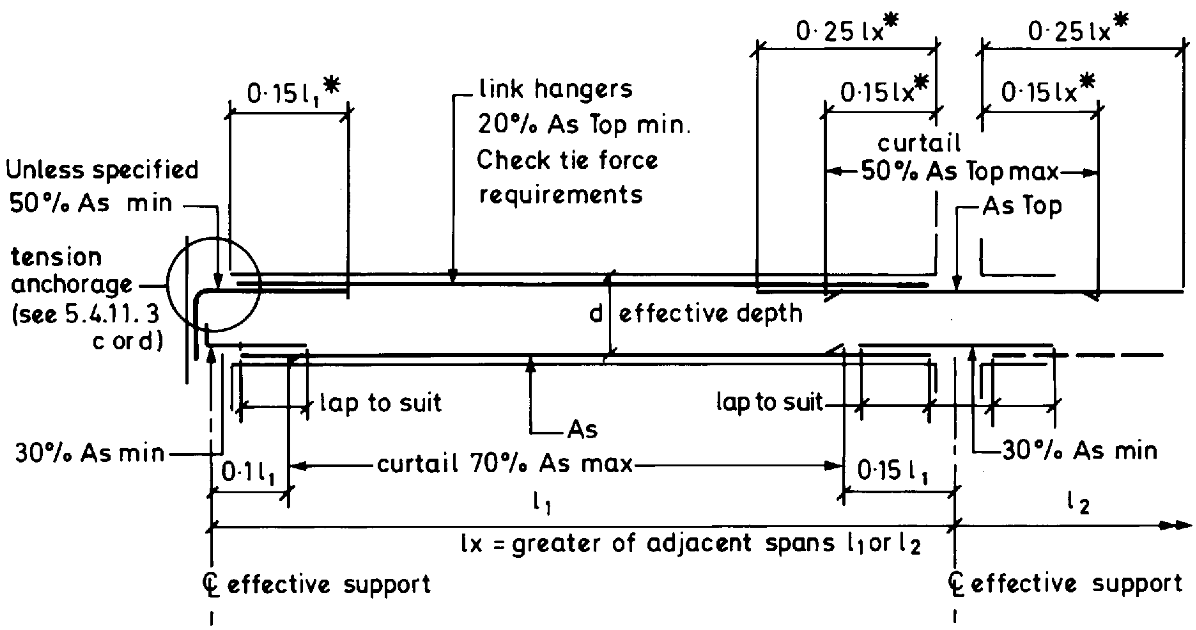
(a) Continuous spans are approximately equal (within 15% of longest)
(b) Beams support dominantly uniformly distributed loads
(c) Characteristic imposed loads do not exceed characteristic dead loads
(d) Tie force requirements should also be considered.



(i) simply supported end

(ii) cantilever end

* or 45 ø, whichever is greater

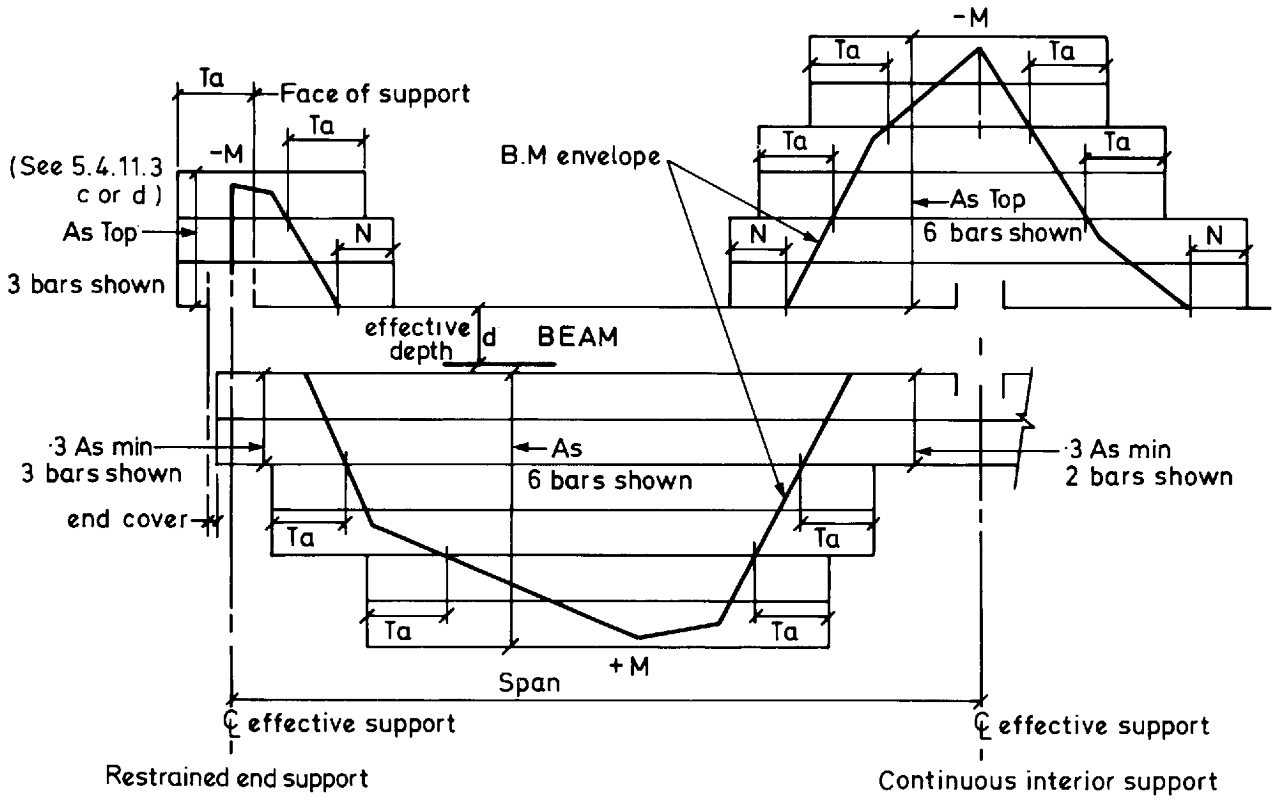


(iii) restrained end

(iv) continuous interior

5.4.11.2 Bar curtailments for beams based on BS 8110: general recommendations (3.12.9†)

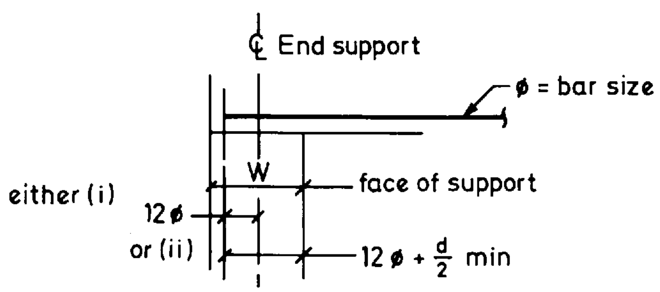
Ta = Tension Anchorage Length or effective depth d whichever is the greater
N = Nominal 12ø or beam effective depth d whichever is the greater

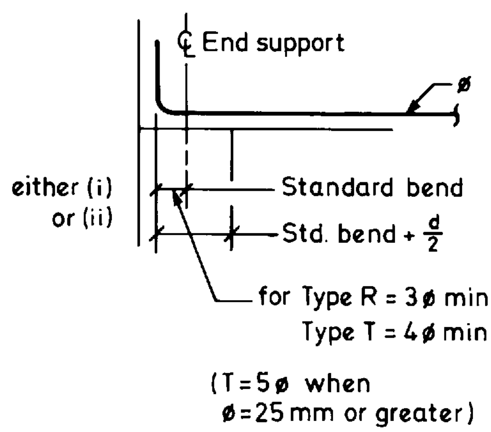


5.4.11.3 Anchorage alternatives based on BS 8110: general recommendations

Simply supported ends (3.12.9.4†)

(a) Straight bars in bottom or *(b) Bent bars in bottom*



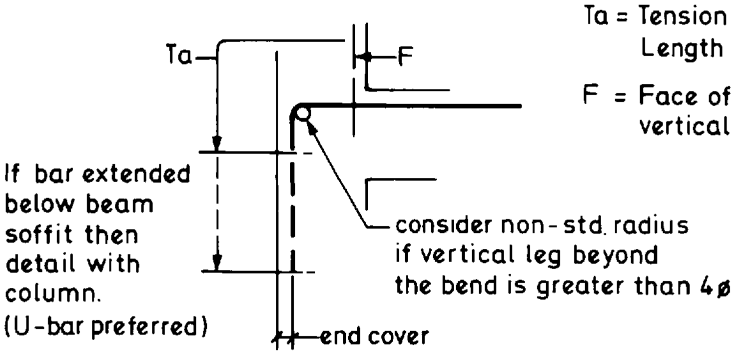


d = effective depth

Restrained ends

(c) L-bars in top

(d) U-bars in top



Ta = Tension Anchorage Length

F = Face of restraining vertical bar

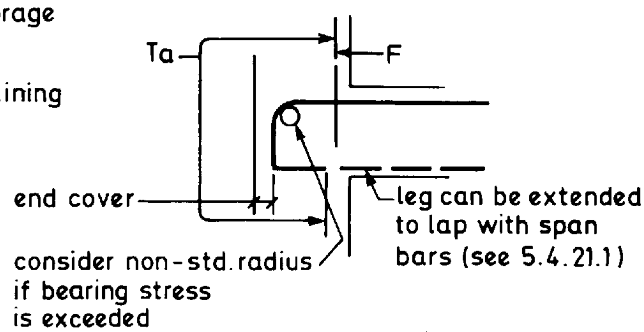


Table 18 Areas of reinforcement for various link combinations

nominal bar size	no. off link legs	areas, mm^2									
		pitch of links (maximum $0.75d$), mm (3.4.5.5.†)									
		75	100	125	150	175	200	225	250	300	400
6	2	754	566	452	378	324	284	255	226	189	142
	4	1508	1132	904	756	648	568	510	452	378	284
	6	2262	1698	1356	1134	972	852	765	678	567	426
	8	3016	2264	1808	1512	1296	1136	1020	904	756	568
	10	3770	2830	2260	1890	1620	1420	1275	1130	943	710
8	2	1342	1006	804	670	574	504	453	402	336	252
	4	2684	2012	1608	1340	1148	1008	906	804	672	504
	6	4026	3018	2412	2010	1722	1512	1359	1206	1008	756
	8	5368	4024	3216	2680	2296	2016	1812	1608	1344	1008
	10	6710	5030	4020	3350	2870	2520	2265	2010	1680	1260
10	2	2100	1570	1256	1046	898	786	707	628	524	393
	4	4200	3140	2512	2092	1796	1572	1414	1256	1048	786
	6	6300	4710	3768	3138	2694	2358	2121	1884	1572	1179
	8	8400	6280	5024	4184	3592	3144	2828	2512	2906	1572
	10	10500	7850	6280	5230	4490	3930	3535	3140	2620	1965
12	2	3020	2260	1810	1508	1292	1132	1018	904	754	566
	4	6040	4520	3620	3016	2584	2264	2036	1808	1508	1132
	6	9060	6780	5430	4524	3876	3396	3054	2712	2262	1698
	8	12080	9040	7240	6032	5168	4528	4072	3616	3016	2264
	10	15100	11300	9050	7540	6460	5660	5090	4520	3770	2830
16	2	5360	4020	3220	2680	2300	2020	1804	1608	1340	1010
	4	—	8040	6440	5360	4600	4040	3608	3216	2680	2020
	6	—	12060	9660	8040	6900	6060	5412	4824	4020	3030
	8	—	16080	12880	10720	9200	8080	7216	6432	5360	4040
	10	—	20100	16100	13400	11500	10100	9020	8040	6700	5050
20	2	8380	6280	5020	4180	3600	3140	2830	2520	2100	1570
	4	—	12560	10040	8360	7200	6280	5660	5040	4200	3140
	6	—	18840	15060	12540	10800	9420	8490	7560	6300	4710
	8	—	25120	20080	16720	14400	12560	11320	10080	8400	6280
	10	—	31400	25100	20900	18000	15700	14150	12600	10500	7850

Check that clear distance between groups of multiple links is 60mm minimum.
Maximum pitch of link legs at 90° to span = 1.0 effective depth, d (3.4.5.5.†)

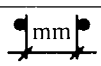
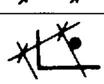
Table 19 Minimum areas of shear reinforcement

$$A_{sv} = \frac{0.4\, b_v s_v}{0.87 f_{yv}}$$

A_{sv} (mm²)		minimum area links (A_{sv}) at any section — pitch of links along beam(s_v), maximum 0.75d, mm: 100		150		200		250		300		350		400	
f_{yv}, N/mm²		250	460	250	460	250	460	250	460	250	460	250	460	250	460
breadth of beam b_v mm	150	28	15	42	23	56	30	69	38	83	45	97	53	111	60
	200	37	20	56	30	74	40	92	50	111	60	129	70	148	80
	225	42	23	63	34	83	45	104	57	125	68	145	79	166	90
	250	46	25	69	38	92	50	115	63	138	75	161	88	184	100
	275	51	28	76	42	102	55	127	69	152	83	178	97	203	110
	300	56	30	83	45	111	60	138	75	166	90	194	105	221	120
	325	60	33	90	49	120	65	150	82	180	98	210	114	240	130
	350	65	35	97	53	129	70	161	88	194	105	226	123	258	140
	375	69	38	104	57	138	75	173	94	207	113	242	132	276	150
	400	74	40	111	60	148	80	184	100	221	120	258	140	295	160
	450	83	45	125	68	166	90	207	113	249	135	290	158	332	180
	500	92	50	138	75	184	100	230	125	276	150	322	175	368	200
	600	111	60	166	90	221	120	276	150	332	180	387	210	442	240
	750	138	75	207	113	276	150	345	188	414	225	483	263	552	300
	1000	184	100	276	150	368	200	460	250	552	300	644	350	736	400

Note: Maximum pitch of link legs in section = 1.0d (3.4.5.5.†)
examples: 1. f_{yv} = 460, b_v = 400, s_v = 300. ∴ A_{sv} = 120 — Use 2 legs T10 (157) @ 300
2. f_{yv} = 250, b_v = 500, s_v = 200. ∴ A_{sv} = 184 — Use 4 legs R8 (201) @ 200

Table 20 Maximum distance between tension bars Table 3.30† (3.12.11.2.3†) (3.12.11.2.5†)

f_y = 460 N/mm²	% Redistribution of moments: −30	−25	−20	−15	−10	0	+10	+15	+20	+25	+30
 mm	115	120	130	135	145	160	180	185	195	200	210
	57	60	65	68	72	80	90	93	97	100	105

Note: For minimum distance between bars see subsection 4.7.

Table 21 Minimum areas of reinforcement, mm² Table 3.2.27÷ (3.12.5.3÷)

Flanged beams
web in tension due to flexure

		breadth of web, mm													
f_y = 460 N/mm²		250		300		350		400		450		500		600	
web/flange		<0.4	≥0.4	<0.4	≥0.4	<0.4	≥0.4	<0.4	≥0.4	<0.4	≥0.4	<0.4	≥0.4	<0.4	≥0.4
minimum %		0.18	0.13	0.18	0.13	0.18	0.13	0.18	0.13	0.18	0.13	0.18	0.13	0.18	0.13
depth of beam mm	250	113	82	135	98	158	114	180	130	203	147	225	163	270	195
	275	124	90	149	108	174	126	198	143	223	161	248	179	297	215
	300	135	98	162	117	189	137	216	156	243	176	270	195	324	234
	325	147	106	176	127	205	148	234	169	264	191	293	212	351	254
	350	158	114	189	137	221	160	252	182	284	205	315	228	378	273
	375	169	122	203	147	237	171	270	195	304	220	338	244	405	293
	400	180	130	216	156	252	182	288	208	324	234	360	260	432	312
	425	192	139	230	166	268	194	306	221	345	249	383	277	459	332
	450	203	147	243	176	284	205	324	234	365	264	405	293	486	351
	475	214	155	257	186	300	217	342	247	385	278	428	309	513	371
	500	225	163	270	195	315	228	360	260	405	293	450	325	540	390
	525	237	171	284	205	331	239	378	273	426	308	473	342	567	410
	550	248	179	297	215	347	251	396	286	446	322	495	358	594	429
	575	259	187	311	225	363	262	414	299	466	337	518	374	621	449
	600	270	195	324	234	378	273	432	312	486	351	540	390	648	468
	750	338	244	405	293	473	342	540	390	608	439	675	488	810	585

Note: Rectangular section subjected to flexure: minimum % reinforcement = 0.13
(use ≥0.4 table above)
Maximum tension/compression reinforcement = 4% gross cross-section concrete (3.12.6.1÷)

Table 22 Minimum areas of reinforcement, mm^2 Table 3.27† (3.12.5.3†)

Flanged beams
flange in tension due to flexure over a continuous support

		breadth of web, mm													
f_y = 460 N/mm^2		250		300		350		400		450		500		600	
flange type		T	L	T	L	T	L	T	L	T	L	T	L	T	L
minimum %		0.26	0.20	0.26	0.20	0.26	0.20	0.26	0.20	0.26	0.20	0.26	0.20	0.26	0.20
	250	163	125	195	150	228	175	260	200	293	225	325	250	390	300
	275	179	138	215	165	251	193	286	220	322	248	358	275	429	330
	300	195	150	234	180	273	210	312	240	351	270	390	300	468	360
	325	212	163	254	195	296	228	338	260	381	293	423	325	507	390
	350	228	175	273	210	319	245	364	280	410	315	455	350	546	420
depth	375	244	188	293	225	342	263	390	300	439	338	483	375	585	450
of	400	260	200	312	240	364	280	416	320	468	360	520	400	624	480
beam	425	277	213	332	255	387	298	442	340	498	383	553	425	663	510
mm	450	293	225	351	270	410	315	468	360	527	405	585	450	702	540
	475	309	238	371	285	433	333	494	380	556	428	613	475	741	570
	500	325	250	390	300	455	350	520	400	585	450	650	500	780	600
	525	342	263	410	315	478	368	546	420	615	473	683	525	819	630
	550	358	275	429	330	501	385	572	440	644	495	717	550	858	660
	575	374	288	449	345	524	403	598	460	673	518	748	575	897	690
	600	390	300	468	360	546	420	624	480	702	540	780	600	936	720
	750	488	375	585	450	683	525	780	600	878	675	975	750	1170	900

Note: For (i) Flanged beam with web in compression
or (ii) Rectangular beam in compression
Minimum % reinforcement for either if required for ULS = 0.20% (use L-column in table)

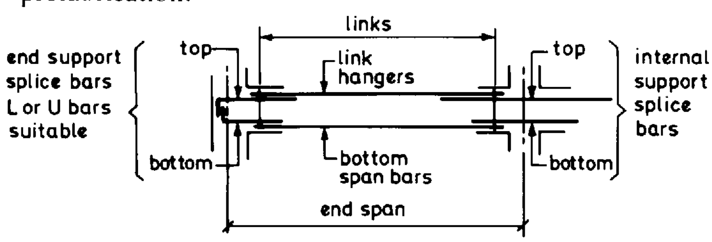
5.4.20 Detailing

5.4.21 Methods of detailing beams

Careful consideration should be given to the relationship of the beam with its column junction, including the construction technique to be adopted. General-arrangement drawings and design calculations should be at their final stage.

5.4.21.1 Splice-bar method

This simple method uses many straight bars and is ideal for prefabrication.

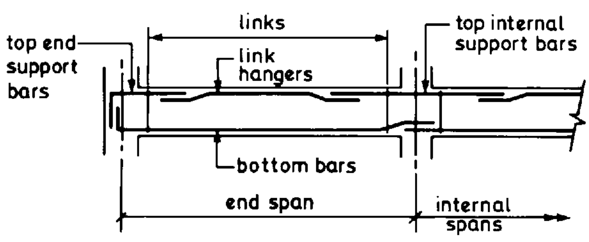


Span and link hanger bars stop usually 50mm inside the face of the support. These bars together with the links form the span cage, which during construction can be lifted then lowered between supports. For continuity the separate splice bars are threaded through the vertical bars at the support and lap alongside the span bars in the cage. The cover to the splice is independent of the span, allowing greater freedom to deal with the various clearances required to avoid other bars, including those from intersecting beams and columns. Normally it can be arranged that column bars simply run through (see clause 5.3.21.3a).

Each beam can conveniently be detailed separately as a unit span and can be allocated a 'reinforcement-type' reference number — similar beams sharing the same reference. For location these reinforcement-type references can be added to the general-arrangement drawing alongside the unique beam reference number (see subsection 2.20), or perhaps added to a separate key plan or separate schedule.

5.4.21.2 Alternative method

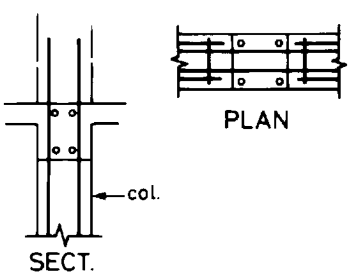
With this method bottom-span bars are normally lapped at the centre-line of internal supports, although at wide supports butted bars may be more suitable. Link hangers lap with the ends of top support bars. Obstructions are avoided either by stopping or by joggling bars, resulting in fewer straight bars. Adjacent spans are often detailed together in beam 'runs'.



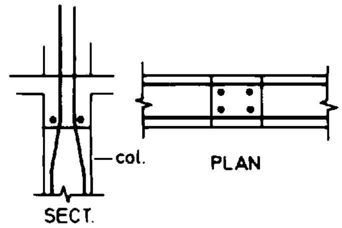
Critical detailing often occurs at intersections as follows:

(a) *Beams same breadth as column*

(i) If column bars (see Columns 5.3.21.3a) are run through the junction, then obstructed beam bars are stopped.

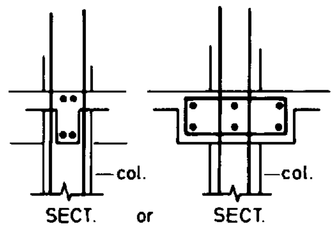


(ii) Column bars (see clause 5.3.21.3b) can be joggled to allow the outer beam bars to pass, particularly when members are narrow.



(b) *Beams of different breadth to column*

Column bars are normally allowed to run through the junction and the beam bars are usually unaffected but this should be checked. Wide beams will require extra links alongside the column.



(c) *Secondary beams same depth as main beam*

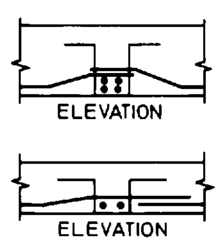
Generally the cover to the top beam steel is increased to allow clearance for the main beam and slab reinforcement. Bottom bars can be joggled over at the support.

(d) *Narrow members*

Care should be taken to avoid congestion, particularly at laps in bottom bars at column supports. If butted bars are unsuitable, i.e. a lap is required for compression or for tie force purposes, consider either:

(i) extending joggle to lap outside column →

or (ii) using splice bar method (see clause 5.4.21.1)

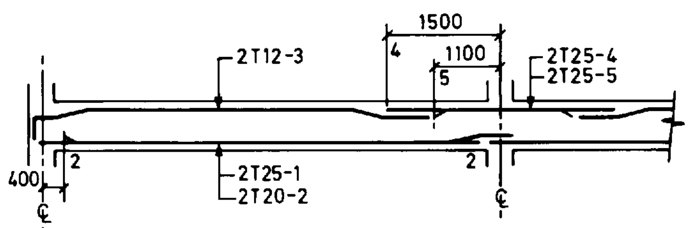


5.4.22 Bar detailing on beams

5.4.22.1 On elevation

(a) *Longitudinal bars*

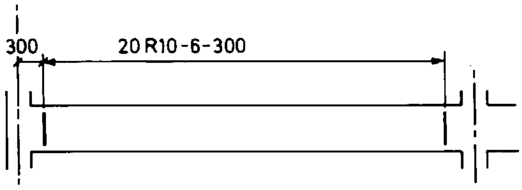
Generally each bar mark is illustrated by a typical bar drawn as a thick line and related to its supports and the formwork. Bends and joggles are shown to scale where possible. The 'calling up' of bars is indicated approximately midway along the bar — maintaining design 'groups' where possible, to assist checking. Ends of curtailed bars are identified by short obliques drawn at 30° and tagged with the appropriate bar mark.



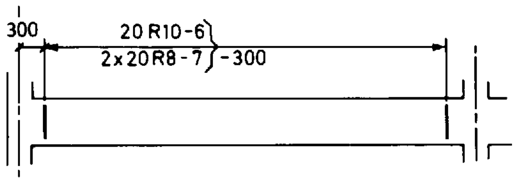
(b) *Shear links*

Usually the spread of links is indicated above the elevation with an indicator line terminated by arrowheads.

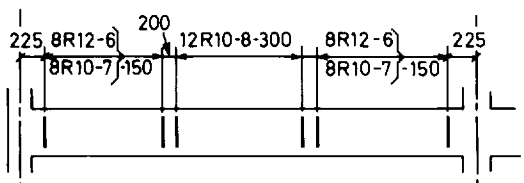
(i) Single zone, single links
End links should be a maximum of 0.5 pitch inside the edge of support



(ii) Single zone, multiple links

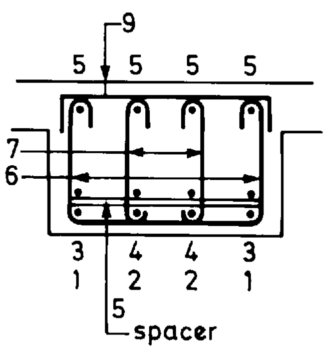


(iii) Multiple zones
Dimension all but one of the 'gaps' between link zones — usually adjacent to the nominal zone — to allow some tolerance for fixing. Gaps should not exceed the adjacent pitch.The first link is usually located 75mm inside the edge of support.



Ensure that all corners of links contain a longitudinal bar, especially near the supports where bars curtail.

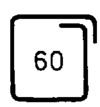
5.4.22.2 On section



Typical sections are selected to clarify the fixing of the longitudinal bars within the link cage, including any nibs, upstands, etc. Sections are drawn looking left at the elevation. Bars cut in section appear as black dots, with appropriate mark. Those bars beyond, if required, appear as open circles. If not evenly spaced, bars should be located from one side face. Links are drawn in a thick line with a mark indicator.

5.4.22.3 Links on section
When selecting links consider the following:

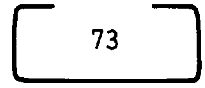
Normally provide closed link shape code 60



Open link shape code 72 allows easier access but check that hooks do not foul other bars

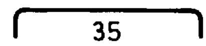
For torsion-link shape code 74 is used

For wider beams use shape code 73 — which has no hooks, but anchor ends with minimum $8d$ straight beyond the bend. These links can also be employed nominally reinforced side beams, with one leg extended into slab



If cage is to be lifted provide nominal link top closers shape code 35 — for stiffness

Combinations of these links can be employed on wider beams to suit.



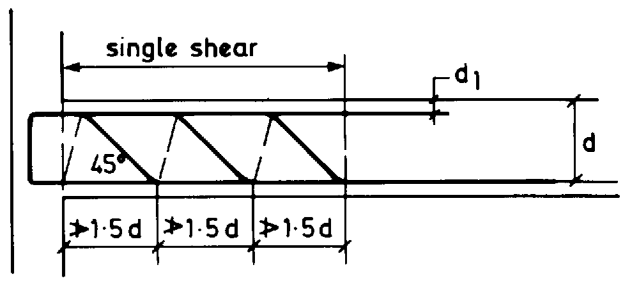
5.4.23 Other requirements for beams

5.4.23.1 Special notes for beams
In addition to the standard notes for reinforcement drawings (see Section 2) the following note should appear on all beam drawings:

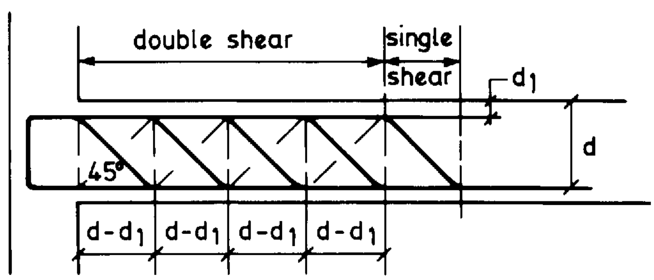
nominal cover to links, mm
Top ....
Bottom ....
Sides ....
Ends ....
} unless noted

5.4.23.2 Bent-up shear bars (3.4.5.6.÷)
These are occasionally used in conjunction with shear links to resist up to 50% shear force.

