Standard Method of Detailing Structural Concrete

A manual for best practice

Third edition

This document is intended to become a standard reference that can be used in conjunction with the normal design codes and manuals for work in structural design offices. The objective has been to provide 'good practice' guidance within a working document on structural concrete that can be used to interpret the designer's instructions in the form of drawings and schedules for communication to the site.

This edition considers the effects of Eurocode 2 on detailing principles and materials and attempts to provide guidance consistent with the Eurocodes. In addition, recent changes in practices and procurement of detailing services have been considered, such as the development of increased off-site fabrication and detailing being undertaken later in the construction sequence through initiatives such as contractor detailing.

The information and advice is based on Eurocodes and UK practice, which is associated with UK materials and labour costs. The principles and details are relevant for use in most parts of the world with only minor adjustment.

As with the original Standard method, the Steering Group was formed from members of both the Institution of Structural Engineers and the Concrete Society. Views have been taken from a wide consultation on the drafts prepared. All have been considered in finalising the document. Consequently the document reflects the current concerns and developments in the field of detailing.

The Steering Group is grateful for the funding provided by the Department of Trade & Industry in support of this project.

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CONTENTS

The *Standard method of detailing reinforced concrete* was published in 1970 and followed in 1973 by the Concrete Society's publication on *Standard reinforced concrete details*. This was updated in 1989 to incorporate a section on prestressed concrete and the title was amended to the *Standard method of detailing structural concrete*.

As with the original *Standard method*, the Steering Group was formed of members of both the Institution of Structural Engineers and the Concrete Society. We have taken the views from a wide consultation on the drafts prepared and are grateful for the variety of comments received, all of which have been considered in finalising the document. We are confident the document provides a reflection of the current concerns and developments in the field of detailing.

This document is intended to become a standard reference for work in structural design offices in conjunction with the normal design codes and manuals.

The previous documents were based on the design guidance in BS 8110. The new document considers the likely effects of Eurocode 2, as far as we can say at present, on detailing principles and materials and attempts to provide guidance that is consistent with Eurocode 2. Recent changes in practices and procurement of detailing services have also been considered such as the development of increased off-site fabrication and detailing being undertaken later in the construction sequence through initiatives such as contractor detailing. These can all blur the distinction between the work of the detailer and that of the designer. In practice, many decisions that are taken by the detailer may technically be the province of the designer. We have attempted to provide guidance of good practice in this document and to suggest the key items and information exchange that needs to be clarified to enable the various members of the design team to be clearly briefed to allow them to efficiently carry out their part of the works.

The Steering Group is grateful for the funding provided by the DTI to support this project. In developing and updating this guidance my particular thanks must go to John Clarke and Robin Whittle; the former for managing to succinctly record the many debates and finer points that had to be addressed and the latter for rising to the daunting task of drafting the document and preparing responses to the comments in a way that satisfied the wide variety of comments and viewpoints raised.

The original *Standard method* was widely distributed and accepted both in the UK and the rest of the world. Good designs invariably use the principles set out in the documents and we are confident that the new edition brings a timely update that properly reflects current developments and changes to this aspect of the construction industry.

J K Kenward
Chairman

1 INTRODUCTION AND SCOPE

The objective of this manual is to provide a working document on structural concrete that can be used to interpret the designer's instructions in the form of drawings and schedules for communication to the site.

The information given in the manual is essential for both the Designer and Detailer and both have a responsibility for ensuring that the correct information is provided. It should be noted that the Designer may be one of many different parties depending on the contractual arrangements.

The information and advice is based on Eurocodes and UK practice, which is associated with UK materials and labour costs. The principles and details are relevant for use in most parts of the world with only minor adjustment.

The purpose of this manual is to provide a standard reference that can be used on training courses and by detailers and design engineers alike. During the early stages of the development of the original document Arup made their detailing manual available to the Joint Committee and this proved a useful base document. As a consequence the concept of using Model Details to indicate the preferred method of detailing each type of structural element has been adopted. These Details can be found at the end of the appropriate section within Chapter 6.

A basic assumption in the preparation of this manual has been that it is the responsibility of the Designer to clearly specify 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 the end user. In detailing structural concrete, the impact on all parties involved in the construction process should be borne in mind; details 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 Designer, although it is recognised that certain details have design implications; therefore Designers should design with full knowledge of this manual. The term 'standard method' also needs clarification. It is not intended that any one detail should be copied slavishly for all situations, but 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 utilise the materials most readily available in a particular location or on site. It is believed that such different objectives can be satisfied by using the principles covered in this manual. The details have been prepared with the following priorities in mind:

- technical correctness and safety
- buildability and speed of construction
- labour and material costs.

This major revision of the manual introduces detailing rules that conform to BS EN 1992-1-1, *Eurocode 2: Design of concrete structures. Part 1.1: General rules and rules for buildings*[1] (EC2), BS EN 1992-1-2, *Structural fire design*[2] (EC2, Part 1.2), BS EN 1992-1-2, Eurocode 2: *Concrete bridges*[3] (EC2, Part 2) and BS EN 1992-3: *Liquid retaining and containing structures*[4] (EC2, Part 3). Where information incorporates National Determined Parameters from the UK National Annexes the values are given in '**bold**'.

In general, the conventional use of materials covered by Euronorms or British Standards is assumed. Where other authoritative documents exist, this manual refers to them rather than repeating them in full. It refers to generic rather than any particular proprietary system.

This revision also places more emphasis on the communication of information and the responsibility for detailing. The use of Contractor Detailing is recognised and the difference this makes to the process of detailing is considered.

Within the UK the use of mild steel reinforcement is no longer common practice and has now become more expensive than high yield reinforcement. Class C high yield reinforcement is considered to provide the required ductility for the specific situations where mild steel was considered necessary. Accordingly reference to mild steel has been removed. In deriving details and standards it is assumed that reinforcement will be supplied by a company holding a valid certificate of approval from a recognised third party product certification body, e.g. UK CARES (Certification Authority for Reinforcing Steels, www.ukcares.co.uk).

There is growing use of stainless steel for reinforcement for situations where greater durability is required. BS 6744: 2001[5] provides details on its use and testing.

The principles covered by BS 8666[6] have been adopted. BS 8666 defines a standard method of scheduling and a set of bar shapes that, in suitable combination, are normally sufficient for any detailing situation; it is considered to be an essential companion document to the manual.

The division between civil and structural engineering is somewhat arbitrary, and it follows that good practice is common to both structural engineering and civil engineering. There are, however, a number of factors that occur in large-scale works of which account be taken when detailing reinforcement. These include:

- provision of access for concrete to be safely placed in massive concrete sections such as raft foundations
- adjustments of reinforcement to take account of the effects in large pours of concrete. Attention is drawn to CIRIA report 135, *Concreting deep lifts and large volume pours*[7]
- 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 (also important for building slabs)
- recognition of the effects of different concrete mixes and aggregates.

It should be noted that this manual does not cover

- the detailing of structures designed for seismic situations. For such situations reference should be made to BS EN 1998: *Design of structures for earthquake resistance*[8] and other relevant documents
- the detailing of joints and reinforcement for ground slabs. For such information reference should be made to the Concrete Society Technical Report 34, *Concrete industrial ground floors – A guide to their design and construction*[9]
- water resistance of wall and slab elements in contact with the ground. For such situations reference should be made to CIRIA Report 91[10] and CIRIA Report 139[11]
- the detailing of marine structures. For such structures reference should be made to BS 6349[12]
- the use of lightweight aggregate concrete. Reference for this should be made to EC2, Section 11.

2.1   General

Accurate detailing has an important role in the procurement and durability of reinforced concrete structures. The actual process of detailing normally comes relatively late in the procurement process. Concepts and working details can be decided during the early design phases but the preparation of final reinforcement drawings and schedules is generally squeezed into a period between completion of final design and the start of construction on site. Thus, very often it becomes a critical process in the construction programme. In the UK, pressure on construction timescales and moves towards non-traditional forms of construction has tended to make detailing an even more critical and pressured activity.

2.2   The reinforcement process

Detailing can only really begin in earnest once the final design is available. The design requirements are normally given to the detailer in the form of design calculations, marked up GA drawings, beam schedules or completed pro forma or similar.

It is important that detailing is carried out with responsibilities and adequate timescales clearly defined. Issues such as site constraints, relevant standards, laps, covers, concrete grades, holes, detailing preferences, etc must all be covered. These requirements should be formalised into a detailing specification (see Construct's *Guide to contractor detailing*[13]) whether detailing is carried out in-house or outsourced. Ideally the contractor's preferred methods and sequence of construction should be made known and accommodated.

The requirements for the whole structure should be handed over and explained to the detailer at a single point in time. Packages of information that need to be provided to match the construction sequence or phasing must be defined. For instance sufficient information for the detailing of foundations and (wall and column) starter bars may be the first package required to be delivered.

Drawings and schedules can then be prepared by the detailer.

Once drawings and schedules have been completed, they are usually checked by the detailers themselves, checked by the designer for design intent and compliance with standards, and where appropriate, checked by contractors for buildability

and completeness, all in according with the relevant contracts, specifications and Quality Assurance procedures.

As far as possible, design changes once detailing has started should be avoided. Any changes significantly affect and interrupt work flows, increase workloads and greatly increase the risk of errors. However, there are often situations where final design information is not available and design developments and checks cause alterations or requirements to change. While not ideal, changes are almost inevitable and their control needs to be addressed. An agreed system of design freezes is most beneficial.

Once the reinforcement drawings and schedules gain the status of construction drawings they are distributed to the relevant parties. In traditional contracts, the reinforcement drawings and schedules will be issued to the Contract Administrator and to the main contractor, client's Quantity Surveyor, etc. The main contractor normally distributes the information to site staff, quantity surveyors, buyers etc and to specialist subcontractors. The schedules will be sent to the reinforcement fabricator/supplier.

The reinforcement is usually 'called off' from site. As the work proceeds and reinforcement is required, the site will ask for reinforcement from certain schedules to be delivered. Again depending on circumstances, these may be bulk deliveries, individual pages of schedules or schedules recast by site into work packages. On site, deliveries of reinforcement call for inspection, craneage, sorting, storage, and document processing. Unless just-in-time deliveries are feasible or suitable storage areas are available adjacent to the work area, the reinforcement may need to be sorted and moved again just prior to fixing. Prefabrication, e.g. prefabricated pile, column and beam cages, may be carried out on or off site.

The reinforcement supplier or fabricator has to predict 'call offs' so that sufficient stock and manpower is available to answer their many customers' requirements. The cutting and bending process is well documented but of most concern are addressing issues such as price changes, clarity of information, off-cuts, non-standard shapes, full deliveries and most especially delivery timescales. Deliveries that are required within 48 hours of the receipt of a call off usually attract a premium.

The reinforcement is placed and fixed by steel fixers then checked in-situ. Responsibility for checking reinforcement should be covered in the specification. Formal pre-concreting checks should include checks of the reinforcement, covers, inserts and specialist items etc. The reinforcement should be checked again during concreting for position and afterwards dowels and starter bars should be treated and/or protected. The specification may also require a cover meter survey of after concreting.

Through all these processes correct and current reinforcement drawings and schedules play a vital role in getting it right on site. The schedules also play another vital role as they form the basis for payments to suppliers and contractors.

The communication of reinforcement detailing information from the design office to the site must be as efficient as possible. Traditionally the Designer has also been responsible for preparing the reinforcement detail drawings and schedules, i.e. 'Designer Detailing'. The emergence of specialist concrete contractors has provided an alternative means of producing the information through 'Contractor Detailing'. Both systems handle the same technical information but differ in the timing and the emphasis of the way it is produced. Some of the advantages and disadvantages are listed in Table 2.1.

Irrespective of the method of detailing chosen, it is essential that all the design information, that is required for detailing, is provided. Furthermore a standard way of providing the information reduces the scope for mistakes and speeds up the process. Currently for any particular type or size of project, the calculations, and consequently the detailing instructions, produced by different Designers vary considerably both in format and content. These variations affect the efficiency of the industry, particularly in that:

- The variations make the checking of calculations and instructions by Designers time-consuming and laborious. In addition the communication of design information to external checking authorities can be unnecessarily confused and protracted.

- It takes longer for the Detailer to absorb the reinforcement information given and increases the possible need for clarification. It can also lead to a degree of abortive work and misunderstanding between Designer and Detailer.

Table 2.1 Advantages/disadvantages of Designer and Contractor Detailing	
Advantages of Designer Detailing/ Disadvantages of Contractor Detailing	**Advantages of Contractor Detailing/ Disadvantages of Designer Detailing**
Details from Designer Detailing are produced as an integral part of the design and can be more easily tailored to the demands of the Designer.	Contractor Detailing can more readily take into account the Contractor's preferred method of working.
Production of reinforcement details by Designer Detailing can take place while the design is still being finalised, thus saving elapsed time. A typical example where it might be more efficient for the designer to produce details is for foundations.	Reinforcement details by Contractor Detailing can be prepared taking account of the Contractor's preferred methods of construction and final material selection.
Preparing clear design information for Contractor Detailing takes longer and is likely to be later than for Designer Detailing with less time for checking or changes.	Preparing reinforcement details by Contractor Detailing benefits from following the actual construction programme.
The approval process for Contractor Detailing can take longer because of the rechecking required.	Designer detailed work may require re-working to take account of the Contractor's method of working.

Although it is clearly more efficient for the construction process to invoke a time freeze on the provision of new or altered information (e.g. mechanical and electrical information) this may not always be in the interests of the Client who is looking for the optimum solution.

The following includes the typical information required for detailing (see 2.6 for examples):

• General Arrangement (GA) drawings: they must be fully dimensioned, with sufficient sections and details, and should show or reference all necessary service holes, provisions for ducts and cast fittings.

• Project specification: Unless noted otherwise, the requirements of EC2 and this manual will be deemed suitable and applicable. Special requirements should be stated (e.g. seismic).

• Design requirements in one of the following forms:
  – the structural design calculations
  – marked-up GAs: This is common practice for small uncomplicated projects
  – element schedules: Sketches of the required reinforcement by element
  – pre-printed drawings (completed proformas)
  – sketches and tables incorporated with Computer Aided Design (CAD).

The efficient communication of information from Designer to Detailer is important. However, it is not suggested that a rigorous format for calculations be adopted throughout the industry. It is preferred that the Designer should recognise and tailor the guidelines given in this manual to suit the different situations that arise. The following points should be considered when the Designer is preparing instructions to the Detailer:

• Instructions should be indexed. An edited calculation index is normally sufficient.

• Basic design information relating to concrete and reinforcement grades, fire resistance, durability and associated concrete covers should be given by a Detailing Notice Sheet preceding the detailing instructions.

  Where information is available concerning the construction process (e.g. construction method, pour sequence etc.) this should be provided to the Detailer.

  Any special requirements should be noted on individual calculation/instruction pages.

• Detailing instructions should comprise only the calculation sheets describing the geometric and reinforcement requirements of a particular structural element. Information concerning general analysis of the structure, e.g. stability analysis, computer listings, is not required.

  The instructions should include clear diagrams of the reinforcement layering directions, TI, T2 etc. and the layering at cross-over of elements, consistent with the design calculations.

  Reference should be made to the Model Details in this manual where appropriate or alternative sketches supplied.

• Detailing information should be normally given in the right hand margin of the calculation sheet. Where the calculations for an element or series of elements are lengthy or complex the relevant reinforcement information should be extracted and presented in a summary sheet.

• The use of marked-up outline drawings as a summary should be accompanied by calculations for congested areas or where the section is small.

• Sketch details. All instructions should explicitly address the curtailment of reinforcement including the angle of strut assumed in shear design (see 6.3.2). Where conditions permit the use of standard arrangements these should be adopted. The instructions should also note where the standard curtailments may still be used where the elements fall outside the conditions for their use.

  Where only bending moment and shear force diagrams are provided these should be accompanied with clear instructions concerning curtailment. This method can be inefficient for detailing unless the Designer has given thought to the rationalisation of the layout (e.g. beam cages).

  Where reinforcement is congested or there are particularly complex connections e.g. corbels, nibs, deep beams to thin cross-section walls or columns, details should be sketched at a large size, even full-size, to confirm buildability. The sequence of installation must be considered to ensure beams can be lifted and placed.

• Each particular structural element requires specific design and geometric information. The list of information required is given in 'Detailing Information' sub-section of Chapter 6 for each element.

• Always provide the Detailer with the latest revision of relevant GAs and sections to avoid abortive work and the possible issue of incorrect details.

• The Designer should seek to maintain regular direct contact with the Detailer during the detailing process.

It is recommended that in the absence of an instruction from the Designer for a particular detail, or for nominal reinforcement, the Detailer should assume that the standards described by this manual are to be applied.

Where the Model Details given in this manual are not applicable to the geometric configuration, the Detailer should provide suitable alternatives based on similar principles.

2.3   Designer detailing

In order that the detailing is carried out in the most efficient manner, wherever possible, the Designer should seek to discover the Contractor's preferred methods and agree a sensible programme and sequence of work eliminating any unrealistic demands. Where the construction sequence is dependent on the design the Designer should provide a description of the design philosophy and constraints in addition to the information listed in 2.1.

Provide a description of the design intent and the form of construction assumed in design.

All sketches and rebar correspondence should be given a unique identification sketch or instruction number.

'Nominal' reinforcement should be assumed to be in accordance with the relevant element in Section 6 unless clearly stated by the designer.

2.4   Contractor detailing (see also *A guide to contractor detailing of reinforcement in concrete*[13])

Where detailing is commissioned through the Contractor under Works Contract for a project the following managerial points should be noted:
- The sub-contract should clearly state and define the responsibilities of each party.
- Legal advice should be sought, where necessary, to remove any doubts over contractual liabilities.
- The Specialist Concrete Contractor should be satisfied with the obligations and duties imposed by the contract and any warranties.
- The Specialist Concrete Contractor should have adequate insurance cover commensurate with the exposure to the relevant risks and liabilities.

2.5   Electronic data interchange (EDI)

The key to successful data exchange is to ensure that the specification of the data to be transferred from one party to another is clearly and rigorously defined.

Electronic transfer of data allows contractors to manage schedules and their revisions more quickly and are less prone to error than the old fax or postal methods which required re-keying of data. The widespread adoption of electronic data interchange (EDI) by the industry brings with it the need for careful and consistent schedule formats complying with BS 8666[6]. This allows the data to be transferred across the entire supply chain.

Minimum requirements
The following is a list of the minimum requirements for setting up accurate electronic data which can be universally accepted:
- Use of consistent nomenclature for drawing and revision numbers or letters, i.e.:
    - Revisions 1 and 2 should never be succeeded by revisions C and D.
    - The number 0 should never be interchanged with the letter O.
    - A revision at bar mark level should be consistent with the Drawing level, e.g. if a bar mark revision is marked 2 the drawing and schedule revision should be marked 2, although lower revisions can be displayed against the appropriate bar mark, if they were not changed in the new revision.
- Every bar mark must have a Member Name against it.
- Member Names must remain consistent through a schedule. The name itself is not important but a member called, for example 'garage-1' in one part of a schedule and later abbreviated to 'grge-1' in another part will be recognised by software as 2 different members.
- The same bar mark must never repeat within the same member name.
- When a library of Shape Code 99s is created (e.g. 99-01, 99-02 etc.) the shapes should be defined graphically and remain consistent for the duration of the contract.

Recommended procedures
- When a revision is issued, each schedule page should display this revision, regardless of whether any bar marks have changed on that page.
- Revised bar marks should be individually labelled with the revision number or letter. A bar mark should retain the revision number or letter at which it was last revised for accurate revision history.
- When schedules are produced we recommend a naming convention of drawing number_revision, e.g. 213_02.

2.6 Examples of typical methods of providing the required information for detailing

Example 1

Flat slab Example of a marked up general arrangement drawing for a flat slab. Notes on drawing should include concrete grade and cover, or reference to these. The general arrangement drawings should also be provided.
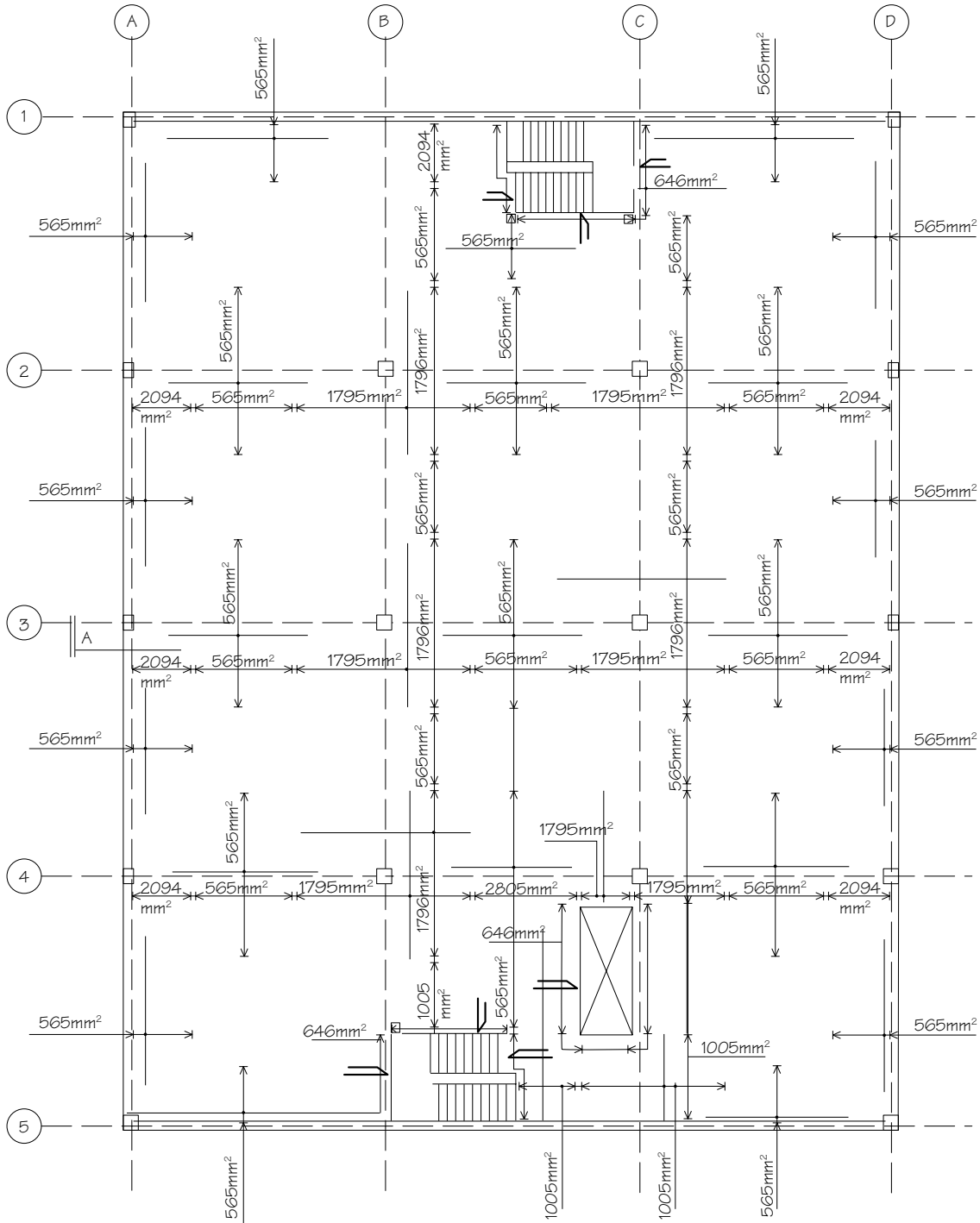
Where contour plots from proprietary systems are provided the level of rationalisation to be applied should be agreed between the Designer and Detailer. Alternatively where crack control is important a schematic layout of Bars should be given.

The method of showing where holes and the associated reinforcement trimming details required for M&E purposes must be clearly stated (see also 6.2.2).

Example 2

Beams: Details given in calculation sheet.