(a) Setting-out of a single 45° system



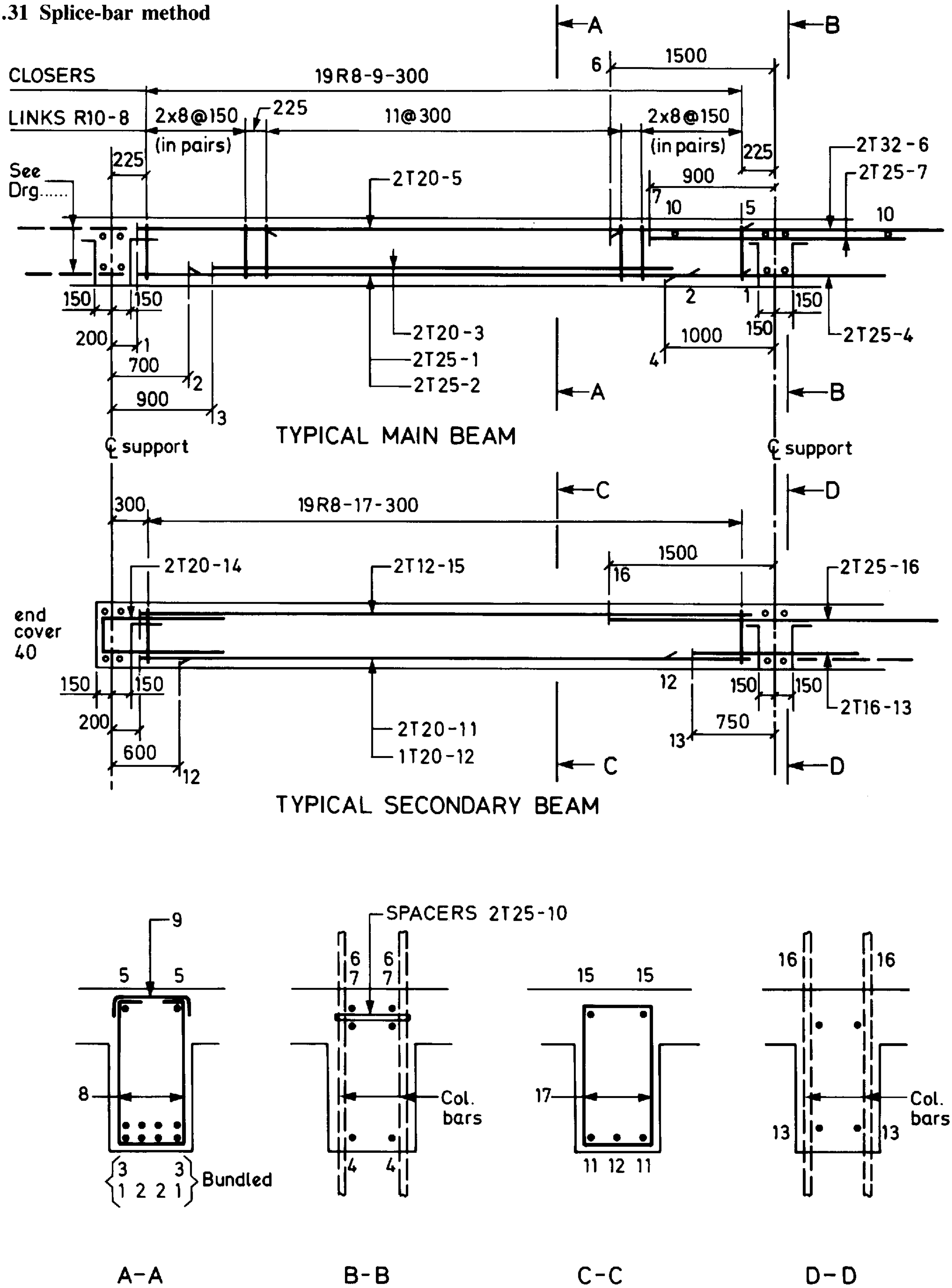
(b) Setting-out of a double 45° system



Each horizontal leg should extend at least a tension anchorage length Check radius of bend for bearing stresses on the concrete. This radius is likely to be at least 6 × bar necessitating a shape 99 bar (3.4.5.7÷)

5.4.30 Examples of detailing

5.4.31 Splice-bar method



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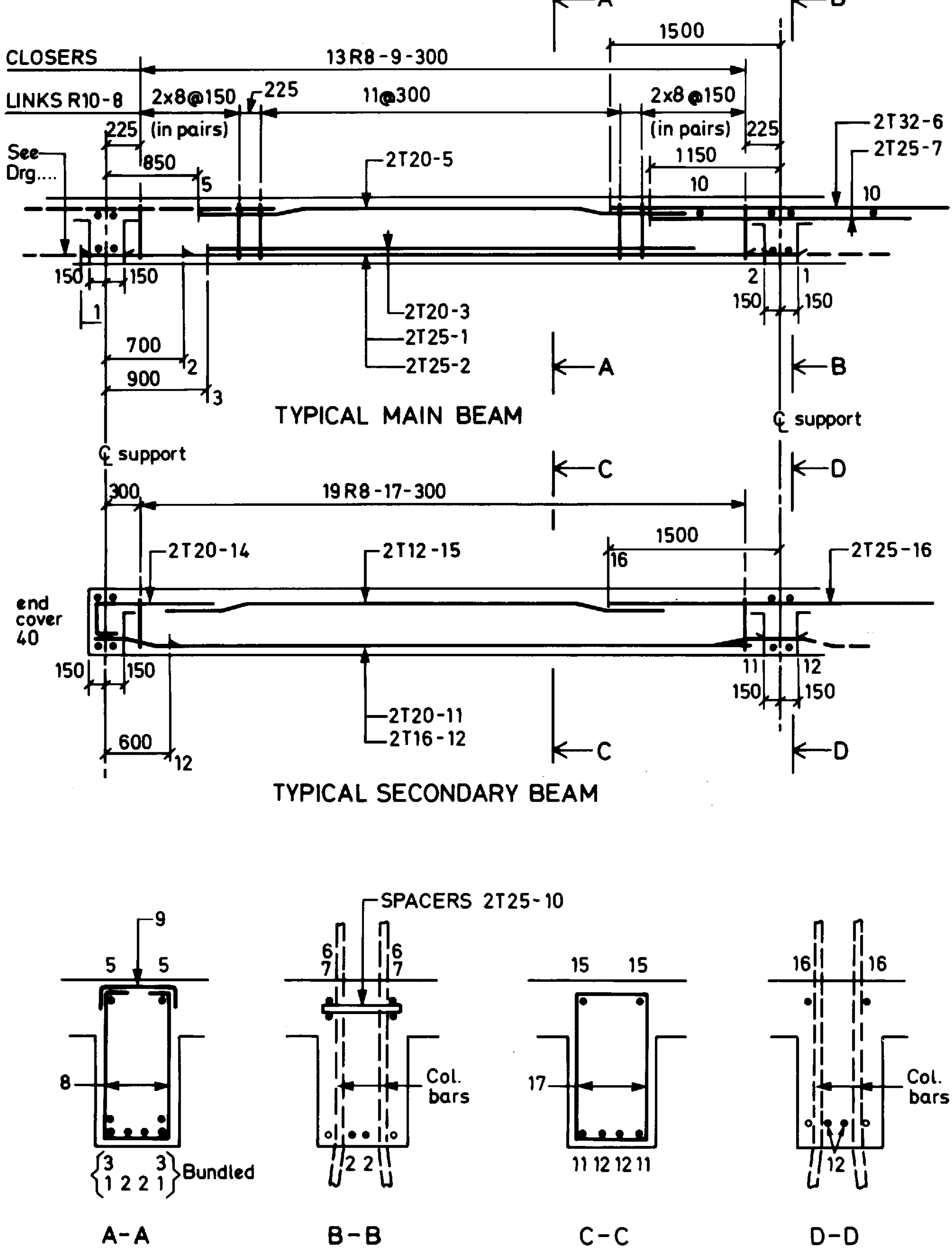
5.4.32 Alternative method



5.5 FOUNDATIONS

This subsection deals with the following types of foundations:

pads
pilecaps
tie beams for pilecaps
strip
ground beams
continuous footings
anchor or strap beams
rafts.

The methods of detailing these items, in particular tie beams and rafts, are similar to those employed in detailing slabs and beams (see subsections 5.2 and 5.4.), but there are certain additional considerations to take into account, and described in this subsection.

Ground floor slabs are dealt with in clause 5.2.26d. Retaining walls are dealt with in subsection 5.6.

Caissons, cofferdams, basements, shafts, piles and diaphragm walls are not illustrated specifically, but can be detailed using the principles and details in this section.

5.5.10 Design information

These data are output from the approved foundation design calculations and should indicate:

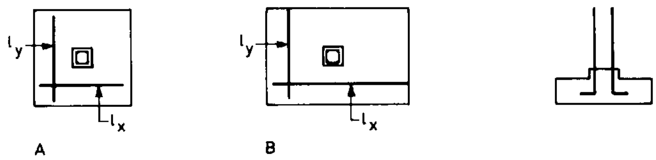
(a) (i) concrete grade to determine laps, durability, etc.
(ii) dimensions of each foundation
(iii) level to top of each foundation
(iv) type of reinforcement and any size restrictions
(v) required area and distribution of all reinforcement
(vi) lap, anchorage and splice lengths
(vii) curtailment of reinforcement
(viii) link type, size and pitch
(ix) position of reinforcement to avoid cut-off tops of piles
(x) cover requirements, bottom, sides, top
(xi) position, number, size of starter bars
(xii) type and thickness of blinding
(xiii) position, number and size of holding down bolts, if any
(xiv) any other special requirements
(xv) type of backfill between the top of the bases and the underside of the ground floor slab.

(b) *Summary of calculations*
For convenience and simplicity it is often possible to rationalize reinforcement:

(i) For pad footings, simple strip footings, pilecaps — by tabulating the reinforcement for the foundation pad, lacer bars, column starters bars and starter bar links, and cross referencing to preliminary general arrangements for orientation of columns.

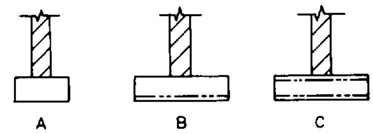
Pad footings

type	reinforcement l_x	reinforcement l_y	starters	links
A	10T16	10T16	4T25	T12-200
B	10T20	20T16	4T25	T12-200



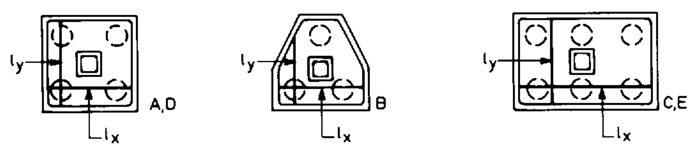
Strip footings

type	Fabric Reinforcement BS reference
A	none
B	C283 B
C	C283 T & B



Pilecaps

type	reinforcement l_x	reinforcement l_y	lacer bars	starters	links
A	10T20	10T20	4T16	4T32	T12-200
B	10T16	10T16	4T16	4T25	T12-200
C	10T20	15T16	4T16	6T25	T12-200
D	12T16	12T16	4T16	4T25	T12-200
E	15T16	20T16	4T16	5T25	T12-200



(ii) For solid rafts, grillage rafts, combined or continuous footings, tie beams and strap or anchor beams, the reinforcement can be presented or summarized for the detailer by the methods outlined for slabs (see clauses 5.2.10c and 10d) or beams (see clauses 5.4.10c and 10d).

5.5.11 Design code requirements

5.5.11.1 General

(a) *BS 8004*
BS 8004: 1984: *Code of practice* for *foundations* deals with the overall design of all types of foundations for all types of buildings and various types of soils. It does not deal with the detailing of individual elements of RC foundations.

(b) *BS 8110*
BS 8110: 1985: *The structural use of concrete* contains guidelines for detailing individual elements of RC foundations.

(c) *Cover*
Covers recommended by BS 8110 are set out in subsection 3.9. Where concrete is cast directly against earth faces, the nominal cover should be a minimum of

75mm. Where concrete is cast against blinding concrete, the nominal cover should be a minimum of 40mm (excluding blinding).

(d) *Minimum area of reinforcement* (3.12.5.3†)
Refer to subsections 5.2 and 5.4.

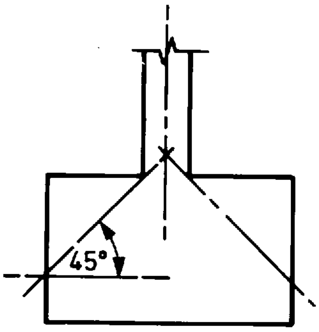
(e) *Maximum area of reinforcement* (3.12.6†)
Refer to subsection 5.4.

(f) *Spacing of reinforcement* (3.12.11†)
Refer to subsections 5.2 and 5.4.

(g) *Anchorage and lapping of bars* (3.12.8†)
Refer to Appendix 3B.

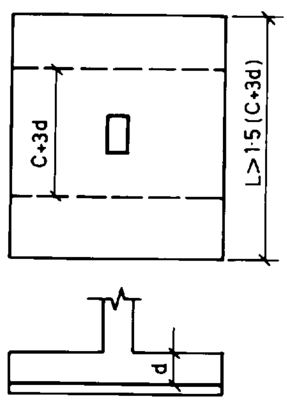
5.5.11.2 Pad footings

(a) In certain conditions, i.e. when loads are small or when the allowable ground pressures are high, reinforcement may not be required. In this event the depth should be such that a line at 45° from the edge of the supported column or base intersects the vertical face of the base.



(b) In reinforced bases the arrangement of the reinforcement must be specified by the designer.

The total area of reinforcement should generally be evenly spread across the section considered. However, if the breadth of the section is greater than 1.5 $(c+3d)$ where c is the breadth of the column measured parallel to the section breadth and d is the effective depth of the base, at least two-thirds of the area of reinforcement should be concentrated in a band width of $(c + 3d)$ centred on the column (see also examples below).



(c) *Distribution of reinforcement in pad footings*

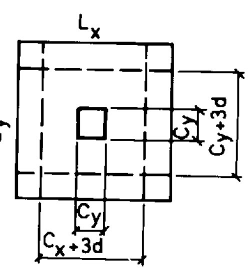
Example EG1

(a) *If* $l_y > 1.5\ (c_y + 3d)$:

two-thirds of reinforcement spanning in l_x direction to be banded within a width of $(c_y + 3d)$, where d is the effective depth of the base.

(b) if $l_x > 1.5\ (c_x + 3d)$:

two-thirds of reinforcement spanning in l_y direction to be banded within a width of $(c_x + 3d)$.



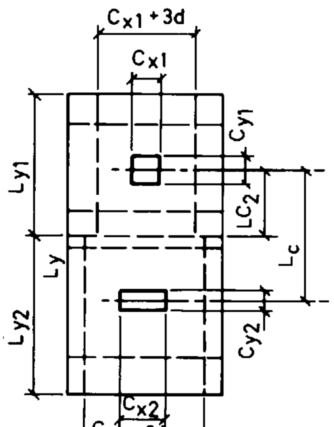
Example EG2

(a) Reinforcement spanning in l_x direction:

l_{y1} and l_{y2} should be considered separately.

(b) Reinforcement spanning in l_y direction:

Band width to be considered as lesser of $(c_{x1} + 3d)$ and $(c_{x2} + 3d)$.



Example EG3

(a) Reinforcement spanning in l_x direction:

as example EG2a above

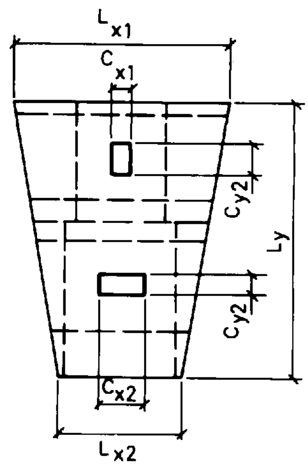
(b) Reinforcement spanning in l_y direction:

(i) bottom reinforcement under columns:

as example EG2b above

(ii) Top reinforcement (if any) between columns:

all reinforcement should lie within l_{x2}. If $l_{x2} > 1.5\ (c_{x2} + 3d)$, two-thirds of this reinforcement should lie within central $(c_{x2} + 3d)$.



5.5.11.3 Pilecaps

The distribution of reinforcement for pilecaps should be as for pad footings, except that the arrangement of the reinforcement should be specified by the designer where the pile centres are greater than 3 times the pile diameter.

5.5.20 Layout of foundations

5.5.21 Foundation plan

Refer to subsection 5.1 for more information on the preparation of general arrangements drawings.

The position of each foundation will be given relative to the grid lines. The width, length and depth will be given and the level of the bottom of the foundation will be given relative to a given datum.

This information is often given in tabular form. Each foundation is given a distinguishing letter that will serve as a cross-reference for the foundation details, detailed elsewhere.

The minimum allowable safe ground bearing pressure should be shown in note form on the drawing. The bearing thickness and type of blinding should be noted.

It is usual to have a separate general arrangement or piling plan, when piling is employed. This takes the form of a plan showing the position of piles relative to grid lines and will contain a schedule and notes including the following relevant items depending upon the project:

pile reference number
diameter
safe working load of pile
imposed moment
imposed horizontal force
cut-off level
minimum toe level
main reinforcement
hoop reinforcement
angle of rake
pile positional tolerances.

It is normally stated in the piling specification what the horizontal dimensional permissible deviation should be, but it should also be repeated on the piling plan.

5.5.30 Detailing

5.5.31 Pad footings

5.5.31.1 Introduction

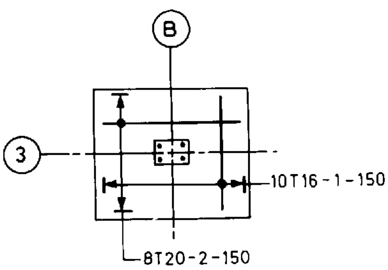
These can be detailed in two ways:

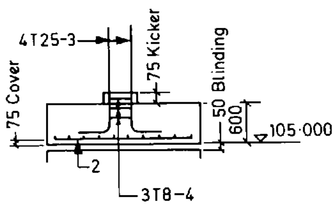
(i) traditional method
(ii) tabular method

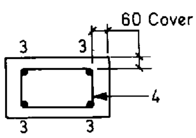
5.5.31.2 Tradition method

This method in normally used when the project is small or when there is little repetition. Individual pad footings are detailed usually in the form of a plan and a section. Grid lines are shown on each detail. The detail will give reinforcement information in the base, in the stub column if there is one, starter bars where the foundation is supporting an RC column or holding-down bolts in the case of steel columns.

Where kickers are specified care should be taken that the length of the starter bar is an appropriate lap length (for the stress in the bar) from the top of the kicker and that the starter bars do not clash with the column bars. It may be more economical in some cases to use the bottom length of the column reinforcement as starters. Minimum cover should be indicated. End anchorages should be avoided where possible, but their use or otherwise should be confirmed by the designer.

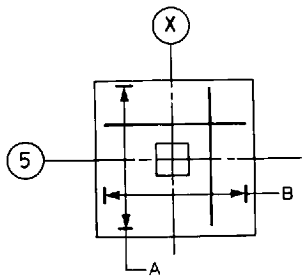


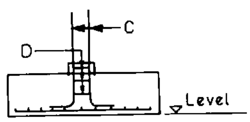


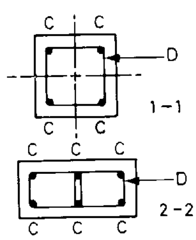


5.5.31.3 Tabular method

Where there are large numbers of bases and/or extensive repetition the details can be drawn schematically and the information for the individual bases given in tabular form. This can save time and drawings, but care must be taken that clarity is not sacrificed by producing tables that are too complicated. It is usual to draw a plan, section and enlarged stub column or column starter details, all not to scale, cross-referenced to a table.







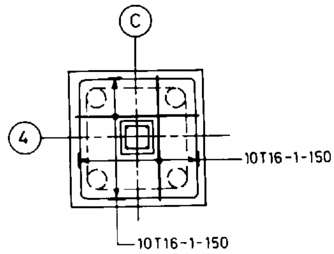
column reference	no. off	level	base reinforcement A	base reinforcement B	section	links D	starters C
A1, A2, A3	3	105.000	10T20-1-150	10T20-1-150	1-1	3T8-2	4T25-3
B3, B4	2	108.000	8T20-4-150	10T16-5-150	1-1	3T8-2	4T25-3
C1, C2	2	104.500	8T20-6-150	12T16-7-150	2-2	6T8-8	6T25-9
D1, D2	2	104.500	10T20-10-150	12T16-11-150	2-2	6T8-8	6T25-9

5.5.32 Piled foundations

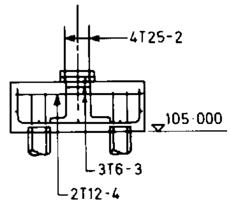
These can also be detailed by traditional or tabular methods.

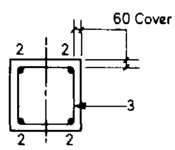
5.5.32.1 Traditional method

The notes on pad footings apply to pilecaps with the following additions:



The pile cut-off is usually carried out with pneumatic tools, leaving a very rough surface to the piles. Bottom steel should therefore be detailed, such that the bottom of the bars is a minimum 75mm above the theoretical cut-off level. The cut-off level should be 75mm above the bottom of the base.





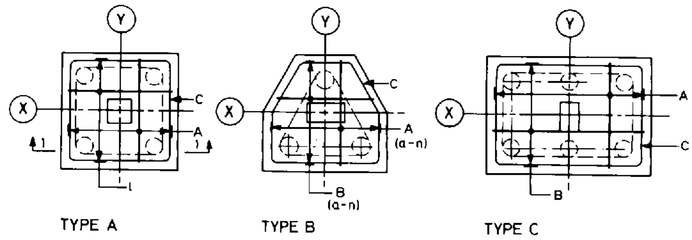
If moment has to be transmitted from column to pile via the pilecap, then sufficient reinforcement from the pile should be left projecting into the pilecap to transfer that moment. Care should be taken that the reinforcement does not clash with reinforcement in the base or with starter bars in the column. It should be remembered that piles are not always accurately placed and the pilecap details should allow for such inaccuracies.

It is usual for pilecaps to have horizontal loop steel around the perimeter of the pilecap. These should be at 200–300mm centres and a minimum of 12mm in size.

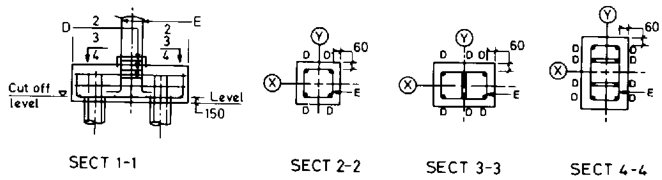
The designer should be consulted to check if large-radius bends are required on the bent-up bars.

5.5.32.2 *Tabular method*

This can be successfully employed when large numbers of pilecaps and/or repetitious details are required. The table should contain all the relevant information as for pad footings plus pile-cut off levels and hoop-steel details.



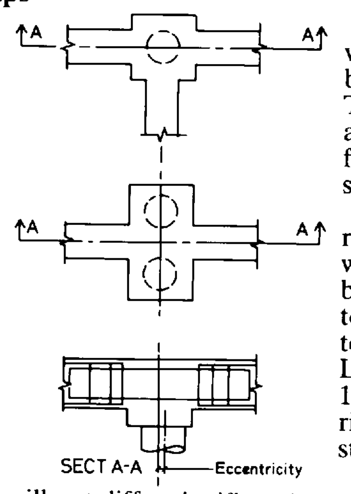
'X' relates to lettered grids
'Y' relates to lettered grids



column reference	base type	no. off	base level	cut-off level	base reinforcement A	B	C	section	links D	starters E
A1, A5	A	2	105.000	105.150	10T20-1-150	10T20-1-750	3T12-2-200	2-2	3T8-3	4T25-4
A2, A3, A4	B	3	105.000	105.150	8T20-5-150	8T20-6-150	3T12-7-200	3-3	6T8-8	6T25-4
B4, B5	A	2	105.000	105.150	12T20-9-175	12T20-9-175	3T12-10-200	2-2	3T8-11	4T25-4
B2, B3, B4	C	3	105.000	105.150	12T20-9-150	8T20-12-150	3T12-13-200	4-4	9T8-14	8T25-4
C1, C5	A	2	104.500	105.150	10T20-1-150	10T20-1-150	3T12-2-200	3-3	6T8-8	6T25-4
C2, C3, C4	B	3	104.500	105.150	10T25-15-200	10T25-16-150	3T12-17-200	3-3	6T8-18	6T25-4

5.5.33 Tie beams for pilecaps

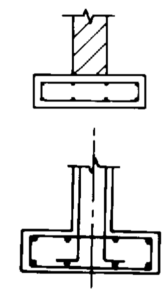
When piles are used singly or in pairs it is necessary to tie the pilecaps together using tie beams. Piles cannot be driven accurately, and it is usual to specify a horizontal permissible deviation in position, usually 75mm, both in the specification and on the drawings. The moment caused thereby should be added to any other imposed moments and should be a minimum design case even if neither moment nor horizontal forces exist at the bottom of columns.



The detailing of these beams will not differ significantly from other beams except that the amount of cover should be carefully checked for the particular ground conditions. It is, however, usual to have equal top and bottom reinforcement, since inaccuracies can occur on any axis.

Tie beams are not normally required where piles are placed on groups of three or more.

Steps in strip footings, necessary when the ground is sloping, should be in brick dimensional increments. The foundation should be lapped for at least twice the thickness of the foundation or twice the depth of the step, whichever is the greater.



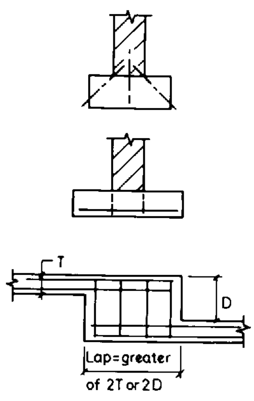
In bad ground, top and bottom reinforcement may be necessary, in which case it is better to use cages of bar reinforcement since it is difficult to maintain fabric in position in the top of the slab during concreting. Longitudinal bar reinforcement should be a minimum of 12mm with 8mm links in order that cages are sufficiently rigid. Reinforcement should be adequately lapped in stepped foundations in sloping ground.

Care should be taken that the cover is adequate for the type of ground in which the concrete is to be placed. Cover should be generous since the sides and bottom of the excavations will be rough.

For larger strip footings, where loading is heavier or for foundations for RC walls, the strip footings should be detailed as beams and the rules in subsection 5.4 should be applied.

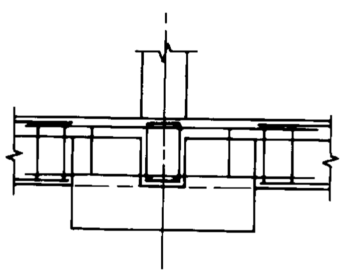
5.5.34 Strip footings

These are foundations that are continuous and where the loads are applied continuously, as in the case of brick or blockwork or reinforced-concrete walls. The amount of reinforcement required in simple strip footings varies with the type of ground on which they are placed. In domestic building, footings are often unreinforced, providing the depth is adjusted such that a line at 45° from the edge of the brickwork intersects the vertical face of the footing.



5.5.35 Ground beams

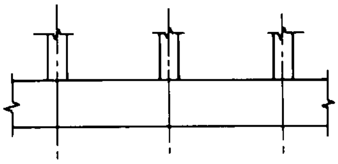
When the upper layer of ground has such a low bearing pressure that it is incapable of sustaining the loads imposed on a ground floor slab, the floor slab is suspended and supported on beams, cast in the ground.



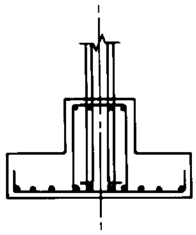
The beams are in turn supported at column positions on pad or piled foundations.

Care must be taken that adequate cover is allowed for, depending on the ground conditions, acidity, etc.

5.5.36 Continuous footings



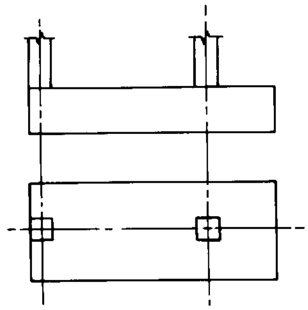
These are footings that sustain two or more columns, often in ground of low bearing capacity and where the centres of the columns are so close that independent pad footings would be so large and so close together that they become uneconomic.



Care must be taken that adequate cover is allowed for, depending on ground conditions, acidity, etc.

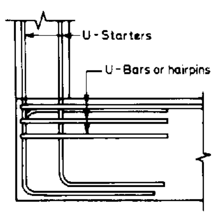
In some cases depending on ground conditions, they may be more economically designed, and therefore detailed, as inverted T-beams.

5.5.37 Anchor, strap or cantilever footings



These foundations are similar to combined footings, but the term is applied when one or more of the loads is positioned on the edge of the foundation, usually because of the proximity of other buildings, foundations, etc. An internal column is used as a counterweight, and consequently, main reinforcement is required in the top of the beam.

Again, the normal rules for detailing beams (see subsection 5.4) will apply, and attention should be paid to cover.