		Job No.		Sheet No.		Rev.
	Calculation sheet	56789		FB.3		
		Member/Location Beam, Level 2, Grid 4, B-C				
Job Title. Euro House		Org. Ref L02				
		Made by AB	Date Nov 2004		Chd CD	

EC2   <u>Beam, Level 2, Grid 4, B-C</u>   <u>Beam, Level 2</u>

f_{ck} = 30 MPa f_y = 500 MPa   <u>Grid 4, B-C</u>

<u>Supports B & C</u>   <u>Supports B & C</u>

M_{Ed} = 645 kNm   h = 500, b_N = 400

For x/d = 0.5, max. moment without comprssn   40 cover
20 allowance
for slab steel

3.1.7(3) steel, M_u = 0.32 bd²f_{cd} 12 link

$\therefore M_u = 0.32 \times 0.4 \times 0.42^2 \times \dfrac{0.85 \times 30}{1.5} \times 1E3$ $d = 500 - 40 - 20 - 20$
= 384 kNm   = 420

$d_c = 40 + 12 + 13$

$A_{SC} = \dfrac{M_{Ed} - M_u}{f_{yd}(d - d_c)} = \dfrac{(645 - 384) \times 1E3}{\dfrac{500}{1.15}(0.42 - 0.065)}$ = 65

= 1691 mm²   <u>Use 4H25 bottom</u>
(1963mm²)
1.2%

$A_S = A_{SC} + \dfrac{M_u}{f_{yd}\,0.8d} = \dfrac{1691 + 384E3}{\dfrac{500}{1.15} \times 0.8 \times 0.42}$

= 4320mm²   <u>Use 4H40 top</u>
(5027mm²)
3.0%

<u>Span</u>   <u>Span</u>
M_{Ed} = 615 kNm   h=500, b_{eff} = 3340
40 cover
5.3.2.1(3) b_{eff} = 400 + 2 × 1470 = 3340mm   12 link

$x = 1.25d - \sqrt{1.56d^2 - M/(0.32\,b_{eff}\,f_{cd})}$ $d = 500 - 40 - 12 - 20$
= 428

$= 1.25 \times 0.428 - \sqrt{1.56 \times 0.428^2 - \dfrac{0.615}{0.32 \times 3.34 \times \dfrac{0.85 \times 30}{1.5}}}$

= 33mm (within slab)

$A_{SC} = \dfrac{M_{Ed}}{f_{yd}(d - 0.4_x)} = \dfrac{615E3}{\dfrac{500}{1.15}(0.428 - 0.4 \times 0.033)}$

<u>Use 4H40 bottom</u>
(5027mm²)
= 3400mm²   2.9%

Example 2 (Continued)

	Calculation sheet	Job No.		Sheet No.		Rev.
		56789		FB.4		
		Member/Location Beam, Level 2, Grid 4, B-C				
Job Title. Euro House		Org. Ref L02				
		Made by AB	Date Nov 2004		Chd CD	

<u>Shear at supports</u>

V_{Ed} = 512kN

$Z_{support}$ = $\dfrac{645E6}{4320 \times \dfrac{500}{1.15}}$ = 343mm

<u>Shear at supports</u>

$Z = 343, b_w = 400$

6.2.3(3)   Calculate maximum value of cot θ

$V_{Ed} \leqslant V_{Rd}, max = \alpha_{cw}\, b_w\, z\, \nu_1\, f_{cd} / (cot\,\theta + tan\,\theta)$

$\therefore cot\,\theta + tan\,\theta \leqslant \dfrac{1 \times 0.4 \times 0.343 \times 0.6\, (1 - \dfrac{30}{250}) \times 1 \times \dfrac{30}{1.5}}{0.512}$

$\leqslant 2.83$

$\therefore cot\,\theta = 2.42\ (\leqslant 2.50)$

$\therefore \dfrac{A_s}{S} = \dfrac{V_{Ed}}{zf_{ywd} . cot\,\theta} = \dfrac{512E3}{0.343 \times \dfrac{500}{1.15} \times 2.42}$

$= 1419mm^2/mm$

<u>Use 2legsH12@150</u>
(1508mm²/m)

9.2.13   Shift rule

$a_l = \dfrac{z\ cot\,\theta}{2} = \dfrac{343 \times 2.42}{2}$ = 415mm

Shift rule

<u>a_l = 415mm</u>

Example 3

Pile cap: These details were sketched out on calculation sheets

Core 6.
GL. A13, B2

Mark	No.	Type/Size	Spacing
6	-	H16	250
7	4	H40	-
8	4	H16	-
9	-	H16	@ same spacing as 08
10	5	H40	-
11	-	H16	-

Example 4

Examples of typical proforma
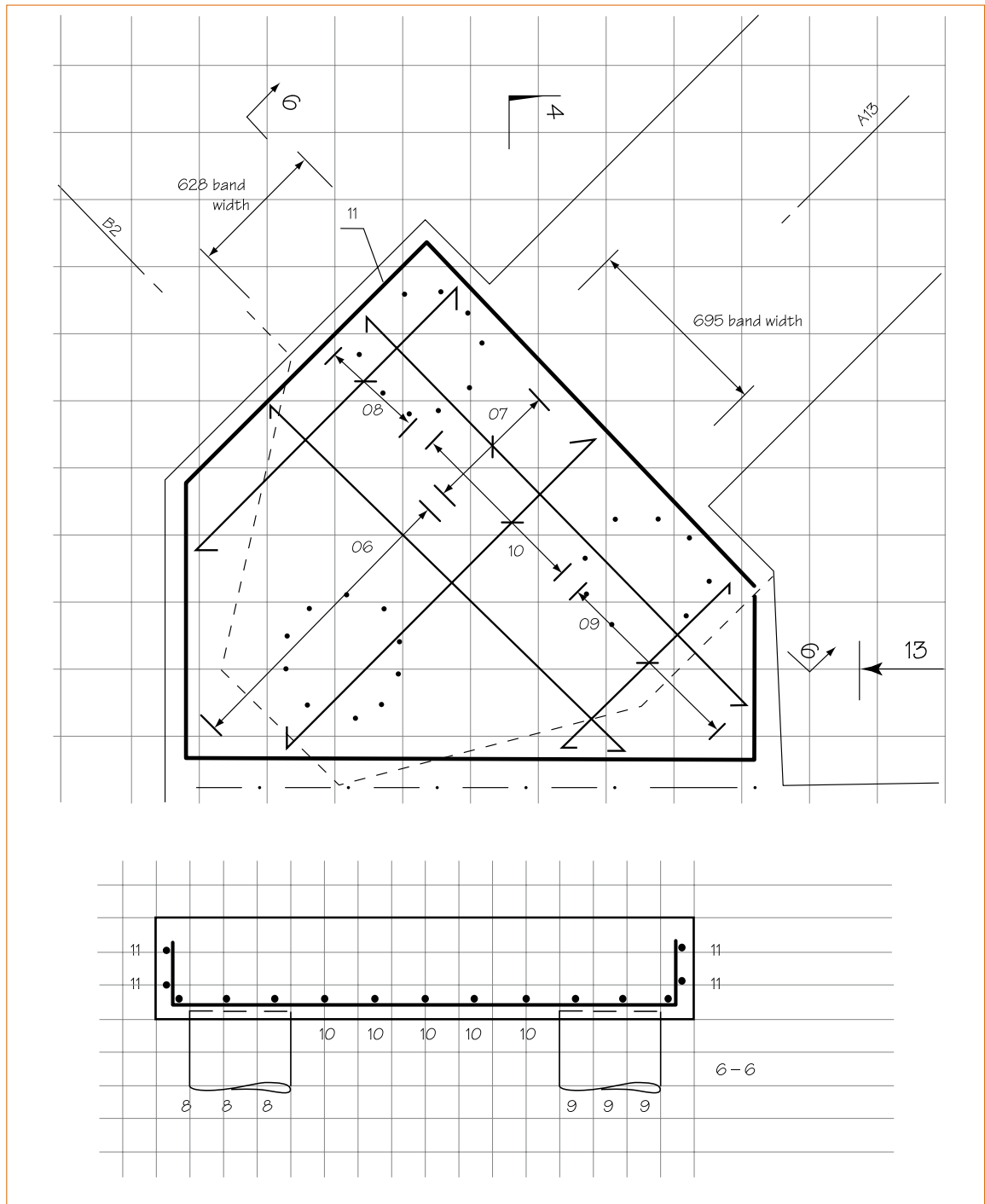
3.1 General

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

Drawings sent to the Detailer (or Contractor Detailer) are likely to be electronic.

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.

It is recommended that A1 size drawings are generally used for General Arrangements, larger sized drawings being used only when unavoidable. A3 and A4 are recommended for details. 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.

3.2 Types of drawings

The main purpose of preparing structural drawings is to explain the shape and position of all the parts of the structure. Such drawings are used to progress the Architect's concept and then to enable construction of the structure on site. Structural drawings are also necessary for the preparation of the reinforcement drawings.

3.2.1 Structural drawings

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.

They also provide the detailer with the layout and sectional information required to specify the length, shape and number of each type of reinforcing bar.

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

Detailed examples of structural layout drawings and guidance notes are illustrated in 3.20.

3.2.2 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 not be indicated on the reinforcement drawings. All other holes should be indicated on the reinforcement drawing and should be trimmed, where necessary, 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. voided bridge decks and box girders 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 may be appropriate.

3.2.3 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.

3.2.4 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 be drawn to scale.

3.2.5 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. The record drawings should be included in the Safety Plan compiled under CDM Regulations[14] and submitted to the client for safekeeping at handover of the project.

3.3   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 (see 3.15). These include:

• the chosen range of line thickness
• the size and nature of the script used
• 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.

It is recommended that checking of reinforcement is undertaken on full size prints. Errors can easily occur if reduced sizes prints are used, e.g. A1 to A3.

3.4   Abbreviations

Standard abbreviations are recommended but, if there is any risk of confusion or ambiguity with their use 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. The following symbols are commonly used:

reinforced concrete	RC
blockwork	blk
brickwork	bwk
drawing	drg
full size	FS
not to scale	NTS
diameter	dia or ø
centres	crs
setting-out point	SOP
setting-out line	SOL
centre-line	℄
finished floor level	FFL
structural slab level	SSL
existing level	EL
horizontal	horiz
vertical	vert
pocket	pkt

3.5   Dimensions of drawing sheets

The recommended dimensions of drawing sheets are given in Table 3.1. Figure 3.1 shows the relative sizes.

Table 3.1 Size of drawing sheets

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

Note
Margins and information panels are contained within these dimensions.
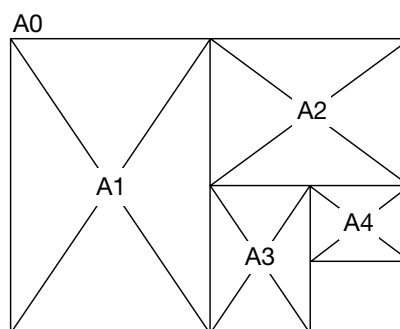
Figure 3.1 Relative size of recommended drawings

3.6 Borders

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

3.7 Title and information panels

Key information relating to the job and drawings should be placed in the bottom right-hand corner of the drawing sheet (Figure 3.2, 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[15])
- drawn by (name)
- checked by (name)
- date of drawing.
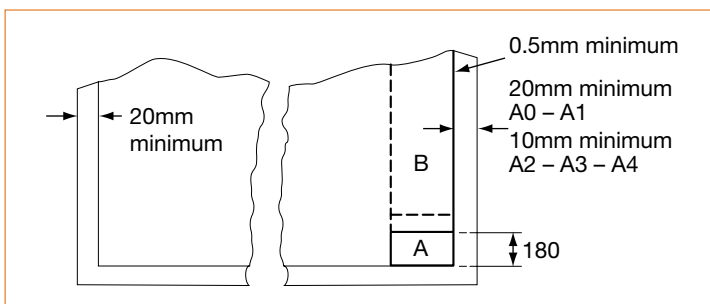
Figure 3.2 Layout of key information on drawings

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 GAs, a list of abbreviations, the grade of concrete, specified covers and the relevant 'schedule refs'.

3.8 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.

3.9 Orientation

3.9.1 Site plans

The direction of the north point should be clearly shown.

3.9.2 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.

3.10 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.

3.11 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.

3.12 Spelling

The spelling of all words should be in accordance with BS 6100-6.2[16] or otherwise the Little Oxford Dictionary[17], e.g. asphalt, kerb, lintel, etc.

3.13 Dimensions

The general arrangement drawing should show all setting-out dimensions and sizes of members. The reinforcement drawings should contain only those
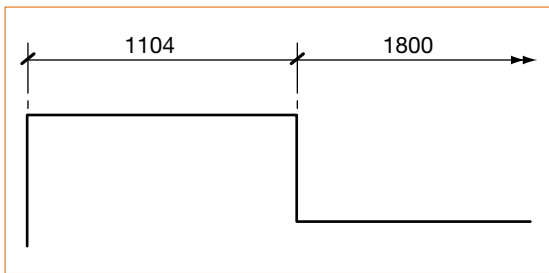
Figure 3.3 Dimension lines

dimensions that are necessary for the correct location of the reinforcement. The points to which the dimension lines relate should be as shown in Figure 3.3.

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
   1725

3.14 Levels
3.14.1 Datum
On civil engineering and major building works it is usually necessary to relate the job datum (a temporary benchmark, 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.

3.14.2 Levels on plan
It is important to differentiate on site layout drawings between existing levels and intended levels (see 3.20.2 (n)).

3.14.3 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.
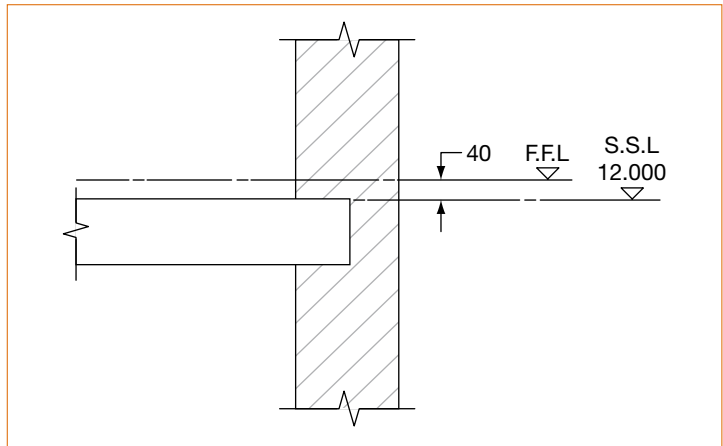
Figure 3.4 Levels on sections

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 Figure 3.4.

3.15 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[18] are: 1:10, 1:5, 1:2 or full size.

It is quite common for a drawing to be printed at a different scale than that for which it was drawn. For this reason further information should be added indicating the original size of drawing (e.g. 1:100 for A1).

3.16 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.

3.17 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 dashed lines.

3.18 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.

3.19 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 as shown in Figure 3.5.

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.
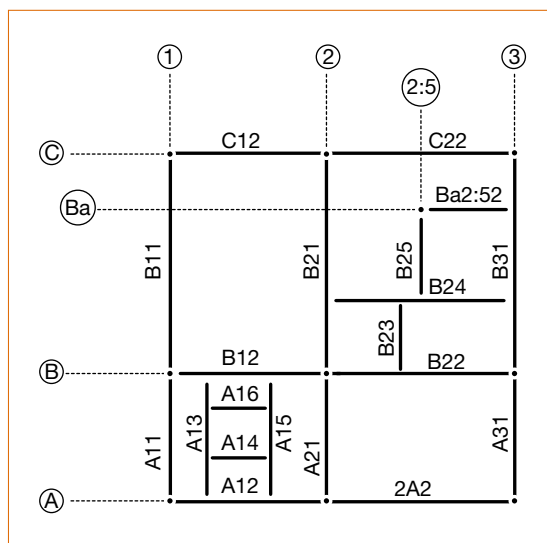
Figure 3.5 Framing plan

Referring to the framing plan sketch Figure 3.5:

- All beams within a floor panel are referenced from the column situated in the lower left corner of that panel, e.g. *column* reference B2 occurs at the intersection of grids B and 2.
- Each *beam* reference includes the column reference plus a suffix number, e.g. B2l, B23, etc. for beams spanning up the panel, and B22, B24, etc. *for* beams across the panel.
- Similarly for supplementary column Ba 2.5.

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: 'beams along grid line B/1 to 3'.

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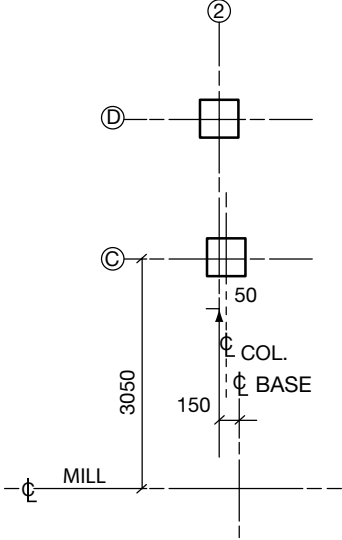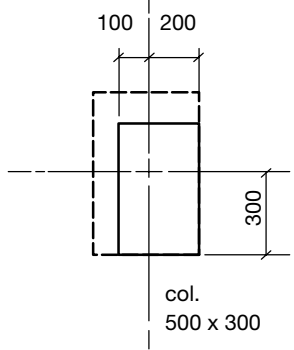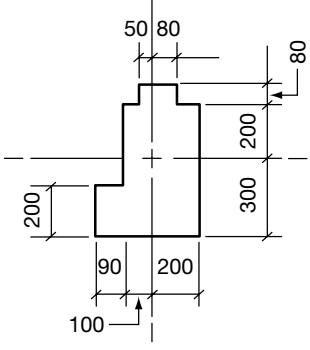
Layout drawings, commonly known as general arrangement drawings (or GAs) are developed over a period of time and coordinated from dimensional information provided by the architect, engineer and specialists. The dimensions should be checked and approved before commencing the detailing of reinforcement.

3.20.1 Methods of preparing general arrangement 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.

3.20.2 Information shown on general arrangement drawings for concrete structures

On plan

a) Grid lines These form a network across the job and provide a convenient datum for dimensioning and referencing elements (see 3.19). 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 (with clear indication of orientation) 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 3.19) and overall concrete size (h×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.
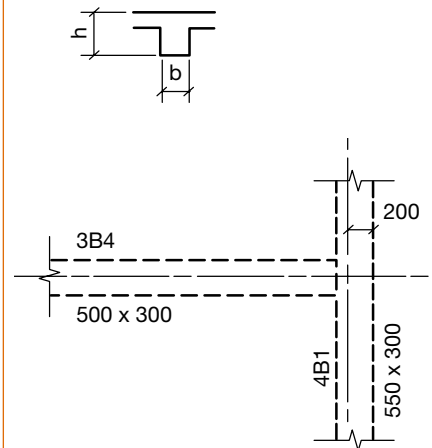
f) Upstand beams

State beam reference and overall concrete size (h×b). Add level to top of beam and/or draw section to clarify.
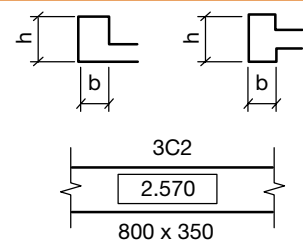
g) Nibs and kerbs on beams
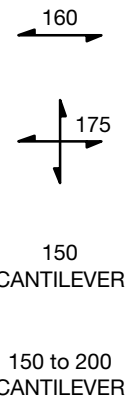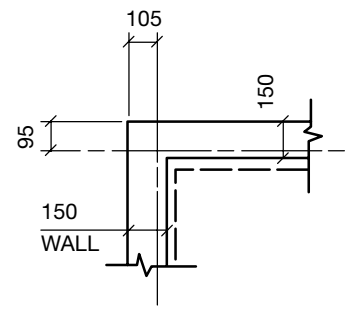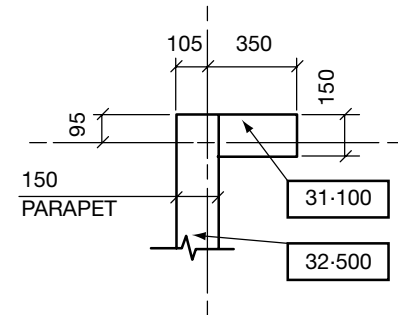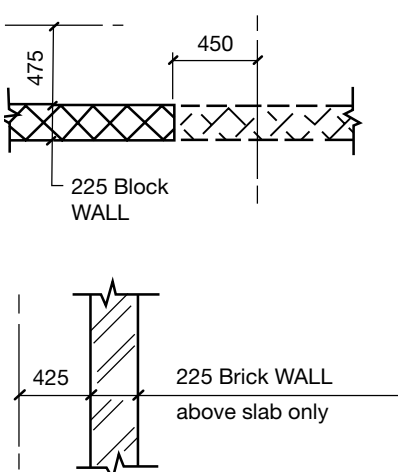
Locate extent of projection on plan and notate, indicating depth. Clarify with section and/or add levels to top.
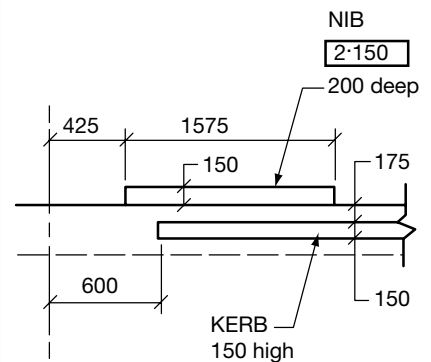
h) Bases and ground slabs

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 tapered cantilever (add section and indicate direction of taper).	160 175 150 CANTILEVER 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.	105 150 95 150 WALL
l) Dwarf walls and parapets These walls are viewed just above their top and notated. Sections and/or levels are added for clarity.	105 350 150 95 150 PARAPET 31·100 32·500
m) Load bearing walls • 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. • Locate and identify walls above floors that are not continuously supported by walls below. Generally non-load bearing partitions are not shown on structural drawings.	475 450 225 Block WALL 425 225 Brick WALL above slab only

n) Levels These provide a vertical datum and should be displayed prominently at each level as appropriate, thus: • top level of concrete, e.g. foundation base • top of structural slab level • top of finished floor level • top of existing level • arrow indicates direction of down slopes and falls and up slopes • arrow indicates level to top surface as noted.	125.000 SSL 150.050 FFL 150.075 EL 150.075 50 FALL UP ⟶ LEDGE 245.750
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 nearest datum appropriate.	50 STEP 150.000 150.050 150 45° splay under 2000 100
q) Joints Any special joint required by the Designer should be located and notated on plan with a bold chain-dotted line and supported by a section if required for clarification.	Description of JOINT 5250
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.	down up STAIR See drg..

s) Holes

All should be drawn to scale, sized and located to the nearest datum (holes ⩽ 150mm × 150mm will not always be shown):

- hole through slab.
- groups of holes.
  Identify holes with a cross.

- 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.
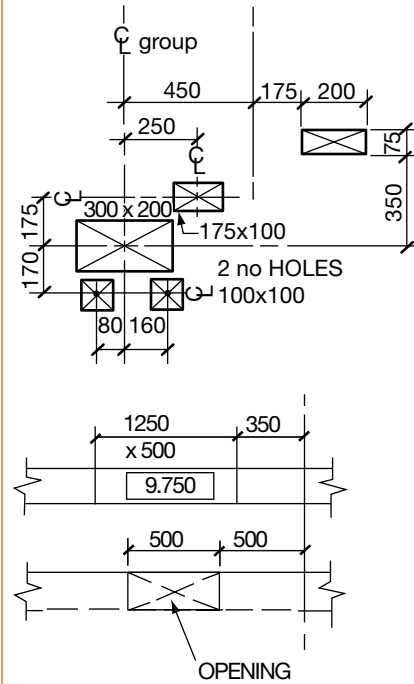
t) Pockets and recesses

- similar to holes but identify area with diagonal only and notate.
- small pockets such as those used for anchor bolts are usually identified by a large dot and notated.
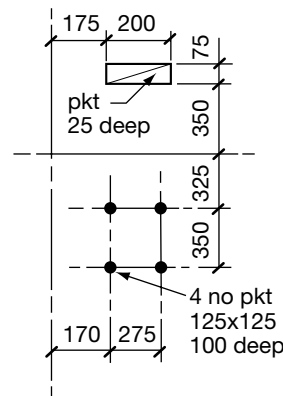
On section

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 shown. Complicated profiles etc. may remain undimensioned; these are shown by local section prepared with the floor layouts. The elevation of background walls and columns are often included to increase 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.
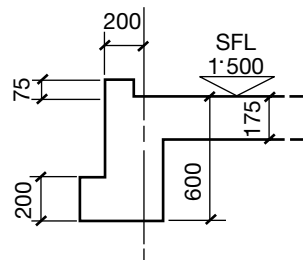
3.20.3 Fixing in concrete

Where ancillary 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 should also be given to any extra reinforcement required.

3.20.4 Example of general arrangement drawing for concrete structures

KERB
150 high

H42
450 x 300

H52
600 x 300

N

150 STEP

G54   400 x 300

STAIR
See
drg......

150 STEP
SSL
112.000

G51
600 x 300

150
WALL

G53

G41
450 x 300

300 x 250

G61
600 x 300

NIB
200 deep

175

PLINTH
1500 x 750 x 300 high
with 4 no pkt
75 x 75 x 75 deep

SSL
112.150

Up   Down
125

G42
500 x 300

G52

400 x 300

COL.
500 x 300

1

F41
450 x 300

F51
600 x 300

F61
600 x 300

150 STEP

F42

F52

450 x 300
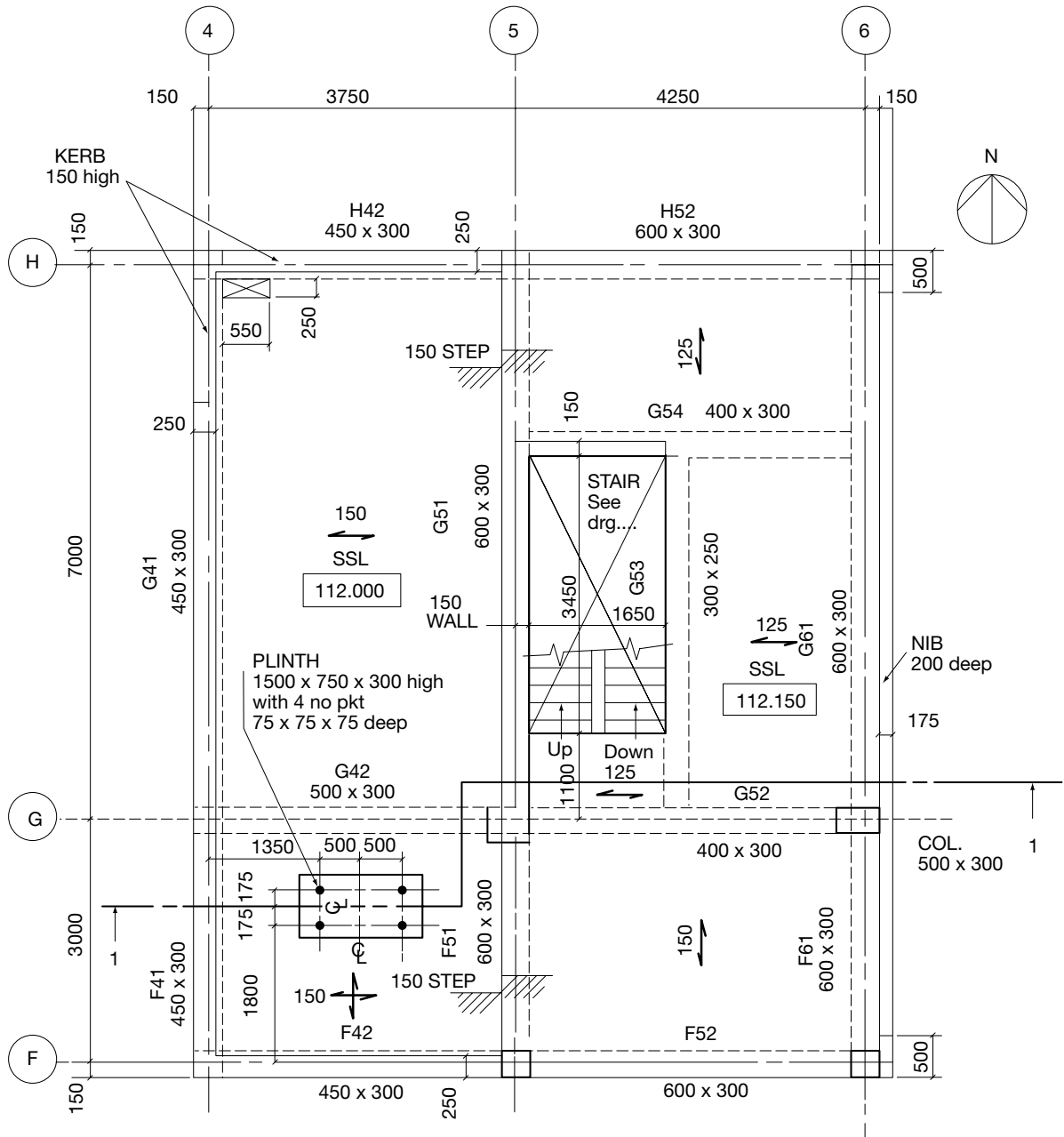
600 x 300

7TH FLOOR LAYOUT
All columns 300 x 300 and centred on grids, unless noted.