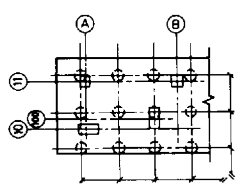
COLUMN/BASE JUNCTION

The detail at the junction of the column on the edge of the foundation needs particular attention. Since the top steel in the foundation is often highly stressed at this point, large-radius bends (see section 3) may be needed, and care should be taken that the column reinforcement does not clash with beam reinforcement. It is advisable to provide horizontal U-bars around the starter bar cage.

5.5.38 Rafts

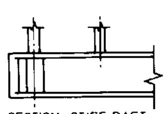
There are several different types of raft foundations:

piled
stiff
flexible
light rafts
cellular

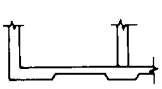


PILED RAFT

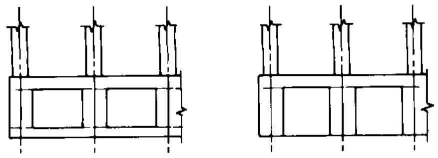
The design varies with each type, but the common purpose of all rafts is to spread a whole system of loads over a large area generally to give a low linearly-imposed load on to the ground below. The exception to this is the flexible raft, which results in a variable, yet tolerable, imposed ground pressure.



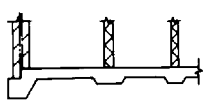
SECTION - STIFF RAFT



SECTION - FLEXIBLE RAFT

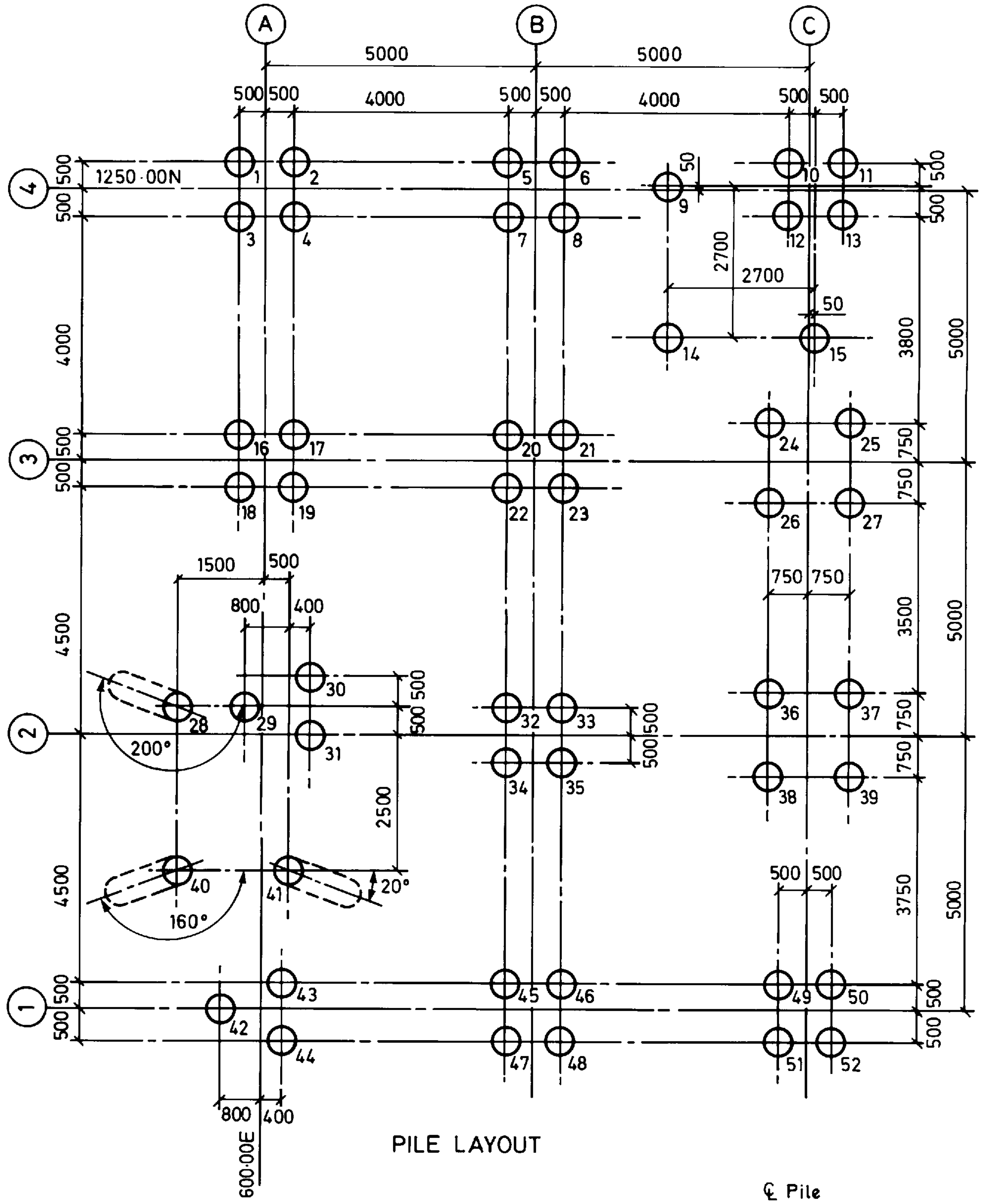


SECTION - CELLULAR RAFTS
a) With bottom slab
b) Without bottom slab

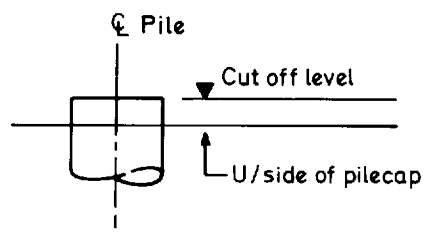


SECTION - LIGHT RAFT

5.5.40 Examples of general arrangement drawing for foundations



PILE LAYOUT



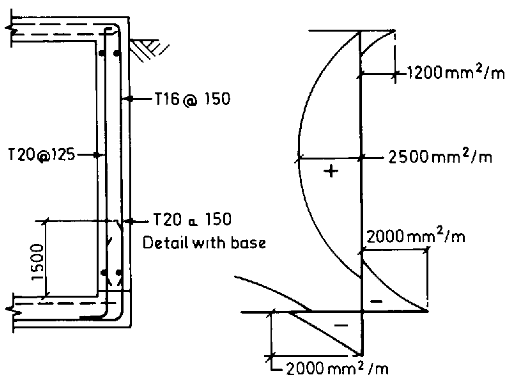
PILE SCEDULE			
PILE Nos.	CUT OFF L.	MIN TOE L.	REMARKS
1–8	97·825	87·000	
9–15	95·575	85·000	
16-19;20-27 32-38 42-52	98·075	87·000	
29-31	97·925	87·000	
28,40 & 41	97·925	87·000	RAKE 1:15

5.6.10 Design information

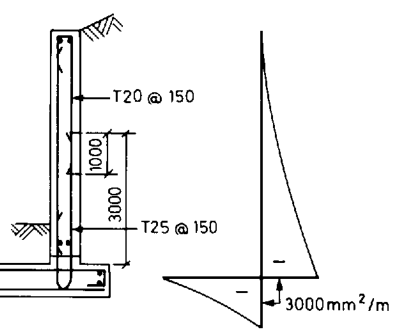
These data are output from the approved calculations for each wall type, which should indicate:

- *(a)* concrete grade, to determine laps, durability, etc.
- *(b)* design type assumed, i.e. plain or reinforced vertical loadbearing wall, propped or full cantilever retaining wall, etc.
- *(c)* cover to outer bars each face
- *(d)* orientation of outer bars, i.e. whether horizontal or vertical
- *(e)* type of reinforcement, and any size restrictions
- *(f)* area of main/secondary reinforcement required A_s or A_{sc}(mm^2/m) or, preferred type/size and pitch (actual)
- *(g)* wall faces with minimum reinforcement requirements (see tables)
- *(h)* any special requirements, i.e. data for links, tie bars, trimming for holes, etc.

Provide sketches where appropriate, e.g.



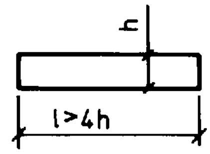
Propped-cantilever retaining wall



Cantilever retaining wall

Provide minimum reinforcement, unless shown.

5.6.11 Design code requirements



5.6.11.1 A vertical loadbearing member is defined as a wall when its length exceeds four times its thickness (1.2.4.1.†)

5.6.11.2 Walls may be either plain or reinforced: (1.2.4.7†)

(a) Plain walls
Plain walls contain either zero reinforcement or less than the minimum requirements for reinforced walls. Any reinforcement that is provided however is ignored in design when considering the strength of the wall. To counteract possible flexural, thermal and hydration shrinkage cracks, particularly in external walls and at the junction of internal members, minimum reinforcement is required. This should be provided as a mat of small bars at relatively close spacings, with reinforcement areas expressed as a percentage of the gross concrete cross-sectional area. The horizontal bars should be placed in the outer layer.

		grade 250	grade 460
Minimum reinforcement in both horizontal and vertical directions	1 face, or	0.3%	0.25%
	½ each face	0.15%	0.125%

(b) Reinforced walls
Reinforced walls are considered to contain at least the minimum area of reinforcement expressed as a percentage of the gross concrete cross-sectional area

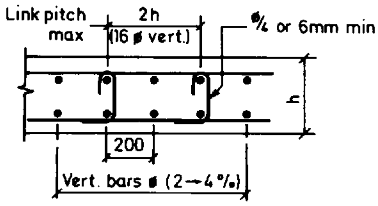
(i) *Vertical reinforcement*
Minimum A_{sc} not less than 0.4% (0.2% each face) (3.12.5.3†) Table 3.27†
Maximum A_{sc} not to exceed 4% (3.12.6.3†)
Maximum bar spacing, when A_{sc} exceeds 2%, should not exceed 16 × vertical bar size (3.12.7.5†)

(ii) *Horizontal reinforcement*
This reinforcement should be evenly spaced in the outer layers to minimize crack widths and contain the vertical compression bars.

Where vertical bars are in tension, particularly in retaining walls, these are sometimes placed in the outer layer to facilitate fixing and to maximize the lever arm.

		grade 250	grade 460
Minimum horizontal reinforcement	1 face, or	0.3%	0.25%
	½ each face	0.15%	0.125%

The minimum size of bar should not be less than one quarter the size of the vertical bar and preferably not less than 8mm diameter. (3.12.7.4†)



Additional horizontal restraining links should be provided through the thickness of the wall when the area of vertical compression reinforcement exceeds 2%. Link spacing should not exceed twice the wall thickness in any direction. Any unrestrained vertical bars should be within 200mm of a linked bar. (3.12.7.5†)

5.6.11.3 Plain and reinforced walls in tension (3.9.3.6†)

Bars should be arranged in two layers and the maximum spacing of tension bars should generally not exceed 150mm where F_y = 460 N/mm^2 or 300mm where F_y = 250 N/mm^2 (3.12.11†)

Table 23 Optimum bar spacing for varying % reinforcement and different wall thicknesses

minimum reinforcement	*bar nominal size mm* / *wall thickness, mm*: *8*					*10*					*12*					*16*				
%	100	150	200	250	300	100	150	200	250	300	100	150	200	250	300	150	200	250	300	350
0.125	—	250	200	150	125	—	—	300	250	200	—	—	—	—	300	—	—	—	—	—
0.15	300	200	150	125	100	—	300	250	200	150	—	—	—	300	250	—	—	—	—	300
0.2	250	150	125	100	—	—	250	175	150	125	—	—	275	225	175	—	—	—	300	250
0.25	200	125	100	—	—	300	200	150	125	100	—	300	225	175	150	—	—	300	250	200
0.3	150	100	—	—	—	250	150	125	100	—	300	250	175	150	125	—	—	250	200	175
0.4	125	—	—	—	—	175	125	100	—	—	275	175	125	100	—	—	250	200	150	125
0.45	100	—	—	—	—	150	100	—	—	—	250	150	125	100	—	275	200	175	150	125
0.8	—	—	—	—	—	100	—	—	—	—	125	100	—	—	—	150	125	100	—	—

maximum reinforcement	*Bar nominal size mm* / *Wall thickness, mm*: *20*					*25*					*32*					*40*				
%	100	150	200	250	300	100	150	200	250	300	100	150	200	250	300	100	150	200	250	300
2.0	150	100	—	—	—	240	160	120	90	80	400	260	200	160	130	610	420	310	250	210
4.0	—	—	—	—	—	120	80	—	—	—	200	130	100	80	—	310	210	150	120	100

Note: These tables can be used for plain and reinforced walls, etc. (see clause 5.6.11)

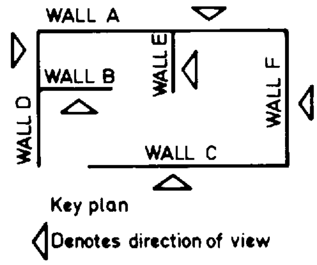
5.6.20 Detailing

5.6.21 Method of detailing walls

Most walls are detailed on elevation supplemented by sections drawn to clarify the fixing, especially at member junctions, openings, etc. The concrete profile dimensions are abstracted from the relevant general-arrangement drawings, which together with the design calculations, should be at their final stage.

5.6.21.1 Wall layout

When elevating walls for detailing, the direction of view should be consistent, i.e. normally viewing from the bottom/right edges of the drawing. Walls cast against an inaccessible face should be viewed from the 'open' side. A key plan is useful particularly when the plan is complex, e.g. lift shafts, more especially if the above convention is unable to be followed, e.g. walls 'A' & 'D'.

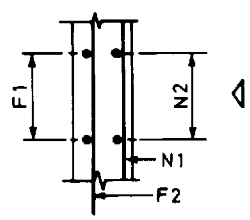


5.6.22 Bar detailing on walls

5.6.22.1 On elevation

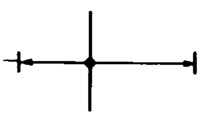
(a) *Notation for layers of reinforcement*
Reinforcement is fixed in two layers at right-angles to form a mat, normally one mat at each wall face

(i) Abbreviation for near face, outer layer N1
(ii) Abbreviation for near face, second layer N2
(iii) Abbreviation for far face, outer layer F1
(iv) Abbreviation for far face, second layer F2

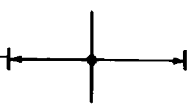


(b) *Typical bar and indicator line*
The convention for illustrating and 'calling up' bars on walls follows closely that of slab (see subsection 5.2) e.g.:

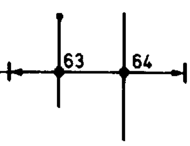
(i) A zone of similar bars in one face 20T10-63-150N1



(ii) A zone of similar bars in two faces 40T10-63-150 (20N1-20F2)



(iii) A zone of dissimilar bars in two faces 20T10-63-150N1 20T10-64-150F2

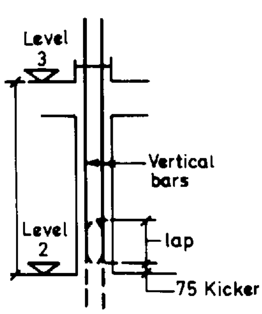


Note that identical bars appearing on different faces are itemized separately.

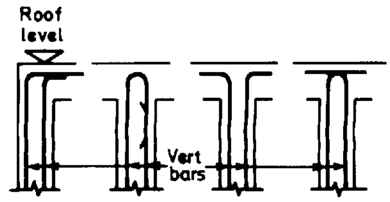
To avoid congestion in thin walls less than 150mm thick, a single mat of reinforcement may be provided, if design requirements permit.

5.6.22.2 On section

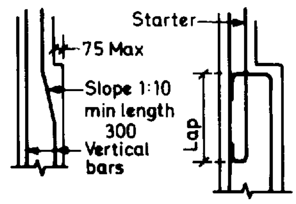
(a) *Intermediate storeys*
Walls are normally cast in storey-height lifts, with standard 75mm high kickers at each floor level. Kickers help to align the formwork above. The vertical reinforcement should not be less than 12mm and is lapped above the kicker to provide structural continuity.



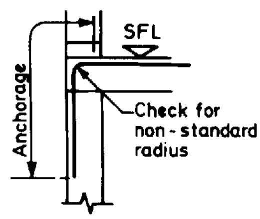
(b) *Top storeys*
A variety of details are possible depending on design and construction requirements. Allow sufficient top cover for clearance of intersecting reinforcement.



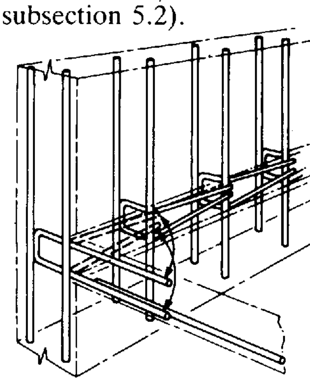
(c) *Offset walls above*
Normally offsets of up to 75mm can be achieved by joggling the relevant vertical bars. Otherwise, the lower bar is terminated below the floor and a separate splice-bar starter provided.



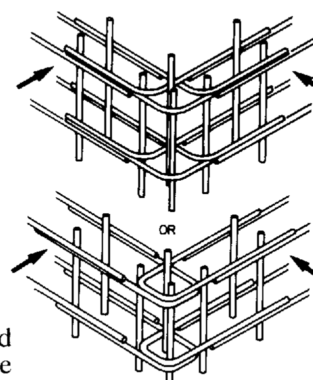
(d) *External wall/slab junction*
In the case where a significant bending movement is transmitted into the wall from the slab, it may be necessary to use a L-shaped bar to provide full anchorage. If the L-bar is to be cast with the wall it should be scheduled with the wall reinforcement, but this is a non-preferred detail (see subsection 5.2).



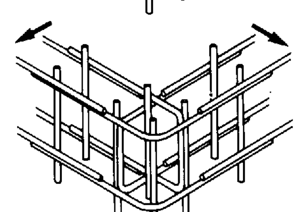
(e) *Half-landings*
A 20mm deep rebate is preformed in the supporting wall to provide bearing for the slab poured later. The junction is provided with up to 12mm, preferably mild steel, U-bars which are temporarily folded back behind the formwork and later rebent into their correct position for the slab.



(f) *Corner details*
(i) *Closing corners*
For corners that are closing, two simple alternatives are shown. Bars should be provided with adequate anchorage and appropriate laps to suit.



(ii) *Opening corners*
For corners that ar 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 above 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 difficult to bend and fix. The recommended detail shown is more practical and has a high structural efficiency.



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

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5.6.23 Other requirements

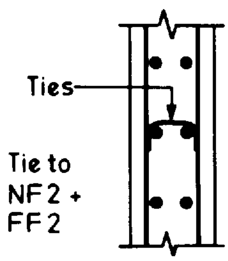
5.6.23.1 Special notes

In addition to the standard notes for reinforcment drawings (see subsection 2.8), the following notes should appear on all wall drawings.

(*a*) cover to outer reinforcement N1....F1....End....
(*b*) bar-layer notation: Near face outer bar N1
Near face second bar N2
Far face outer bar F1
Far face second bar F2

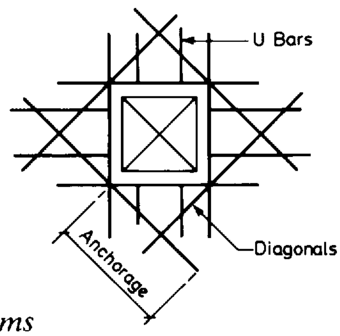
5.6.23.2 Wall reinforcement spacers

Where links are not required to restrain vertical compression bars, reinforcement spacers can be used to stabilize the two faces during construction. Adopt say R10 @ 1000, shape code 38. Cover to the outer bars is normally achieved by using plastic spacers



5.6.23.3 Trimming of holes in walls

To prevent cracks springing from corners, provide nominal bars placed diagonally as shown. Additional trim requirements should be indicated in the calculations.



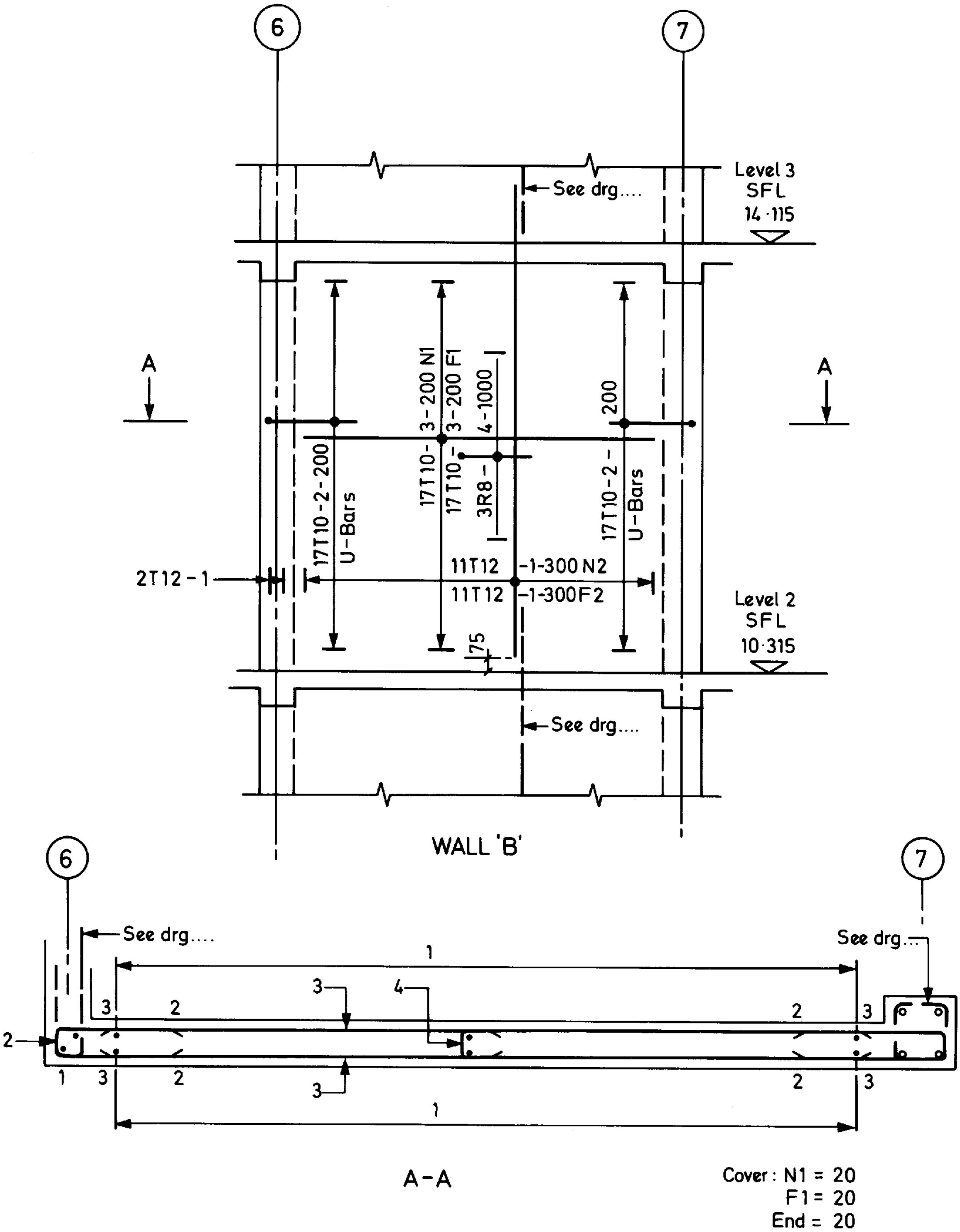
5.6.23.4 Miscellaneous items

When detailing reinforcement, ensure that adequate clearance is allowed for items such as fixings, pipes, water bars, weep holes, etc.

5.6.23.5 Fabric reinforcement in walls

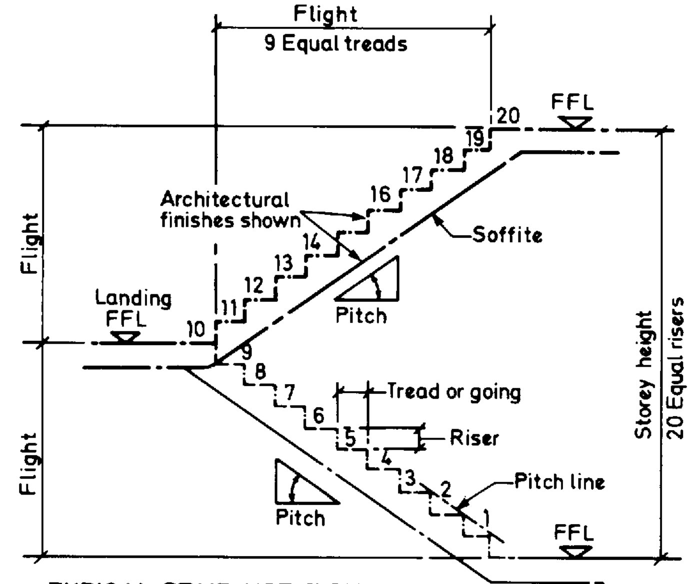
Conventional wall layouts lend themselves to the advantages of fabrication as described in clause 5.2.26. Purpose-made wall sheets can be ordered to deal effectively with lapping and intersection details. For guidance, consult the manufacturers of fabric.

5.6.30 Examples of detailing
5.6.31 Typical internal wall panel

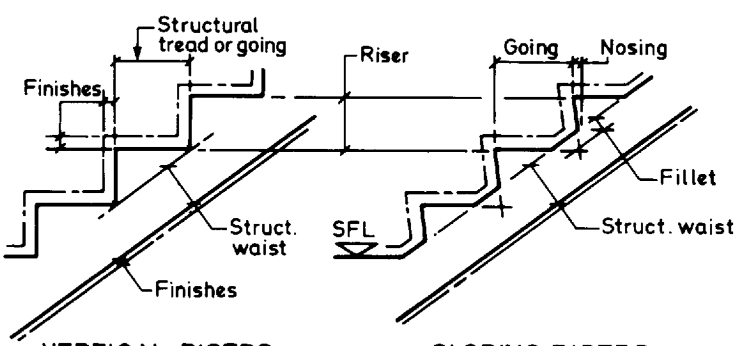


5.7.10 Design information

Requirements for stairs are similar to those indicated for slabs (see subsection 5.2).

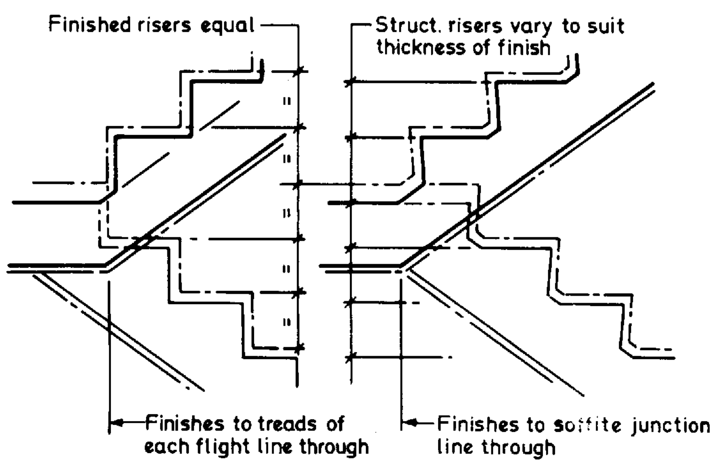


TYPICAL STAIR NOTATION



VERTICAL RISERS

SLOPING RISERS WITH FILLETS



Notes on setting-out

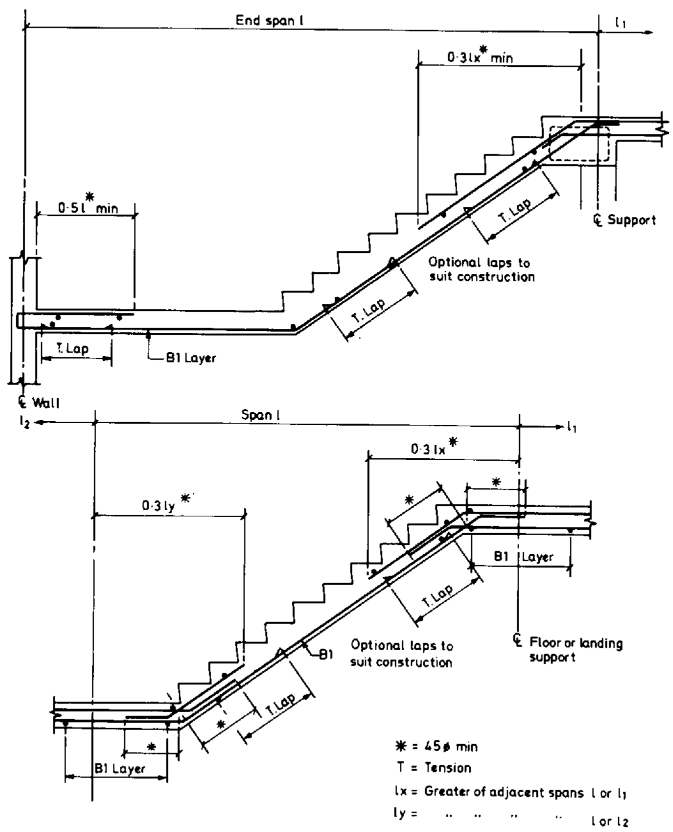
The stair structural-layout or general-arrangement drawing should indicate all the dimensions required to set out the concrete profile.