SSL
112.150
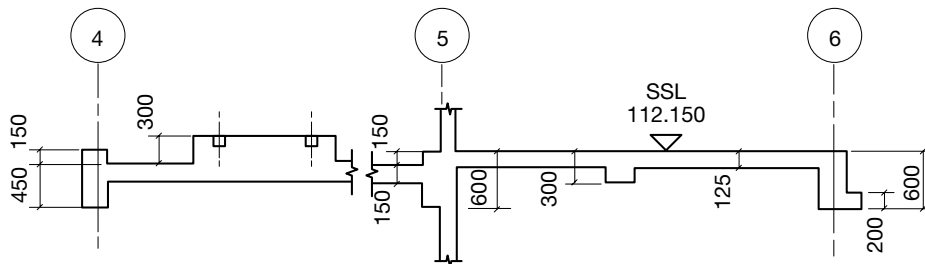
3.21 Layout of foundations

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

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

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

When piling is employed it is usual to have a separate general arrangement or piling plan. This takes the form of a plan, showing the position of piles relative to grid lines, that contains a schedule and notes which includes 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
*   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.

3.22 Layout of stairs

The stair structural layout or general-arrangement drawing should indicate all the dimensions required to set out the concrete profile as shown in Figure 3.6.

The architect will normally locate the stair between floors using the top of the finishes as the 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 (see Figure 3.7).

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.
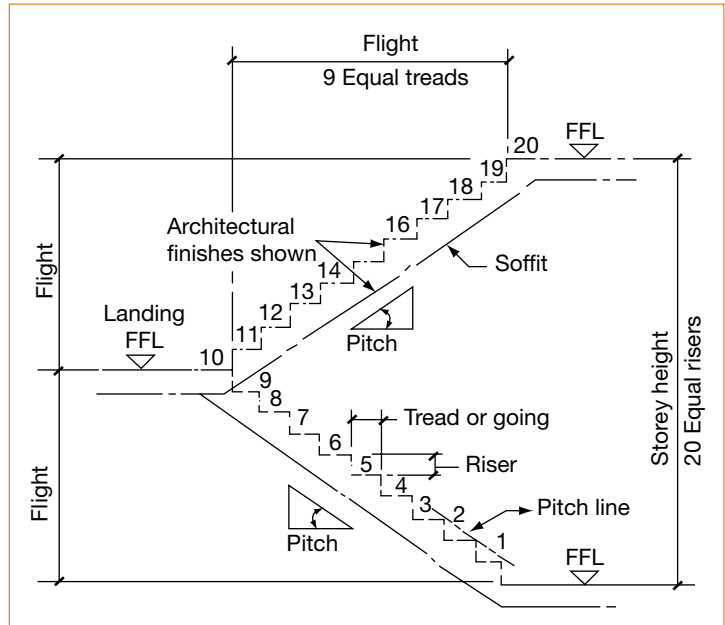
Figure 3.6 Typical stair notation
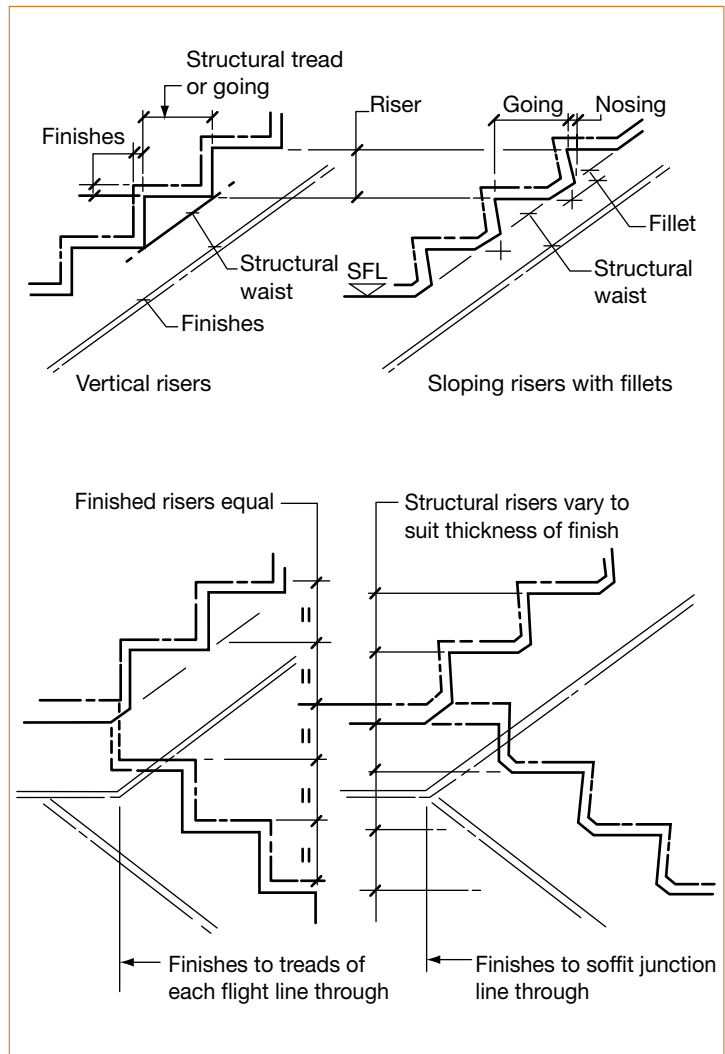
Figure 3.7 Typical stair shapes

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, 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.

4.1.1 Tabular method of detailing

The tabular method may be adopted where a number of concrete elements have a similar profile and reinforcement arrangement but have differing dimensions and quantity of reinforcement (see Tables 4.1a and b). 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.

Advantages
- a large number of similar elements may be detailed on a few drawings
- quicker to produce and thus saves 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.
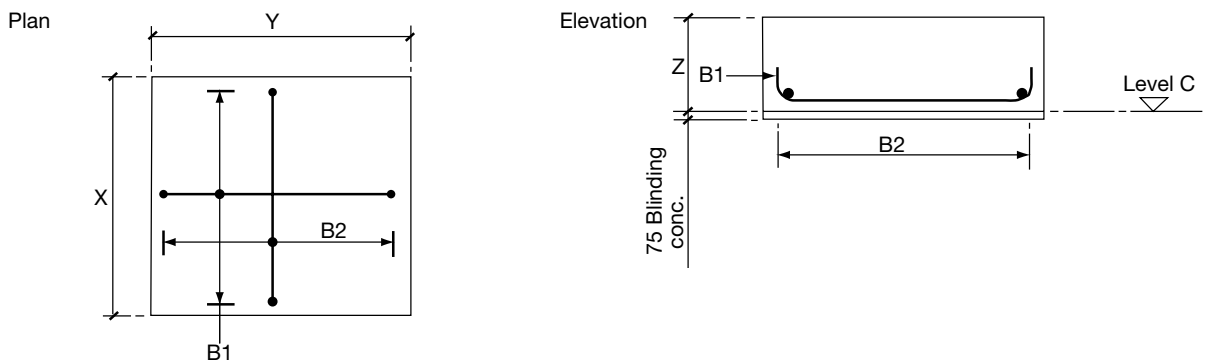
Table 4.1 Examples of the tabular method of detailing

Table 4.1a Column bases

Base	No. off	X	Y	Z	Reinforcement		Level – C
					B1	**B2**	
7A, 7B, 7C	3	1800	1800	400	12 H20-1-150	12 H20-1-150	19.000
8A, 8B, 8C	3	1800	1350	400	9 H16-2-150	12 H20-1-150	19.000
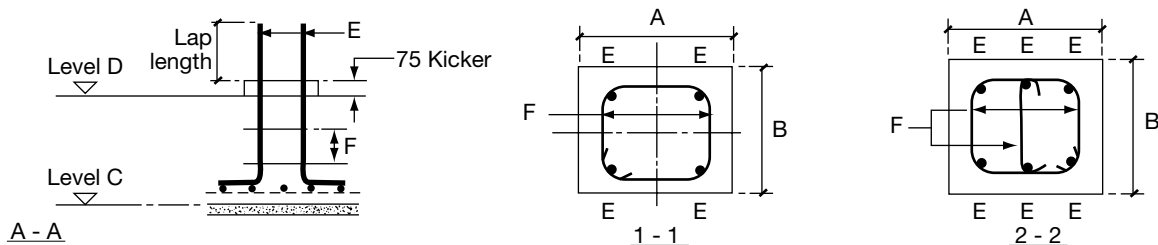
Table 4.1b Column starters

Col	No. off	Level		Reinforcement		Sect	Elev	Column dims	
		C	**D**	**E**	**F**			**A**	**B**
7A, 7B, 7C, 7D	3	19.000	19.400	4 H32-3	3 H10-4-150	1-1	A-A	350	550
8C	3	19.500	19.950	6 H25-5	6 H10-6-150 + 6 H10-7-150	2-2	A-A	575	575

4.1.2 Template drawings/Typical details

These are used where a library of typical elements and details have been set up. The advantage 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 they reflect the requirements of the Client and Architect.

4.1.3 Overlay drawings

These are layers of information which are brought together and printed to form a single drawing.

4.1.4 Computer-aided detailing and scheduling

Detailing and scheduling of a reinforced concrete structure takes a significant part of the total design time. Automatic methods of detailing and scheduling now have a significant effect on the efficiency of design office procedures.

The relative advantages of different computer-aided methods vary from office to office depending on the hardware, software and staff that are available. It is important to note that computer-based detailing and scheduling systems should be used in a responsible way by a suitably experienced person in order to achieve buildability.

4.2 Detailing reinforcement
4.2.1 General

Reinforcement detailing should be kept as simple as possible consistent with showing its shape and exact location (a list of standard shapes is given in the Tables at the end of this manual). The information given on a drawing should be in accordance with BS 8666[6]. The standard sequence of description is as follows:

Number, type and grade, size, mark, bar centres, location or comment.

For example, in a slab 20H16-63-150B1 describes 20 No. high yield deformed bars of 16mm nominal size at a pitch of 150mm in the bottom outer layer. The bar mark is -63-.

The bar centres, location or comment, are not usually required for beams and columns (see 6.3 and 6.4). To avoid confusion when totalling quantities for entry on the schedule, the number of bars in a group should be stated only once on the drawing.

The position of reinforcement should be established by dimensions to the faces of the concrete or the formwork. The notation for specifying the layering of reinforcement should be as follows:

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

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

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 should be detailed with the floor. Although the elements of a structure, such as beam, 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 for 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, which is likely to be cast into the concrete before the beam reinforcement is fixed
- 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 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.

Detailing should be carried out so that reinforcement cages can be prefabricated. Figure 4.1 shows a typical layout to achieve this. The decision to preassemble the reinforcement will normally be taken by the Contractor. However the Designer and Detailer should bear the possibility in mind.
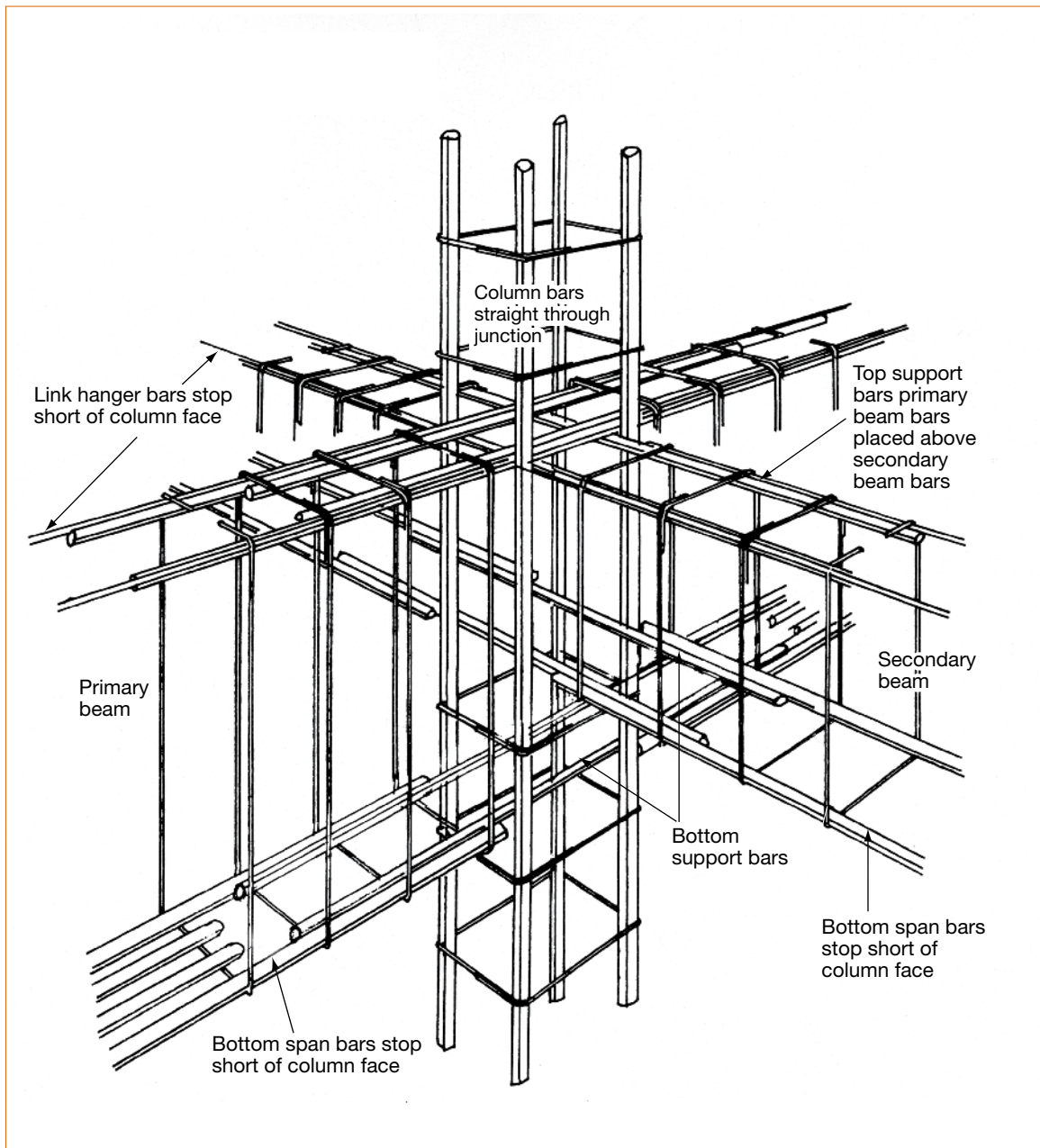
Figure 4.1 Internal beam/column intersection showing flexible detailing of reinforcement

Labels on figure:
- Column bars straight through junction
- Link hanger bars stop short of column face
- Top support bars primary beam bars placed above secondary beam bars
- Primary beam
- Secondary beam
- Bottom support bars
- Bottom span bars stop short of column face
- Bottom span bars stop short of column face

4.2.2 Intersection and layering of reinforcement

The physical size and shape of bars affects how the intersection and layering of bars is arranged. Figures 4.2, 4.3 and 4.4 show the intersection of a complex beam and column intersection. The notes on the figures provide guidance to the Detailer.

The following notes relate to Figures 4.2, 4.3 and 4.4:

1 Every column bar must be retained by a link except where the distance between column bars is 150mm or less, in which case every other bar should be retained by a link.

2 Where column reinforcement is bent out, e.g. top lift of column, the position should be clearly shown in order to maintain the correct concrete cover and clearance for slab and beam reinforcement.

3 Where the secondary-beam reinforcement has increased top cover check that the resulting reduction in lever arm is satisfactory (see also 5.15).

Column reinforcement
from above
cranked inside
Crank 1:10

Check that when column
bars are cranked in they
do not foul any other
reinforcement

50

1
10

Compression or tension
lap depending on design

Kicker

See note 3

See note 2

Spacer bars

See enlarged detail

Hole for vibrator, allow
75mm space for every 300mm
of beam width

Check sufficient space for slab
reinforcement at correct cover

Nominal longitudinal lacing bar

Cross ties at 1000 crs to limit
free height of link to 400mm

Check concrete cover is
maintained to link

Check if chamfers
and fillets are required.
(They may affect the
cover to the reinforcement)

Figure 4.2 Elevation of reinforcement at beam/column intersection

see 5.2.5

If corner bar has to
move to the right use
smaller diameter to fit
into radius of link.
Check with Designer

Link

Space bars at 1000

Link

Check that if main bar is
displaced it will not foul
any other bar

Check that standard radius for both links and secondary
beam reinforcement will pass between main reinforcement

Beam bar
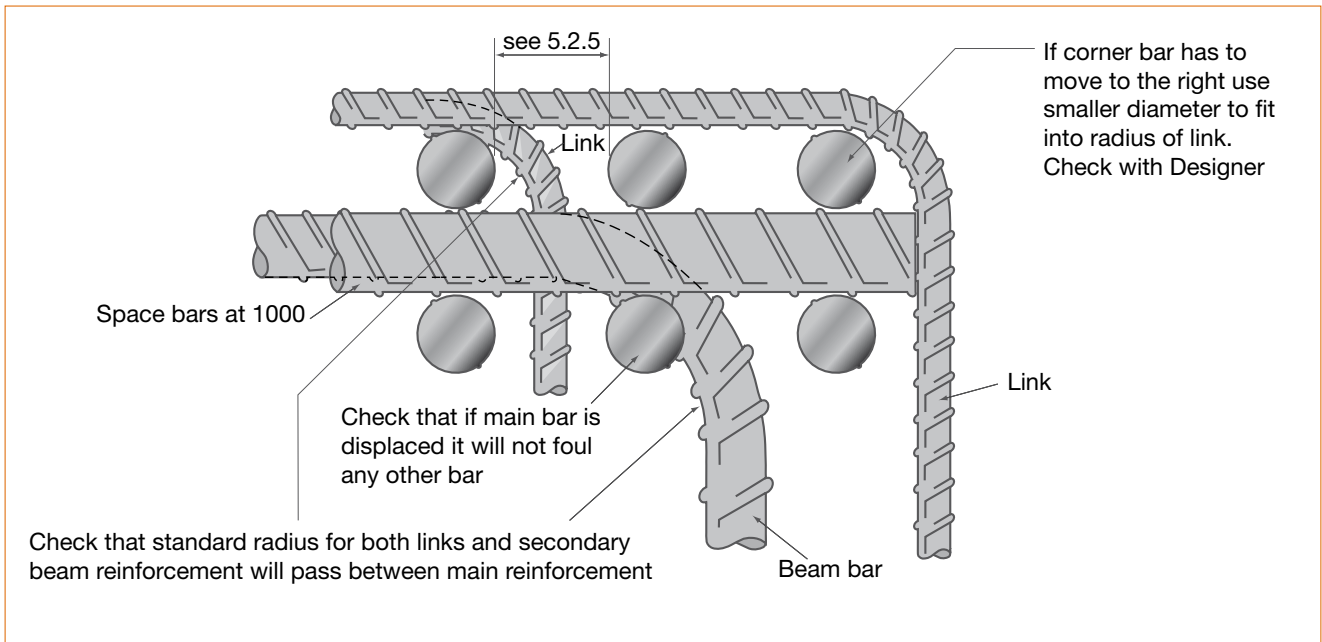
Figure 4.3 Detail of beam corner

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

Figure 4.4 Plan of reinforcement at beam/column intersection

4.2.3 Preformed cages

The use of preformed cages can improve the speed and efficiency of work on site (assuming adequate storage, craneage and correct handling). It allows the Contractor to assemble a large proportion of the reinforcement in one place and from there to lift the cages into position using cranes. Prefabrication of reinforcement cages in either a designated site or off site, may have site safety benefits.

Flexible detailing

The term 'Flexible detailing' is used to mean the method of detailing end bars separate from the main longitudinal bars of an element. This method ensures that the correct end cover can be achieved by a limited amount of telescoping at the splice. It also encourages the detailing of preformed cages. A typical example of this is the detail of separate bottom splice bars at the supports of continuous beams which lap on to the main span bars.

Internal beam/column intersection (see Figure 4.1)

The beam/column intersection demonstrates some basic rules in the preferred method of detailing such cages, namely:

- neither the bottom span bars nor the link hanger bars extend into the column, and
- continuity through the column is provided by the main support bars and by bottom support bars of appropriate sizes.

This arrangement of steel has two major advantages. First, the links, bottom span bars and link hanger bars can be completely prefabricated. Second, since the support bars do not have to be positioned in the corners of the links, there is considerable scope, without resorting to cranking, for them to be positioned to avoid column or intersecting beam reinforcement.

External beam/column intersection (see Figure 4.5)

The method of connecting a beam with an edge column should take account of the construction sequence. U-bars may be placed into the column reinforcement. These bars can be fitted after the column below has been cast and before the prefabricated beam cage is fixed in position. It is important to note that the U-bars must be positioned as close to the far face of the column as possible.
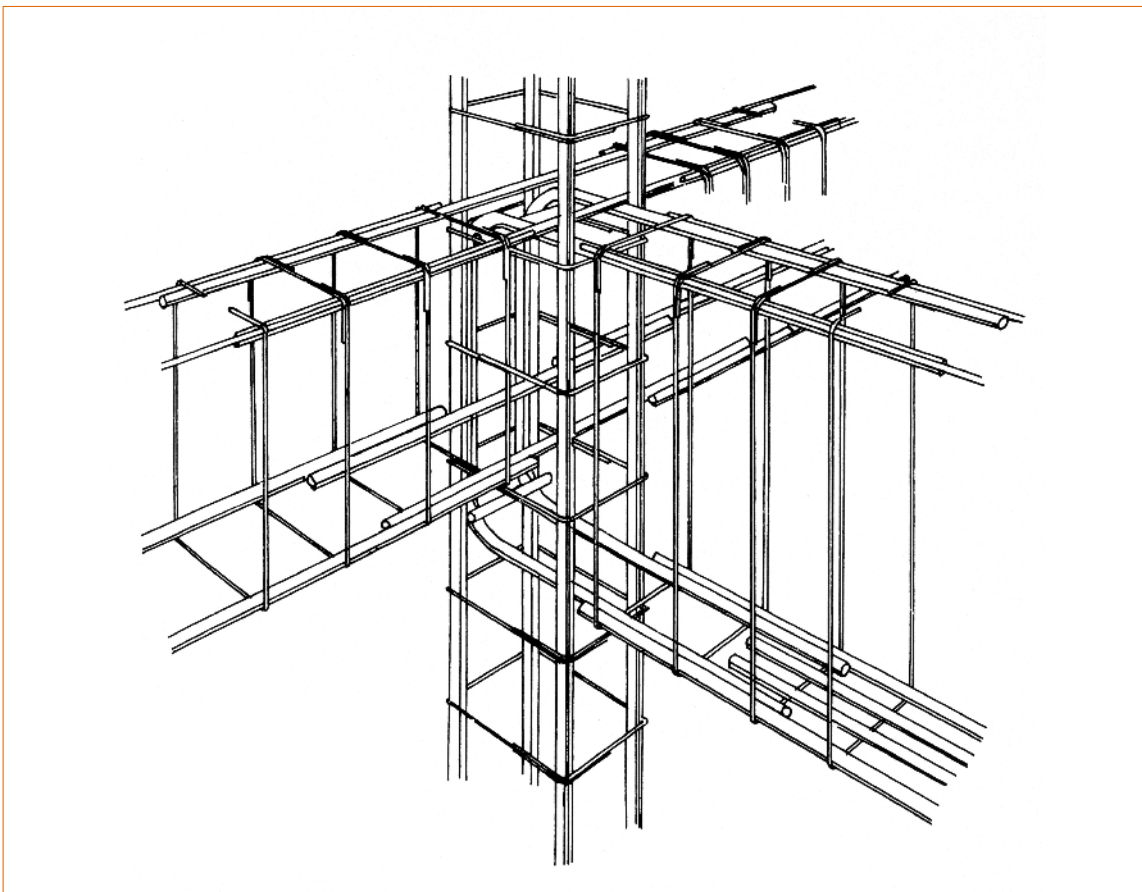
Figure 4.5 External beam/column intersection showing flexible detailing of reinforcement
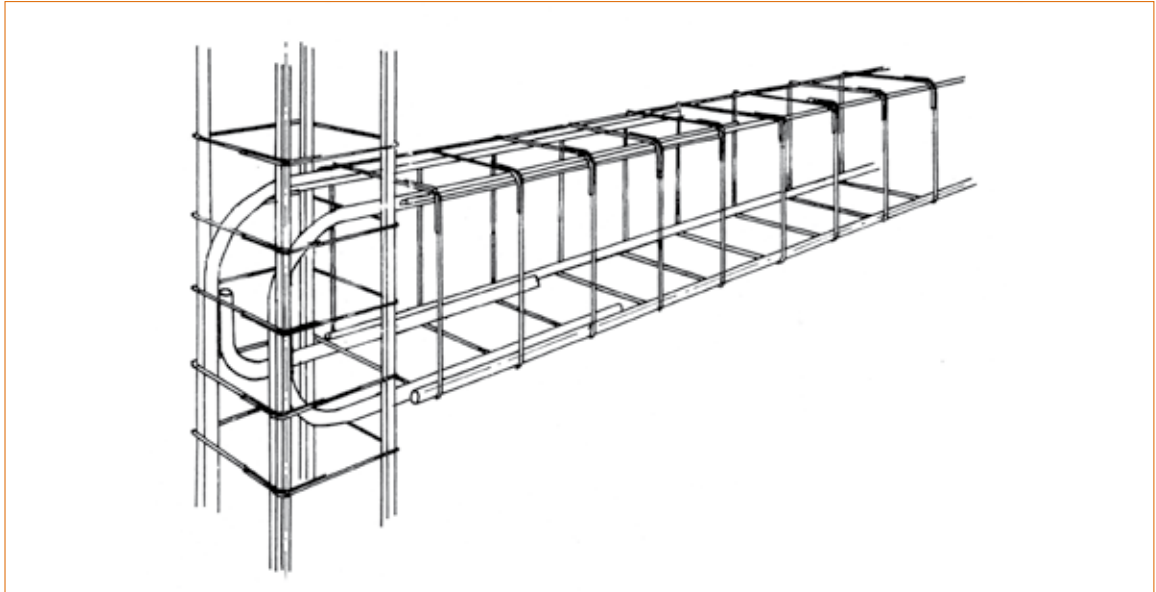
Figure 4.6 External beam/column intersection showing main top beam bars bent down into the column

Where the design requires L-bars with the vertical leg to be fixed into the lower column (See Model Detail MS2), the position of these need to be clearly shown on the drawings. The beam bottom L-bars are cast into the lower column before the prefabricated beam cage is placed in position (see Figure 4.6). It should be noted that this detail can delay construction, if the reinforcement is not fixed in the correct position.