The architect will normally locate the stair between floors using the top of the finishes as his vertical datum. The height of risers will be equal but the thickness of finish may vary, particularly at floors and landings. It follows that structural risers may vary in height. Treads may require sloping risers to provide a nosing, and fillets may be needed to maintain a constant waist thickness.

It is often arranged that the finishes to nosings of adjacent flights will line through across the stair. Sometimes the junctions of all soffits are made to line through.

5.7.11 Design code requirements

Bar curtailment rules for stairs follow the simplified or general rules recommended for slabs (see clause 5.2.11).



TYPICAL STAIR FLIGHTS SHOWING REINFORCEMENT
(Bar curtailments based on BS8110 simplified rules (3.12.10.3)[†] fig 3.25

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5.7.20 Detailing

5.7.21 Methods of detailing stairs

In all cases concrete profiles are extracted from the relevant general-arrangement drawings. Each different flight is drawn in section to a suitable scale, and the appropriate reinforcement is carefully related to the profile.

5.7.21.1 Simple flights

These can be detailed on section alone, probably with the aid of a key plan to identify various flights and sections taken. Separate sections may be necessary across landings.

5.7.21.2 Stair complexes

Reinforcement is shown on the plan of flights and landings where they differ for each storey height. Sections taken should clarify the positioning of the bars.

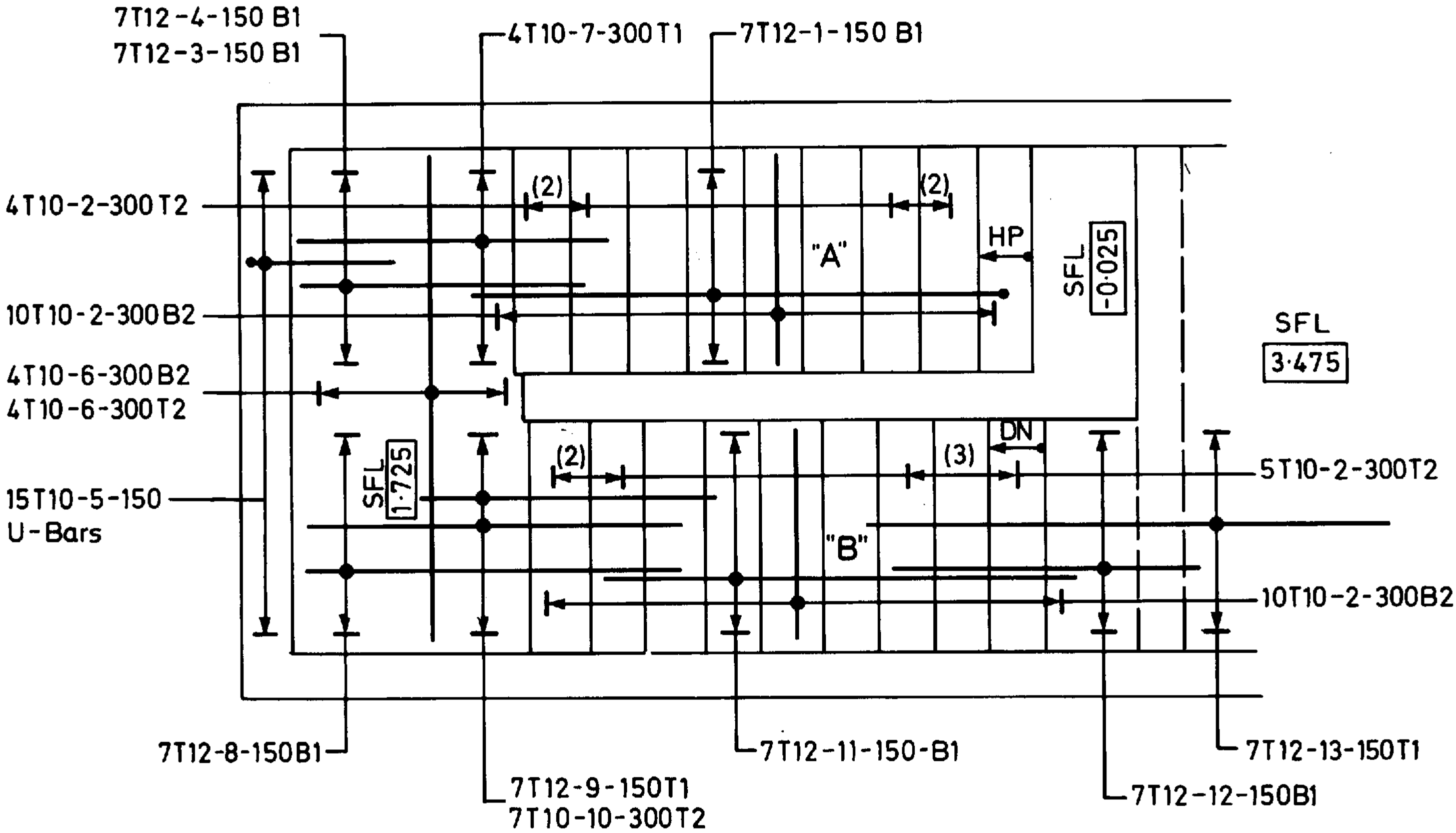
5.7.21.3 Surrounding structures

Starter bars for landings etc. may be required to project from supporting members for the stair construction to proceed at a later date. These bars may be folded back from behind the formwork (see clause 5.6.22.2) and should be detailed with the support.

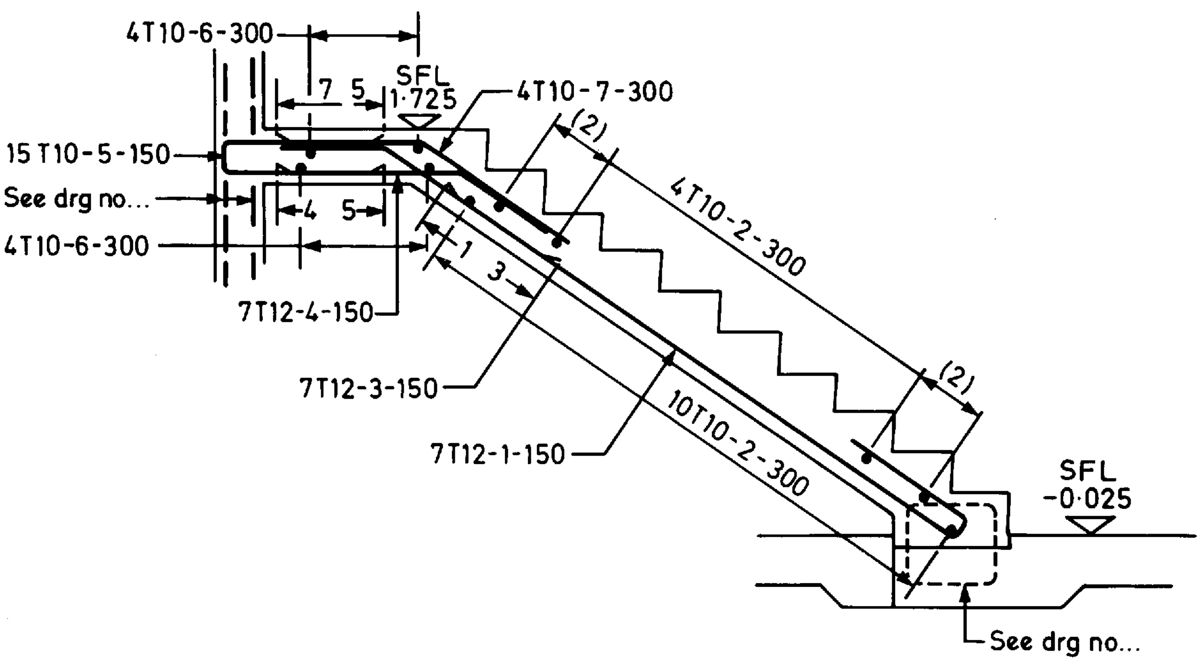
5.7.22 Bar detailing on stairs

This follows the conventions used for detailing slabs (see clause 5.2.22).

5.7.30 Examples of detailing



TYPICAL STAIRS
Shows flights "A","B" and landing detailed on plan



TYPICAL STAIR FLIGHT
Shows flight "A" and part-landing detailed on section

6 Specific details

6.1 Concrete inserts

6.1.1 Types

Concrete inserts may be of the following types:

cast-in
bonded with resins
bonded with cementitious grout
expanding
shot-fired.

Fixings are usually characterized by their shape, or the way in which anchorage to the concrete is achieved and sometimes by the purpose for which they are used. A wide variety of studs, eyes, rods, hangers, loops, bolts, channels, sockets, blocks and nails may be installed, but in all cases the manufacturer's advice and installation instructions must be strictly adhered to.

6.1.2 Problems and solutions

Problems are usually brought about by a lack of technical knowledge of the fixing, a failure in communications between supplier and installer or a misunderstanding of the principles of the fixing. Problems may also be induced by the location of the reinforcement, the formwork system employed or the compactive effort used in placing the concrete.

Always consult the supplier of a fixing before it is detailed and ensure that the installation is specified on the detail drawings and contract documents. Particular attention should be paid to the following:

edge distances and spacings of fixings, particularly when used in groups
concrete strength and aggregate size
hole diameter and depth
proximity of reinforcement and any special reinforcement to hold the fixing in place
fixings to be used with lightweight aggregate concrete
specification of components to be set in concrete using jigs to prevent displacement
setting-out of fixings on drawings using reference lines and running dimensions
cover requirements for fixing and reinforcement
recommendations regarding compatibility of materials.

6.1.3 Durability

This covers three aspects:

corrosion (normally applies only to ferrous fixings, although the normal rules of galvanic action must still be observed)
fire resistance (if the fixing is not protected with the requisite amount of fireproof material a fire test should be carried out)
long-term performance.

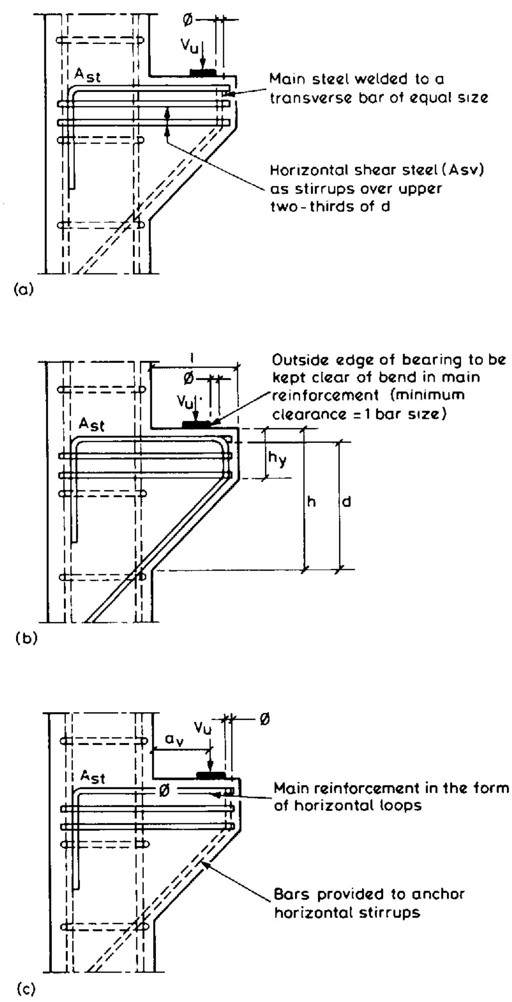
In all these, guidance must be sought from the manufacturer before the installation is specified.

6.2 Corbels, half-joints and nibs

The detailing of these elements must relate to the design assumptions, and the designer should in all circumstances ensure that the detailed design is clearly specified.

6.2.1 Concrete corbels

In details (a) and (c) (see Fig. 27) the edge of the bearing and the inside of the welded transverse bar or the inside of the main reinforcement in the form of horizontal loops should not be less than the bar diameter. For detail (b) the bend should not commence before a bar size beyond the edge of the bearing plate. In all cases these distances should be increased to the cover to the bar where this is greater than the bar diameter. It can be seen that the total projection of the corbel will be much greater in detail (b) than in the other two details because a larger radius bend than the standard radius may be required to limit the bearing stress of the concrete inside the bend. Because of this, details (a) and (c) may be preferable; it is suggested that detail (a) be used when using bars of size 20mm or greater (see also Fig. 28) and detail (c) for bars of 16mm and smaller (see also Fig. 29).



Detailing rules

1. $h_y \nless 0{\cdot}5h$
2. $0{\cdot}4 < 100A_{st}/bd < 1{\cdot}3$
3. $0{\cdot}6 < 100(A_{st} + A_{sv})bd < 2{\cdot}0$
4. Other details as per diagrams

Fig. 27

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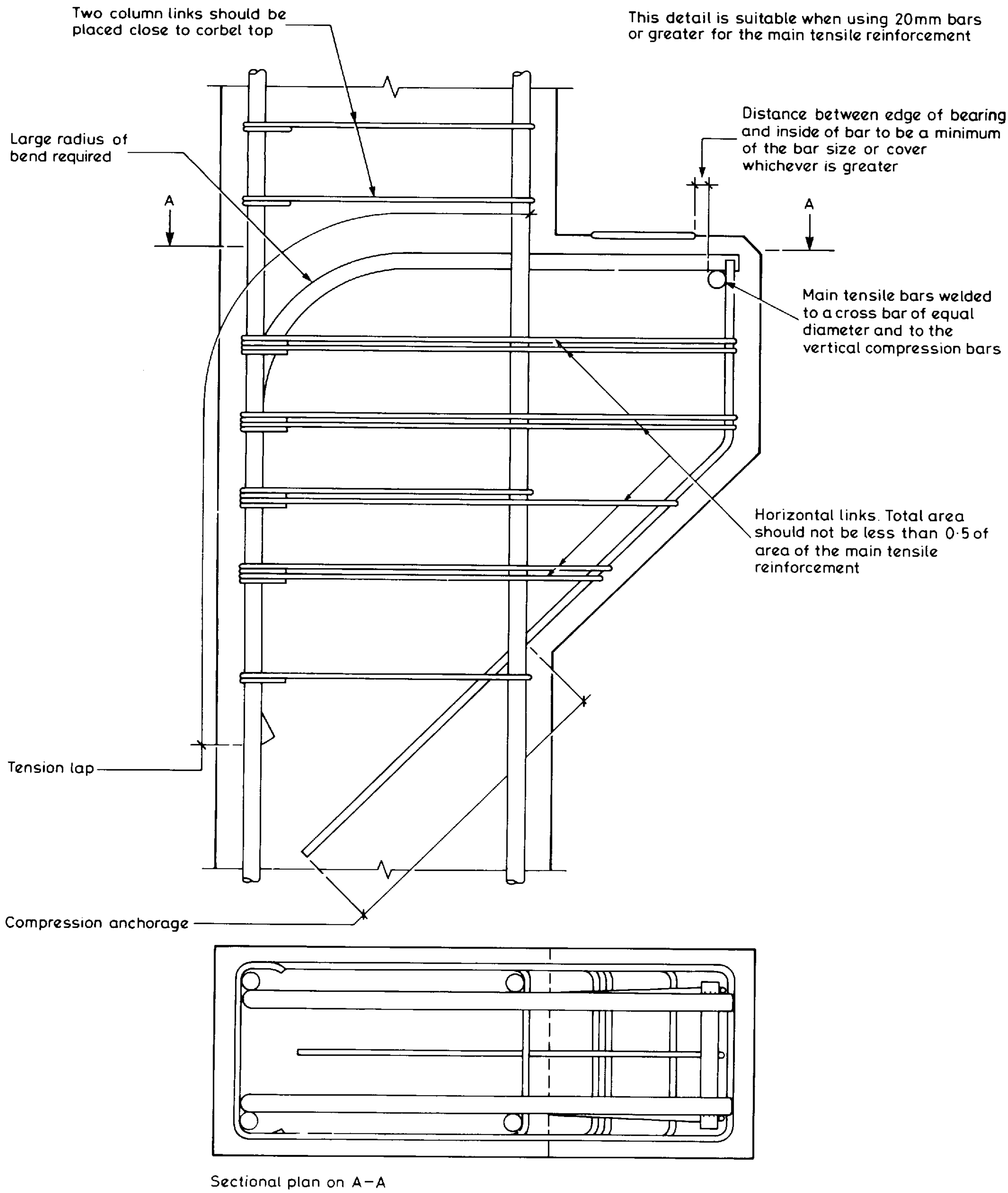
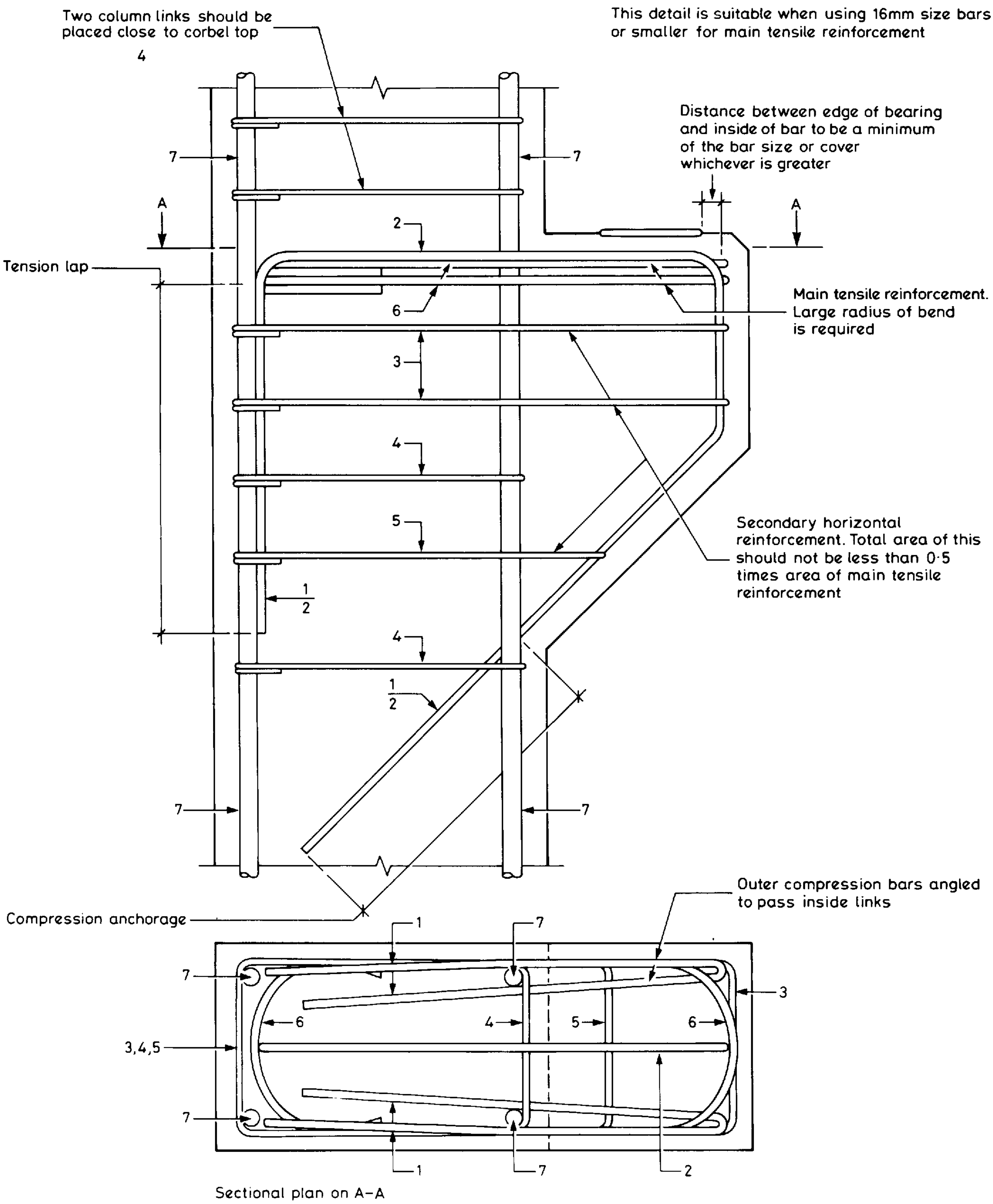

Two column links should be placed close to corbel top
This detail is suitable when using 20mm bars or greater for the main tensile reinforcement
Distance between edge of bearing and inside of bar to be a minimum of the bar size or cover whichever is greater
Large radius of bend required
A
A
Main tensile bars welded to a cross bar of equal diameter and to the vertical compression bars
Horizontal links. Total area should not be less than 0·5 of area of the main tensile reinforcement
Tension lap
Compression anchorage
Sectional plan on A–A

Fig. 28



Two column links should be placed close to corbel top
4
This detail is suitable when using 16mm size bars or smaller for main tensile reinforcement
Distance between edge of bearing and inside of bar to be a minimum of the bar size or cover whichever is greater
7
A
A
2
Tension lap
6
Main tensile reinforcement. Large radius of bend is required
3
4
5
Secondary horizontal reinforcement. Total area of this should not be less than 0·5 times area of main tensile reinforcement
1
2
4
1
2
7
7
Compression anchorage
Outer compression bars angled to pass inside links
1
7
7
3
6
4
5
6
3,4,5
7
1
7
2
Sectional plan on A–A

Fig. 29

Horizontal forces

When corbels are designed to resist horizontal forces then additional reinforcement should be provided to transmit this force in its entirety. This reinforcement should be welded to the bearing plate.

6.2.2 Concrete nibs

Nibs are not usually greater than about 300mm deep. For detailing requirements, the tension reinforcement that will be near the top surface of the nib can be in the form of U-bars in the vertical or horizontal plane or straight bars welded to a transverse bar.

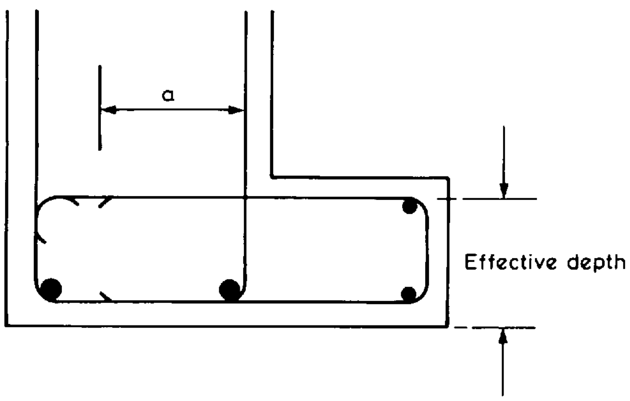


Fig. 30 Vertical loops

(a) Vertical loops (see Fig. 30)

- (i) size of links or U-bars to be not greater than 12mm
- (ii) depth of nib not less than 8ϕ plus two covers for high-yield bars or 6ϕ plus two covers for mild-steel bars
- (iii) dimension *a* to be a tension anchorage length if U-bars are used and the width of beam is sufficient to allow this. If the width is not sufficient then a closed link can be used with an additional longitudinal bar introduced as indicated
- (iv) if the nib is supporting a reinforced concrete member then there should be a minimum horizontal overlap of reinforcement in the nib and reinforcement in the supported member of 60mm
- (v) horizontal spacing of the links or U-bars to be not greater than 3 times the effective depth.

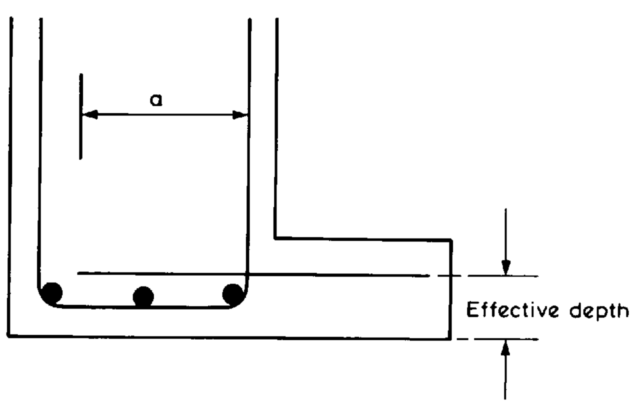


Fig. 31 Horizontal loops

(b) Horizontal loops (see Fig. 31)

- (i) size of bar to be not greater than 16mm
- (ii) depth of the nib to be sufficient to provide adequate top cover to reinforcement in nib
- (iii) nib reinforcement to be placed on and wired to the main reinforcement in the beam. If main reinforcement is too low, then additional bars should be provided (see below)
- (iv) dimension *a* should be a tension anchorage length and wired to at least two main longitudinal bars
- (v) lacer bar in the nib to be the same diameter as the horizontal U-bar
- (vi) Horizontal spacing of the legs of the U-bar or between the legs of the U-bars to be not greater than 3 times the effective depth.

(c) Welded bars (see Fig. 32)

Requirements will be the same as for horizontal loops.

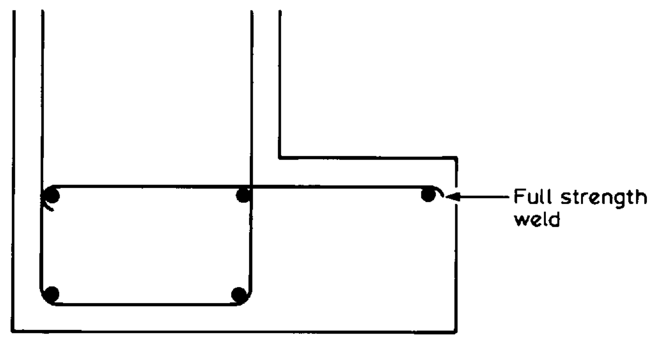
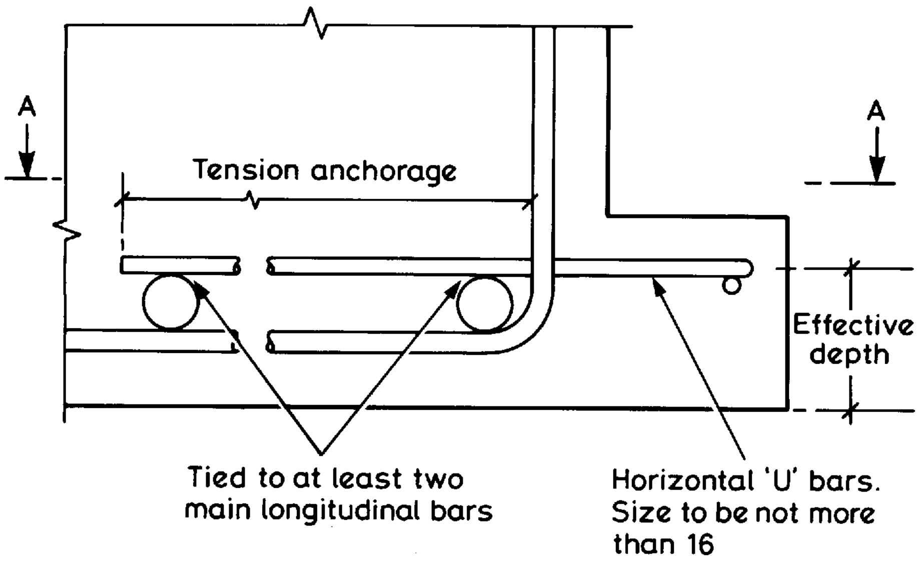
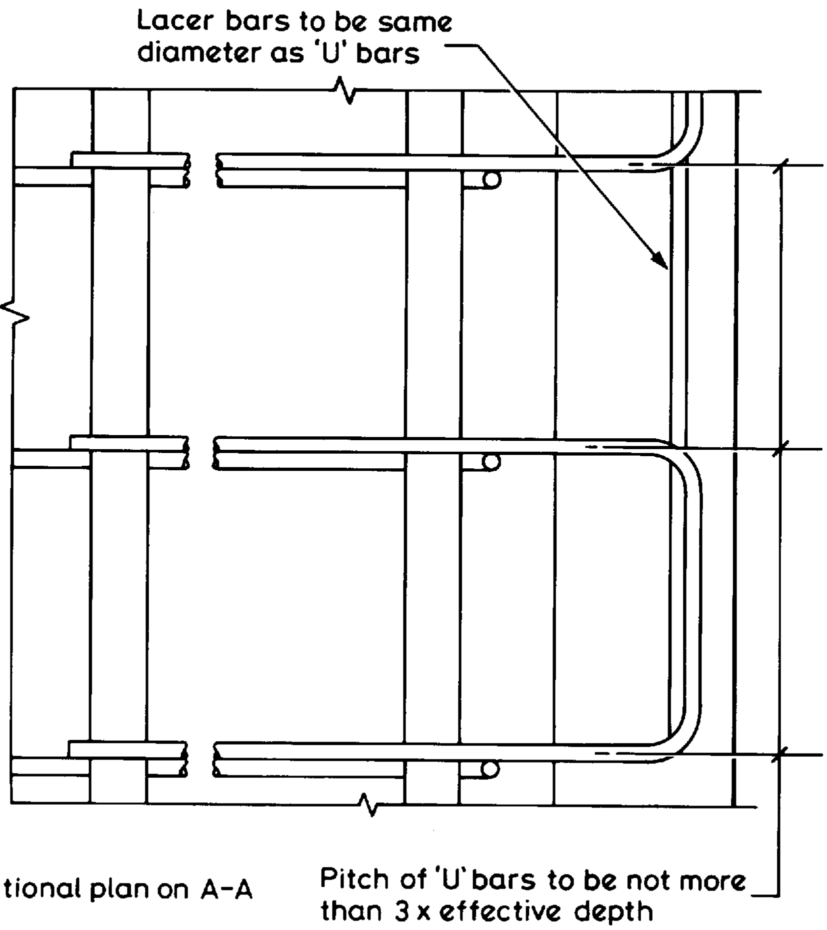


Fig. 32 Welded bars

6.2.3 Halved-joints

The preferred arrangement shown (see Fig. 34) does not include inclined links or bars as these are often difficult to fix properly. However, inclined links or bars can be used especially when large size bars are required and a welded solution is adopted.





Sectional plan on A-A

Fig. 33

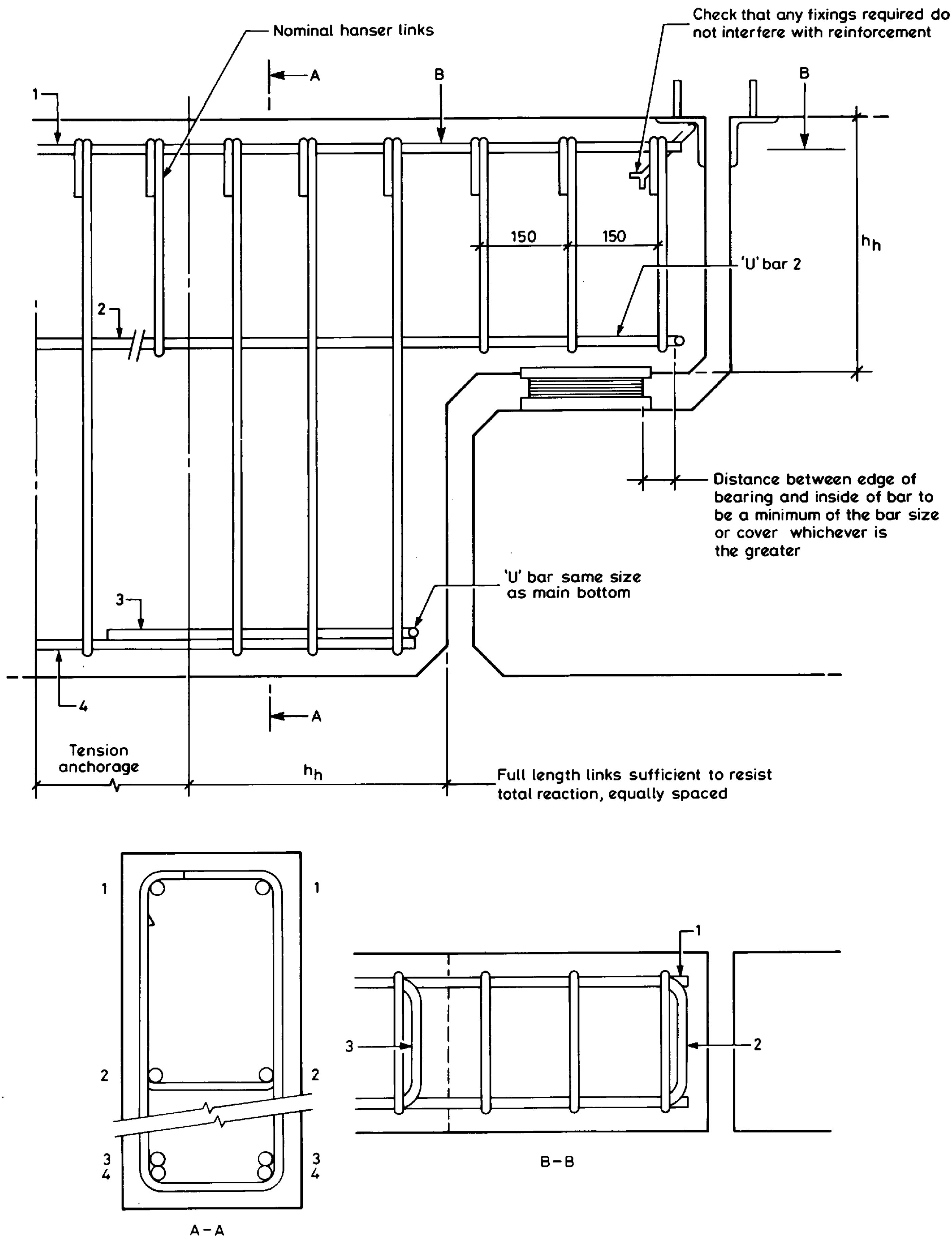


Fig. 34 Halved joint.

7 Prestressed concrete

7.1 Introduction

Design and detailing of prestressed concrete are to a large extent inseparable and this section is therefore addressed to the designer/detailer. Only those structural members that are commonly used are reviewed, although the principles are applicable to other prestressed concrete members.

7.2 Drawings

In addition to the drawings showing the general arrangement of the prestressed concrete structure and reinforcement details, a separate set of drawings should be prepared detailing the prestress to be applied. This set of drawings should include the following information for each prestressed concrete member:

layout and arrangement of tendons
setting-out data for each tendon profile and tolerances
tendon and duct types and sizes
anchorage recess dimensions (if any)
the prestressing system that is detailed (if any)
force to be applied to each tendon and tensioning sequence
location of grouting points and vents
for pretensioned members any tendons to be debonded should be marked on sections and elevations and the method and length of debonding specified as illustrated in Fig. 35

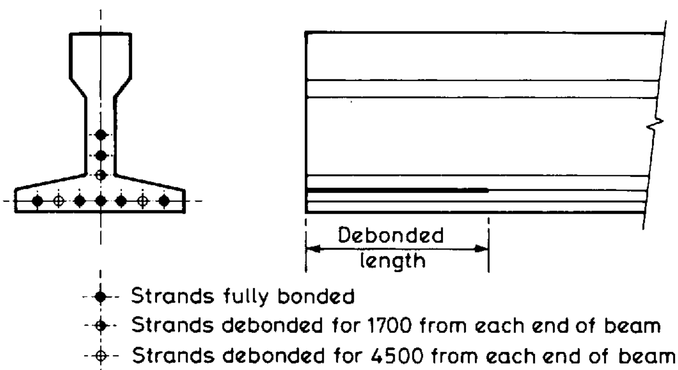


Fig. 35 Debonded tendons

tendons to be deflected should be clearly indicated and dimensioned both horizontally and vertically see (Fig. 36) (radius of curvature to comply with the recommendations of the manufacturer of wire or strand)
concrete grade and minimum strength required at transfer of prestress
relevant design parameters assumed:

relaxation of prestressing steel
friction characteristics
anchorage draw-in
modulus of elasticity of steel and expected tendon extensions
movements of permanent structure at stressing
variations in camber

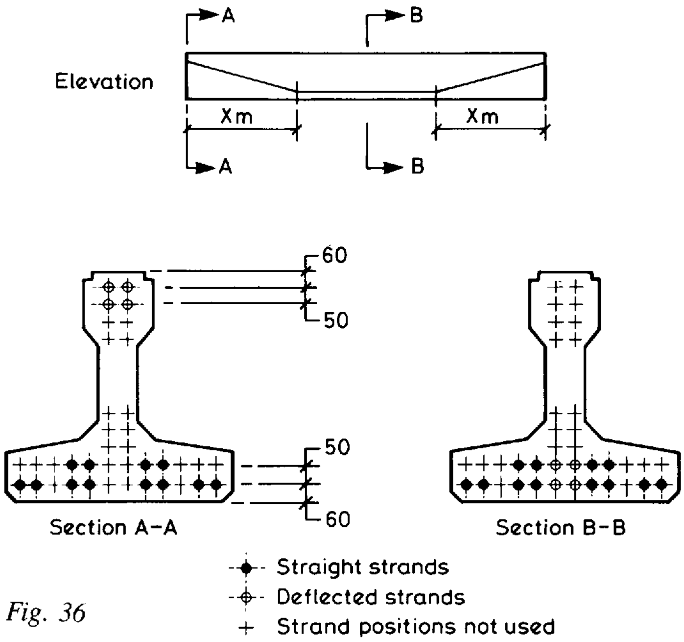


Fig. 36

for precast members: test arrangements, handling and stocking requirements.

It should be clearly stated that the choice of prestressing system is left to the contractor where no system is shown on the drawings or where an alternative system to that detailed is permitted.

It should also be stated on the drawings that any alternative proposed by the contractor should be checked by the original detailer/designer, particularly any reinforcement modifications that may be required.

7.3 Components

7.3.1 Pretensioned units

Pretensioned units must be suitable for precasting. Bearing plates or similar components should not project below the element in to the soffit form to allow elastic shortening to the member to take place.

Tendons

Tendons should be in vertical rows with spacing and edge cover compatible with the maximum size of aggregate to allow placing and compaction of the concrete. For symmetrical concrete sections, the centroid of the tendons should lie on the vertical centroidal axis (see Fig. 37).

7.3.2 Post-tensioned units

Tendons and anchorages

(*a*) Tendons may consist of wires, strands or bars, produced in accordance with BS 5896 or BS 4486. Several diameters and types of wire and strand are in common use, but it is recommended that only one particular type should be employed on a specific project to obviate errors during installation. Prestressing bars are

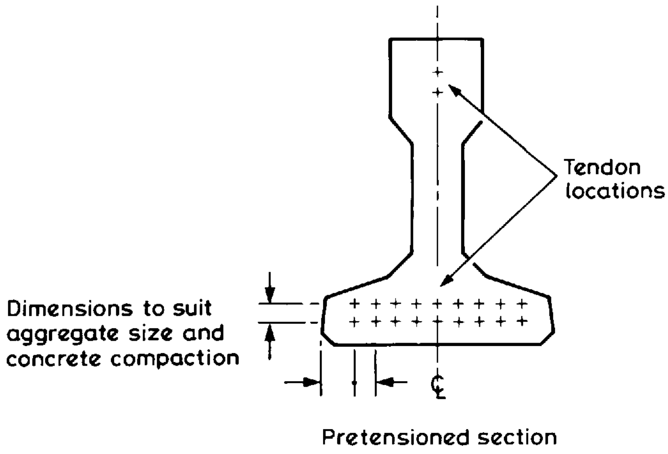


Fig. 37 Symmetrical tendon locations

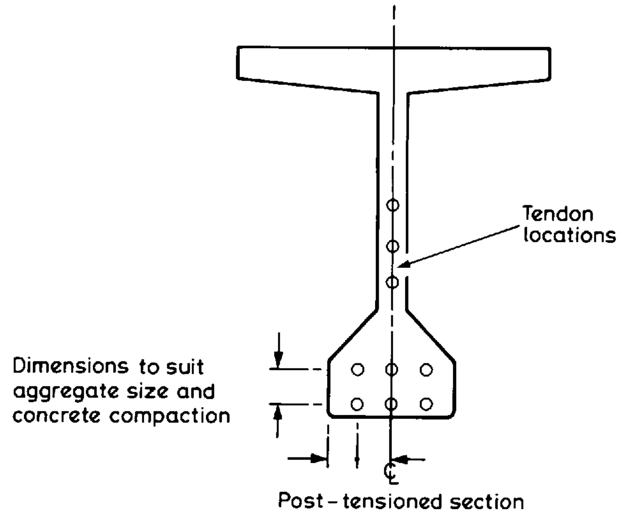


Fig. 38 Symmetrical tendon locations (multiple-layer tendons)

also available in several diameters (see Tables 24, 25 and 26).

(b) Post-tensioning anchorages should be of proprietary manufacture and meet the requirements of BS 4447. They may be either live (stressing), dead-end or passive anchorages or anchorage couplings. Each manufacturer produces a range of suitable anchorages.

Tendon ducts

(a) A tendon duct should be identified by its internal diameter, which should be that recommended by the prestressing equipment supplier for each size and type of tendon.

(b) Ducts may be formed in several ways, most commonly by using semi-rigid corrugated steel sheathing, which may be bent to suit the tendon profile. Rigid steel sheathing is occasionally used on special projects, sometimes pre-bent to radius.

(c) External diameters of sheathing vary, depending on the type and depth of corrugations, for which due allowance should be made when considering spacing, clearances and reinforcement details.

(d) The detailing should enable the sheathing or duct formers to be adequately fixed or supported to prevent displacement.

Duct spacing and cover

The minimum spacing and cover to ducts are specified in Codes of Practice and Standards, taking account of the grouping of tendons, the exposure conditions of the structure and the maximum size of aggregate. Tolerances relating to the position of ducts should be stated in accordance with the relevant Codes of Practice.

Multiple layer tendons

Multiple layer tendons should be arranged in vertical rows with sufficient space between the rows to facilitate proper placing and compaction of the concrete without damage to the sheathing (see Fig. 38).

Curved tendons

Where tendon profiles are curved, vertically and/or horizontally, sufficient concrete must be provided to give full support to the duct to prevent the radial force from pulling the tendon through the wall of the duct. The spacing of ducts may need to be adjusted to comply with Codes of Practice. The radial stresses on the insides of curves of small radius are considerable. Increased duct spacing and tensile reinforcement will normally be required (see also subsection 7.4).

Recommendations on the minimum radius of curvature of tendons may be obtained from the prestressing equipment supplier who will take into account the bending, without damage, of the sheathing and the installation of the tendon. Very small radii may require the use of specially made preformed rigid sheathing. In some circumstances, larger diameter sheathing may be required locally.

Minimum straight length of tendon

In order to ensure that the elements forming the tendon bear an equal proportion of the prestressing force at the anchorage, it is necessary for the duct to be straight where it connects to the anchorage. The recommended length of straight tendon may usually be obtained from the anchorage manufacturer (see Fig. 39).

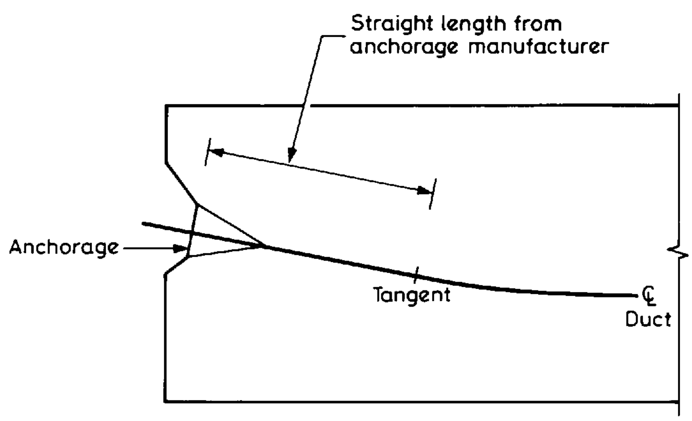


Fig. 39 Minimum straight length of tendon

Grouting points and vents

Grouting points (see Fig. 40) are associated with anchorages and should have facilities for connection to high-pressure grouting equipment. Vents are required at all high points to prevent air-locks. For long tendons, intermediate vents may be advisable at low points, and in an emergency, these can be used as intermediate grouting points.

Grout vents may be combined with sheathing couplers in which a short steel tube is riveted to the coupler. Alternatively, a plastic saddle vent is placed in the desired position against a compressible gasket to prevent leakage and wired to the sheathing.

A hole is punched in the sheathing through the vent pipe, using a soft steel punch so as not to damage the tendon. A plastic pipe is connected to the vent pipe and placed vertically to protrude above the surface of the concrete; an internal diameter of not less than 20mm is recommended.

Table 24 Dimensions and properties of cold-drawn wire from Table 4 of BS 5896: 1980

nominal diameter mm	*nominal tensile strength* N/mm^2	*nominal cross-section* mm^2	*nominal mass* g/m	*specified characteristic breaking load* kN
7 7	1570 1670	38.5	302	60.4 64.3
6 6	1670 1770	28.3	222	47.3 50.1
5 5	1670 1770	19.6	154	32.7 34.7
4.5	1620	15.9	125	25.8
4 4	1670 1770	12.6	98.9	21.0 22.3

Table 25 Dimensions and properties of strands from Table 6 of BS 5896: 1980

type of strand	*nominal diameter* mm	*nominal tensile strength* N/mm^2	*nominal steel area* mm^2	*nominal mass* g/m	*specified characteristic breaking load* kN
7-wire standard	15.2 12.5 11.0 9.3	1670 1770 1770 1770	139 93 71 52	1090 730 557 408	232 164 125 92
7-wire super	15.7 12.9 11.3 9.6 8.0	1770 1860 1860 1860 1860	150 100 75 55 38	1180 785 590 432 298	265 186 139 102 70
7-wire drawn	18.0 15.2 12.7	1700 1820 1860	223 165 112	1750 1295 890	380 300 209

Table 26 Dimensions and properties of hot-rolled and hot-rolled-and-processed high-tensile alloy steel bars from Table 1 of BS 4486: 1980

type of bar	*nominal size* mm	*nominal tensile strength* N/mm^2	*surface*	*nominal cross-sectional area* *smooth bar* mm^2	*ribbed bar* mm^2	*nominal mass* *smooth bar* kg/m	*ribbed bar* kg/m	*characteristic breaking load* kN
hot rolled	20 25 32 40	1030	smooth or ribbed	314 491 804 1257	349 538 874 1348	2.47 4.04 6.31 9.86	2.74 4.22 6.86 10.58	325 505 830 1300
hot rolled and processed	20 25 32	1230	smooth or ribbed	314 491 804	349 538 874	2.47 4.04 6.31	2.74 4.22 6.86	385 600 990

Plastic vent pipes should be adequately supported — possibly by the insertion of a loose-fitting reinforcing bar or length of prestressing strand.

The grouping of grouting and vent pipes at a single point should be avoided.

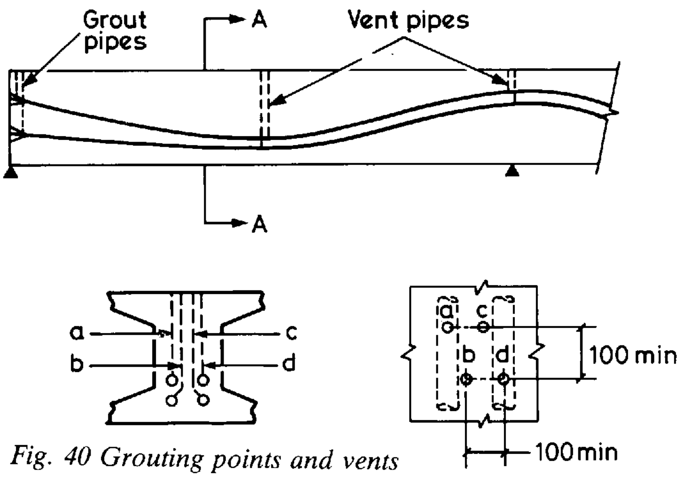
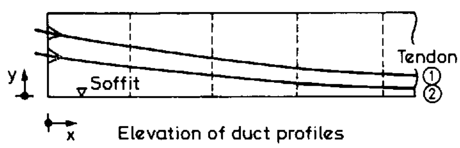


Fig. 40 Grouting points and vents

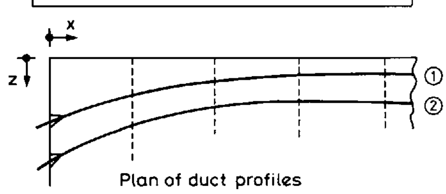
Duct profile

The duct profile should preferably be given in tabular form, the horizontal and vertical dimensions being based on a datum that is easy to identify on site. The profiles for each vertical row of ducts should be tabulated separately, with x-, y- and z-coordinates (see Fig. 41).

Dimensions should be to the centre of the duct or ducts and should be sufficiently frequent to define adequately the profile, taking account of its radius of curvature.



Distance along member (intervals at 1/10 or 1/20 of span)	0	0·05	0·10	0·15	0·20
Ordinate above soffit, y mm					
Tendon ①	1340	1203	1061	938	833
Tendon ②	888	771	679	602	536



Distance along member.	0	0·05	0·10	0·15	0·20
Distance from outside face, z mm					
Tendon ①	560	300	150	105	105
Tendon ②	1020	770	600	570	570

Note : All dimensions to duct centre lines

Fig. 41 Duct profiles

Anchorages

If the structure is detailed for a particular prestressing system, an outline of the anchorage should be shown; it should be axially in line with the last straight length of tendon. The spacing and edge distance should not be less than those recommended by the manufacturer.

If the structure is not detailed for a particular system then a general outline should be drawn that would generally encompass approved systems.

Anchorage recesses (see Fig. 42) should be dimensioned to provide adequate working clearance to the stressing equipment and sufficient depth to ensure that they can be subsequently filled with mortar or concrete to provide corrosion protection. Reinforcement may be required to retain the concrete or mortar filling; a convenient method is to screw small diameter bars into sockets provided in the faces of the recess.

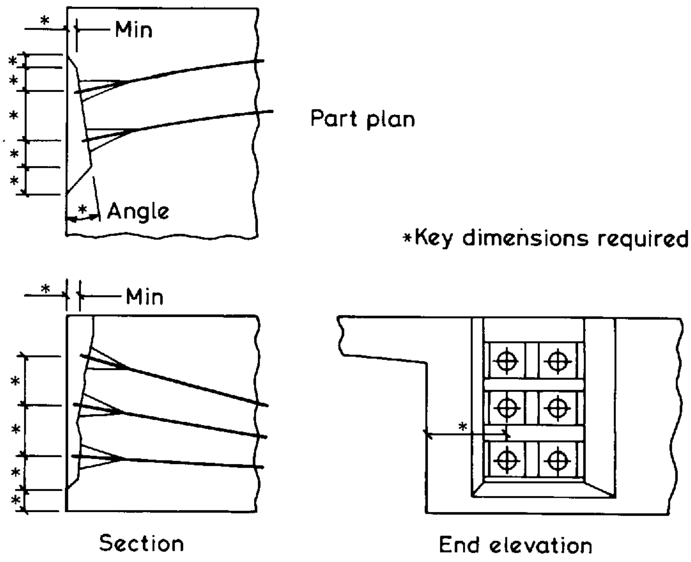
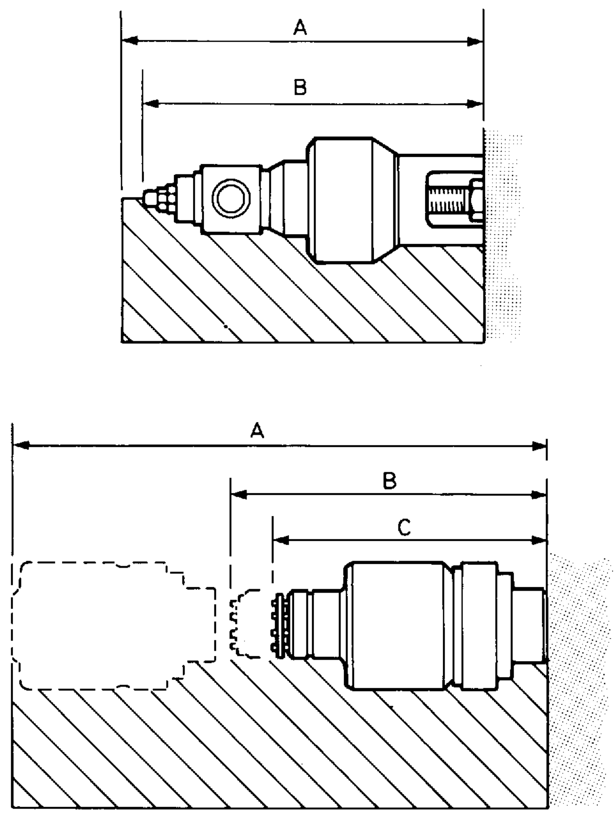


Fig. 42 Anchorage recesses in end block

Working clearances

Space should be provided in front of the anchorages to enable the stressing jack to be lowered into position with its oil pipes, to be extended in line with the tendon and to be removed after stressing (see Fig. 43). There must be



A Total clearance recommended to allow removal of equipment after completion of stressing

B Overall length of stressing equipment including extension

C Overall length of equipment before stressing

Fig. 43 Jack clearances

sufficient space for the operators to stand alongside the jack.

Where the permanent works cause a temporary obstruction to the stressing operations, they should be detailed to allow for the completion of construction after stressing, e.g. wing and facing walls.

7.4 Reinforcement detailing

It is necessary to identify the areas in the structure that are subject to tensile forces, and the clauses in this subsection relate to the detailing of reinforcement in these areas. As for reinforced concrete, all the reinforcement in any one part of a concrete member should be detailed on one drawing.

7.4.1 End blocks in post-tensioned members (see reference 10.4.1)

An 'end block' is that zone of a prestressed concrete member in which the prestressing force is dispersed from the tendon anchorages to an approximately linear distribution across the section.

Reinforcement in end blocks should be detailed to ensure satisfactory behaviour of the end block under the following effects:

(a) Overall internal equilibrium of the end block

Both vertical and horizontal equilibrium should be considered and reinforcement provided to resist the tensile forces induced (see Fig. 44).

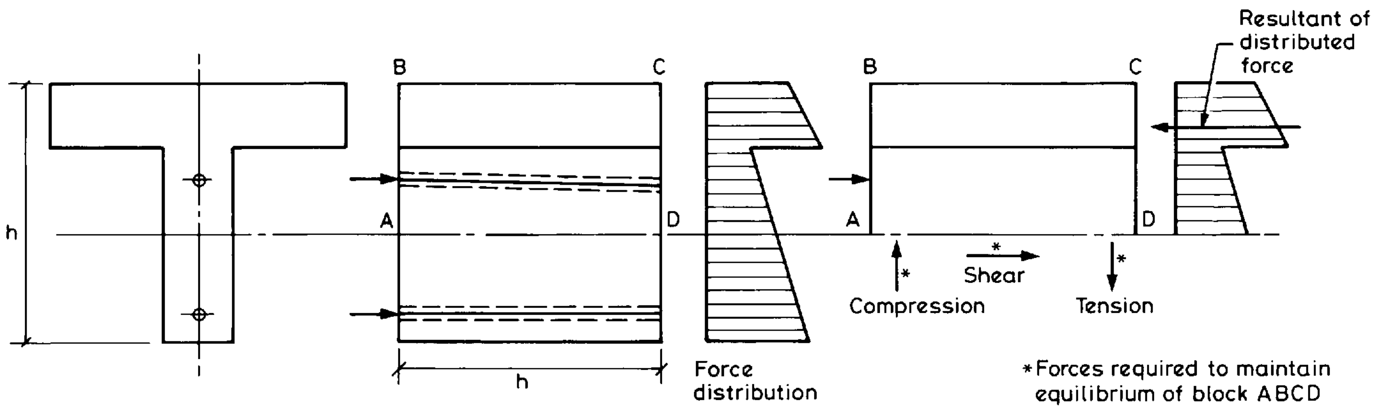


Fig. 44 Overall equilibrium of end block

(b) Tensile bursting forces behind the anchorage

These forces act normally to the line of the prestressing force in all lateral planes. The reinforcement to resist these forces is normally provided as closed hoops or spirals. Because the tensile forces act in all lateral planes the reinforcement will be stressed throughout its length, and it is essential that any hoops or links are detailed with full tensile laps (e.g. BS 4466, shape code 74, but with large radius bends to avoid crushing the concrete).

To restrain the bursting forces effectively the reinforcement should be positioned as near as possible to the outer edge of the largest prism whose cross-section is similar to and concentric with that of the anchor plate having regard to the direction in which the load is spreading, and at least 50mm outside the edge of the anchor plate (see Fig. 45).

Reinforcement links for adjacent anchorages should be overlapped and longitudinal bars positioned in the corners. Where spirals are provided with some proprietary anchorages as part of the anchorage system, additional reinforcement may be required to resist the bursting forces.

(c) Tensile stresses occurring on the faces of end blocks adjacent to the anchorages

To resist these stresses and prevent concrete spalling, reinforcement should be placed in two directions at right-angles as close to the end face as cover considerations permit.