4.2.4   Straight bars

Straight bars are easier to detail, supply and fix than bars with bends. They should be used wherever possible. Bars of size 12mm and over should normally be scheduled with a maximum length of 12m. Bars of size of 10mm and less should normally be scheduled with a maximum length of 6m.

4.2.5   Welded fabric
(see also 5.1.10 and 6.2.2)

Where the same fabric is used throughout it is normal to identify the perimeter and note the type of fabric (including orientation), layers, laps etc. Where the fabric type varies, individual locations should be shown.

The number of sheets of fabric in a set should be stated only once on the drawing.

Layering of fabric sheets can be avoided by the use of 'flying end' fabrics, or by suitable detailing of purpose made fabrics.

Where complicated detailing of fabric sheets is required, such as for voided slab construction, manufacturers will often be able to assist.

4.2.6   Chairs

BS 7973[19] provides the specification for proprietary chairs. In general this manual does not include the detailing of top steel support chairs since this is considered to be the contractor's responsibility. An exception to this concerns multi-column foundations and rafts (see 6.7.2).

4.3   Precast concrete

Where congestion of reinforcement occurs in precast concrete it may be necessary to fabricate a prototype before finalising the details. It is essential to check:
- the cover shown on the drawing with that assumed in the calculation
- the cover to reinforcement actually achieved on site.

4.4   Check list for detailer

- 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.
- Decide which scales are to be used.
- Plan drawings for content and therefore number of drawings required.
- 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.
- Determine setting out of column reinforcement.

- Consider any difficult junctions and draw sketch details to a scale of 1:10 or larger to clarify.
- Check that beam reinforcement will pass column reinforcement.
- Check beam-to-beam connections and ensure layers of reinforcement do not clash.
- Check location of laps remembering maximum lengths of bar available.
- Detail all beams in one direction, then all beams in the other direction.
- Draw sufficient sections or details to show reinforcement arrangement not only in simple areas but particularly in congested areas of reinforcement.
- Check wording required for title boxes, notes, job number and drawing number.
- 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.
- Provide check prints of both drawing and schedules for checking by another competent person.

4.5   Schedules and scheduling

4.5.1   General

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 Table 4.2). 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 Table 4.3). 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
- person checking the drawing
- contractor who orders the reinforcement
- organization responsible for fabricating the reinforcement
- steel fixer
- clerk of works or other inspector
- the quantity surveyor.

Table 4.2 Typical bar schedule

Table 4.3 Typical fabric schedule

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 8666[6]. The preferred shapes of that 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 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 8666, 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 8666 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 8666.

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:

8H20-1(a to h)-150

The bar mark given on the schedule is therefore la, 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 or drawing both the drawing and schedules should be re-issued.

4.5.2 Allowances for tolerances/deviations

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 (see 5.9.1) and the correct size of chairs to achieve 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 5.5.

It should be noted that the actual size of the bar is larger than the nominal size (see 5.1.5).

4.6 Procedure for checking reinforcement 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.

4.6.1 Stage 1: Design check

Check that:
- The drawing correctly interprets the design as described in and supported by the checked calculations.

4.6.2 Stage 2: Detailing check

Check that:
- The drawing has been prepared in accordance with current standards and meets the requirements of that particular job.
- 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.
- The details shown can, in practice, be constructed.

Where standard drawings are used they should be checked to ensure they represent the actual structure correctly, and when alterations are made to them, they should be checked to ensure that the original design intentions have not been lost.

4.6.3 Stage 3: Overall check

Check that:
- The checks under stages 1 and 2 have been carried out.
- The drawing is in all respects suitable for its purpose and truly reflects the requirements of the project.
- Each drawing has 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. The items set out below are some that could form the basis for a checklist:
- Is general presentation and orientation correct?
- Are title, scales, drawing numbers correct?
- Are revision letters correct and their location shown?
- Are sufficient sections and details given?

- Are general notes complete and can they be understood?
- Is spelling correct?
- Have all standards and codes of practice been complied with?
- Are setting out dimensions correct?
- Have check dimensions been included?
- Do running dimensions agree with overall dimensions?
- Can materials specified be obtained?
- Do number, sizes and reinforcement agree with the relevant calculations and other drawings?
- Has cross-referencing to other drawings and bar and fabric schedules been provided?
- Where applicable is 'No. off' correct?
- Are chamfers, fillets and drips and similar features shown?
- Are all projections reinforced?
- Is the cover specified and correct?
- Are splices and laps in correct position?
- Do splices suit construction joints?
- Is there congestion of reinforcement?
- Are large-scale details required?
- Are cranks required where bars cross?
- Is spacing of reinforcement correct both on plan and section?
- Is reinforcement required for anti-crack or fire resistance?
- Do hooks foul other reinforcement?
- Are schedules correct?
- Have drawings been signed by the detailer and checker?
- Where required are the spacers and chairs shown/specified?

4.6.4 Method of checking

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

> blue or yellow – correct
> red – additions and corrections.

When the amendments have been completed it is important to check the finished drawing against the check print.

5.1 Reinforcement

5.1.1 General

BS 4449[20] specifies the requirements for weldable reinforcing steel manufactured from bar, coil and decoiled product in accordance with EC2, Annex C. BS 4449 meets the requirements of EN 10080[21].

BS 4483[22] specifies the requirements for factory-made machine-welded steel fabric manufactured from deformed wires conforming to BS 4449 and Annex C of EC2. BS 4483 meets the requirements of EN 10080.

BS 4482[23] contains provisions for plain, indented and ribbed wire. The characteristic strength and ductility requirements are aligned with grade B500A of BS 4449. This standard is complementary to the requirements of EN 10080 and Annex C of EC2, except that no fatigue performance is specified and EC2 only relates to ribbed and not plain or indented steel.

In the UK, CARES is the certification body that ensures that reinforcement is correctly produced, processed and handled. It covers the steel production and billet casting, reinforcement rolling, cutting and bending of reinforcement and the fabrication and welding of reinforcement.

5.1.2 Strength/ductility properties

BS 4449 and Annex C of EC2 specify the strength and ductility requirements for three grades of ductility, Grade A, Grade B and Grade C. The tensile properties are given in Table 5.1.

Grade 250 (mild steel) plain bars are no longer commonly available. Where available they may be found in sizes 8, 10, 12 and 16.

Other types of bars are as defined in the project specification.

5.1.3 Bar identification

Reinforcement can be identified by the arrangement of ribs together with dots or spaces between them.

For Grade A steel the bars have two or more series of parallel transverse ribs with the same angle of inclination and the same direction for each series.

For Grade B steel the bars have two or more series of parallel transverse ribs. For bars with two or three rib series, one of the series is at a contrary angle to the remainder; and for bars with four rib series, two of the series are at a contrary angle to the remainder.

For Grade C steel the bars have the same rib series as for Grade B. However, in each rib series, the ribs shall alternate between a higher and lower angle with respect to the bar axis (differing by at least 10º).

Figure 5.1 shows a typical rib layout for a Grade B500A bar with the CARES 'dot-dash-dot' mark together with the country and mill identity.

The identification of Country of origin is as follows:

UK, Ireland, Iceland	5 ribs
Austria, Germany, Czech Republic, Poland, Slovakia	1 rib
Belgium, Netherlands	2 ribs
Luxembourg, Switzerland	2 ribs
France, Hungary	3 ribs
Italy, Malta, Slovenia	4 ribs
Denmark, Estonia, Finland, Latvia, Lithuania, Norway, Sweden	6 ribs
Spain, Portugal	7 ribs
Greece, Cyprus	8 ribs
Other countries	9 ribs

Table 5.1 Ductility properties of reinforcement

Grade	Yield strength R_e (N/mm^2)	Stress Ratio R_m/R_e	Total elongation at maximum force (%)
500A	500	$\geqslant 1.05$	$\geqslant 2.5$
500B	500	$\geqslant 1.08$	$\geqslant 5.0$
500C	500	$\geqslant 1.15 < 1.35$	$\geqslant 7.5$

Note
R_m is the tensile strength and R_e is the yield strength

Figure 5.1 Example of manufacturer's identification mark for Grade B500A (using dots)

5.1.4 Notation

Type of reinforcement/ fabric according to BS 4449[20]	Notation	Strength (MPa)
Reinforcement Grade 500A, Grade 500B or Grade 500C	H	500
Reinforcement Grade 500B or B500C	B	500
Reinforcement Grade 500C	C	500

Other types of reinforcement and fabric.

The notation remains as given in the present BS 8666[6]:

- S: a specified grade and type of stainless steel of ribbed bars conforming to BS 6744[5]

- X: reinforcement of a type not included in the above list having material properties that are defined in the design or contract specification.

5.1.5 Sizes of reinforcing bars

Design and detailing of reinforcement is based on nominal sizes of bars and wires. The nominal size is the diameter of a circle with an area equal to the effective cross-sectional area of the bar or wire.

The word 'size' rather than 'diameter' is used to describe the nominal size of bar. For example, on a size 20 bar no cross-dimension measures 20mm because of the surface deformations. Most deformed bars can be contained in a circumscribing circle 10% larger than the nominal size of 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 Table 5.2). Examples where special care is required are given in 5.3.

Preferred sizes of high yield reinforcing bars are 8, 10, 12, 16, 20, 25, 32 and 40mm. Size 6 is not commonly 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 commonly available size 40mm in bundles instead of using 50mm.

It should be noted that the large bar sizes may be difficult to handle and may require suitable cranage in accordance with Health and Safety regulations. Table 5.3 gives the cross sectional area and mass of the bars calculated on the basis that steels have a mass of 0.00785kg per square millimetre per metre run.

Table 5.2 Comparison between nominal size of bar and the actual maximum size (mm)

Nominal size	6*	8	10	12	16	20	25	32	40	50*
Actual maximum size	8	11	13	14	19	23	29	37	46	57
* Not a preferred size of bar										

Table 5.3 Actual area and mass of bars (see BS 4449[20])

Bar size (mm)	Cross-section (mm²)	Mass per metre run (kg/m)
6	28.3	0.222
8	50.3	0.395
10	78.5	0.616
12	113.1	0.888
16	201.1	1.579
20	314.2	2.466
25	490.9	3.854
32	804.2	6.313
40	1256.6	9.864
50	1963.5	15.413

5.1.6 Length and overall dimensions of reinforcing bars

The standard length of bars available from stock for sizes 12 and above is 12m. For sizes 8 and 10 the stock sizes are 8, 9 or 10m. The maximum length of bar available and transportable is 18m, but extra cost 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.

5.1.7 Rebending bars

The minimum mandrel diameter for bending of bars for sizes less than or equal to 16mm is 4ø and for bar sizes larger than 16mm is 7ø. Generally rebending bars on site should not be permitted. Where it can be shown that the bars are sufficiently ductile (i.e. Class B or Class C steel) bars not exceeding 12mm size may be rebent provided that care is taken not to reduce the mandrel size below four times the bar size. Larger bar sizes may be rebent only where they are within a proprietary system which holds a Technical Approval issued by a suitably accredited certification body (e.g. CARES UK) and it has been shown by testing that no damage to the properties of the bar occur.

It should be noted that where rebending of bars is undertaken it can cause damage to the concrete surface.

5.1.8 Large diameter bends

The Designer will normally be responsible for the calculation of large diameter bends, but the Detailer should be aware of their existence and should be able to recognise the difference between the occasion when a large radius bend is required and when a standard bend us required. Tables at the end of the manual give values of mandrel size for various concrete grades for a given steel design stress. Examples of where larger diameter bends are required include:

- end of column and wall connections to beams or slabs
- cantilever retaining walls
- corbels
- bottom bars for pile caps.

5.1.9 Structural tying reinforcement to ensure robustness *(EC2, Clause 9.10)*

Tying reinforcement is not intended to be additional reinforcement to that required by the design but is required as a minimum to ensure the robustness of the structure.

Peripheral ties

At each floor and roof level there should be an effective continuous peripheral tie within 1.2m from the edge of the structure. The peripheral tie should be able to resist a design tensile force equal to $(20 + 4n_0) \leqslant 60\text{kN}$ where n_0 is the number of storeys.

Internal ties

At each floor and roof level there should be internal ties in two directions approximately at right angles. They should be effectively continuous throughout their length and should be anchored to the peripheral ties at each end, unless continuing as horizontal ties to columns or walls. They may, in whole or in part, be spread evenly in the slabs or may be grouped at or in beams, walls or other appropriate positions. In walls they should be within 0.5m from the top or bottom of floor slabs.

In each direction, internal ties should be capable of resisting a design tensile force of:

$$F_{\text{tie,int}} = [(g_k + q_k)/7.5](l_r/5)(F_1) \geqslant F_t \text{ kN/m}$$

where $(g_k + q_k)$ is the sum of the average permanent and variable floor loads (in kN/m²), l_r is the greater of the distances (in m) between the centres of the columns, frames or walls supporting any two adjacent floor spans in the direction of the tie under consideration and $F_t = (20 + 4n_0) \leqslant 60\text{kN/m}$. The maximum spacing of internal ties = $1.5 \, l_r$.

Horizontal ties to columns and/or walls

Edge columns and walls should be tied horizontally to the structure at each floor and roof level. Such ties should be capable of resisting a design tensile force **which is the greater of 2 $F_t \leqslant l_s/2.5 \, F_t$, where l_s is the floor to ceiling height in m, and 3% of the total design ultimate vertical load carried by the column or wall at that level. The force is in kN per metre run of wall and in kN per column.**

Tying of external walls is only required if the peripheral tie is not located within the wall.

Corner columns should be tied in two directions. Steel provided for the peripheral tie may be used as the horizontal tie in this case.

All precast floor, roof and stair members should be effectively anchored whether or not such members are used to provide other ties. Such anchorages should be capable of carrying the dead weight of the member to that part of the structure that contains the ties.

Vertical ties

Each column and each wall carrying vertical load should be tied continuously from the lowest to the highest level. The tie should be capable of carrying a tensile force equal to the design load likely to be received by the column or wall from any one storey under accidental design situation (i.e. loading calculated using Expression 6.11b of BS EN 1990).

Continuity and anchorage of ties

Ties in two horizontal directions shall be effectively continuous and anchored at the perimeter of the structure. They may be provided wholly within the in-situ concrete topping or at connections of precast members. Where ties are not continuous in one plane, the bending effects resulting from the eccentricities should be considered.

Ties should not normally be lapped in narrow joints between precast units. Mechanical anchorage should be used in these cases.

5.1.10 Fabric reinforcement *(see also 4.2.5 and 6.2.2)*

There are three classifications of fabric reinforcement:
- Designated or Standard Fabric
- Scheduled or Non-Standard Fabric
- Detailed or Purpose Made Fabric

For detailing and scheduling of fabric see Section 4. For British Standard fabrics see Tables at the end of this manual.

Designated (Standard fabric)

These are categorised by BS 4483[22], and have distinct classifications according to the wire orientation and the cross-sectional steel area. Standard sheet size is 4.8m long × 2.4m wide, with the edge overhangs being 0.5 × wire centres. There are three main types:

- 'A' or square fabric has wires of equal size at 200mm centres in both directions. Wire sizes are from 5mm to 10mm, but exclude 9mm.
- 'B' or structural fabrics have the main reinforcement in the long direction at 100mm centres, with transverse reinforcement at 200mm centres. Main wire sizes are from 5mm to 12mm, excluding 9 and 11mm.
- 'C' or long fabrics have the main wires at 100mm, with the transverse steel being nominal size at 400mm centres. Main wire sizes are from 6mm to 10mm.

In addition there is a lightweight fabric (D49), which is often used for crack control.

'Flying end' fabrics are also available as a standard product from most manufacturers. These have extended overhangs, which are designed to eliminate the build-up of layers that occurs at lapping points with standard fabric. Sheet sizes and overhangs may vary between manufacturers.

Scheduled (non-standard fabric)

These use standard wire sizes, often with standard configurations, but are a non-standard size sheet. It is also possible to have a non-standard wire spacing, preferably with increments of 50mm. There should be consistency across a project to avoid incurring extra production costs. Maximum wire size is typically 12mm. Non-standard overhangs can be specified to avoid lap build-up.

Detailed (purpose-made) fabric

Purpose made 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.

Bending of fabric

Generally, all fabrics can be cut to size, and bent to most BS shapes. Manufacturers will normally be able to offer guidance. Wire sizes in excess of 12mm may not be possible by automatic machine manufacture.

Laps in fabric

Layering of fabric sheets can be avoided by using 'flying end' fabrics, or by suitable detailing of purpose made fabrics (see 5.3.4).

5.2   Cover to reinforcement
5.2.1   General
(EC2, Section 4 and Section 5, Part 1.2)

The required nominal cover should be specified by the Designer.

Cover to reinforcement is required to ensure:

- the safe transmission of bond forces. The minimum cover should not be less than the bar size (or equivalent bar size for bundles of bars)
- the protection of the steel against corrosion
- adequate fire resistance (BS EN 1992-1-2[2] refers to 'axis distance' for cover. This is the distance from the centre of reinforcing bar to the surface of concrete).

The importance of achieving cover cannot be overstressed since the durability of the structure is often determined by this.

Nominal cover (EC2, Clause 4.4.1.1)

Nominal cover is the cover specified by the Designer and shown on the structural drawings. Nominal cover is defined as the minimum cover, c_{min}, plus an allowance in design for deviation to all steel reinforcement, Δc_{dev}. It should be specified to the reinforcement nearest to the surface of the concrete (e.g. links in a beam).

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) plus Δc_{dev}. Where no links are present the nominal cover should be at least equal to this size of the bar) plus Δc_{dev}.

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

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

Deviation, Δc_{dev} (EC2, Clause 4.4.1.3)

Where it is specified that only a contractor with a recognised quality system shall do the work (e.g. member of SpeCC, the Specialist Concrete Contractors certification scheme) Δc_{dev} = **5mm**, otherwise Δc_{dev} = **10mm**.

5.2.2 Cover for durability
(EC2, Clause 4.2)

The exposure conditions to which the structure may be subjected determine the required cover to the reinforcement.

5.2.3 Cover for fire resistance

The required size of structural members and cover (axis distance) required for fire resistance should be specified by the Designer.

5.2.4 Fixing reinforcement to obtain the correct cover

Non-structural connections for the positioning of reinforcement should be made with steel wire tying devices (e.g. No. 16 gauge annealed soft iron wire) or by welding (but see 5.6). It is not necessary to tie every bar intersection provided that rigidity of the cage or mat can be obtained while the concrete is being placed and vibrated.

The most common way of maintaining cover is by the use of spacers and chairs. A wide range of plastic and cementitious spacers and steel wire chairs is available. BS 7973[19] provides information concerning spacers and their use. 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.

Normally the method of achieving cover and position is left entirely to the Contractor. However where the detailing is complicated the Designer may specify spacers and detail chairs, which should be in accordance with the requirements of BS 7973.

It should be noted that the weight of reinforcement can damage inserts (e.g. Styrofoam inserts) if it is not properly supported.

5.2.5 Minimum spacing of reinforcement
(EC2, Clause 9.3.1)

The minimum clear distance between bars (horizontal or vertical) should not be less than the bar size, ø, (d_g + 5mm), or 20mm, where d_g is the maximum size of aggregate.

Where bars are positioned in separate horizontal layers, the bars in each layer should be located vertically above each other. There should be sufficient space between the resulting columns of bars to allow access for vibrators and good compaction of the concrete.

5.3 Cutting and bending tolerances
(BS 8666[6])

Normally bending dimensions of reinforcement are given without taking account of cutting and bending tolerances. However, where close fit conditions exist, these should be considered at an early stage otherwise increases in member size may occur at a much later and more expensive stage in the job. Large scale sketches may help to show up any problems. Where an overall or an internal dimension of a bent bar is specified the tolerance, unless otherwise stated, is as given in Table 5.4.

The cutting length is the sum of the bending dimensions and allowances specified, rounded up to the nearest 25mm.

'Closed' detailing tolerances

Where a closed system of detailing has been used and the reinforcement is required to fit between two concrete faces (e.g. beams, columns), a deduction for cover to include member dimensional and bending tolerances is given in Table 5.5. This assumes a tolerance on the member size of 5mm for a size of member up to 2m, 10mm otherwise. An allowance should also be made for the deformities of the bar.

Table 5.4 Cutting and bending tolerances	
Bar dimension	**Tolerance (mm)**
Straight bars, all lengths including bars to be bent	± 25
Bending dimensions less than 1m	± 5
Between 1 and 2m	+ 5 to -10
Greater than 2m	+ 5 to -25
Wires in fabric	greater of ± 25 or ± 0.5% of length

Table 5.5 'Closed' detailing tolerances		
Distance between concrete faces (m)	**Type of bar**	**Total deduction (mm)**
0 – 1	Links and other bent bars	10
1 – 2	Links and other bent bars	15
Over 2	Links and other bent bars	20
Any length	Straight bars	40

Examples

The following examples are given to highlight typical situations which crop up regularly. The fitting of the whole arrangement can affect the actual position of a bar and can sometimes make compliance difficult.

Example 1: Beam corner detail

The actual size of H16 may be 18mm (+10%).

The curve in the H16 link causes further increase of cover to main bar (H32).

Main bar in position A has increased cover to one of the faces of 48mm.

Main bar in position B has increased cover to both faces of 14mm.

The position of the bar will affect both the crack-width and fire resistance. It may also cause problems at the column intersection where clashes of reinforcement may occur.
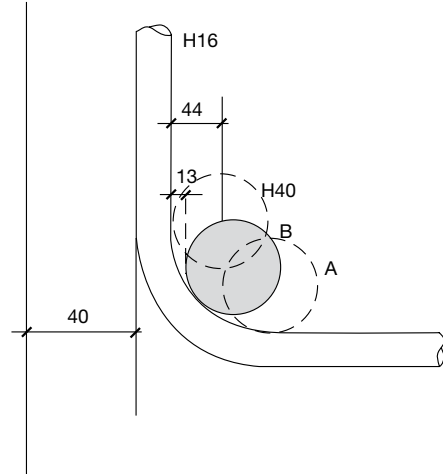
Example 2: Beam/column junction

Since the tolerance deduction is 10mm for the bending dimensions it is possible that the space inside the link (H12) could be 275 − 80 − 2(12+1) − 10 = 159mm.

This is just under 5×H32. Unfortunately it does not take into account the actual bar size (+10%). The actual space required by these bars is 176mm.

Hence, they won't fit.
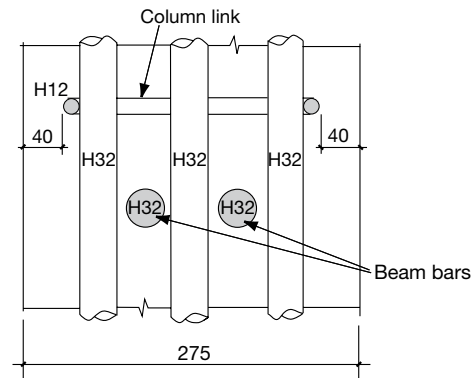
Example 3: Flanged beam

Without taking tolerances into account the gap between bars A and B is 3mm. However with the link tolerance of 5mm and the effect of the actual size of bar the position of bar A could be 12mm lower.

The weight of the cage is likely to cause the tolerance to be taken out at the top and *the cover to bar B could finish up less than 10mm* if the level of the slab formwork was 2 or 3mm out.
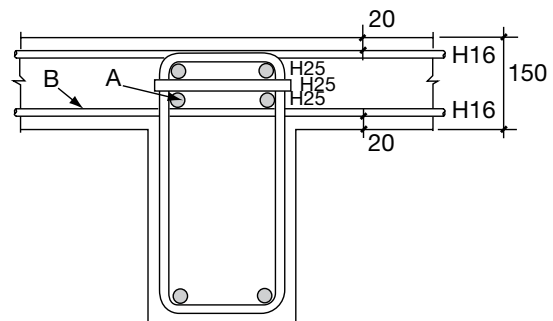
5.4 Anchorage and lap lengths

5.4.1 General *(EC2, Clause 8.4)*

The bond between the concrete and reinforcement determines the anchorage and lap lengths. The description of bond conditions for different positions of the reinforcement in the concrete are indicated in Figure 5.2.

5.4.2 Anchorage lengths

Anchorage lengths, lap lengths and dimensions of shear reinforcement should be determined by the Detailer unless noted otherwise.