End blocks distribute high forces requiring large quantities of reinforcement in relatively small spaces. This has two consequences:

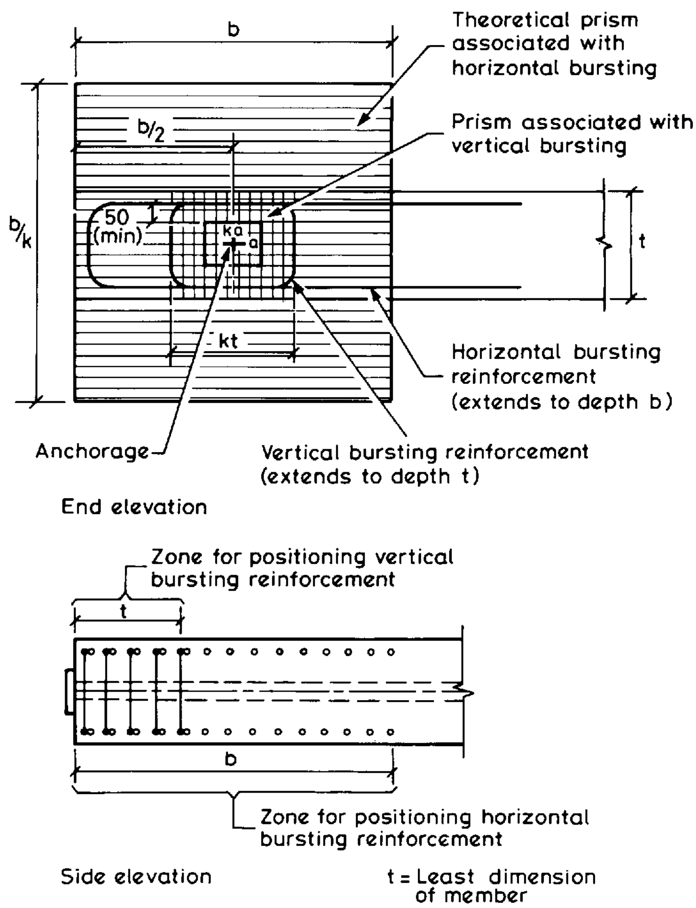


Fig. 45 Location of bursting reinforcement

(i) The forces in the reinforcement build up quickly over relatively short lengths, and great care should be taken to ensure that the bars are anchored effectively. At all corners, the bars should have large radius bends to avoid crushing the concrete or should pass round a longitudinal bar or tendon of at least the same diameter.

(ii) As well as the tensile forces described above there are significant compressive forces in end blocks, particularly immediately behind the anchorages, which must be resisted by the concrete. The reinforcement should be detailed to allow the concrete to be properly placed and compacted.

7.4.2 Secondary reinforcement

While prestress is normally introduced into a member to enable it to resist bending moments and axial loads, it may also contribute to the shear and torsion capacity. However, secondary reinforcement may be required to enhance shear and torsion resistance, for crack control and for fire resistance.

Shear reinforcement in post-tensioned beams should consist of open links or pairs of lapping U-bars so that the tendons can be easily positioned (see Fig. 46).

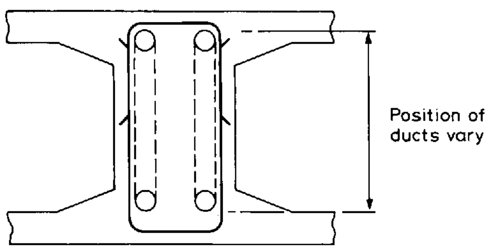


Fig. 46 Shear reinforcement

The detailer should be aware that Codes of Practice may require that:

- minimum areas of reinforcement be provided to control cracking in end blocks or shear requirements for
- reinforcement be provided longitudinally to resist tensile forces caused by restraints to early thermal movement (e.g. by the falsework) before the member is stressed.

7.4.3 Additional reinforcement around holes

When holes occur in prestressed concrete members, the compressive stresses in the direction parallel to the line of action of the prestress may be significantly increased (see Fig. 47). Tensile stresses of the same order as the longitudinal stresses are also induced normal to the line of action of the prestress. Reinforcement may be required to resist the tensile forces and the enhanced compressive stresses. The reinforcement should be fully anchored into the surrounding concrete.

Local reductions in cross-sectional area also occur at coupler positions and at ducts for transverse, vertical or diagonal tendons. These reductions may lead to substantially increased stresses that require additional reinforcement.

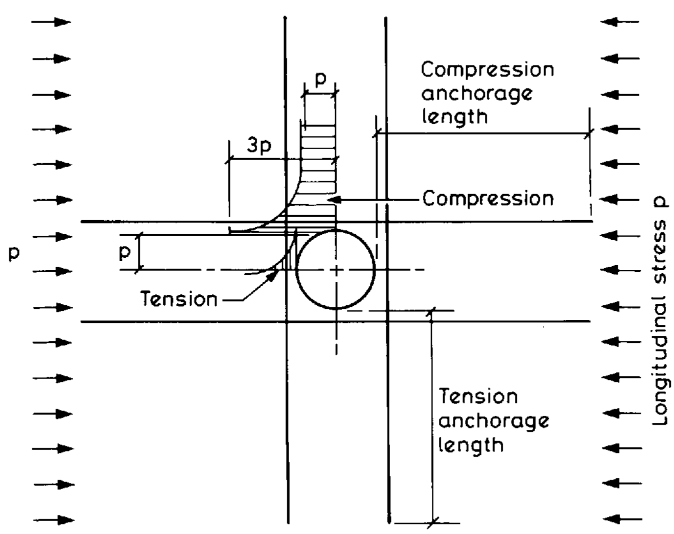


Fig. 47 Stress distribution and additional reinforcement around circular hole

7.4.4. Reinforcement to resist the normal component of the prestress

Angular deviation of the tendon line causes forces normal to the tendon. Although these lateral forces are in equilibrium when the member is considered as a whole, local shear forces and moments are induced, and these should be resisted by reinforcement,

As an example consider an anchorage blister on the flange of a box girder (see Fig. 48). The radial component of the prestress force (PR) is applied to the concrete along the curved length of the tendon and is balanced by the forces at the end of the tendon (PV1, PH1 and PH2). Reinforcement should be provided to resist the forces and moments induced.

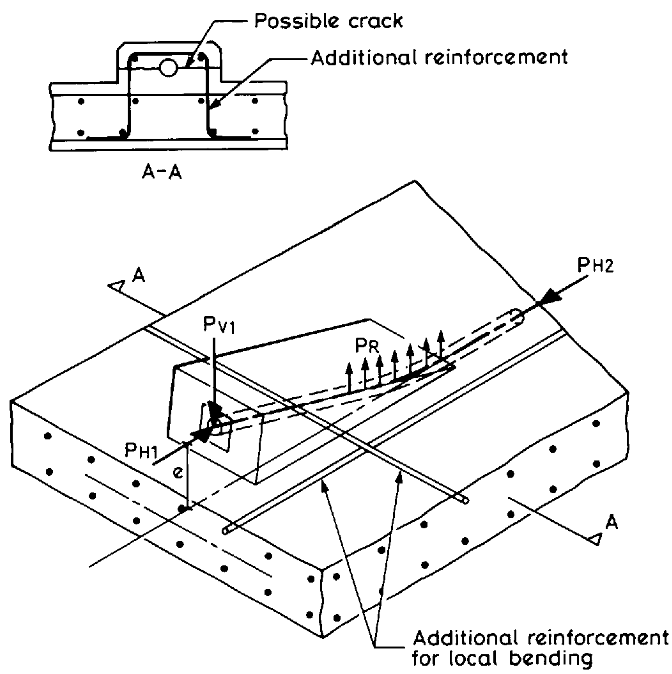


Fig. 48 Forces acting at anchorage blisters

Where the radial prestress component PR is applied near the face of the concrete it may cause spalling. Reinforcement links should be provided to transfer this force into the concrete flange. They should be distributed along the curved part of the tendon. Additional links should be provided beyond the tangent points to allow for any misalignment of the tendon.

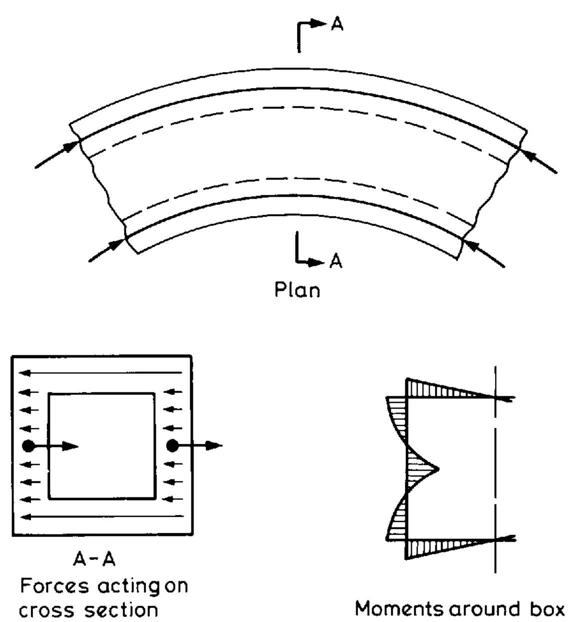


Fig. 49 Forces in box girder curved in plan

When tendons are located in the webs of beams that are curved in plan (see Fig. 49), the lateral force from the tendon is balanced by the combined lateral forces from the compressions in the web and flanges. The distribution of forces induces bending in the web that should be resisted by reinforcement.

The radial component of the prestress force increases with decreasing radius of curvature. In looped anchorages the radial force is large, and local reinforcement similar to that in end blocks is required (see Fig. 50).

7.4.5 Reinforcement against grouting pressure

It is usually specified that tendon ducts should be grouted to a pressure of 0.7N/mm^2 (7 bars). In some circumstances, higher pressure may be used in order to force grout through the duct. Sheathing, anchorages and couplers are not designed to resist grouting pressure, which is consequently transmitted to the concrete where it can induce tensile stresses.

Fig. 51 shows areas where tensile stresses are induced when the ducts are grouted. It may be necessary to provide reinforcement links around the ducts.

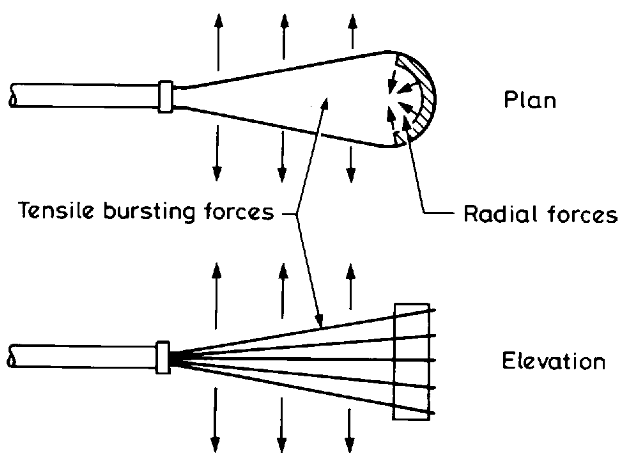


Fig. 50 Forces at looped anchorages

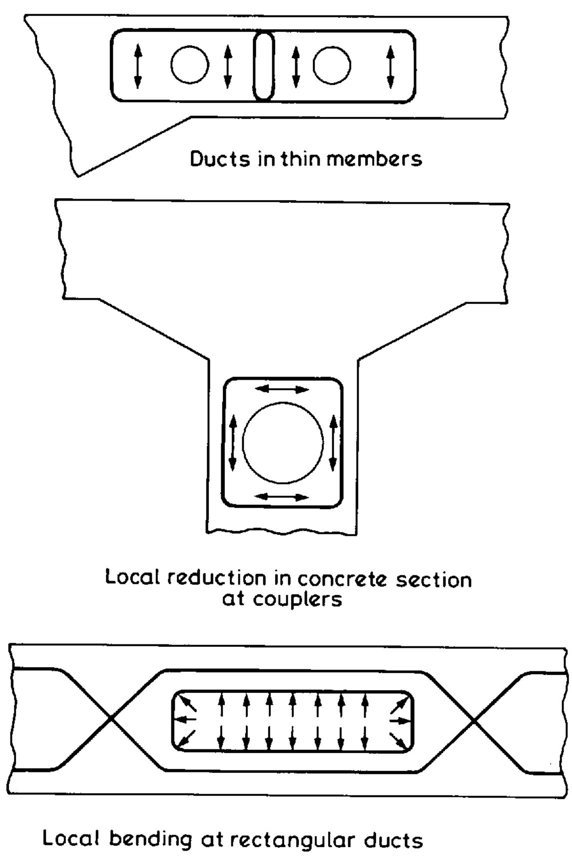


Fig. 51 Tensile forces due to grouting pressure

7.4.6 Intermediate anchorages

Fig. 52 shows an anchorage within the body of a concrete member. Under the localized action of the prestress force, an imaginary line AA will tend to deform to A'A' creating tensile forces parallel to the tendon. These tensile forces may occur even when there is an overall compression in the member from, for example, other prestressing tendons.

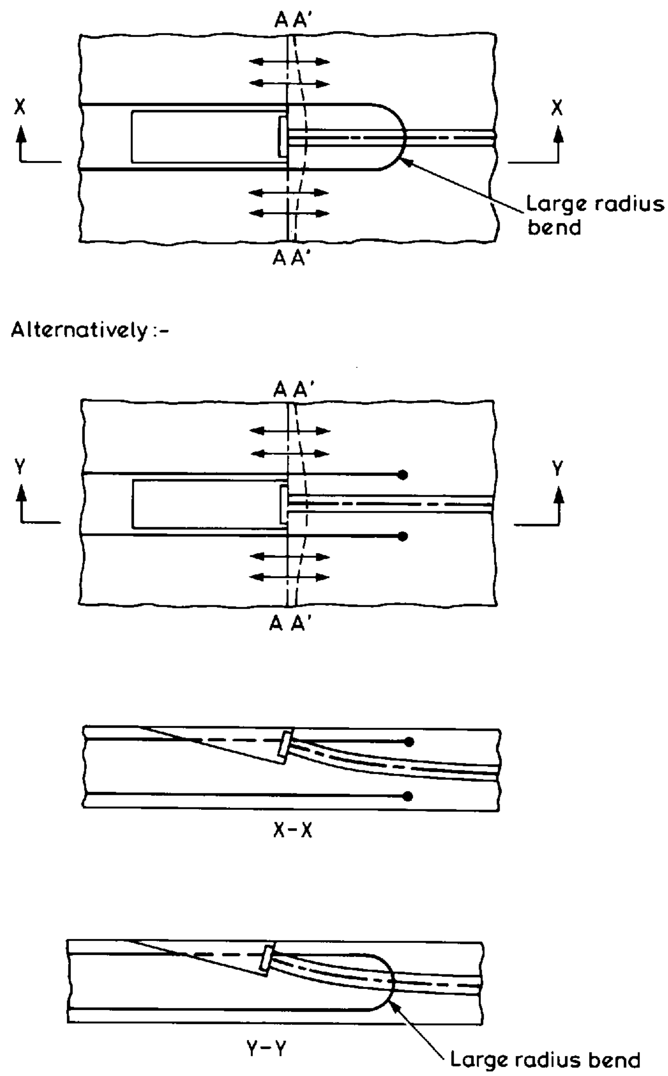


Fig. 52 Tensile forces and additional reinforcement at intermediate anchorages

Reinforcement fully anchored into the surrounding concrete should be provided each side of the anchorage parallel to the prestressing tendon.

Local tensile forces can also occur at anchorage couplings (see Fig. 53). When the coupled tendon is stressed the force between the previously stressed concrete and the anchorage decreases, and the local deformation of this concrete is reduced. Increased compressive forces are induced adjacent to the anchorage and balancing tensile forces between adjacent anchorages. Cracking in the tensile zones should be controlled by distributing tendons around the cross-section, by providing fully anchored reinforcement to resist the tensile forces or by providing some uncoupled tendons across the joint (reference 10.3.1.4).

7.4.7 Pretensioned members

In pretensioned members the axial prestress force is transferred from the tendons to the concrete over a finite length. When the tendons are released from the casting bed the stress within the transmission length is reduced leading to an increase in the diameter of the tendon because of the Poisson effect.

This transmits a radial compressive force into the concrete that is balanced by circumferential tensile forces. Adequately anchored reinforcement should be provided over the whole transmission length to resist these forces. If the tendons are distributed both vertically and laterally in conformity with the linear prestress distribution remote from the transmission zone effects, then the transmission zone will be in internal equilibrium without the need for any additional reinforcement. If the tendons are concentrated in groups the overall internal equilibrium of the transmission zone should be considered and reinforcement provided (see Fig. 54).

It is recommended that the end zone of a beam is designed and detailed as a reinforced concrete member with longitudinal and shear reinforcement as necessary (see reference 10.3.3.13).

It is normal practice to provide sets of standard stirrups at a closer spacing (e.g. 75 mm) in transmission zones that not only occur at the end of members but also where tendons are debonded. This reinforcement is usually sufficient to resist the Poisson effect and equilibrium forces, as well as providing adequate shear capacity (see Fig. 55).

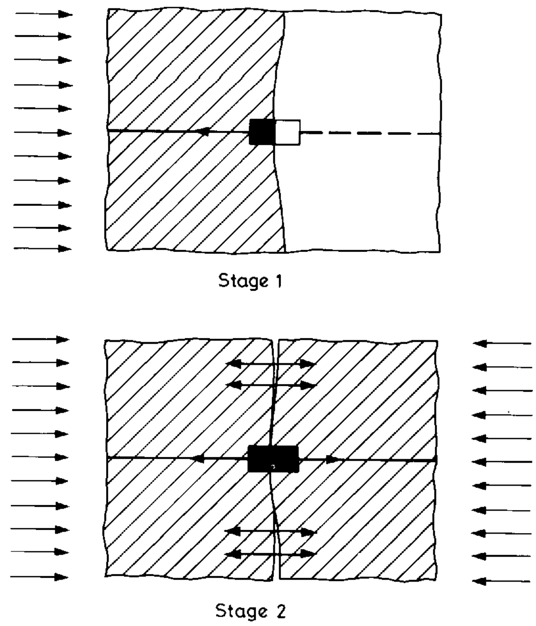


Fig. 53 Tensile forces at anchorage coupling

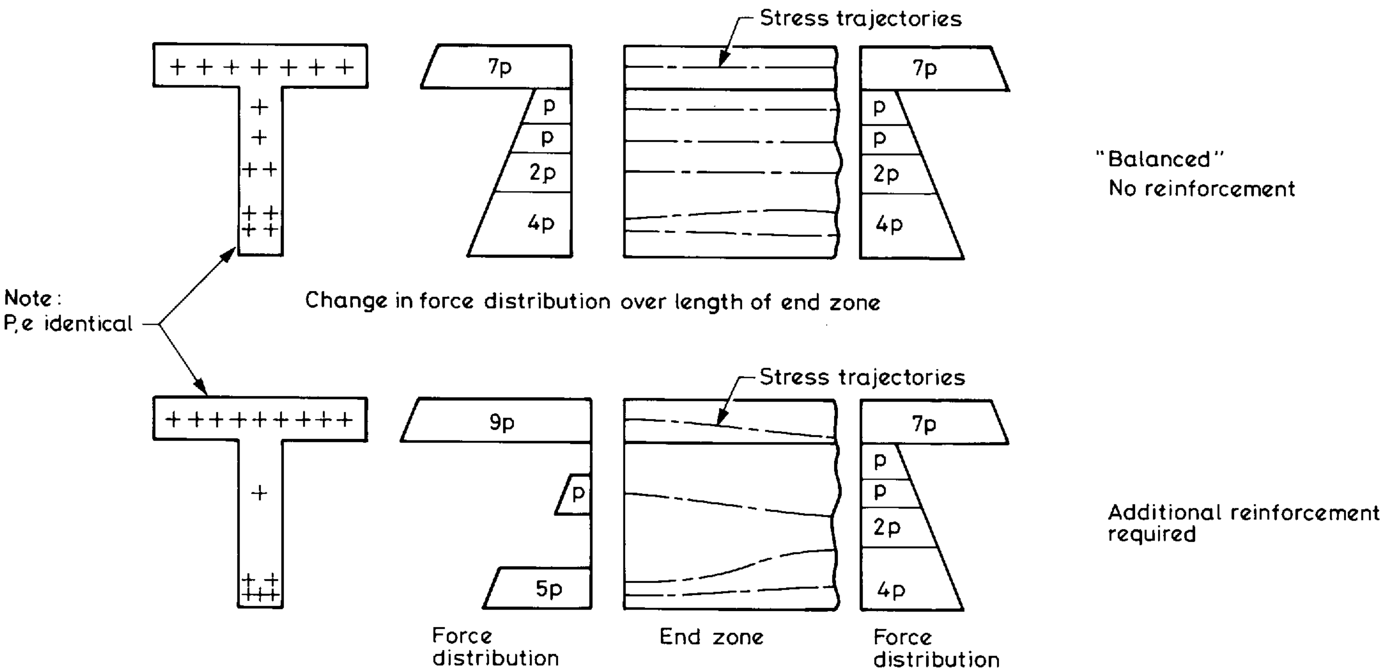


Fig. 54 End zones in pretensioned members

7.4.8 Construction joints

Detailing reinforcement should allow for possible locations of vertical and horizontal construction joints, which should avoid cast-in components such as anchorages and couplers. Where construction joints intersect the planes of tendon ducts, they should be positioned to avoid areas with restricted access for vibration equipment and scabbling tools.

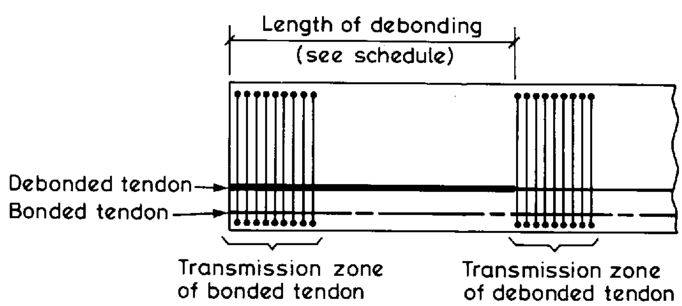


Fig. 55 Transmission zones in pretensioned members

7.5 Other effects of prestressing

Information of the aspects below should be provided on the drawings.

7.5.1 Movements of the permanent structure

During application of the prestressing forces to the permanent structure, horizontal movements arising from elastic shortening of the concrete members and vertical movements due to the induced prestress will take place. The movements will be transmitted to supporting falsework, which in turn will tend to move in sympathy. Clear indications of the expected movements and the method of articulation should be given to avoid overstressing both permanent and temporary structures. In particular, temporary restraints to movements should be identified, e.g. anchored sliding bearings.

Where prestressed concrete structures are formed on long-span falsework that has greater flexibility than that of the permanent structure, consideration should be given to the effect of any residual deflection of the falsework imposing additional upward forces on the permanent structure on completion of the stressing operations (see Fig. 56).

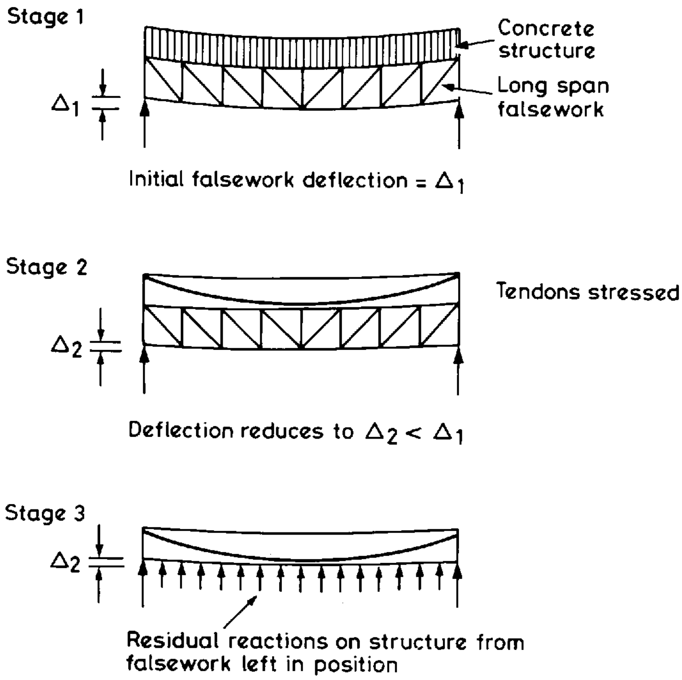


Fig. 56 Effect of leaving falsework in position – case A

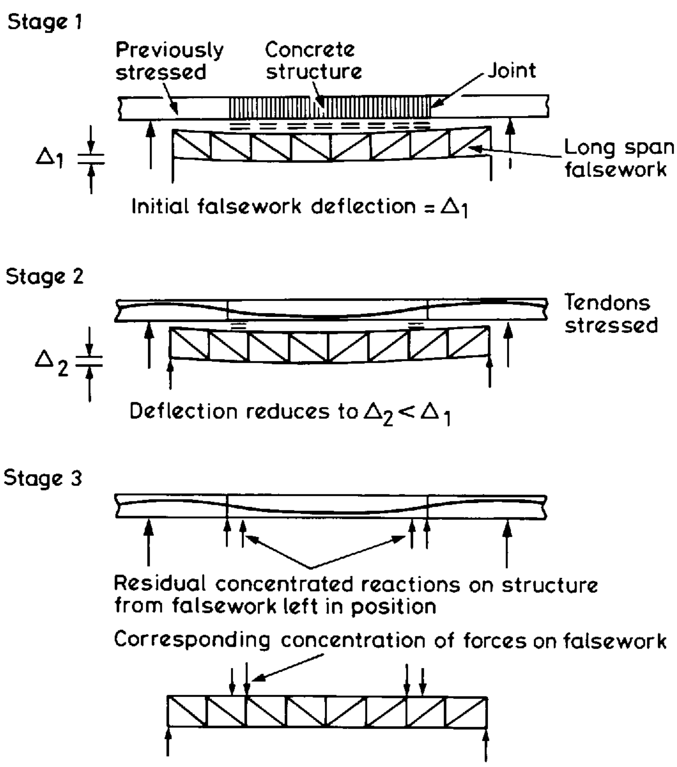


Fig. 57 Effect of leaving falsework in position – case B

To ensure that these temporary upward forces do not overload the permanent structure it may be necessary to release falsework in phase with the application of the prestress. Any tendency during stressing for the permanent works to impose additional vertical downward forces on falsework should be clearly stated on the drawings (see Fig. 57).

7.5.2 Variations in camber

In defining the dimensional tolerances of prestressed concrete members, variations in the modulus of elasticity and elastic shortening of the concrete should be considered. The effects of variations in camber are of great signifiance at the detailing stage. As an example, variations in camber will occur between the adjacent units of a floor, which in turn will influence the average thickness of subsequent floor screeds.

7.6 Typical details

Figs. 58 to 66 illustrate typical details in prestressed concrete members and incorporate the recommendations made in this manual.

Transverse reinforcement in post-tensioned box girder
Fig. 58 shows the variation in reinforcement along a beam to accommodate the changes in level of the tendons.

Post-tensioned end block, reinforcement
Figs. 59 to 62 illustrate reinforcement in an end block. Each figure highlights reinforcement that is provided for a specific function as described in this manual.

Anchorage details for prestressed silo wall
Fig. 63 illustrates typical anchorage reinforcement, which extends over the full height of the silo. The tendon should extend from the tangent point to the anchorage in a straight line, the buttress being dimensioned such that the minimum concrete cover is maintained to the tendons at the junction of the silo wall with the buttress and that adequate jack clearance is provided.

Flat-slab prestressing with unbonded strand
Figs. 64, 65 and 66 show the typical three-drawing method of detailing by which the tendon layout, the tendon support bars and the additional bonded reinforcement are shown separately. A typical example of the legend by which groups of tendons and anchorage types and the tendon placing sequence are indicated is shown in Fig. 64, while Fig. 65 shows a typical support bar layout. The actual layout may be modified by the contractor depending on the support system adopted so that the specified tendon profiles are attained and adequate support provided. Fig. 66 shows the reinforcement that is always required in the top of the slab at columns, the end-block reinforcement and the reinforcement needed in the bottom of the slab at mid-span in some design applications (see references 10.4.4, 10.4.5 and 10.4.6).

In addition to the flat plate shown, other types of flat-slab are used — with drops, coffered or ribbed. The principles of detailing are however applicable to all.