The design anchorage length, l_{bd}, is:

$l_{bd} = \alpha_1 \, \alpha_2 \, \alpha_3 \, \alpha_4 \; \alpha_5 \; l_{b, rqd} \geqslant l_{b,min}$

The coefficients α_1, α_2, α_3, α_4 and α_5 are given in Table 5.6.

a) $45° \leqslant \alpha \leqslant 90°$

c) $h > 250$mm

250

b) $h \leqslant 250$mm

d) $h > 600$mm

300

A Direction of concreting

a) and b) 'good' bond conditions for all bars

c) and d) unhatched zone – 'good' bond conditions
hatched zone – 'poor' bond conditions
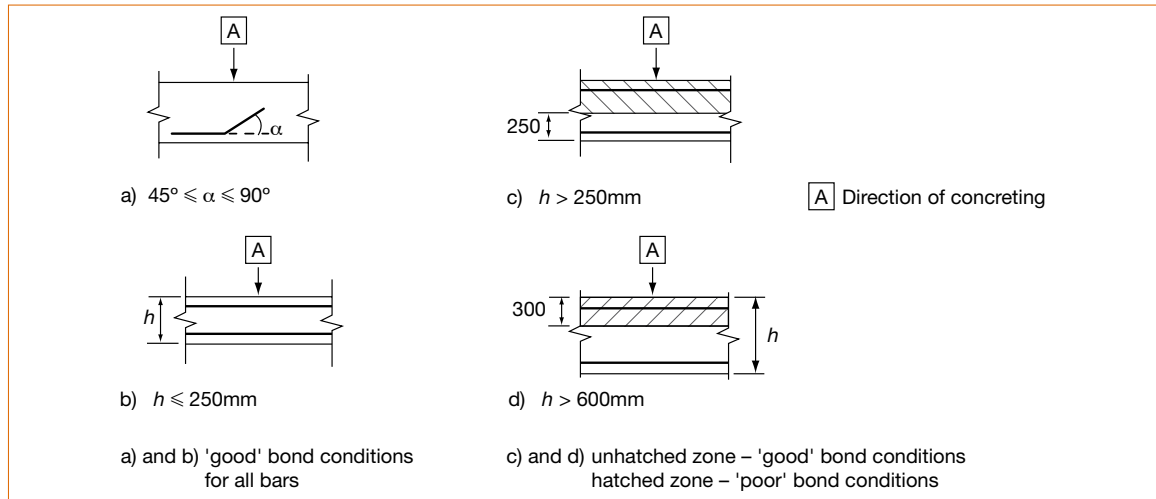
Figure 5.2 Description of bond conditions

Table 5.6 Values of coefficients (α_1, α_2, α_3, α_4 and α_5)

Influencing factor	Type of anchorage	Reinforcement bar	
		In tension	In compression
Shape of bars	Straight	$\alpha_1 = 1.0$	$\alpha_1 = 1.0$
	Other than straight	$\alpha_1 = 0.7$ if $c_d > 3ø$ otherwise $\alpha_1 = 1.0$ (see Figure 5.3 for values of c_d)	$\alpha_1 = 1.0$
Concrete cover	Straight	$\alpha_2 = 1 - 0.15 \, (c_d - ø)/ø$ $\geqslant 0.7$ $\leqslant 1.0$	$\alpha_2 = 1.0$
	Other than straight	$\alpha_2 = 1 - 0.15 \, (c_d - 3ø)/ø$ $\geqslant 0.7$ $\leqslant 1.0$ (see Figure 5.3 for values of c_d)	$\alpha_2 = 1.0$
Confinement by transverse reinforcement not welded to main bars	All types	$\alpha_3 = 1 - K\lambda$ $\geqslant 0.7$ $\leqslant 1.0$	$\alpha_3 = 1.0$
Confinement by welded transverse reinforcement	All types, position and size	$\alpha_4 = 0.7$	$\alpha_4 = 0.7$
Confinement by transverse pressure	All types	$\alpha_5 = 1 - 0.04p$ $\geqslant 0.7$ and $\leqslant 1.0$	

Notes

λ	$= (\Sigma A_{st} - \Sigma A_{st,min})/A_s$
ΣA_{st}	cross-sectional area of the transverse reinforcement along the design anchorage length l_{bd}
$\Sigma A_{st,min}$	cross-sectional area of the minimum transverse reinforcement = 0.25 A_s for beams and 0 for slabs
A_s	area of a single anchored bar with maximum bar diameter
K	values shown in Figure 5.4
p	transverse pressure [MPa] at ultimate limit state along l_{bd}

α_1 is for the effect of the shape of the bars assuming adequate cover

α_2 is for the effect of concrete minimum cover (see Figure 5.3)

α_3 is for the effect of confinement by transverse reinforcement

α_4 is for the influence of one or more welded transverse bars ($\varnothing_t > 0.6\varnothing$) along the design anchorage length l_{bd}

α_5 is for the effect of the pressure transverse to the plane of splitting along the design anchorage length

$$(\alpha_2\, \alpha_3\, \alpha_5) \geqslant 0.7$$

$l_{b,rqd}$ is equal to $(\varnothing/4)\,(\sigma_{sd}\,/f_{bd})$

where σ_{sd} is the design stress of the bar at the position from where the anchorage is measured

$f_{bd} = 2.25\, \eta_1\, \eta_2\, 0.21\, f_{ck}^{(2/3)}$

(for $f_{ck} \leqslant 50$ MPa)

$\eta_1 = 1.0$ for 'good' bond conditions (see Figure 5.2)

$\eta_1 = 0.7$ for 'poor' bond conditions

$\eta_2 = 1.0$ for $\varnothing \leqslant 32$mm

$\eta_2 = (132 - \varnothing)/100$ for $\varnothing > 32$mm

$l_{b,min}$ is the minimum anchorage length if no other limitation is applied:

• for anchorages in tension:
$l_{b,min} > \max\{0.3l_{b,rqd};\ 10\varnothing;\ 100\text{mm}\}$

• for anchorages in compression:
$l_{b,min} > \max\{0.6l_{b,rqd};\ 10\varnothing;\ 100\text{mm}\}$

For direct supports l_{bd} may be taken less than $l_{b,min}$ provided that there is at least one transverse wire welded within the support. This should be at least 15mm from the face of the support.

5.4.3 Laps in reinforcement

Laps between bars should normally be staggered and not located in areas of high moments/forces (e.g. plastic hinges). They should normally be arranged symmetrically in any section.

The arrangement of lapped bars should comply with Figure 5.5:

• The clear distance between lapped bars should not be greater than 4$\varnothing$ or 50mm, otherwise the lap length should be increased by a length equal to the clear space where it exceeds 4$\varnothing$ or 50mm.
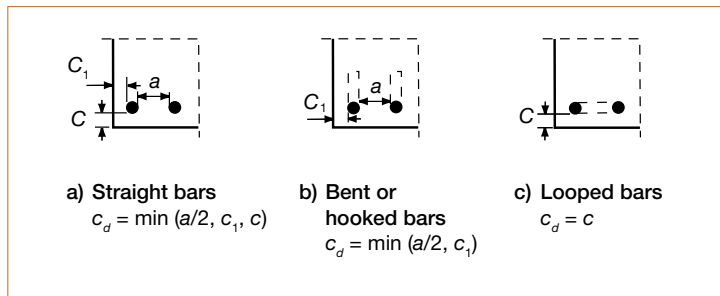
Figure 5.3 Values of c_d for beams and slabs
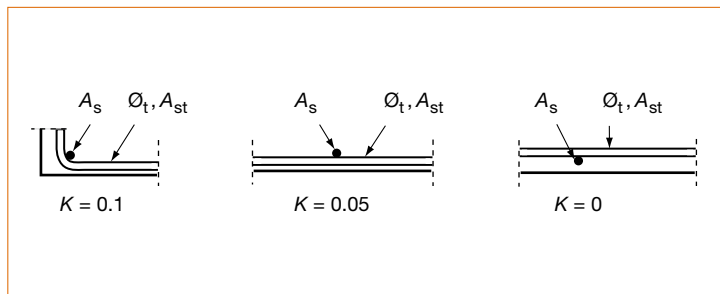
Figure 5.4 Values of K for beams and slabs
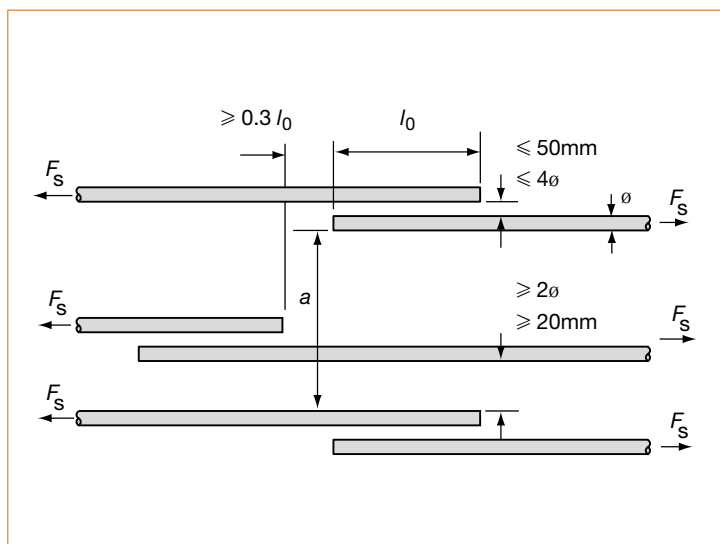
Figure 5.5 Adjacent laps

• The longitudinal distance between two adjacent laps should not be less than 0.3 times the lap length, l_0.

• In case of adjacent laps, the clear distance between adjacent bars should not be less than 2$\varnothing$ or 20mm.

When the provisions comply with the above, the permissible percentage of lapped bars in tension may be 100% where the bars are all in one layer. Where the bars are in several layers the percentage should be reduced to 50%.

All bars in compression and secondary (distribution) reinforcement may be lapped in one section.

The design lap length, l_0, is:

$$l_0 = \alpha_1 \, \alpha_2 \, \alpha_3 \, \alpha_5 \, \alpha_6 \; l_{b, \, rqd} \geqslant l_{0,min}$$

where:

$$l_{0,min} > \max\{0.3 \, \alpha_6 \, l_{b,rqd} \; ; \; 15\text{ø}; \; 200mm\}$$

Values of α_1, α_2, α_3 and α_5 may be taken from Table 5.6; however, for the calculation of α_3, $\Sigma A_{st,min}$ should be taken as $1.0 A_s (\sigma_{sd}/f_{yd})$, where A_s is the area of one lapped bar and σ_{sd} is the design stress in the bar.

$\alpha_6 = (\rho_1/25)^{0.5}$ but not exceeding 1.5 nor less than 1.0, where ρ_1 is the percentage of reinforcement lapped within $0.65 \, l_0$ from the centre of the lap length considered. Values of α_6 are given in Table 5.7.

Table 5.7 Values of the coefficient α_6				
Percentage of lapped bars relative to the total cross-section area	< 25%	33%	50%	>50%
α_6	1	1.15	1.4	1.5
Note Intermediate values may be determined by interpolation.				
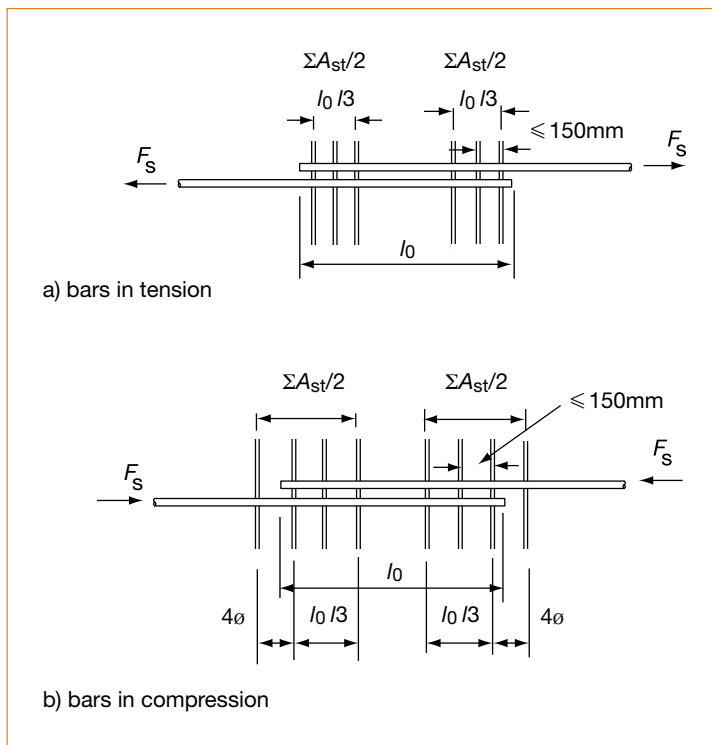
Figure 5.6 Transverse reinforcement for lapped splices

Transverse reinforcement for bars in tension

Transverse reinforcement is required in the lap zone to resist transverse tension forces.

Where the diameter, ø, of the lapped bars is less than 20mm, or the percentage of lapped bars in any section is less than 25%, then any transverse reinforcement or links necessary for other reasons may be assumed sufficient for the transverse tensile forces without further justification.

Where the diameter, ø, of the lapped bars is greater than or equal to 20mm, the transverse reinforcement should have a total area, A_{st} (sum of all legs parallel to the layer of the spliced reinforcement) of not less than the area A_s of one lapped bar ($\Sigma A_{st} \geqslant 1.0 A_s$). The transverse bar should be placed perpendicular to the direction of the lapped reinforcement and between that and the surface of the concrete.

If more than 50% of the reinforcement is lapped at one point and the distance, a, between adjacent laps at a section is $\leqslant 10$ø (see Figure 5.5) transverse reinforcement should be formed by links or U-bars anchored into the body of the section. The transverse reinforcement provided for this should be positioned at the outer sections of the lap as shown in Figure 5.6(a).

Transverse reinforcement for bars permanently in compression

In addition to the rules for bars in tension one bar of the transverse reinforcement should be placed outside each end of the lap length and within 4ø of the ends of the lap length (Figure 5.6(b)).

5.4.4 Additional rules for large bars (EC2, Clause 8.8)

Additional rules should be applied to bar sizes **greater than 40mm**. Splitting forces are higher and dowel action is greater for such sizes. They should preferably be anchored with mechanical devices. However where anchored as straight bars, links should be provided as confining reinforcement in the anchorage zone. These links should be in addition to that provided for shear where transverse compression is not present and the area of these should not be less than the following (see Figure 5.7):

- in the direction parallel to the tension face:
  $$A_{sh} = 0.25 \, A_s \, n_1$$
- in the direction perpendicular to the tension face:
  $$A_{sv} = 0.25 \, A_s \, n_2$$

where:

A_s is the cross sectional area of an anchored bar

n_1 is the number of layers with bars anchored at the same point in the member

n_2 is the number of bars anchored in each layer

The additional transverse reinforcement should be uniformly distributed in the anchorage zone and the spacing of bars should not exceed 5 times the diameter of the longitudinal reinforcement.

Large bars should not be lapped except for sections with a minimum dimension of 1m or over or where the stress is not greater than 80% of the design ultimate strength.

Surface reinforcement may be required for crack (see EC2, Clauses 7.3.4, 8.8 and 9.2.4).

5.4.5 Bundled bars
General

It is sometimes an advantage to bundle bars to provide better compaction of concrete in heavily reinforced members. Generally the rules for individual bars also apply for bundles of bars using the equivalent diameter. In a bundle, all the bars should be of the same characteristics (type and grade). Bars of different sizes may be bundled provided that the ratio of diameters does not exceed 1.7.

In design, the bundle is replaced by a notional bar having the same sectional area and the same centre of gravity as the bundle. The equivalent diameter, $ø_n$ of this notional bar is such that:

$$ø_n = ø\sqrt{n_b} \leqslant 55mm$$

where
> n_b is the number of bars in the bundle, which is limited to:
> $n_b \leqslant 4$ for vertical bars in compression and for bars in a lapped joint,
> $n_b \leqslant 3$ for all other cases.

The clear distance between bundles should be measured from the actual external contour of the bundle of bars. The concrete cover should be measured from the actual external contour of the bundles and should not be less than $ø_n$.

Where two touching bars are positioned one above the other, and where the bond conditions are good, such bars need not be treated as a bundle.

Anchorage of bundles of bars

Bundles of bars in tension may be curtailed over end and intermediate supports. Bundles with an equivalent diameter $< 32mm$ may be curtailed near a support without the need for staggering bars. Bundles with an equivalent diameter $\geqslant 32mm$ which are anchored near a support should be staggered in the longitudinal direction as shown in Figure 5.8.
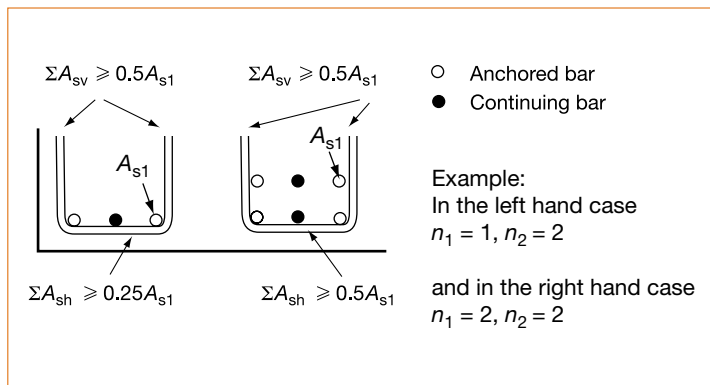
Figure 5.7 Additional reinforcement in an anchorage for large diameter bars where there is no transverse compression
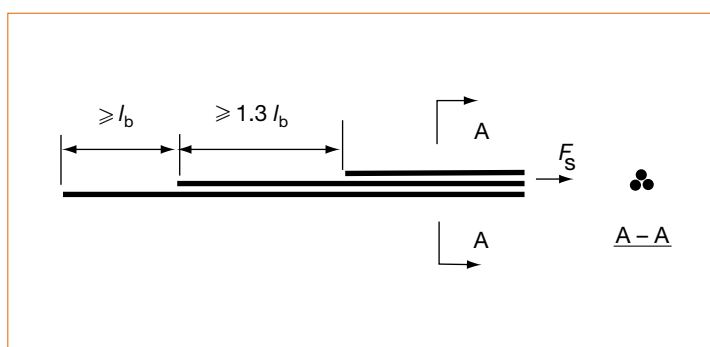
Figure 5.8 Anchorage of widely staggered bars in a bundle

Where individual bars are anchored with a staggered distance greater than 1.3 $l_{b,rqd}$ (where $l_{b,rqd}$ is based on the bar diameter), the diameter of the bar may be used in assessing l_{bd} (see Figure 5.8). Otherwise the equivalent diameter of the bundle, $ø_n$, should be used.

For compression anchorages bundled bars need not be staggered. For bundles with an equivalent diameter $\geqslant 32mm$, at least four links having a diameter $\geqslant 12mm$ should be provided at the ends of the bundle. A further link should be provided just beyond the end of the curtailed bar.

Lapping bundles of bars

The lap length should be calculated as for individual bars using $ø_n$ as the equivalent diameter of bar.

For bundles which consist of two bars with an equivalent diameter $< 32mm$ the bars may be lapped without staggering individual bars. In this case the equivalent bar size should be used to calculate l_0.

For bundles which consist of two bars with an equivalent diameter $\geqslant 32mm$ or of three bars, individual bars should be staggered in the longitudinal
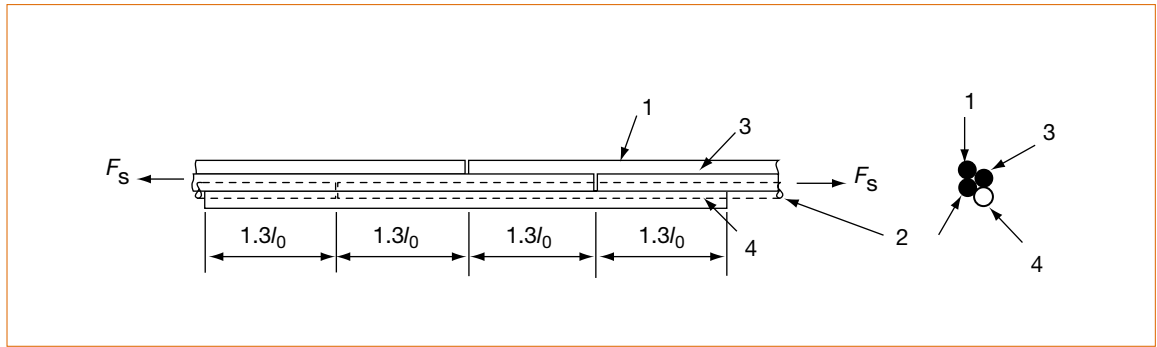
Figure 5.9 Lap joint in tension including a fourth bar

direction by at least $1.3l_0$ as shown in Figure 5.9, where l_0 is based on a single bar. For this case bar No. 4 is used as the lapping bar. Care should be taken to ensure that there are not more than four bars in any lap cross section. Bundles of more than three bars should not be lapped.

a) intermeshed fabric (longitudinal section)

b) layered fabric (longitudinal section)

c) fabric with 'flying ends' (longitudinal section)
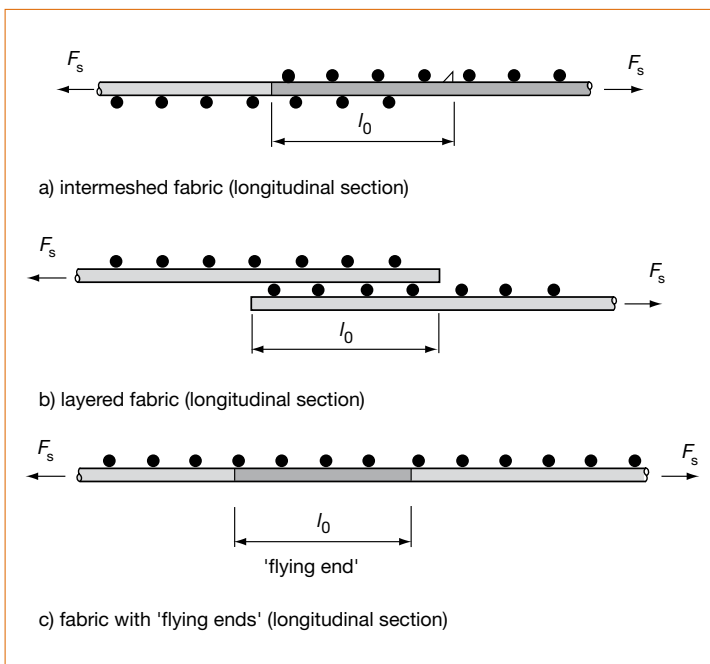
Figure 5.10 Lapping of welded fabric

Table 5.8 Required lap lengths for secondary wires of fabrics	
Size of secondary wires (mm)	Lap lengths
ø ⩽ 6	⩾ 150mm; at least 1 wire pitch within the lap length
6 < ø ⩽ 8.5	⩾ 250mm; at least 2 wire pitches
8.5 < ø ⩽ 12	⩾ 350mm; at least 2 wire pitches

5.4.6 Laps in welded fabric
Laps of the main reinforcement

Laps may be made either by intermeshing or by layering of the fabrics (see Figure 5.10).

For intermeshed fabric, the lapping arrangements for the main longitudinal bars should conform with 5.3.3 Any favourable effects of the transverse bars should be ignored: thus taking $\alpha_3 = 1.0$.

For layered fabric, the laps of the main reinforcement should generally be situated in zones where the calculated stress in the reinforcement at ultimate limit state is not more than 80% of the design strength.

The percentage of the main reinforcement, which may be lapped in any one section, should comply with the following:

For intermeshed fabric, the values given in Table 5.7 are applicable.

For layered fabric the permissible percentage of the main reinforcement that may be spliced by lapping in any section, depends on the specific cross-section area of the welded fabric provided $(A_s/s)_{prov}$, where s is the spacing of the wires:

- 100% if $(A_s/s)_{prov} \leqslant 1200\text{mm}^2/\text{m}$
- 60% if $(A_s/s)_{prov} > 1200\text{mm}^2/\text{m}$

The joints of the multiple layers should be staggered by at least $1.3l_0$.

Laps of secondary or distribution reinforcement

All secondary reinforcement may be lapped at the same location. The minimum values of the lap length l_0 are given in Table 5.8; the lap length of two secondary bars should cover two main bars.

5.5   Mechanical couplers for bars

Where the reinforcement in a section is congested, mechanical couplers may be used to good effect. There are two distinct types of mechanical couplers (see CIRIA 92 *Reinforcement connector and anchorage methods*[24]):

- tension couplers
- compression couplers

Unless specified otherwise tension couplers should be used.

It should be noted that the cover provided for couplers should be that specified for the reinforcement.

The notation used on the drawings and schedules for any special end preparation requirements is given as 'E' just before the mark.

Couplers are mainly tested in tension, but as required, may be tested under compression, cyclic and fatigue regimes. In the UK couplers should be supplied by a company holding a valid third party technical approval (e.g. CARES UK, BBA etc) and should be processed by fabricators being a member of the CARES UK third party certification scheme or equivalent.