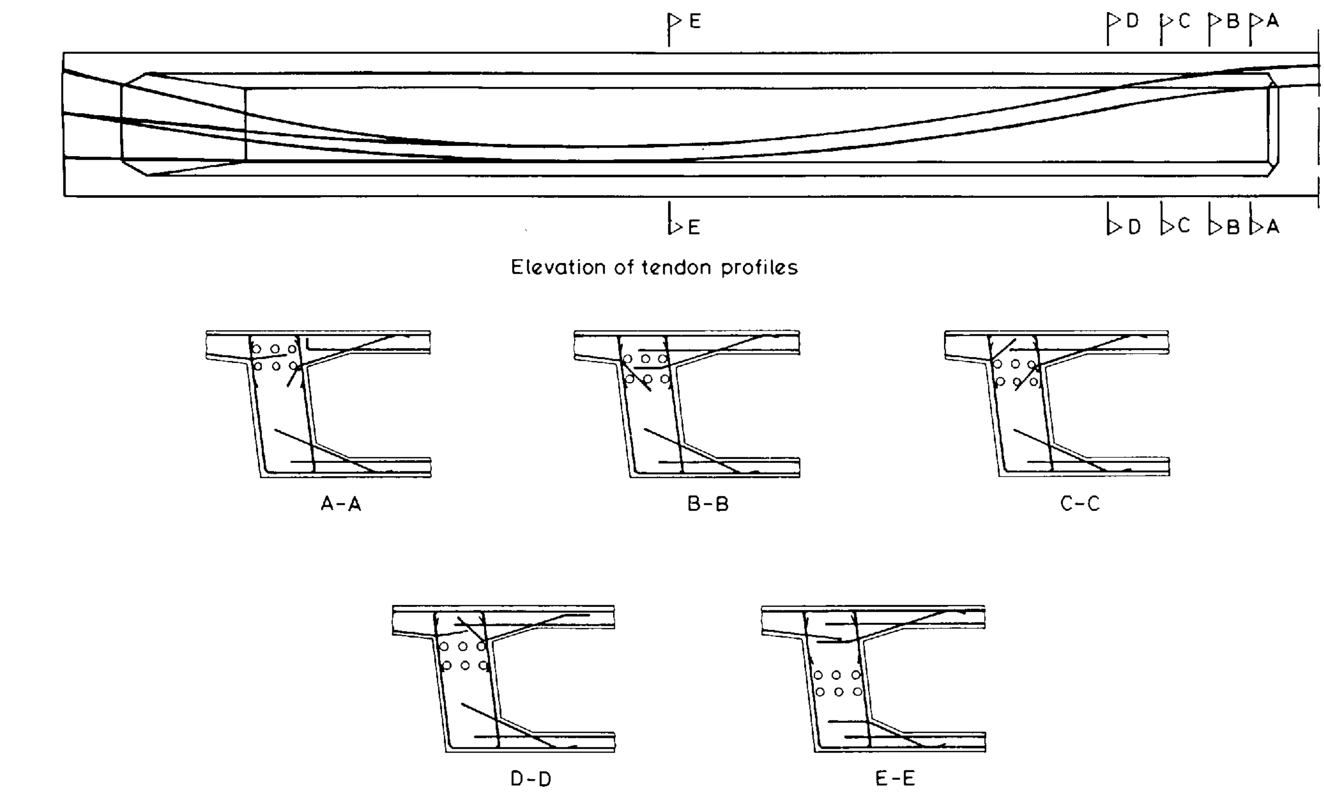


Fig. 58 Transverse reinforcement in post-tensioned box girder

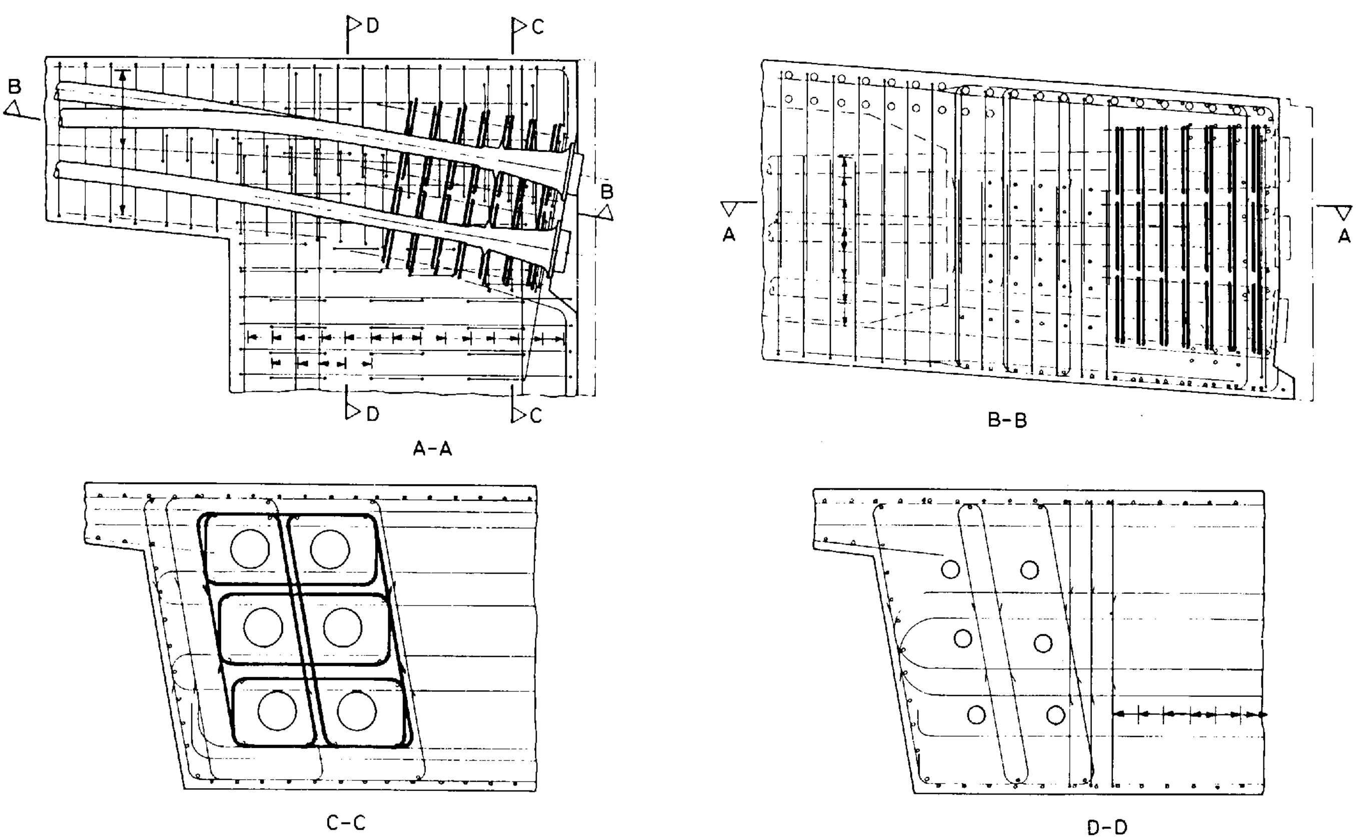


Fig. 59 Post-tensioned end block – bursting reinforcement

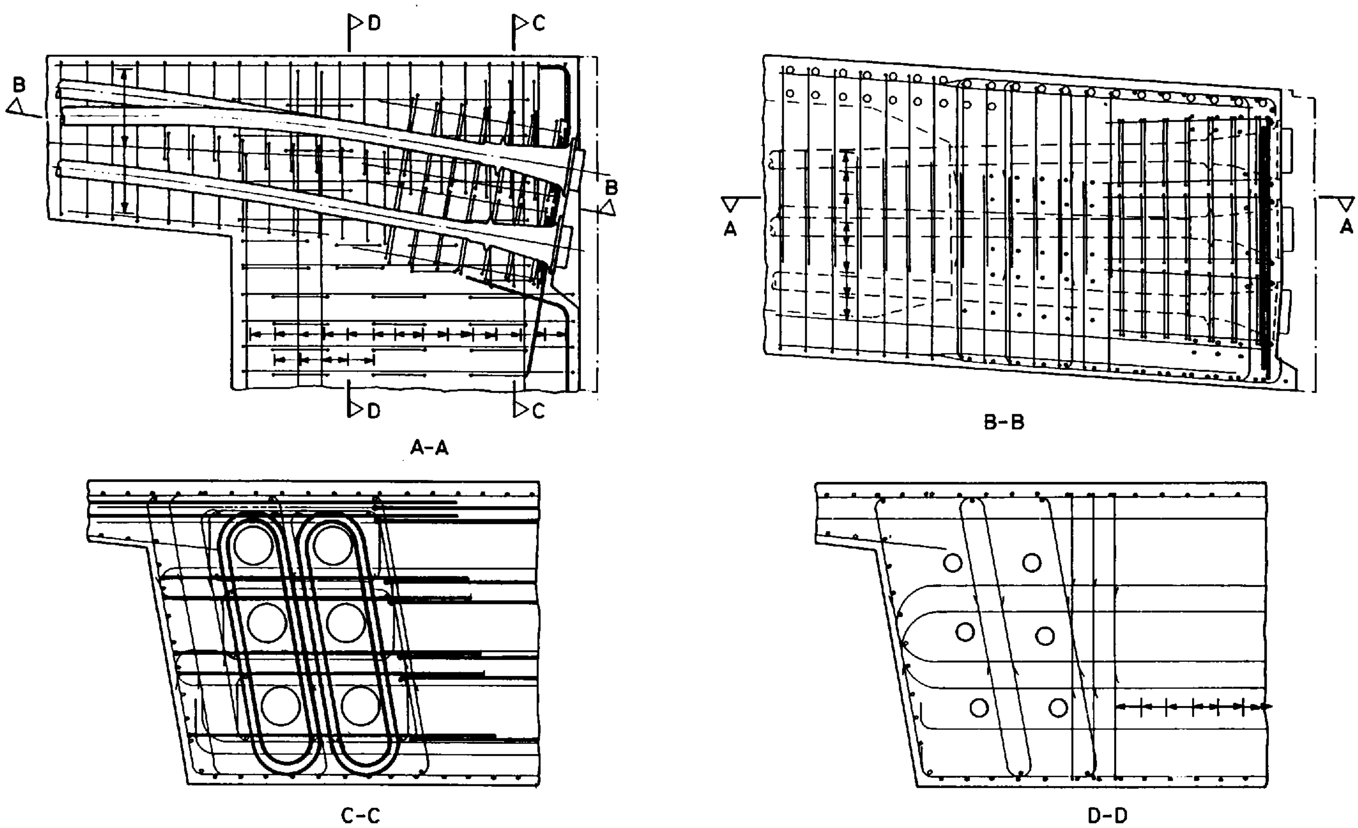


Fig. 60 Post-tensioned end block – spalling reinforcement

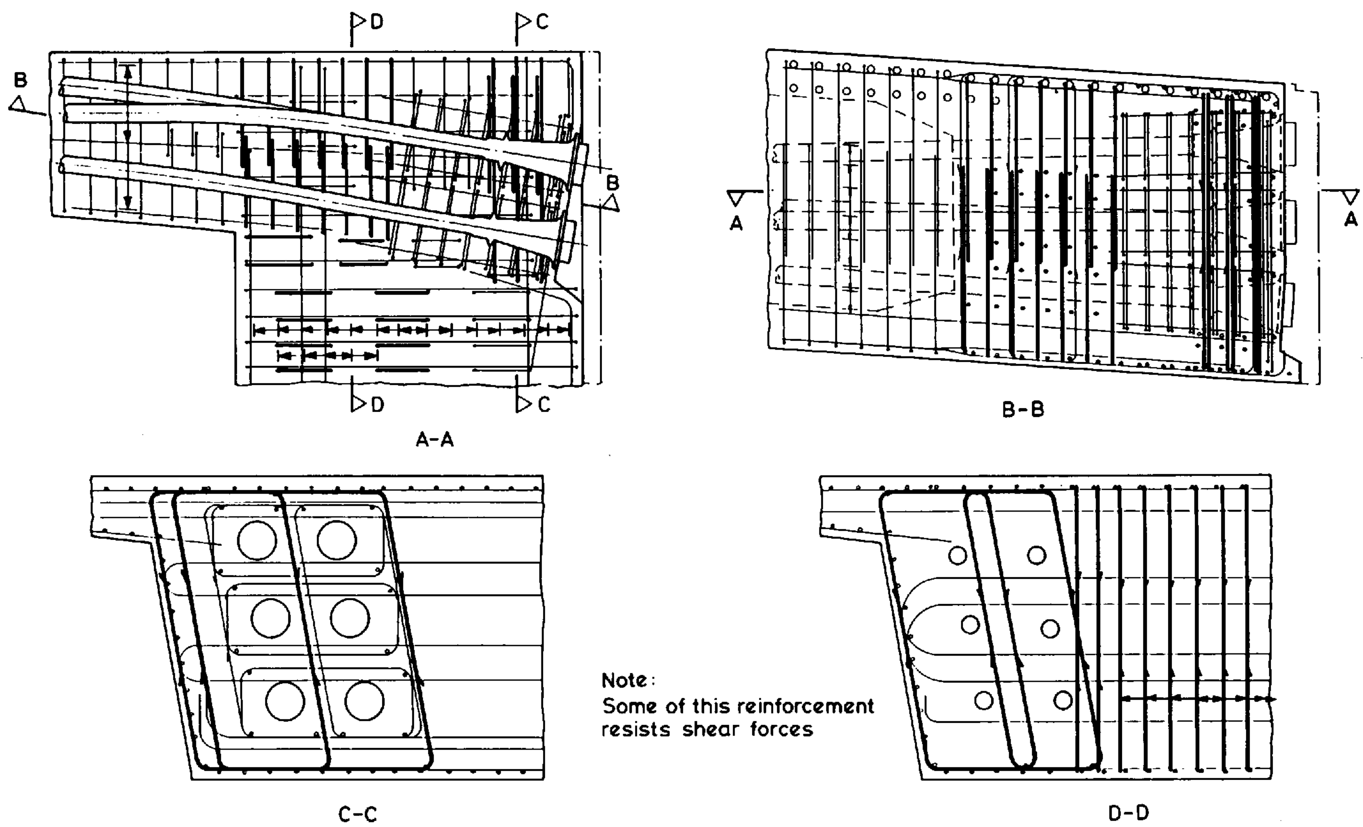


Fig. 61 Post-tensioned end block – vertical equilibrium reinforcement

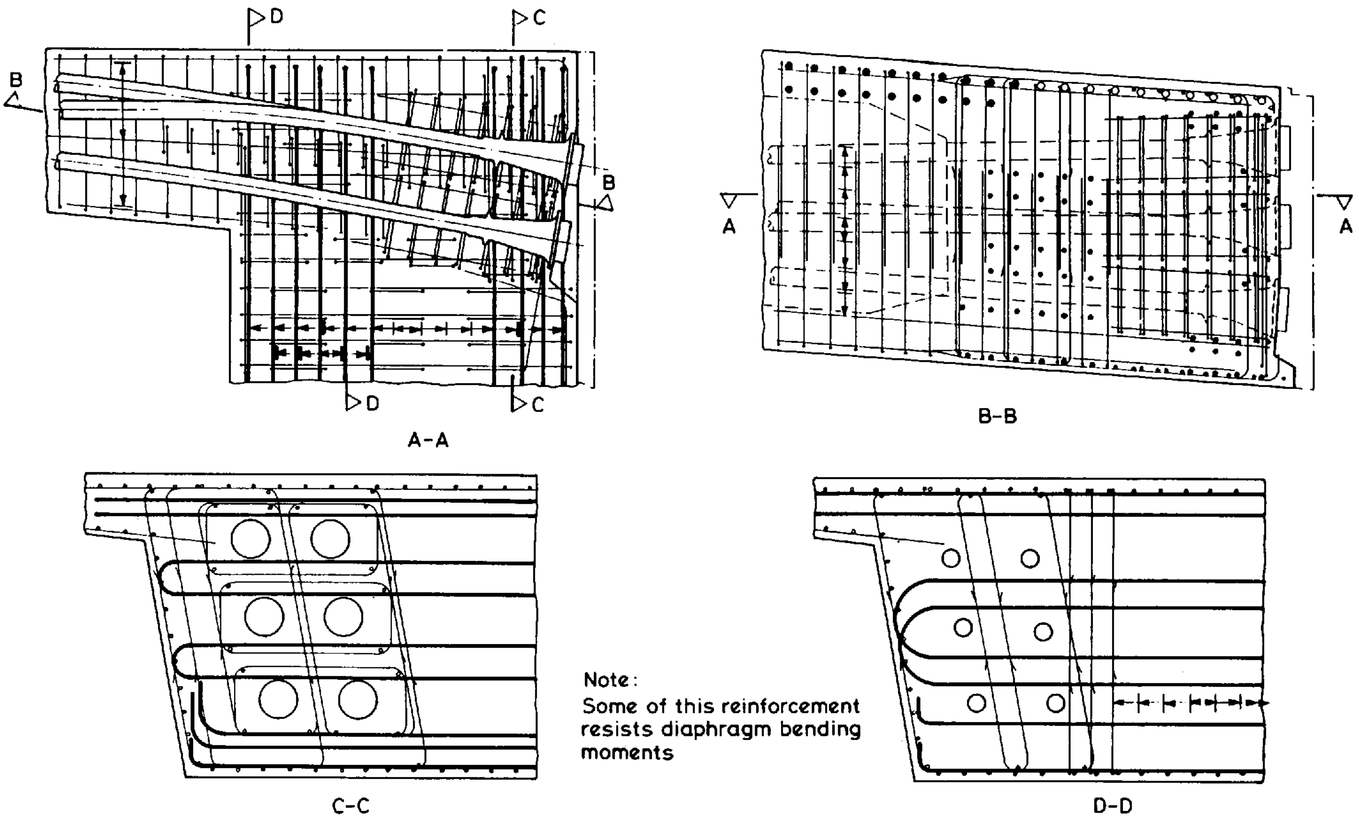


Fig. 62 Post-tensioned end block – horizontal equilibrium reinforcement

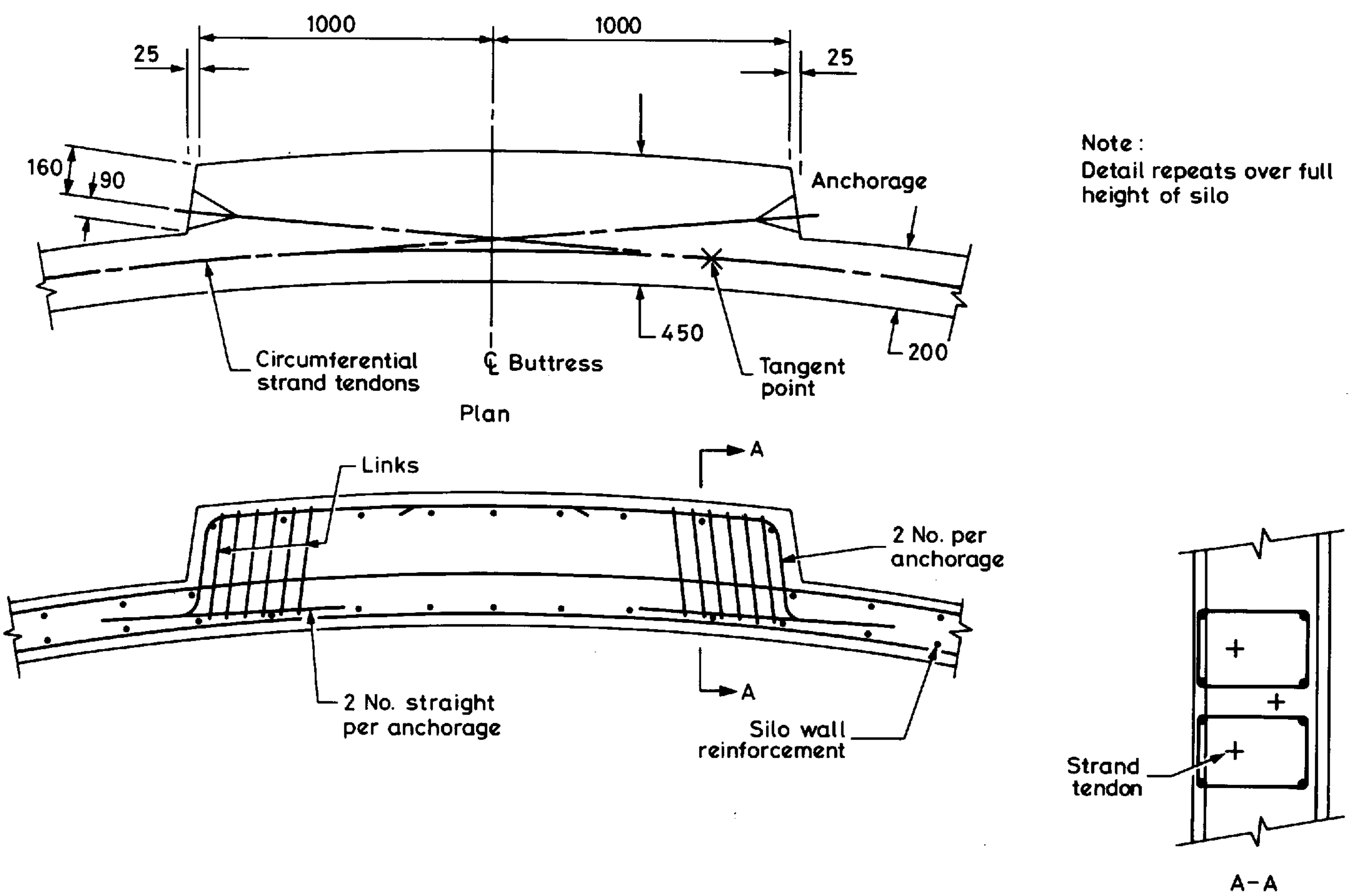
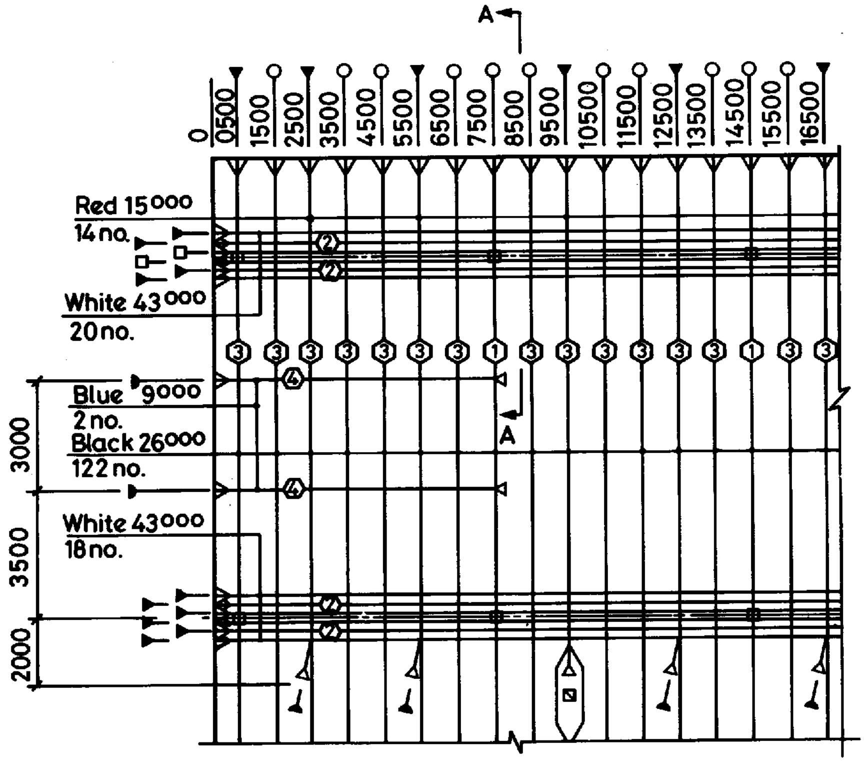
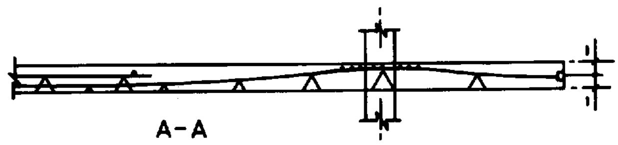


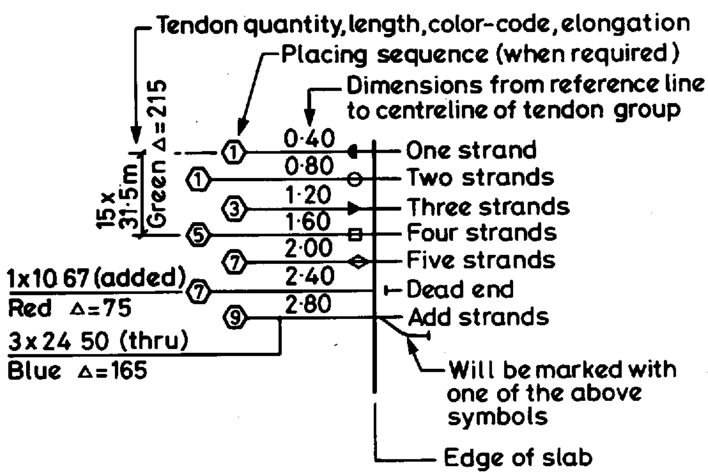
Fig. 63 Anchorage detail for prestressed silo wall



Tendon layout

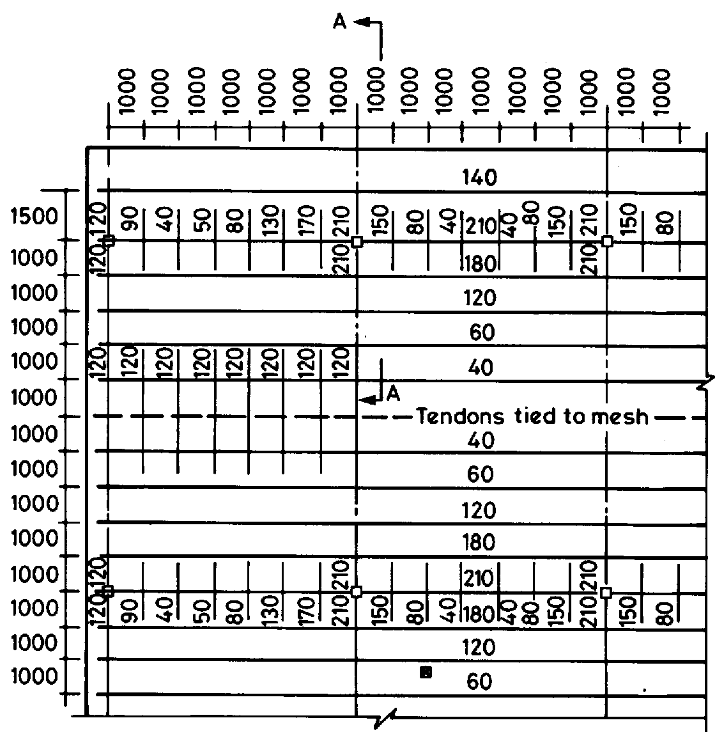


A–A



Note:
When more than one symbol appears on a tendon group, the number of strands equal the sum of the symbol designations.