Several types of coupler are available for tensile and compressive bars. Figure 5.11 shows typical examples of commonly available couplers.
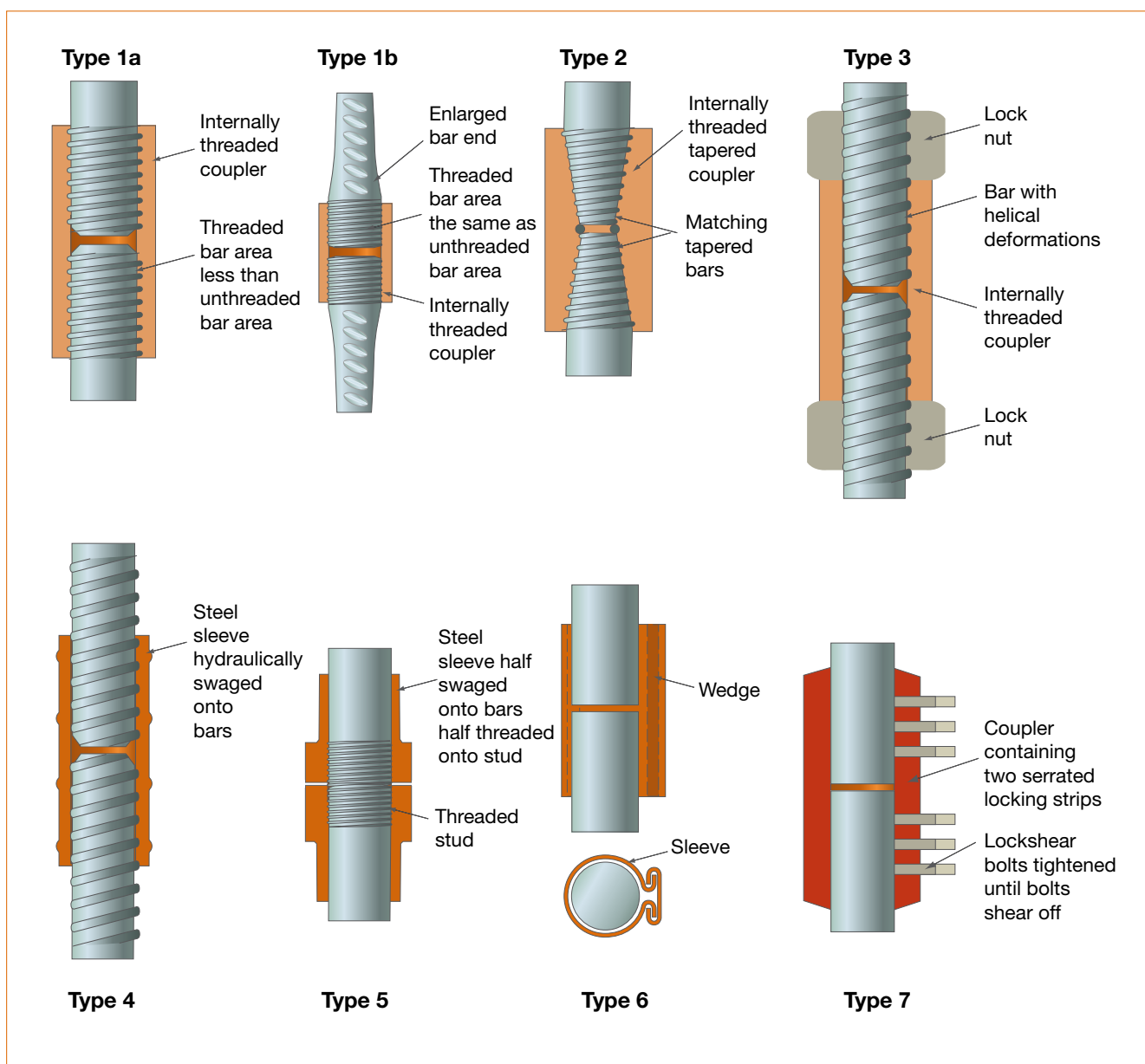
Figure 5.11 Tyically available mechanical couplers

a) Positional coupler

b) Transitional coupler
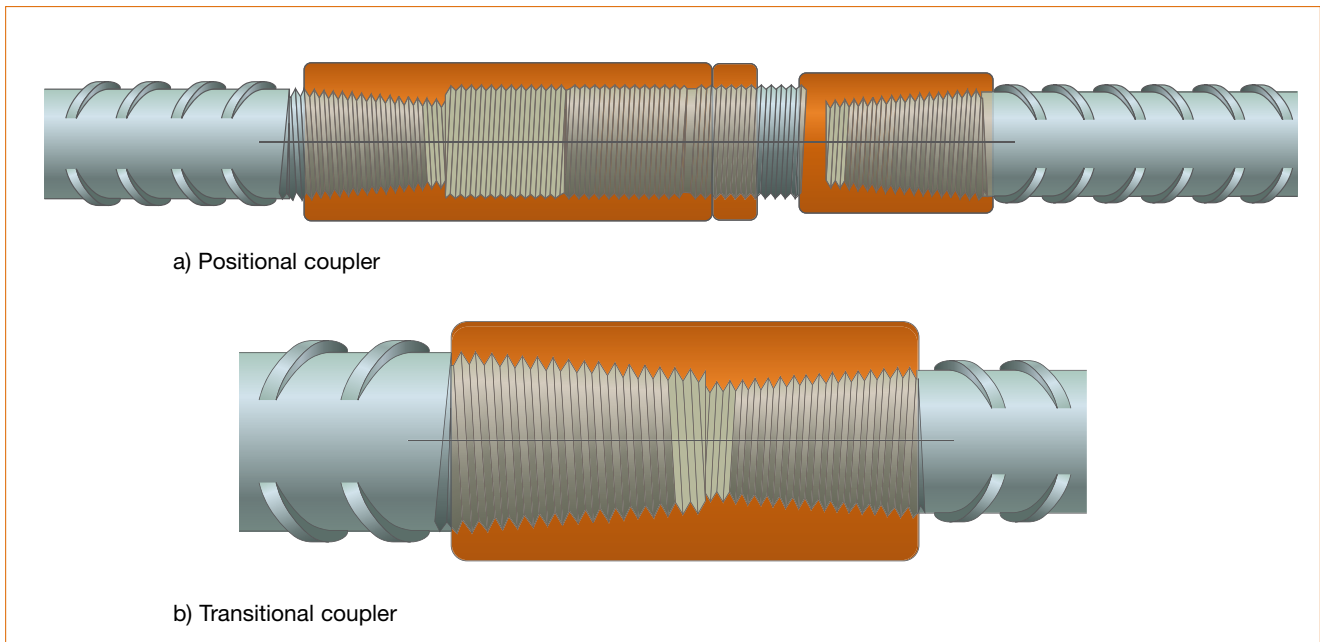
Figure 5.12 Lap joint in tension including a fourth bar

Type 1: Couplers with parallel threads

Threads can be cut, rolled or forged. There are two variations to this type of coupler. Type 1a uses reinforcing bars with the threaded portion having a smaller diameter than the rest. Type 1b uses bars with the threaded portion having a cross sectional area equal or greater than the nominal size. The former is rarely used since the load capacity is reduced; the latter which maintains the parent bar load capacity is widely used. An alternative to Type 1 also includes a variant where one end of a parallel threaded coupler is swaged on to a bar.

The parallel (Type 1) couplers also have transitional and positional variants. The transitional coupler allows two bars of different size to be joined. The positional coupler usually comprises two halves joined by a parallel thread and lock nut arrangement.

Type 2: Couplers with taper-cut threads

This system consists of an internally threaded metal coupler with a tapered thread, and matching tapered bars. Due to its ability to meet the majority of the structural building applications it is popular.

The standard tapered coupler can only be used in situations where the continuing bars can be rotated. This is not always practical and more sophisticated tapered couplers have been developed which allow the joining of bars that can not be rotated, and the joining of bars where the continuing bar can neither be rotated nor moved (e.g. L-bars). Figure 5.12 shows examples of positional and transitional couplers.

Type 3: Couplers with integral threads over full length bar

High yield reinforcing bars are specially manufactured with helical deformations along the full length of the bar. The deformations form a continuous coarse thread onto which an internally threaded coupler can be screwed. Locknuts are used at either end of the coupler to prevent slippage on the coarse threads. A turnbuckle system for when the continuing bar cannot be rotated is not available, but the coupler can be completely threaded onto one bar and then run back onto the continuing bar to form the joint.

Type 4: Metal sleeves swaged onto bars

A seamless malleable steel sleeve is slipped over the abutting ends of two reinforcing bars (see Figure 5.13). The sleeve is then swaged (deformed) onto the ends of the bars using a hydraulic press. This action effectively splices the bars together. The process can be carried out wholly in-situ. The hydraulic press compresses the sleeve laterally onto the bars and several 'bites' are usually necessary to cover the whole joint.

Sufficient working space must be available around the bars to enable the hydraulic press to swage onto the bars. In addition, swaging equipment for large diameter bars (H40 and greater) may require mechanical support for safe operation. It is therefore important to take this into account in likely construction sequencing and detailing reinforcement in confined areas.
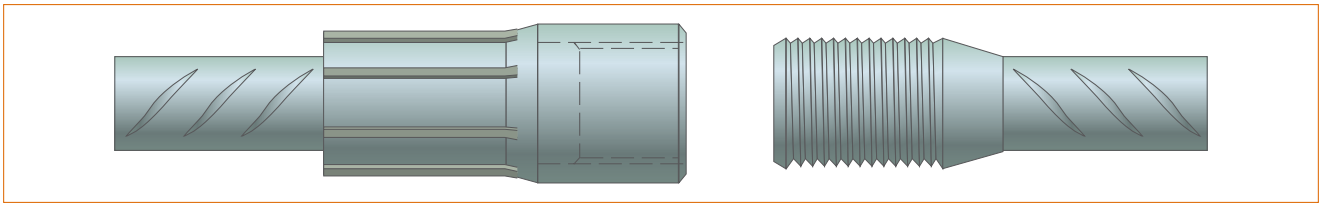
Figure 5.13 Example of swaged coupler

Type 5: Threaded couplers swaged onto the ends of reinforcing bars

In this system two malleable sleeves which are threaded internally for half their length are joined together by a high tensile threaded stud. The unthreaded parts of the sleeves are hydraulically swaged on the two ends of the bar to be joined. These ends can be screwed together using the threaded stud (see Figure 5.13). The swaging process can be performed by the fabricator prior to arrival on site, in a stockyard at the site, or in-situ. For the latter method it must be ensured that there is sufficient working space around the bars. Connection of the bars with the threaded stud is performed in-situ.

Type 6: Wedge locking sleeves

This system can be used for connecting compression bars only. The bars to be joined together are held in concentric bearing by the lateral clamping action of a sleeve and wedge. The sleeve is cylindrical in shape, with a wedge-shaped opening. This opening has collared-shaped flanges, onto which a wedge-shaped piece of metal is driven. This action compresses the sleeve laterally and so clamps the bars together. It is very important that the bar faces are cut accurately and aligned to within a 3° maximum angle tolerance.

Type 7: Couplers with shear bolts and serrated saddles

This type of coupler system has been available in the UK since 1986 and is now widely used. The system does not require rebar threading and consists of a steel coupler with a line of 'lockshear' bolts running along its length. The two bars to be joined are placed inside the coupler on two hardened serrated steel locking strips, 'saddles', using ratchet wrench or electric or air powered nut runner, which forces the bars against the longitudinal saddles. As this happens, the serrated saddles bite into the bar and wall of the coupler. When the predetermined tightening torque for the bolts is reached, the bolt heads shear off leaving the installed bolt proud of the coupler. This provides a visual check of correct installation.

This coupler has proved useful in refurbishment work, joining pile cage steel to pile caps and where couplers are required with minimum lead time. They are, however, relatively bulky couplers requiring space for sockets to tighten bolts. This should therefore be taken into account in considering concrete placement. Often reduced aggregated concrete is required in congested areas.

5.6 Welding of reinforcement

5.6.1 General

Welding of reinforcement should be avoided wherever possible. Where it is essential it should be carried out in accordance with the requirements of BS EN 287-1[25], BS EN 288-3[26] and BS EN 1011-2[27] and Appendices 6 and 10 to the CARES *Steel for the Reinforcement of Concrete Scheme*[28].

Welding procedures and welder qualifications should be subject to the agreement of the Contract Administrator. BS 7123[29] does not adequately cover the requirements for welding and welding procedures in relation to reinforcement.

5.6.2 Semi-structural welding

Semi-structural welding of reinforcement should only be carried out by firms that have achieved certification to CARES Appendix 10 – *Quality and operations assessment schedule for the manufacture of pre-assembled welded fabrications using welded semi-structural and/or structural joints*[28].

5.6.3 Tack welding

Tack welding on site should not be permitted, other than in particular circumstances for which special approval must be sought.

Only firms that have achieved certification to CARES Appendix 6 – *Quality schedule for the tack welding of reinforcing steel*[28], should be permitted to undertake contracts to supply pre-assembled tack welded fabrications.

Where tack welding is proposed for reinforcement with a Carbon Equivalent greater than 0.42, the appropriate procedures in BS EN 1011[27] must be followed.

6.1 General

Where values are shown in bold (minimum reinforcement etc.) they are based on the UK National Annex of EC2.

Typical values of cover are given. The Designer should confirm these are suitable for the specific element being considered.

The information given in the Model Details has been developed over many decades and the current details are those used as standard practice by Arup. The Detailer is expected to follow the Model Details unless the Designer has given specific instructions. The Designer should always check that, where minimum reinforcements are provided, they meet his/her requirements.

The recommendations given in this chapter assume that the Contractor has a recognised quality system in place (see 5.2.1) and as a consequence the value of Δc_{dev} assumed in the Model Details is 5mm.

6.2 Slabs

6.2.1 Scope

The information given relates to:

- single and two way orthogonal slabs
- cantilever slabs
- orthogonal flat slabs
- trough and coffered slabs.

Slabs of irregular shape may often be detailed using the same principles. However, six or more layers of reinforcement may be required and allowance should be made for this in design.

For ribbed and coffered slabs the ribs should be spaced at centres not exceeding 1.5m and their depth, excluding any topping, should not exceed four times their top width. Otherwise they should be designed and detailed as beams.

Ground slabs are not covered by this manual and reference should be made to the Concrete Society Technical Report 34, *Concrete industrial ground floors*[9].

6.2.2 Design and detailing notes
Concrete grade

For reinforced concrete the concrete grade is normally 30/37 MPa (cylinder strength/cube strength) with a maximum aggregate of 20mm.

Nominal cover
(EC2, Clause 4.4)
Solid slabs

- Internal use (Concrete inside buildings with low air humidity, XC1):
  (15mm or bar diameter) + Δc_{dev}, whichever is greater
- External use (Corrosion induced by carbonation, XC3): **35mm + Δc_{dev}.**

See 5.2.1 for values of Δc_{dev}

Ribbed slabs

- For fire ratings greater than 2 hours the need to provide supplementary reinforcement should be considered. (See Model Detail MS8).

Note

Special care is required to ensure adequate cover is specified where drainage channels with 'falls', run along the surface of the slab. In addition where the surface finish effects the cover this should be stated on the drawings.

Minimum area of reinforcement
(EC2, Clauses 9.3.1.1, 9.3.1.2 and 9.2.1.1)
Solid slabs

- Tension reinforcement:
  $A_{\text{s,min}} = 0.26\, b_{\text{t}}\, d\, f_{\text{ctm}}\, /f_{\text{yk}} \geqslant 0.0013 b_{\text{t}} d$ where:
  - b_{t} is the mean width of the tension zone
  - d is the effective depth
  - f_{ctm} is determined from Table 3.2 of EC2
  - f_{yk} is the characteristic yield strength
- For concrete Grade 30/37 and f_{yk} = 500 MPa
  $A_{\text{s,min}} = 0.0015\, b_{\text{t}}\, d$
- This also applies for nominal reinforcement.
- Minimum bottom reinforcement in direction of span:
  40% of the maximum required reinforcement.
- Minimum top reinforcement at support (e.g. where partial fixity exists):
  25% of the maximum required reinforcement in span, but not less than $A_{\text{s,min}}$. This may be reduced to 15% for an end support.
- Secondary transverse reinforcement:
  20% of main reinforcement except where there is no transverse bending (e.g. near continuous wall supports).
- Preferred minimum diameter: 10mm.

Cantilever slabs

- For exposed cantilevers where shrinkage and temperature significantly affect the deflection, the area of bottom reinforcement in the direction of span should relate to the top reinforcement (say 50%).

Ribbed slabs

- Minimum bar diameter in rib: 16mm.
- Minimum reinforcement in flange as for single way slabs.
- If fabric is used, the spacing of wires should not exceed half the pitch of ribs.

Bar spacing
(EC2, Clauses 8.2 and 9.3.1.1)
Recommended minimum pitch of reinforcing bars
75mm (100mm for laps).

Maximum pitch of bars

- Main bars: $3h \leqslant 400$mm (in areas of concentrated loads $2h \leqslant 250$mm)
- Secondary bars: $3.5h \leqslant 450$mm (in areas of concentrated loads $3h \leqslant 400$mm)

Anchorage and lapping of bars
(EC2, Clauses 8.4 and 8.7)
For high yield and 500 Grade steel Table 6.1 gives typical anchorage and lap lengths for 'good' and 'poor' bond conditions (see Figure 5.2).

For ends which are on 'direct supports' (see Figure 6.1) the anchorage length beyond the face of the support may be reduced to d but not less than the greater of $0.3 l_{b,rqd}$, 10ø or 100mm). Where loading is abnormally high or where point loads are close to the support reference should be made to EC2, Sections 8 and 9.

Lap lengths provided (for nominal bars, etc.) should not be less than 15 times the bar size or 200mm, whichever is greater.

The arrangement of lapped bars should comply with Figure 6.2.
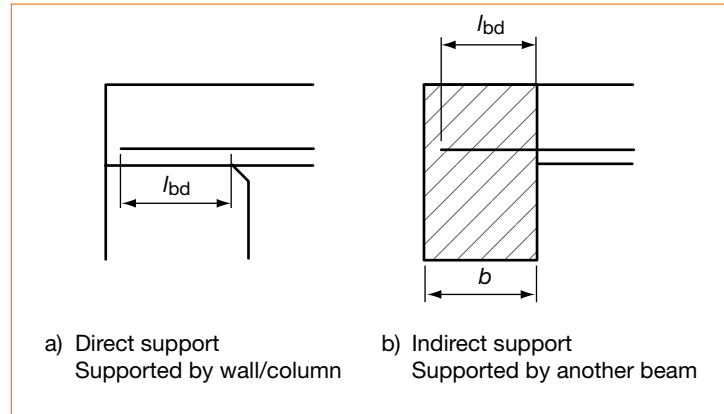
Figure 6.1 Anchorage of bottom reinforcement at end supports
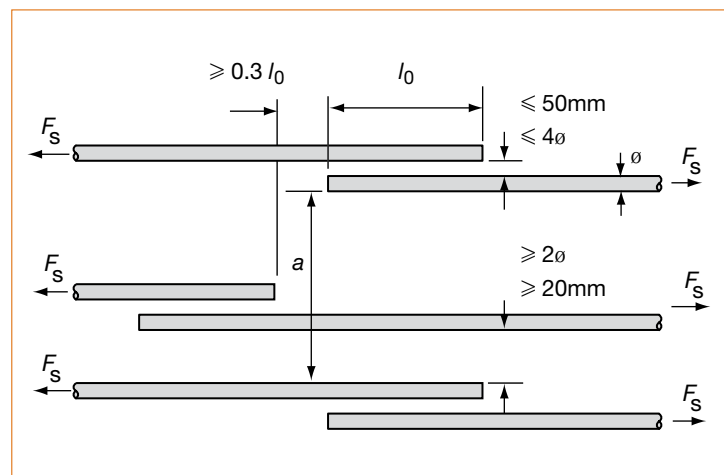
Figure 6.2 Adjacent laps

Table 6.1 Typical values of anchorage and lap lengths					
	Bond conditions	**Length in bar diameters**			
		f_{ck}/f_{cu} = 25/30	f_{ck}/f_{cu} = 28/35	f_{ck}/f_{cu} = 30/37	f_{ck}/f_{cu} = 32/40
Full tension and compression anchorage length, l_{bd}[1]	good	40	37	36	34
	poor	58	53	51	49
Full tension and compression lap length, l_0[2]	good	46	43	42	39
	poor	66	61	59	56

Notes
1 It is assumed that the bar size is not greater than 32mm and α_1, α_2, α_3, α_4 and α_5 all equal 1.
2 It is assumed that not more than 33% of the bars are lapped at one place, α_6 = 1.15.
For other situations refer to EC2, Clause 8.4.4.

Anchorage of bottom reinforcement at end supports
(EC2, Clauses 8.4.4 and 9.2.1.4)

The area of bottom reinforcement provided at supports with little or no end fixity assumed in design should be at least **0.25** that provided in the span.

Simplified rules for the curtailment of reinforcement

When only the minimum percentage of reinforcement is provided, it should not be curtailed.

Simplified rules for curtailment of bars may be used without bending moment diagrams, provided adjacent spans are approximately equal (within 15%) and provided that the loading is uniformly distributed. The curtailment rules for such conditions are shown in Model Details MS1 to MS5.

In other circumstances the curtailment of the main longitudinal reinforcement should be related to the bending/shear moment diagram (See 6.3.2). a_1 may be taken as d for slabs without shear reinforcement.

Where analysis is carried out for the single load case of all spans loaded (see 5.1.3 (1)P of the UK National Annex of EC2) and no shear reinforcement is required, the following simplified method for curtailment of bars may be used.

Top bars (see Figure 6.3)

Calculate the bar size and pitch for the maximum moment and check that twice the pitch for the half moment value does not exceed that permitted.

Calculate the bar length for alternate bars (a + b) and (c + d). If the difference is less than 500mm make the length of all bars equal to the greater value.

Stagger the bars alternately such that points (1) and (2) in sketch below are the outer limits.

Bars over end supports should also be alternately staggered and normally provided as two sets of U-bars.

Whilst not essential it is considered good practice to provide a continuous top mat over the central areas of slabs and flat slabs for the following reasons:
- to control shrinkage cracking
- to reduce deflections
- to remove trip hazards before and during concrete placement. This requires a mesh which is at least heavy enough to walk on. An A252 mesh is recommended as a minimum.

Bottom bars (see Figure 6.4)

Calculate the bar size and pitch for the maximum moment and check that twice the pitch for the half moment value does not exceed that permitted.
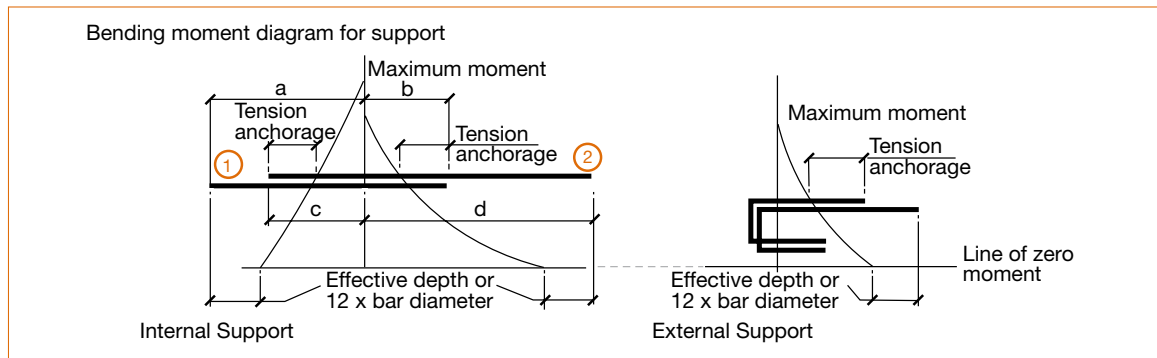
Figure 6.3 Simplified curtailment rules for top bars
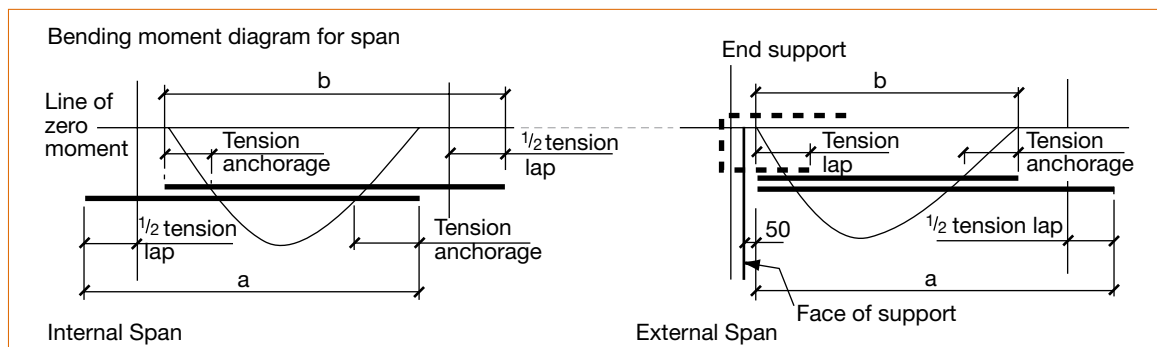
Figure 6.4 Simplified curtailment rules for bottom bars

For internal bays the bar length for all bars should be the greater of 'a' and 'b'. Alternate bars should be staggered as shown.

For end bays the length of alternate bars should be 'a' and 'b'

Notation for the 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:

*   abbreviation for top outer layer   **T1**
*   abbreviation for top second layer   **T2**
*   abbreviation for bottom second layer **B2**
*   abbreviation for bottom outer layer   **B1**

The sketch and notation should be stated on each drawing.
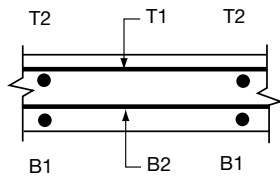
Typical bar and indicator lines

Generally each bar mark is represented on plan by 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.

*   one bar only
    1H10-63-T1

*   two bars
    2H10-63-150T1

*   a zone of three of more bars
    20H10-63-150T1

*   multiple zones, showing similar marks in each zone, with quantities indicated in brackets
    20H10-63-150T1   (12)   (8)

*   multiple zones, showing dissimilar marks in each zone
    12H10-63-150T1   63   64
    8H20-64-200T1
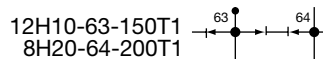
Generally the 'calling up' of bars is located at the periphery of the detail or an extension of the indicator line, as shown above.

*   when space is restricted 'calling up' can be written within the zone of the indicator line,
    20H10-63   150T1
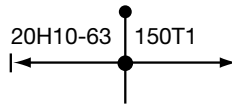
*   or in extreme cases, written along the bar itself
    20H10-63   150T1
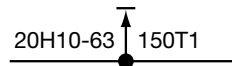
*   instructions to stagger bars of same mark
    Stg.
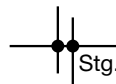
*   instructions to alternate bars of different mark
    63   64
    Alt.
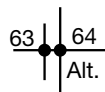
Bars detailed 'elsewhere'
These are shown as a thick dashed line

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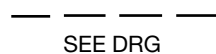
Bars set out from a radius in a 'fan' zone
The indicator line can be located on a datum radius for measuring the pitch of the bars. Locate end of bars to datum.
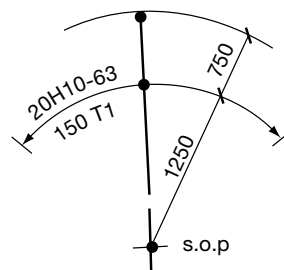
Bars of varying length in a zone

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.

20H10-63 (a to v‾)-150 T1

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.

3x8H10-63-
min. lap | 150 B2
300
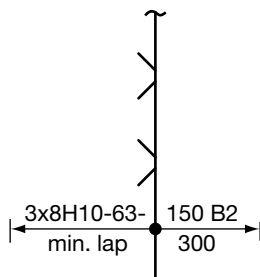
Cranked and bent bars

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.

63
64 Alt.

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.

1750
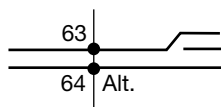
Bars in elevation

Bars in elevation are represented by thick line with mark indicator. First and last bars in a zone are indicated by a dot in section with appropriate mark.

64
63
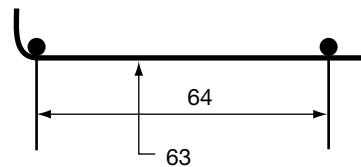
Curtailed bars are identified by short 30° obliques with appropriate mark. If the bars are congested the ends should be clarified with pointers.

2   3
2
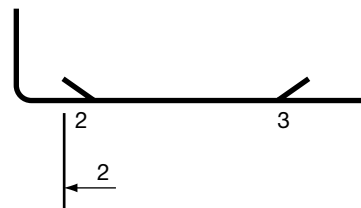
Two way slabs

The recommended arrangement of reinforcement into strips and areas is as shown in Figure 6.5.

Bars in the edge strips should be the same length and diameter as those in the middle strips, but the pitch may be increased to give the minimum reinforcement permitted.

Flat slabs (EC2, Clause 9.4)

The detailing strips shown in Figure 6.6 are for analysis by an equivalent frame method or by the use of coefficients.

Internal panels

Each bay is divided into column and middle strips as shown. The width of column strip in both directions is normally half the shorter panel dimension. Where column drops are used, the column strip is set equal to their width. For aspect ratios greater than 2, the centre of the panel behaves as if spanning one way. Distribution reinforcement should be placed in this strip, parallel to the short side.

Otherwise Table 6.2 indicates the proportion of reinforcement which should be placed in each strip.

Table 6.2 Simplified apportionment of bending moment for a flat slab		
	Negative moments	Positive moments
Column strip	75%	55%
Middle strip	25%	45%
Note Total negative and positive moments to be resisted by the column and middle strips together should always add up to 100%.		
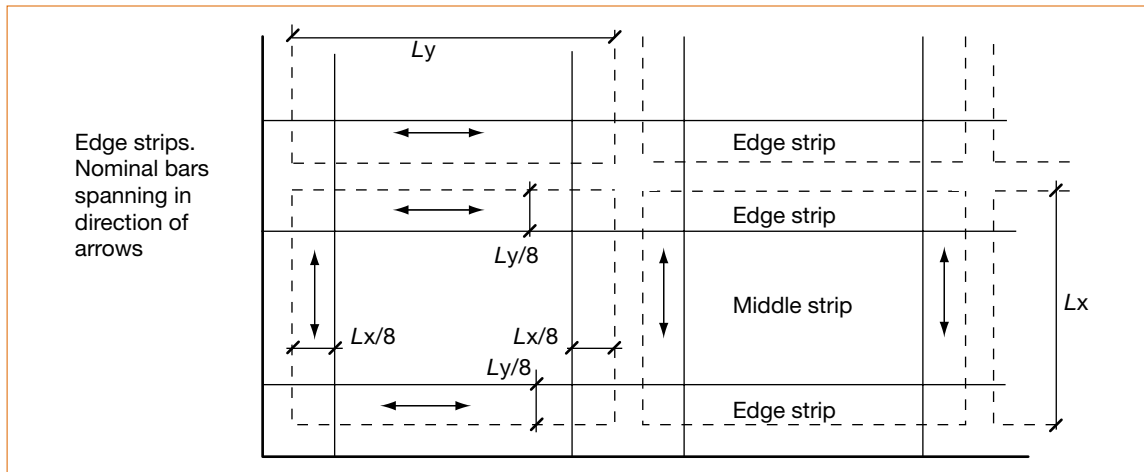
Figure 6.5 Arrangement for reinforcement strips for two-way slabs
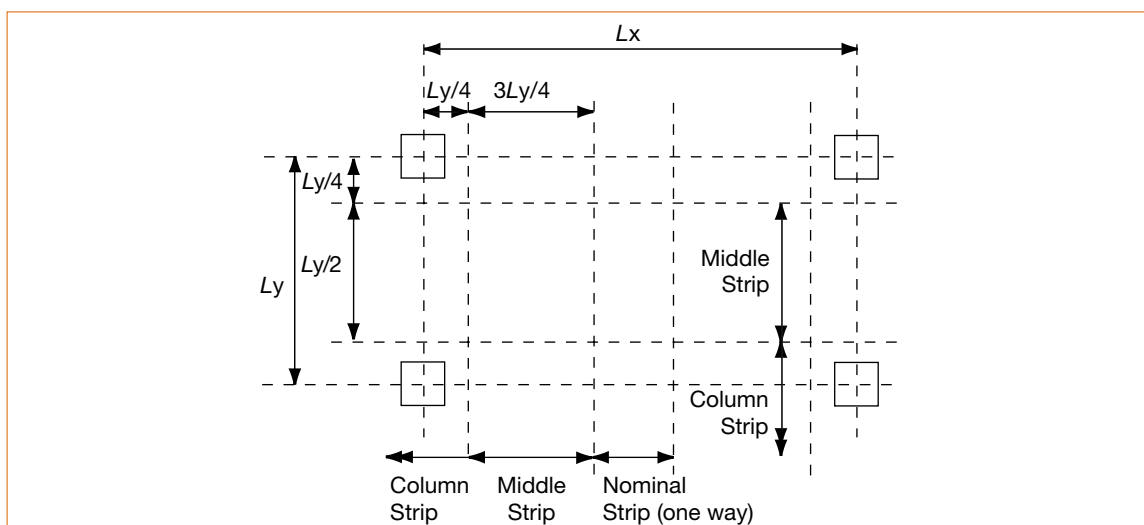
Figure 6.6 Division of reinforcement strips for flat slabs
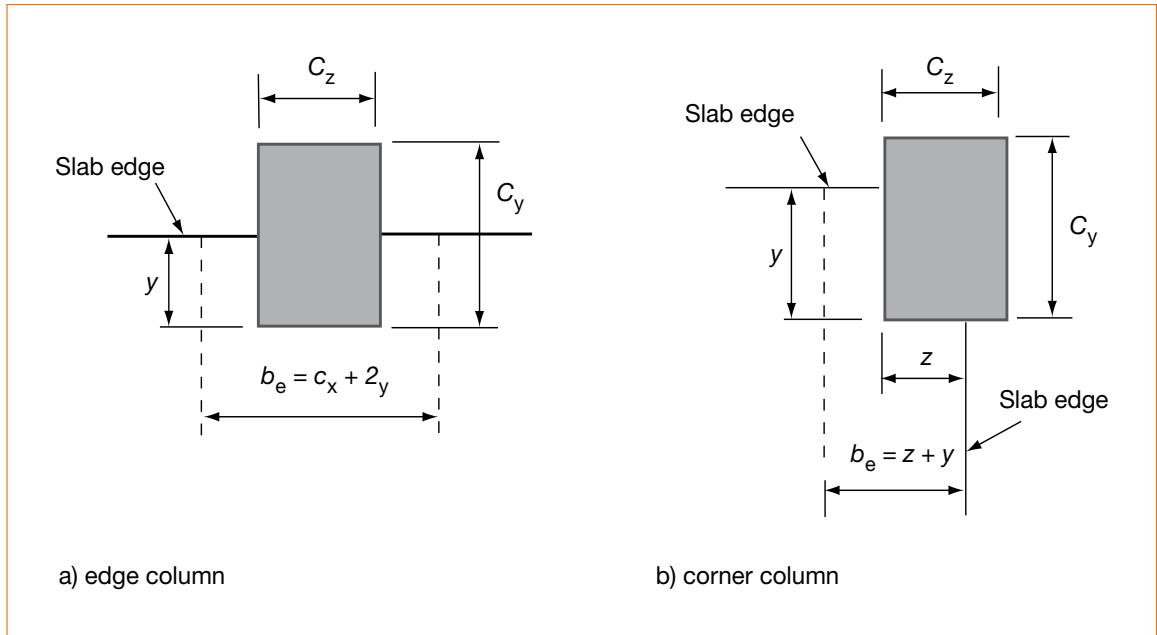
Figure 6.7 Effective width, b_e, of a flat slab

In general two thirds of the amount of reinforcement required to resist negative moment in the column strip should be placed in a width equal to half that of the column strip and central with the column

Note
These rules comply with EC2, Clause 9.4.1 (2).

At least two bottom bars should pass through the column.

Slab at edge and corner columns
The reinforcement perpendicular to a free edge which is required to transmit moments from the slab to an edge or corner column should be placed within the effective width as shown in Figure 6.7. Nominal reinforcement should be placed along the remainder of the edge.
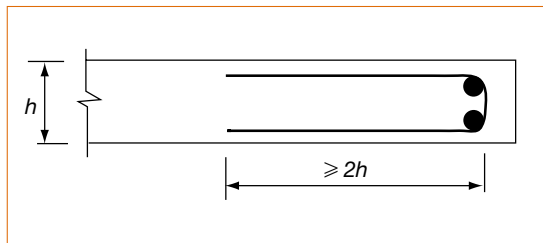
Figure 6.8 Edge reinforcement for a slab

Edge reinforcement
(EC2, Clauses 9.3.1.4 and 9.3.1.4)
Reinforcement should be placed along free (unsupported) edges of slabs and at corners that are supported on both sides. This allows the distribution of local loads which helps to prevent unacceptable cracking.

This reinforcement may be supplied in the form of U-bars as shown in Figure 6.8.

Where the corners of slabs are held down the bars should extend into the slab a minimum distance of at least one fifth of the shorter span as shown in Figure 6.9. The area of this torsion reinforcement required in each leg should be at least three quarters of the area required for the maximum mid-span design moments in the slab. Only half this area is required at a corner with only one discontinuous edge.

Trimming holes in a slab
- 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.
- 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 = 1000mm
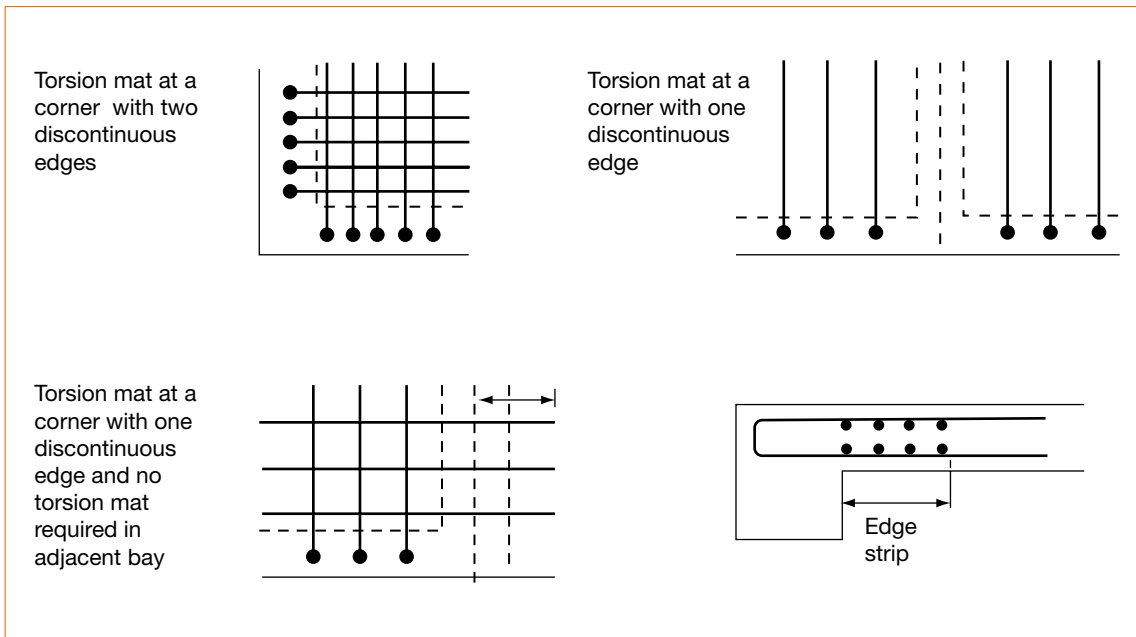
Figure 6.9 Torsion reinforcement at slab corners

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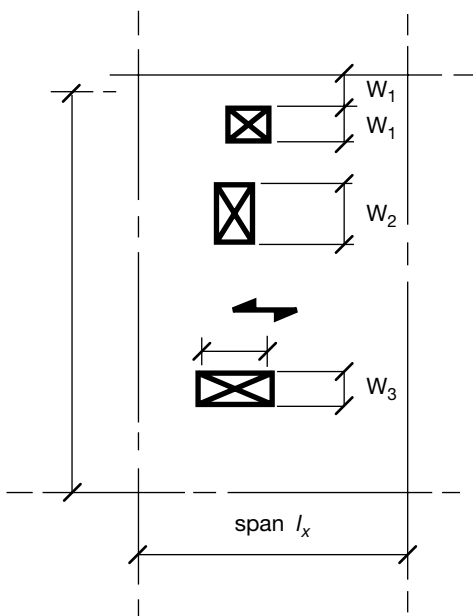
(v) small isolated holes with sides 150mm or less can generally be ignored structurally. Significant holes should be drawn to scale and shown on the reinforcement drawing

(vi) larger isolated holes with sides 500mm or less either: displace affected bars equally either side of hole (see MS1 for spacing details)

or:
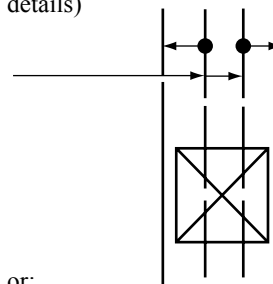
cut or slide back affected bars to face of hole. Compensating bars of equal area should be provided to trim all sides. Trimmers should extend a minimum 45ø (nominal anchorage length) beyond the hole
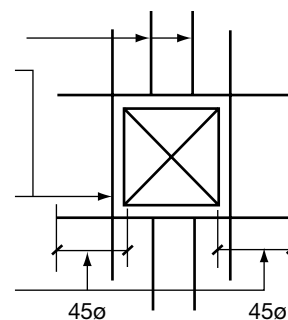
(vii) large isolated holes with sides 500 – 1000 mm. Treat as (vi) above, but in addition trim top of holes with similar bars. If depth of slab exceeds 250mm, where practical, provide diagonal reinforcement of similar area in top and bottom, but consideration should be given to the congestion of multiple layers
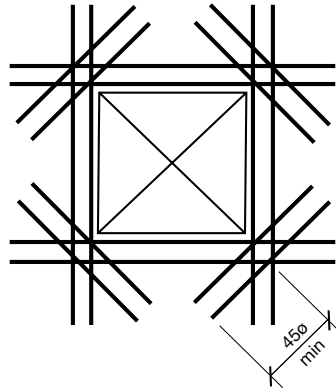
(viii) groups of holes within boundary of 500mm or less. Trim as single hole using methods described in (vi) above. Bars should pass alongside holes where possible
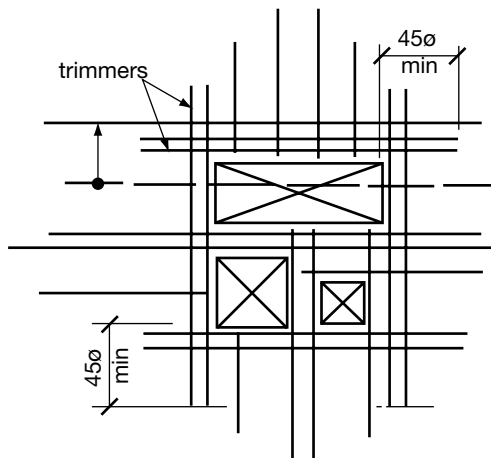
(ix) groups of holes within boundary of 500 – 1000 mm or less. Trim as single hole using methods described in (vi) and (vii) above

Secondary reinforcement (EC2, Clause 9.3.1)

Distribution reinforcement is provided at right angles to the main tensile reinforcement in all circumstances where other main reinforcement is not already included.

Fabric reinforcement (either as loose bars or a welded mat) may be required to control cracking due to shrinkage and temperature in:
- the whole of the top surface of the slab
- the bottom of solid areas around columns of coffered slab construction
- the bottom of solid areas of troughed slabs adjacent to beams.

If welded fabric is used for coffered and troughed slabs it is essential to check that sufficient depth has been given to fit all the layers of reinforcement at the laps in the fabric. This must include, for coffered slabs, two layers of main tension bars together with at least two layers of fabric. Normally the top main tension bars will be positioned to lie within the width of the ribs, even in the solid area of the slab as shown in Model Detail MS8. Although this allows the bars to be fitted with sufficient cover it reduces the effective lever arm.

Supplementary reinforcement may be required in coffered and troughed slabs for fire protection. This should be provided by links and lacer bars for coffered slabs and welded fabric, D49, for troughed slabs as indicated in Model Detail MS8.

Additional reinforcement may be required in prestressed concrete to resist bursting tensile forces in end zones, and to control cracking from restraint to shrinkage due to formwork, before the prestress is applied.

Fabric reinforcement
General
See 4.2.5 and 5.1.10.

Suspended solid floor construction
Where the lever arm is important, the orientation should indicate the level of the primary reinforcement.

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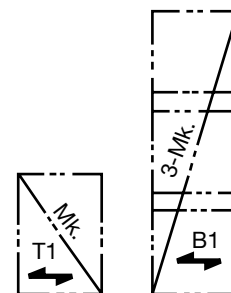
- **Fabric detailing on plan**. Each individual sheet is given a mark number and related on plan to the concrete outline. Indicate the direction of the main reinforcement and its layer notation. Wherever multiple sheets of identical marks occur they can be combined as shown.

Areas of reinforcement can be increased by double 'layering'.
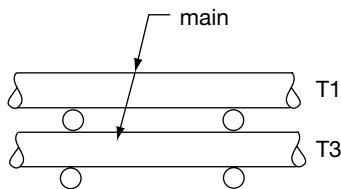
Also consider the possible advantages of 'nesting' the two sheets to maximize the lever arm.
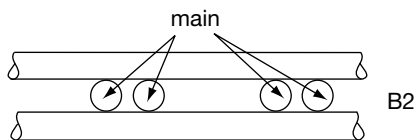
Similarly 'nesting' when main steel is required in two directions, crossing at 90°.
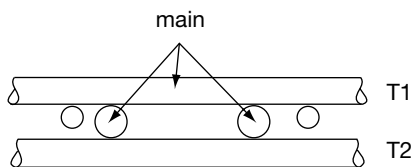
Areas of steel can be increased either by layering, or by using the 'C' fabrics as one directional sheets, laid perpendicularly in two layers. The main bars should always be in the same direction, (e.g. facing down)
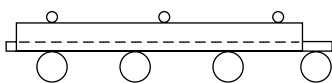
Structural fabric type 'B' is often specified for suspended slabs, possibly with the addition of loose bars. With reasonable production runs, consideration should be given to specifying 'purpose-made' fabric. For each fabric mark indicate its reinforcement in a table alongside the plan.

- **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.
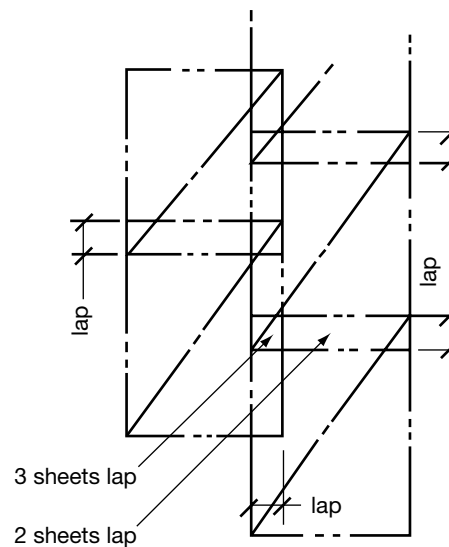
Voided-slab construction

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 m² 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 the method of working. Where more comprehensive detailing of fabric sheets is required, manufacturers will often be able to assist.

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.
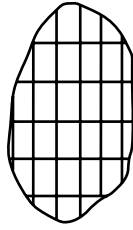
Roll mat reinforcement

Reinforcing bars in a 'roll mat' are connected by steel tapes welded to the reinforcement to ensure the correct spacing. The mats are conveyed to site rolled up and are unrolled in the required layer of the slab. The fixing of the spacers to support the mats is more complicated than for fixing loose bars, but the advantages of this system include:

- Time saving. Rolling out a mat takes minutes compared with hours fixing loose bars.
- Less labour. Rolling out a mat requires only two or three people.

It should be noted that where the roll mat uses bars cut from rod reinforcement (>20mm diameter), if variable lengths are specified this could lead to large wastage of steel from off-cuts. This is not the case where the bars are cut from coils.

It is important to recognise the handling requirements, as well as the possible need to strengthen falsework and spacers to accommodate the initial loading from the roll.

Shear reinforcement in flat slabs (EC2, Clauses 6.4.5 and 9.4.3)

Where punching shear reinforcement is required it should be placed between the loaded area/column and **1.5d** inside the control perimeter at which shear reinforcement is no longer required, subject to a minimum of 1.5d from the column. It should be provided in at least two perimeters of link legs (see Figure 6.10). The spacing of the link leg perimeters should not exceed 0.75d.

The spacing of link legs around a perimeter should not exceed 1.5d within the first control perimeter (2d from loaded area), and should not exceed 2d for perimeters outside the first control perimeter where that part of the perimeter is assumed to contribute to the shear capacity (see Figure 6.10a).
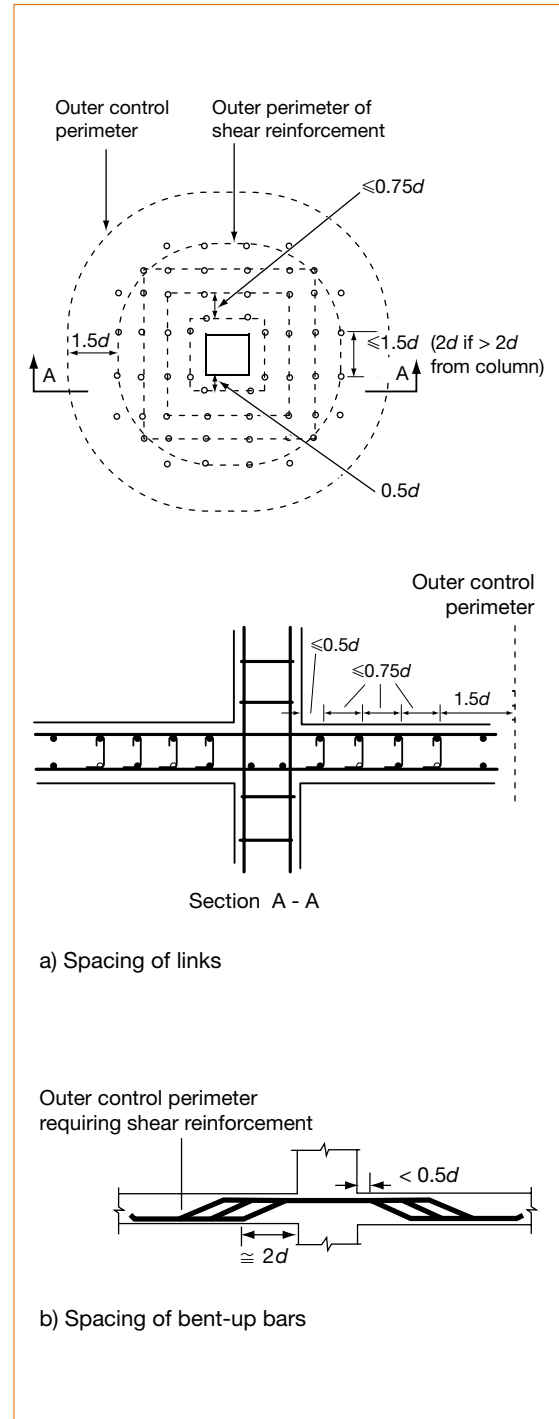
Figure 6.10 Punching shear reinforcement

As the traditional method of fixing conventional shear reinforcement is laborious and time consuming prefabricated shear reinforcement systems should be considered when construction time is limited. It is recommended that the use of these systems is limited to punching shear and not extended to general slab reinforcement. The following examples of proprietary systems are currently available.

Stud rail system (see Figure 6.11)

This system consists of a series of studs with nail heads welded onto a flat strip. These rails are often placed radially so as to fan out from each column and can be lifted easily into position. Although simple to incorporate into a conventional design, care should be taken in construction to ensure adequate cover to rails. Orthogonal layouts use more studs but are less likely to clash with the main reinforcing bars and more likely to satisfy the spacing requirements.

a) Placed radially

Orthogonal grid to fit main bar spacing

Parallel to bottom mat, covers unaffected

Perpendicular to bottom layer ∴ mat pushed up (should not be critical)

Spacer to stud rail

Bottom rail with cover spacers to rail preferred

b) Placed orthogonally
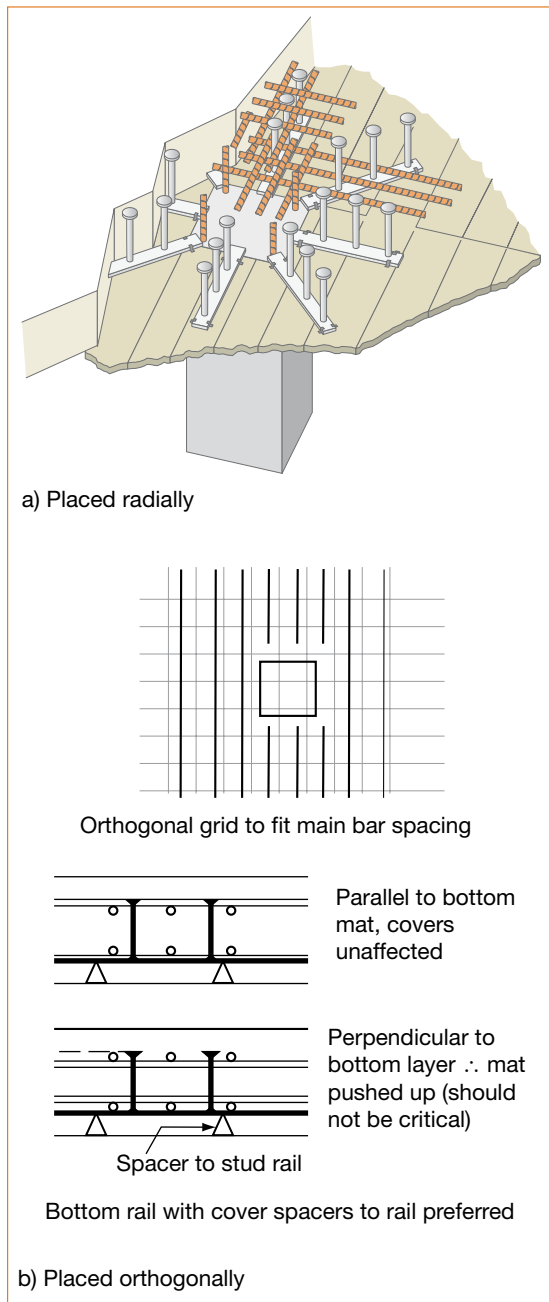
Figure 6.11 Stud rail system

Shear ladders (See Figure 6.12)

This is a system of prefabricated links welded to longitudinal bars to form 'ladders' which can be fixed easily with the normal reinforcement.