Fig. 64 Flat slab – tendon layout



Note:
1. Height given is from soffit of slab to underside of tendon
2. Diameter of support bar is 10mm

Fig. 65 Flat slab – tendon profile and typical support bar layout

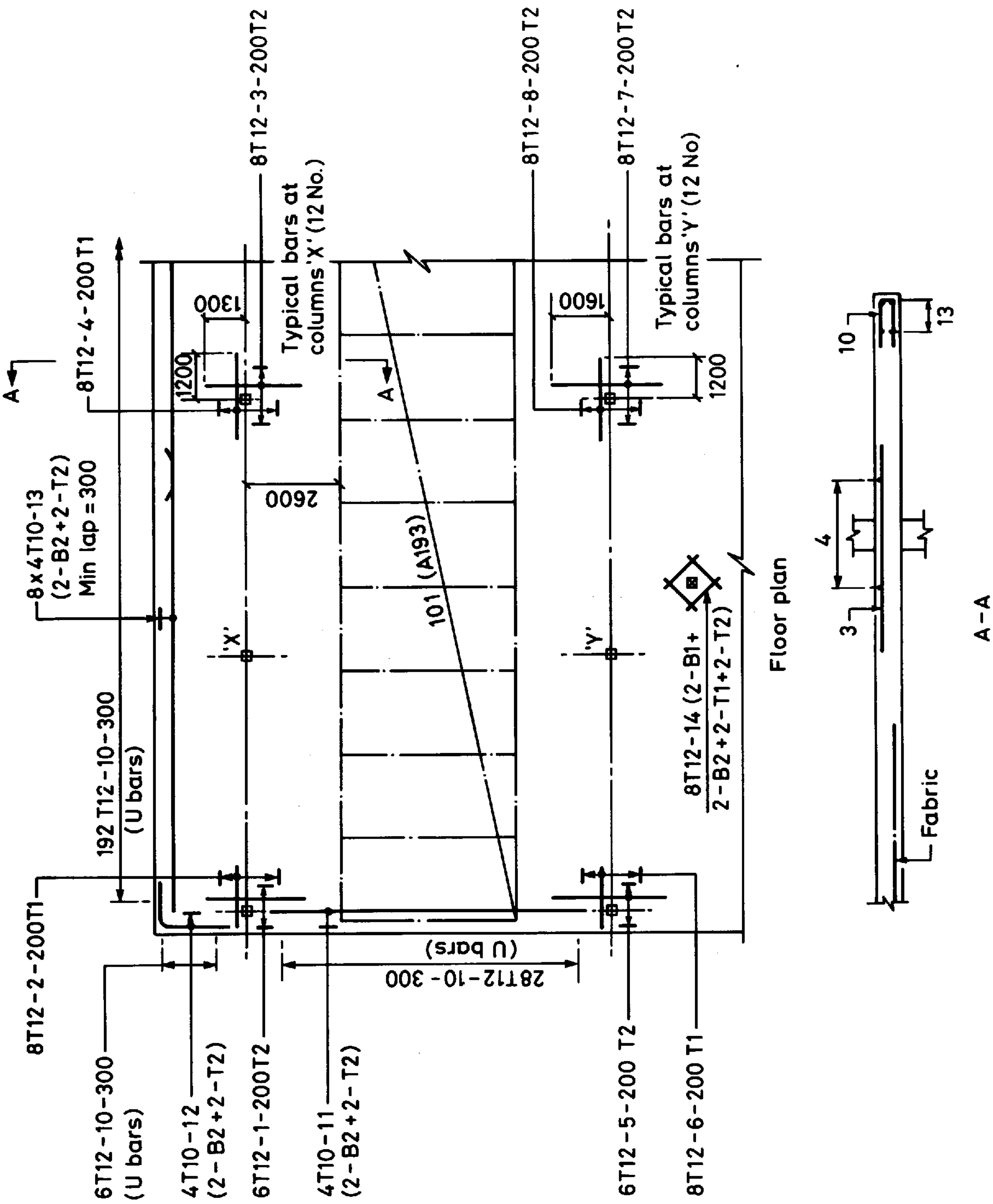


Fig. 66 Flat slab – reinforcement layout

8 Precast concrete

Detailing of precast concrete work requires special disciplines that do not occur with *in situ* concrete. The reason for these are:

The precast unit is, by definition, transported after it is made before it can be incorporated in the works.

The unit is often incorporated into a ready built or part built structure. In these cases, consideration of tolerances is important.

The unit is often made by a third party who may not have visited the site and will not have all the drawings. Clarity of instruction to the precaster and preliminary discussions are therefore vital.

Precast concrete structures usually require special consideration of joints. Sound detailing of these areas leads to attractive, serviceable and safe structures.

Precast units are often cast in a different orientation from that of their final use. The decision of how to cast is often best left with the precaster or should at least be discussed and agreed with him. At the detailing stage the designer should make his intention clear on surface finish and on tolerance. Areas where tolerances different from the specification are required for particular reasons should be clearly noted. Remember that unnecessarily rigid specifications may not be economic in the long run.

It is particularly difficult to form re-entrant or protruding corners without having breakage or an unsightly finish. Acute re-entrant corners are to be avoided as it is difficult to remove the formwork without damage. Acute protruding corners are often broken in handling and are often discoloured because the large aggregate cannot get into the corner. Fig. 67 shows how a notched skew-ended beam should be detailed to overcome these problems. Also shown is a recommendation on the dimensioning of skew-ended beams.

The need to transport a precast concrete element requires that consideration should be given not only to its physical size and weight so that transportation is possible but also to the specification of permissible lifting positions and angles of lifting.

These basic rules are not exhaustive but give a guide for the detailer in proportioning elements:

length	<	27.4m no restriction if also < 32 tonne gross and < 3m wide
	>	27.4m special dispensation required from Department of Transport
height	<	4.0m total load no restriction
	>	4.0m special routing necessary
width		2.9m no restriction
		2.9 up to 4.3m possible with notification to police
		4.3 up to 6.1m special dispensation required from the Department of Transport
weight	<	20 tonne no restriction on normal 32 tonne truck
	<	38 tonne no restriction on special 38 tonne truck
		20 < weight < 60 tonne on low loader or steerable bogie
		60 < weight < 160 tonne police escort required, possible special routing, use of air-cushioned vehicle or hydraulic bogies possible.

The most frequently used loads are with a 20 tonne payload on a 32 tonne gross truck. In these cases, with multiple numbers of units on a load, significant savings can be made if weight of whole number of units approaches but does not exceed 30 tonne, i.e. 2 no. 9.8 tonne per load as against 1 no. 10.2 tonne units.

Permissible support points and packing materials should also be noted.

Lifting strengths for the concrete should be stated on the drawing, remembering that the maximum mould use on a repetitive job will bring all its economies only if the very minimum lifting strength is specified.

The weight of the unit for craneage and for the estimation of transportation should be clearly stated on the drawing.

According to BS 4449, ordinary reinforcement is not suitable for use as lifting hooks. Some precast manufacturers do use reinforcement for lifting purposes, but it is presumed that they do so with proper care and attention to details and lifting practices and on the basis of practical tests and the risks involved.

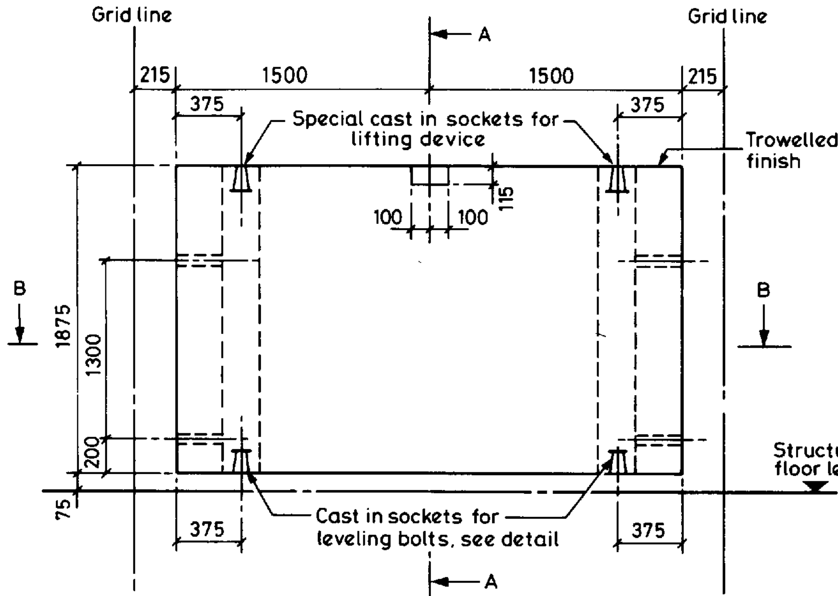
A range of proprietary inserts are marketed, both for fixing and lifting. It is important that these are used to the manufacturer's instructions with adequate factors of safety. It is also important that secondary load effects or structural movements do not put forces on inserts for which they have not been tested or designed. In these cases, means should be sought to isolate the fixings so that only the correct forces may be applied.

Where a drawing not only shows a part of a unit that is cast on to another precast unit, the drawings of each should clearly state where the weights are noted that the weights are only for part units.

Units of complex shapes should be discussed with a precaster before their details are finalized. Units with a requirement for a high quality of finish may be required to be cast in one piece moulds. In these cases, a drawing for demoulding is necessary, and the unit and its surrounding structure should be detailed accordingly.

The design of joints and the requirements for the detailing of reinforcement and concrete (binding links, chamfers, etc.) are covered in the Institution of Structural Engineer's report *Structural joints in precast concrete*, 1978 (reference 10.3.3.12).

For precasting, the detailer needs to be fully aware of the method of moulding and the assembly and handling of the reinforcement cage, but such expert knowledge is normally available only in the office of the specialist precaster.



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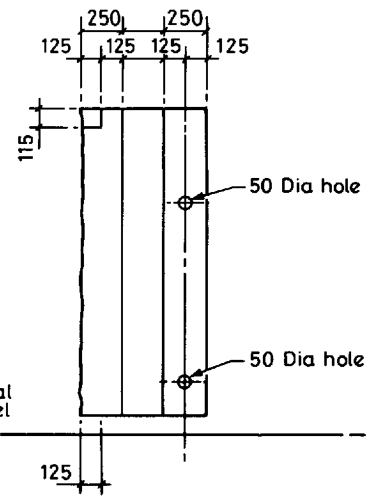

Section A-A
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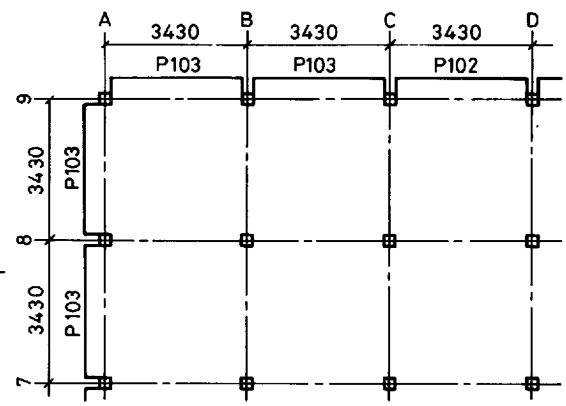
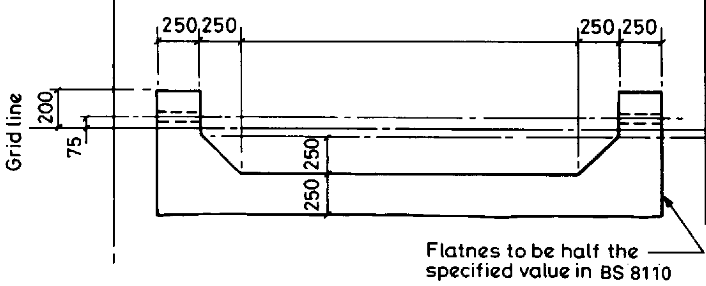
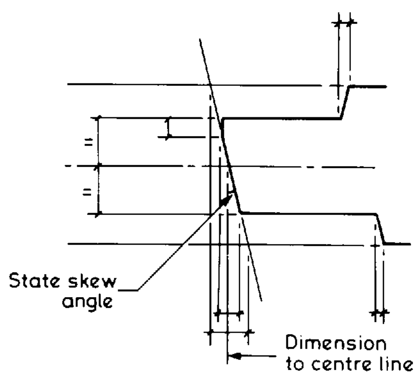




Section B-B 1:25

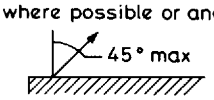
Typical location plan showing layout of units 1:100



Plan of skew ended

Notes:-
Unless otherwise specified all concrete units to be manufactured in accordance with BS 8110

1. Cube strengths: 15 N/mm^2 before demoulding
   40 N/mm^2 at 28 days
2. Cover: 25mm nominal
3. Finishes: Type C except as noted on drawing
4. Cement type: R.H.P.C.
5. Aggregate type: 20mm max
6. Weight of unit: 3·44 tonnes
7. Units to be lifted using special cast-in sockets in top. Lift to be vertical where possible or angle of lift from vertical not to exceed 45°



8. Tolerances: To BS 8110 except as noted on drawing

Fig. 67

9 Water-retaining structures

9.1 General

Water-retaining structures will in general be detailed in accordance with the recommendations for normal reinforced concrete structures except that the provision of reinforcement, spacing of reinforcement, cover and durability requirements are generally more onerous. BS 8007 deals with the design of reinforced concrete service reservoirs and tanks used for the storage of water and other aqueous liquids. In normal structures the most critical aspect of design is generally the ultimate limit state (strength), whereas for structures designed to retain liquids not only is strength to be considered but it is essential to restrict the width of cracks in the concrete. The provision and spacing of reinforcement to satisfy the limit state of cracking may therefore control the design and in many cases exceed that required for strength.

Water-retaining structures designed to BS 8007 require reinforcement to resist tensile forces caused by:

(*a*) structural actions due to applied loads and
(*b*) restraint to thermal contraction and drying shrinkage

The reinforcement to be provided in all slabs and walls in a particular direction is the larger of the amounts required separately for (*a*) and (*b*).

Unlike normal structures where the construction joints are not normally shown on the detailed drawings but are described in the specification, the positions of all construction joints and movement joints must be shown on the drawings (see Fig. 68).

It is the responsibility of the designer and not the contractor to position all joints as the amount of reinforcement to resist the tensile forces arising from thermal contraction and drying shrinkage is dependent on the frequency and spacing of all types of joints.

9.2 Cover

Durability is considered to depend on the concrete grade, cement content, crack width and cover. For reinforced concrete the maximum design surface crack widths for direct tension and flexure or restrained temperature and moisture effects are:

(1) severe or very severe exposure: 0.2 mm
(2) critical aesthetic appearance: 0.1 mm

The nominal cover to any reinforcement given in BS 8007 should not be less than 40 mm. This is satisfactory for severe exposure. For very severe exposure the cover and mix should empty with BS 8110; Part 1. A greater cover may be necessary at a face in contact with aggressive soils or subject to erosion or abrasion.

9.3 Spacing of reinforcement

For tensile reinforcement the bar spacing should not exceed 300 mm.

9.4 Bar anchorage lengths

Table 27 gives anchorage lengths in terms of bar size, according to the allowable steel stress in service conditions for horizontal bars in members in direct tension (e.g. hoop tension).

Table 27 Tension anchorage lengths for structural requirements (*a*)

	member in direct tension				
concrete grade	bar type	plain		deformed (type 2)	
	design crack width	0.1 mm	0.2 mm	0.1 mm	0.2 mm
	allowable stress, f_s, N/mm^2	85	115	100	130
35/40	anchorage length, mm	30ф	40ф	20ф	26ф
45	ancorage length, mm	26ф	35ф	18ф	23ф

Notes:
1. If A_{sprov} exceeds A_{sreq} multiply by $\frac{A_{sreq}}{A_{sprov}}$
2. If in flexure, multiply anchorage length by 0.7

Table 28 gives anchorage lengths in terms of bar size for members in flexure in which the steel area provided is no more than the steel area required for the ultimate limit state.

Table 28 Tension anchorage lengths for structural requirements (*a*)

member in flexure – ultimate limit state

concrete grade	bar type steel strength, f_y N/mm^2	plain 250	deformed (type 2) 460
35/40	anchorage length, mm	33ф	34ф
45	anchorage length, mm	29ф	30ф

Note:
If A_{sprov} exceeds A_{sreq} multiply by $\frac{A_{sreq}}{A_{sprov}}$

Table 29 gives anchorage lengths in terms of bar size for slabs and walls in which the steel ratio provided is no more than the critical steel ratio.

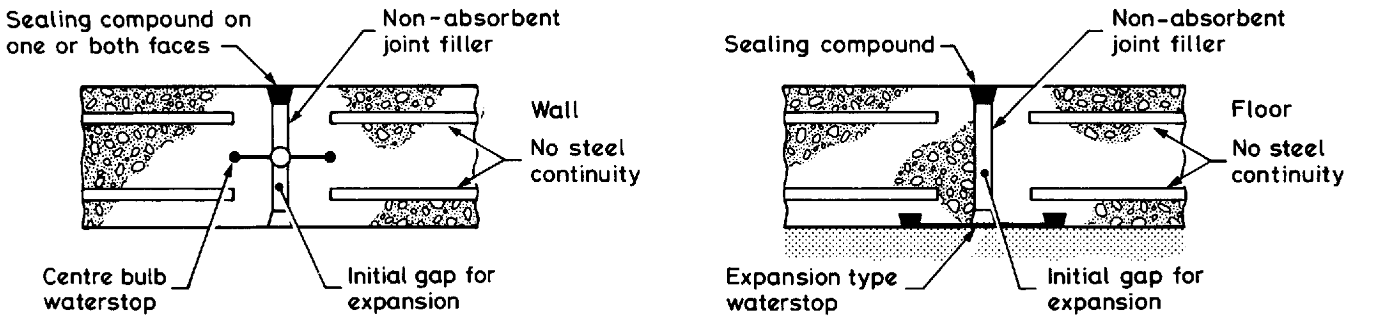
Table 29 Tension anchorage lengths for thermal and shrinkage requirements (*b*)

concrete grade	bar type steel strength, f_y N/mm^2	plain 250	deformed (type 2) 460
35/40	ρ_{crit}	0.0064	0.0035
	lap length, mm	39ф	48ф
45	ρ_{crit}	0.007	0.0038
	lap length, mm	36ф	44ф

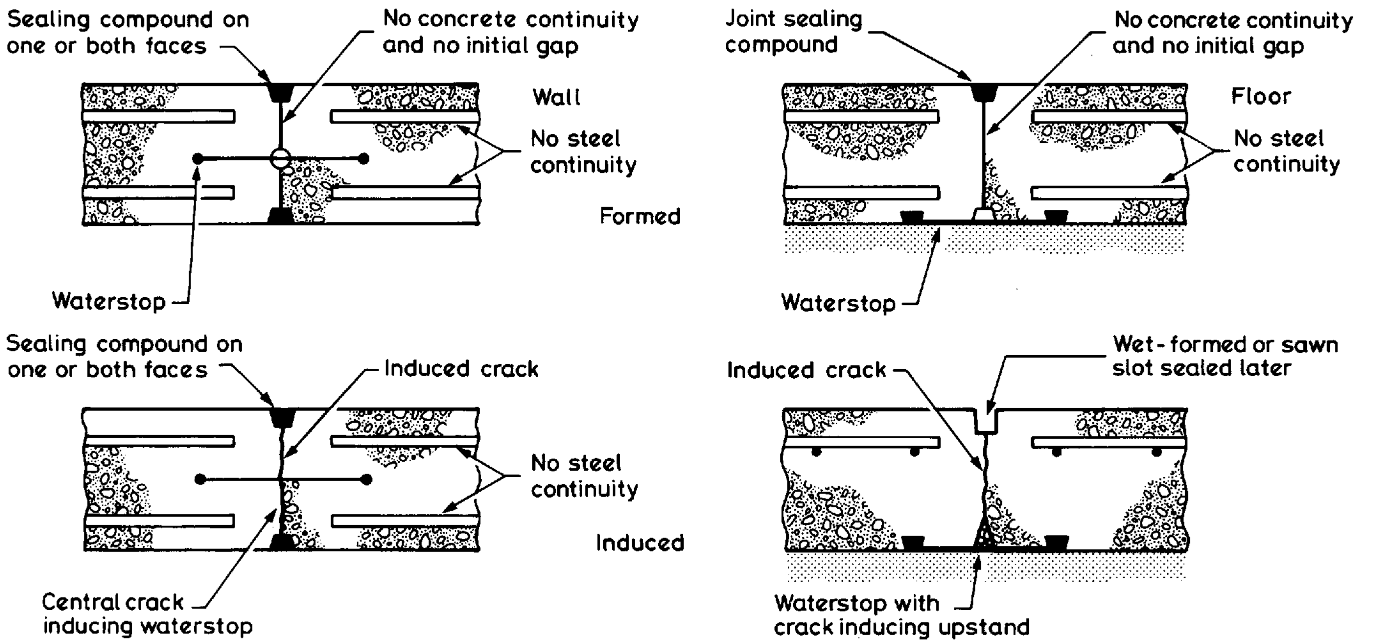
Notes:
1. ρ_{crit} is the critical steel ratio, i.e. the minimum ratio of steel area to the gross area of the whole concrete section required to distribute cracking.
2. If A_{sprov} exceeds A_{scrit} multiply by $\frac{A_{scrit}}{A_{sprov}}$
where $A_{scrit} = \rho_{crit} \times$ gross area of whole concrete section.

General note
Tables 28, 29 and 30 give tension anchorage lengths: The lap length = a factor × anchorage length. The factor may be 1.0, 1.4 or 2.0, and the value to use will depend on cover, position and spacing of bars (BS 8110, clause 3.12.8.13). However in many situations the value will be 1.0 or 1.4. The minimum lap length for bar reinforcement should not be less than 15 times the bar size or 300 mm, whichever is greater.

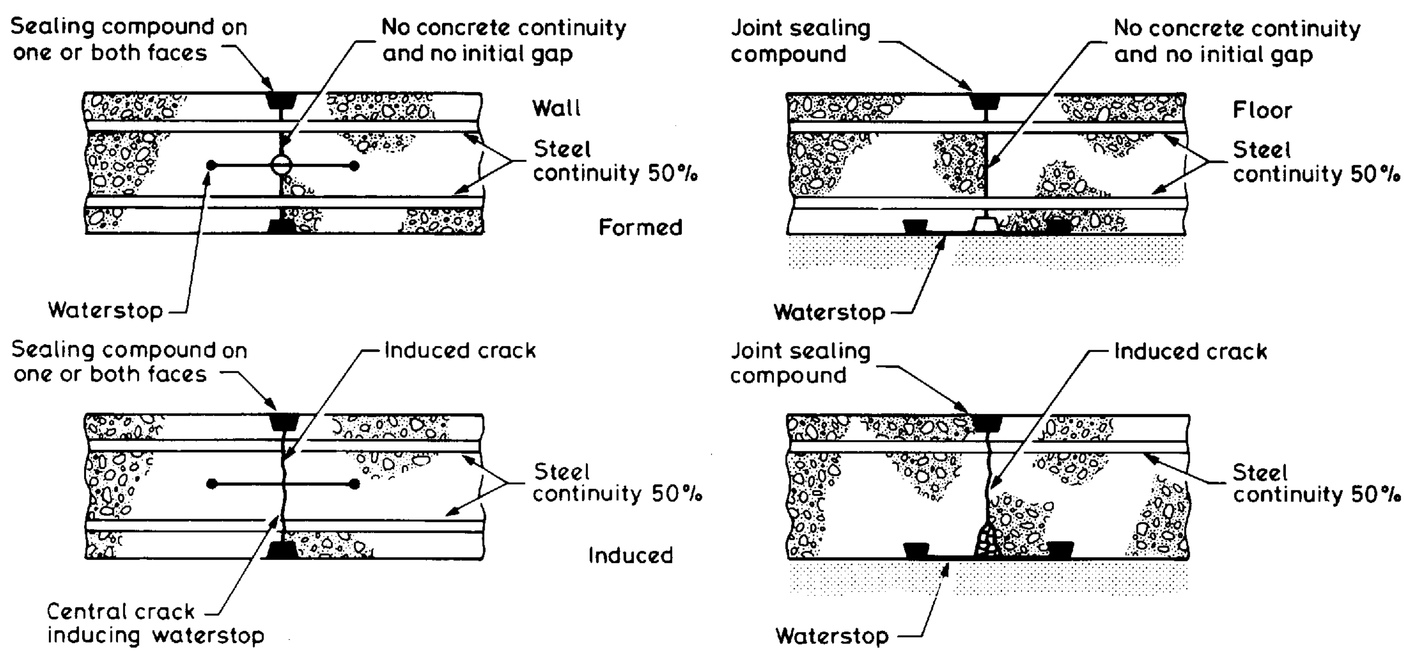
Fig. 68 Examples of movement joints



(a) Expansion joints



(b) Complete contraction joints



(c) Partial contraction joints

10 References

10.1 Essential references for detailers

10.1.1 BS 4466 *Specification for bending dimensions and scheduling of reinforcement for concrete*
10.1.2 BS 1192 *Construction drawing practice*
Part 1: *Recommendations for general principles*
Part 2: *Recommendations for architectural and engineering drawings*
Part 3: *Recommendations for symbols and other graphic conventions*
Part 4: *Recommendations for landscape drawings*

10.2 Important reference documents

10.2.1 BS 8110 *Structural use of concrete*
Part 1: *Code of practice for design and construction*
10.2.2 BS 8007 *Code of practice for the design of concrete structures for retaining aqueous liquids*
10.2.3 BS 5400 *Steel, concrete and composite bridges*
10.2.4 Concrete Society *Standard reinforced concrete details,* Technical report no. 6, ref. 51.066

10.3 Other useful references

10.3.1 Standards and Codes

10.3.1.1 BS 6100 *Glossary of building and civil engineer ing terms*
Section 6.2: *Concrete*
Section 6.3: *Aggregates*
10.3.1.2 *BS 8004 Code of practice for foundations*
10.3.1.3 BS 4210 *Specification for 35mm microcopying of technical drawings*
10.3.1.4 BS 4449 *Specifications for hot rolled steel bars for the reinforcement of concrete*
10.3.1.5 BS 4482 *Specification for cold reduced steel wire for the reinforcement of concrete*
10.3.1.6 BS 4483 *Specification for steel fabric for the reinforcementof concrete*
10.2.1.7 BS 5395 *Stairs, ladders and walkways*
10.3.9 ISO 128 *Technical drawings: general principles of presentation*
10.3.1.10 ISO 1046 *Architectural and building drawings: vocabulary*
10.3.1.11 ISO 1047 *Architectural and building drawings: presentation of drawings, scales*
10.3.1.12 ISO 3098-1 *Technical drawings: Lettering,* Part 1: *Currently used characters*
10.3.1.13 ISO 5455 *Technical drawings: scales*

10.3.2 Cement & Concrete Association publications

10.3.2.1 Balint, P. S., & Taylor, H. P. J. *Reinforcement detailing of frame corner joints with particular reference to opening corners,* 1972, No. 42,462
10.3.2.2. Higgins, J. B., & Rogers, B. R. *Designed and detailed,* 1986, no. 43.501
10.3.2.3 Green, J. Keith. *Detailing for standard prestressed concrete bridge beams,* 1973, no. 46.018
10.3.2.4 McKelvey, K. K. *Drawings for the structural concrete engineer,* 1974, no. 14.008

10.3.3. Other standards and manuals

10.3.3.1 American Concrete Institute *Manual of standard practice for detailing reinforced concrete,* 1988, ACI 315-88
10.3.3.2 Concrete Reinforcing Steel Institute, Illinois *Manual of standard practice,* 1988, MSP-1-80 (3rd ed.)
10.3.3.3. British Reinforcement Manufacturers Association *Reinforced concrete ground slabs,* 1973
10.3.3.4 Canada *National Standard of Canada,* CAN3-B78.3-M77
10.3.3.5 New Zealand *New Zealand Standard,* NZs 5902 Part 2: 1976
10.3.3.6 Concrete Institute of Australia *Code of practice for reinforced concrete detailing manual,* 1975
10.3.3.7 South African Bureau of Standards *Detailing of steel reinforcement for concrete,* 0144-1978
10.3.3.8 Whittle, R. *Reinforcement detailing manual,* Viewpoint Publications, 1981
10.3.3.9 Daltry, C. D., & Crawshaw, D. T., Building Research Establishment *Work drawings in use,* CP18/73, 1973
10.3.3.10 Institution of Structural Engineers/Concrete Society joint report *Design and detailing of concrete structures for fire resistance,* 1978
10.3.3.11 Building Research Establishment *Work drawings and their use on building sites,* CP60/76, 1976
10.3.3.12 Institution of Structural Engineers report *Structural joints in precast concrete,* 1978
10.3.3.13 Construction Industry Research & Information Association *Design of deep beams in reinforced concrete,* Guide no. 2
10.3.3.14 Comite European du Beton/Federation Internationale de la Precontrainte *Model code for concrete structures,* 1978
10.3.3.15 Leonhardt, F., Federation Internationale de la Precontrainte 9th Congress 'Prevention of damage in bridges', Proc., **1**, 1982
10.3.3.16 Birt, J. C. *Large concrete pours: a survey of current practice,* CIRIA report no. 49, 1974
10.3.3.17 Paterson, W. S. & Ravenshill, K. R. *Reinforcement connector and anchorages,* CIRA report no. 92, 1981

10.4 Prestressed concrete

10.4.1 Construction Industry Research & Information Association *A guide to the design of anchor blocks for post-tensioned prestressed concrete members,* Guide no. 1, 1975
10.4.2 Federation Internationale de la Precontrainte *Guide to good practice: practical construction,* 1975
10.4.3 Federation Internationale de la Precontrainte *Guide to good practice: basic reinforced and prestressed concrete construction,* 1978

PART IV

Special procedural provisions for certain orders

PART V

Procedures and objections under paragraph 7 of Schedule 5 to the Local Government Act 1985

PART VI

SCHEDULES

The Secretary of State for Transport and the Secretary of State for Wales, in exercise of their powers under sections 30(6) and 124 of and Part III of Schedule 9 to the Road Traffic Regulation Act 1984**(a)** ("the 1984 Act"), section 8 of and Schedule 5, paragraph 7 to the Local Government Act 1985**(b)** and of all other enabling powers, after consultation with representative organisations in accordance with section 134(2) of the 1984 Act, and after consultation in accordance with paragraph 23 of Schedule 9 to the 1984 Act, hereby make the following Regulations:–

(a) 1984 c.27; section 30 and Schedule 9 were amended by the Local Government Act 1985 (c.51), Schedule 5, paragraph 4(39).
(b) 1985 c.51.