Structural steel shear head

This system forms a column head of steel cross members, sometimes welded to a perimeter of channels facing outwards. These can easily be placed on reinforced concrete columns or pre-welded to steel columns. This method has the advantage of allowing holes to be placed close to the column.

Others

Other types of proprietary systems (e.g. 'flying saucers', shear bands etc.).

Centres of ladders

Centres of links

Col.

Plan

Shear ladder also serves as support to top layer reinforcement
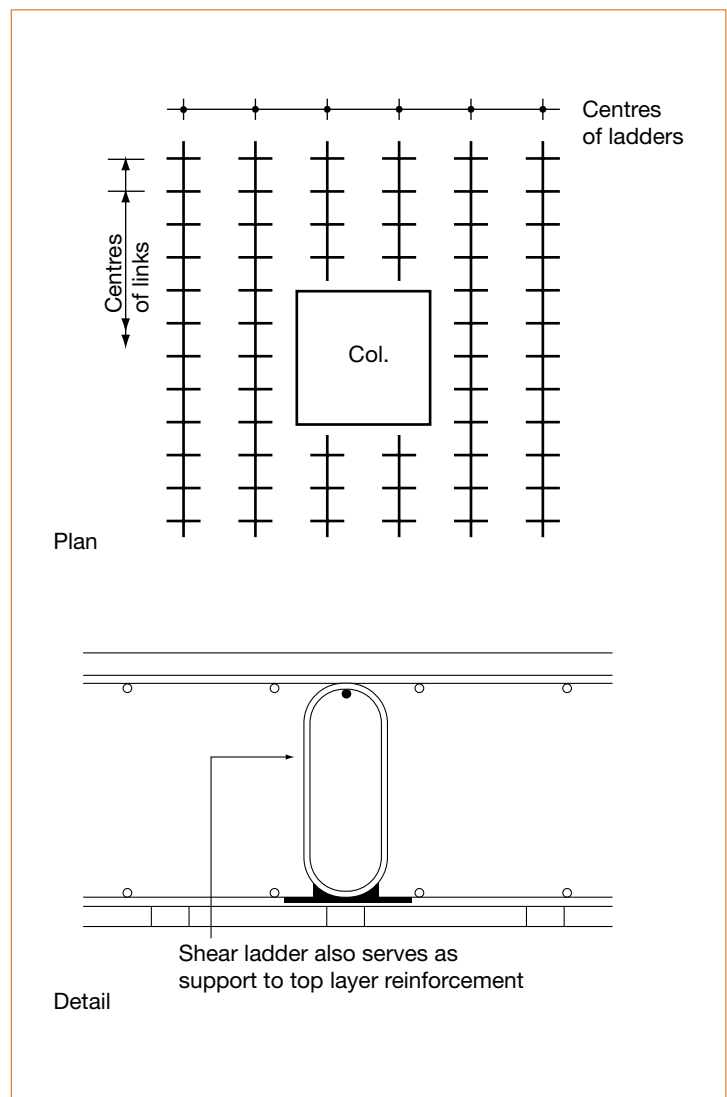
Detail

Figure 6.12 Typical arrangement of shear ladders

Connection to walls

For simply supported conditions (e.g. a roof supported by brickwork) the details given in Model Detail MS3 are relevant.

For conditions where the wall continues above and below the slab the details given in Model Detail MS2A are relevant. However, for situations where the transfer of bending moment from slab to wall is large it may be necessary to pass the top reinforcement from the slab down into the wall (see Model Details MS2B and C). It may be necessary to give such bars easy bends (see 5.1.8).

In situations where the construction process requires that edge bars are cast flush with the face of the wall and then have to be rebent to project into the slab proprietary systems are available.

Movement/construction joints

Mechanical shear sliding dowels may be considered instead of half joints to avoid the use of nibs. The following systems are currently available (see Figure 6.13).

Double dowel system (see Figure 6.13a)

A connection which provides a robust mechanical shear transfer with a sliding joint. This allows a contraction and expansion between the two connected pieces of structure.

a) Double dowel system

b) Single dowel system
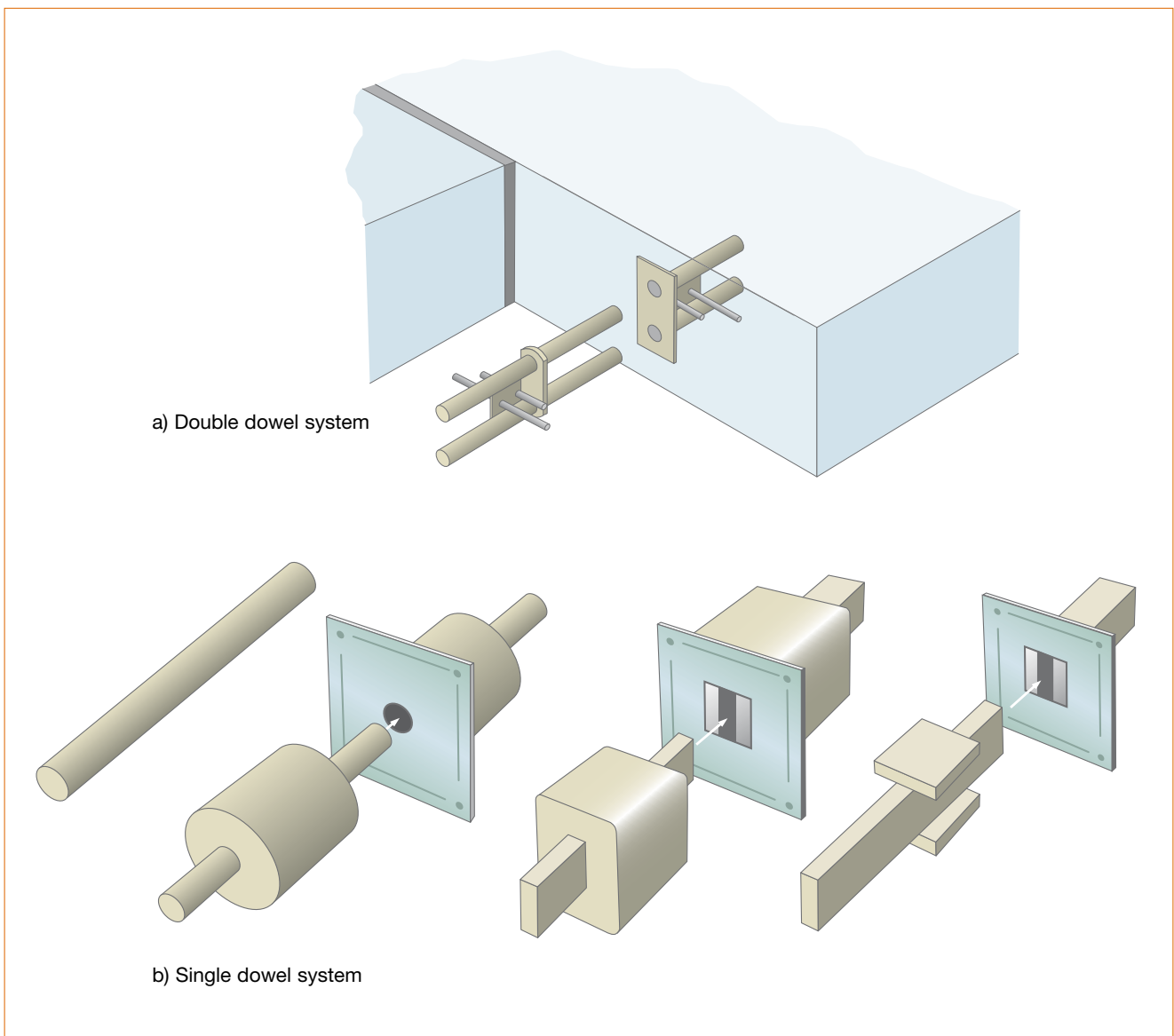
Figure 6.13 Dowel systems

6.2.3 Detailing information

Design information for detailing should include:

- Layout and section drawings including details of holes and upstands, etc.
- Concrete grade and aggregate size (standard 30/37 MPa and 20mm).
- Nominal cover to reinforcement and controlling design consideration, fire or durability (standard 20mm for internal conditions 40mm for external conditions).
- Main reinforcement bar runs and positions. This should include:
  - diameter, pitch of bars and location (e.g. T1, T2, B1, B2, etc.)
  - type of reinforcement and bond characteristics (standard: H)
  - fixing dimensions to position bar runs and ends of bars.

- Details of any special moment bars connecting slab to wall or column.
- Details of cut off rules, if other than standard shown in Model Details.
- Details of fabric required. For coffered slabs this should include the fabric required in the topping and in the bottom of solid sections around columns. Sufficient details should be given to show that the reinforcement will fit in the depth available allowing for laps in the fabric. Guidance should be given for the additional area required for laps otherwise 22% will be assumed for 300mm laps.
- Details of insertions, e.g. conduit, cable ducting, cladding fixings, etc., should be given where placing of reinforcement is affected.

Flat slabs: [Cover should be shown]

BAY A

1 – 1

2 – 2

SEE SLAB
DRG. R012

KEY PLAN

Coffered slab: [Cover should be shown]

PLAN

1 - 1

2 - 2

Shear reinforcement for flat slabs: [Cover should be shown]

H12 10 LACERS
AS REQUIRED

8   32 H8 09 LINKS

8   32 H8 09 LINKS

8   32 H8 09 LINKS

400   400

8   8   8   8   8   8

8

8

8

Columns 2/R, 2/S, 2/T
30 No THUS

275   275   275

MAIN SLAB TOP REINF'T
SEE DRG R010

10   10

09   09

10   10   10   10   10   10

MAIN SLAB BOTTOM REINF'T
SEE DRG R011

H12 10 HANGER BARS
WHERE REQUIRED

SECTION 1 - 1

LINKS TO BE SPACED AROUND
EACH PERIMETER, MAX PITCH
550. PROVIDE H12 10 HANGER
BARS WHERE MAIN REINF'T IS
NOT AVAILABLE

SLABS MS1

One and two way slabs
Span and internal support

For edge support details see Model Detail MS2
Nominal cover specified by designer (At least 20 or bar size whichever is greater)
Generally curtailment of the main longitudinal reinforcement should relate to the bending moment diagram. See design and detailing notes 6.2.2.

Pitch of distribution bars as given in table, unless otherwise specified. Not less than 2 No. bars

Top bars alternately staggered as shown, unless otherwise specified

0.1 x short span or 600 whichever is shorter

0.3 x span   0.3 x span

0.5 x p¹
p¹

optional mesh

p
0.5 x p

0.5 x tension lap

Bottom bars of length 0.8 x span + 0.5 x tension lap alternately reversed as shown, unless otherwise specified

Pitch of distribution bars (mm)

Bar size (mm)	Slab depth (mm)												
	100	125	150	175	200	225	250	275	300	325	350	375	400
10	350	425	425	350	300	275	225	200	200	175	150	150	125
12	—	—	450	450	450	400	350	325	275	250	250	250	200
16	—	—	—	—	—	450	450	450	450	450	425	400	375

SLABS MS2
One and two way slabs
External restrained supports

Distribution bars as for Model Detail MS1
Nominal cover specified by designer (At least 20 or bar size whichever is greater)

This detail is used when 'X' is more than an anchorage length. Otherwise details 'B' or 'C' are used

The area of 'U' bars equals half the bottom steel at mid span unless otherwise specified

A bar is placed inside each corner

0.3 x span

0.5 x p¹   p¹

0.1 x span or 600 whichever is smaller

'U' bars alternately placed

'X'

50

500 or tension lap whichever is greater

DETAIL 'A'

This detail is used when 'X' is less than an anchorage length, provided that the bearing stress inside the standard bend does not exceed the limit. Otherwise detail 'C' is used

Tension anchorage length

Curtailment of top bars in slab as specified. Minimum as for detail 'A'

p

0.5 x p

Bars extending down into wall from slab should be detailed with the wall drawings wherever possible. Otherwise they must be clearly cross referenced

DETAIL 'B'

This detail is used when the bearing stress inside the bend requires a non-standard radius of bend

Tension anchorage length

Curtailment of top bars in slab as specified. Minimum as for detail 'A'

Bars extending down into wall from slab should be detailed with the wall drawings wherever possible. Otherwise they must be clearly cross referenced

DETAIL 'C'

SLABS   MS3
One and two way slabs
External unrestrained supports

These details also apply to free edges

Distribution bars as for Model Detail MS1

Nominal cover specified by designer (At least 20 or bar size whichever is greater)

This detail is used for slab depth 150 or greater. Details 'B' or 'C' are used for slab depth less than 150

End 'U' bars are same dia. as bottom bars
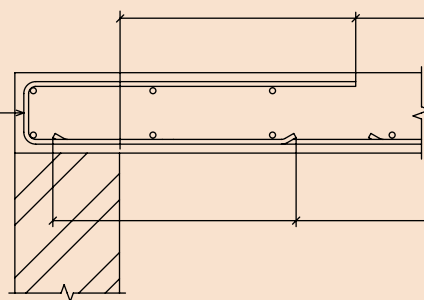
0.1 x span or 45 x bar dia. whichever is greater

500 or tension lap whichever is greater

DETAIL 'A'
(Slab depth 150 or greater)

This detail is used for support width less than 200. Otherwise detail 'C' is used

The greater of d, 0.3 lb, rqd, 10 times bar dia. or 100 (see 6.2.2)

Bobbed bars may be laid over to ensure sufficient top cover

Support width
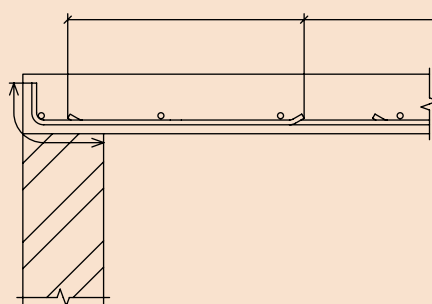
500 or tension lap whichever is greater

DETAIL 'B'
(Slab depth less than 150)

This details used for support width 200 or more.

Otherwise detail 'B' is used.

This detail is also suitable for fabric reinforcement

Support width
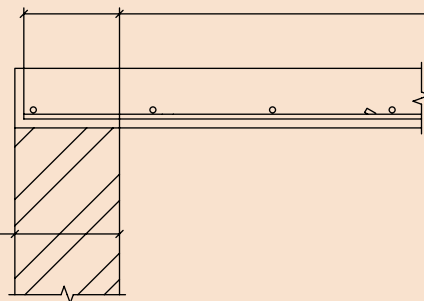
The greater of d, 0.3 lb, rqd, 10 times bar dia. or 100 (see 6.2.2)

DETAIL 'C'
(Slab depth less than 150)

SLABS MS4
Cantilever slabs

Distribution bars as for Model Detail MS1
Nominal cover specified by designer (At least 20 or bar size whichever is greater)

The length of main cantilever top bars should be specified. They should be a minimum of 2 x cantilever length over simple supports alternately staggered as shown

300

0.5 x cantilever minimum

0.5 x tension lap

Area of bottom reinforcement should be at least 0.5 x area of top reinforcement to control deflection

'U' bar ensures lever arm retained
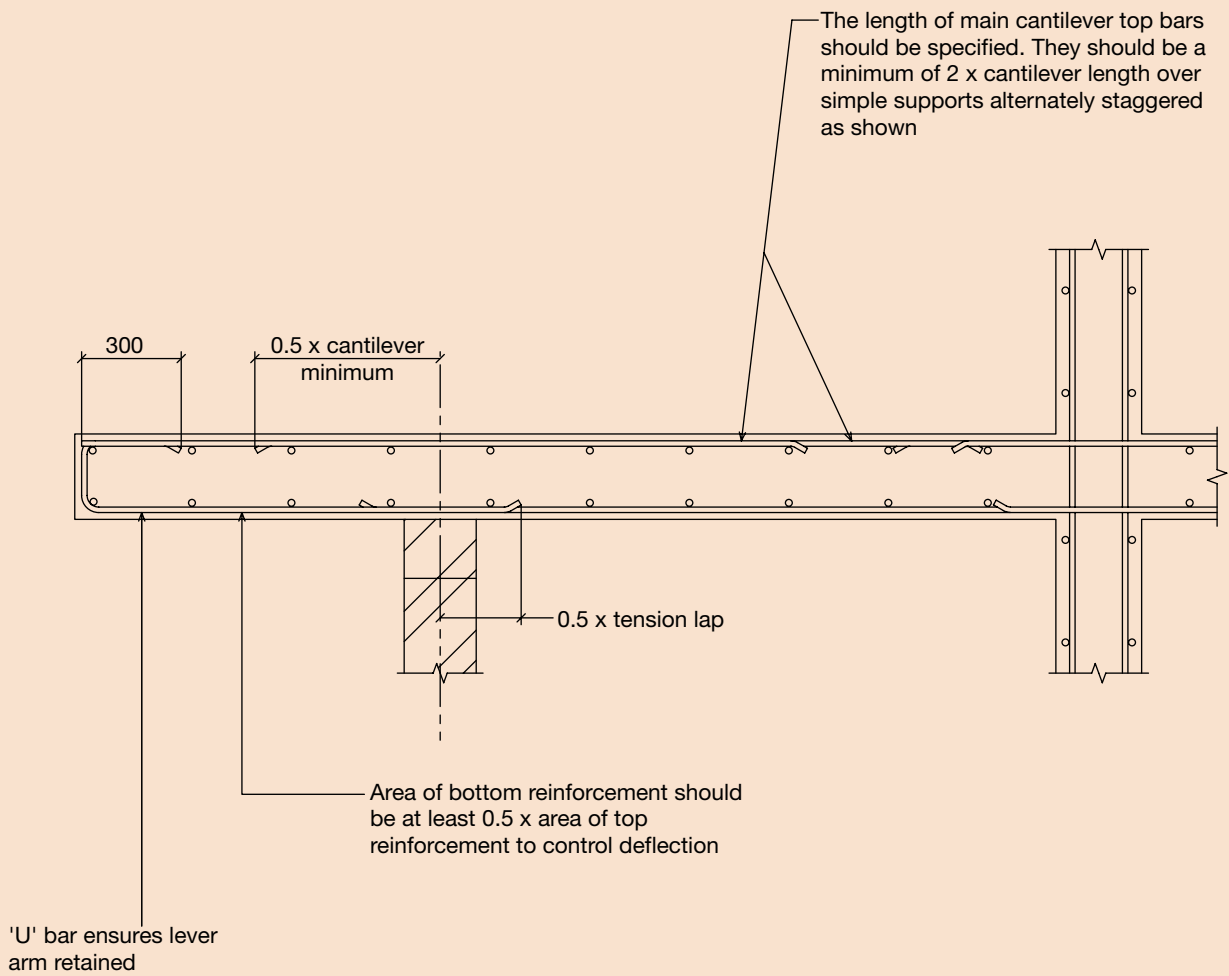
SLABS   MS5
Flat slabs
Span and internal support

Edge details include a 'U' bar as shown in Model Detail MS2 A

Curtailment of main bars as for Model Detail MS1

Nominal cover specified by designer (At least 20 or bar size whichever is greater)

When equivalent column dia. is less than 0.15 x width of panel $\frac{2}{3}$ of the bars for this strip should be placed in the centre half

Distribution bars* of length 0.6 x span. Pitch as for Model Detail MS1

p_1^1 p_1^1 p_1^1 p_1^1 p_2^1 p_2^1

$2 \times p_1$

$2 \times p_2$

Two bottom bars should pass through column

Middle strip

Column strip

SECTION OF COLUMN STRIP

optional mesh

p_1 p_1 p_1

p_2 p_2

SECTION OF MIDDLE STRIP
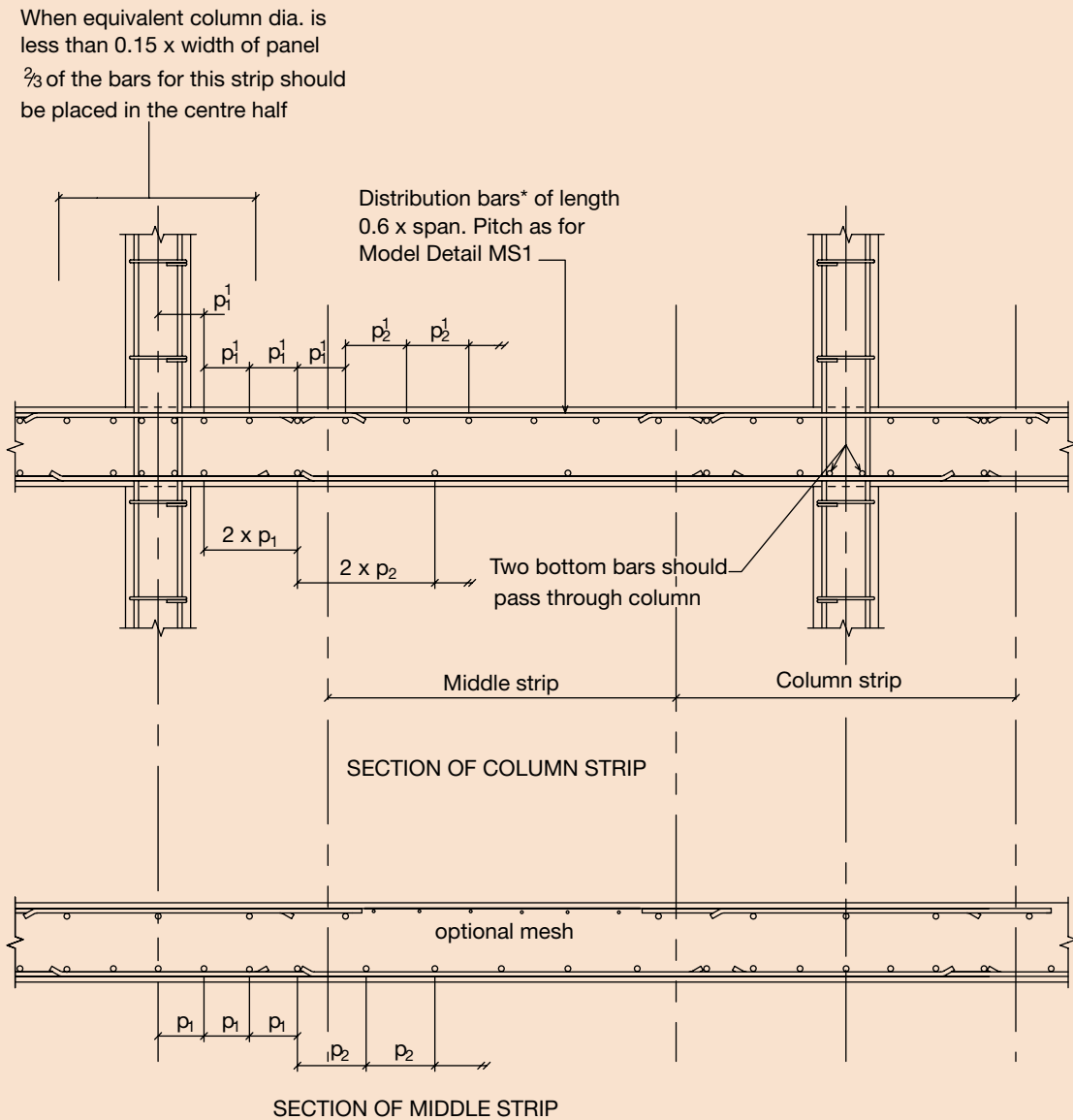
p_1^1: pitch of column strip top bars

p_2^1: pitch of middle strip top bars

p_1 : pitch of column strip bottom bars

p_2 : pitch of middle strip bottom bars

Bars of the longer span are placed in the outer layer unless otherwise specified

Note

* Where the fire rating is R90 and above, the area of the distribution bars should be at least 20% of the total design top reinforcement required.

SLABS   MS6

Flat slabs
Shear reinforcement

Curtailment of main bars as for Model Detail MS1

Nominal cover specified by designer (At least 20 or bar size whichever is greater)

The links may be fixed to the same
levels of reinforcement wherever they
occur on the perimeter, provided that
nominal hanger bars are included
wherever necessary

0.75d   0.75d   0.5d

d

10ø but ⩾ 70
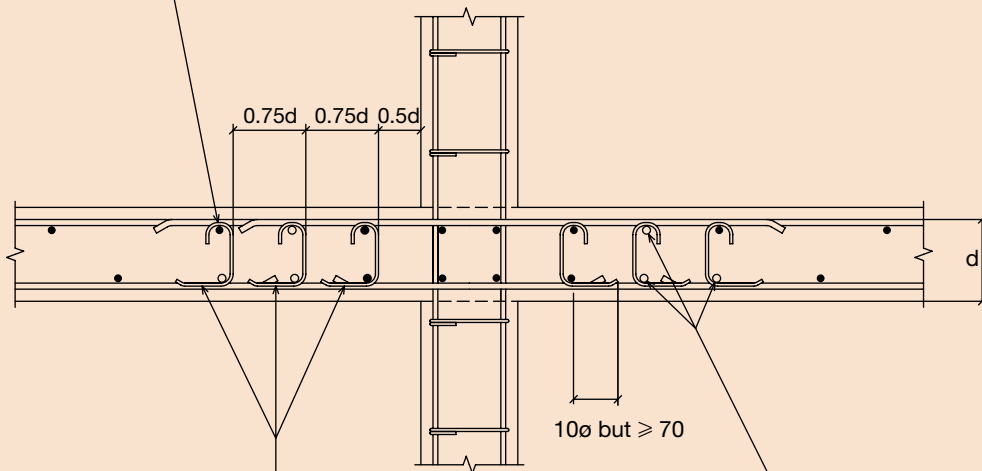
Links should be placed on rectangular plan
perimeters spaced as shown from column
face. The links are spaced evenly around each
perimeter with a maximum pitch of 1.5d within
2d from the column face and a maximum
pitch of 2d outside this

12 dia. fixing bars are required to
locate the links in those positions
where main reinforcement is not
present. These bars should
extend a tension anchorage
beyond the last link

SLABS   MS7
Flat slabs
Column drops

This detail is not suitable when the bottom steel in the column drop is used in design
In such circumstances the reinforcement details should be specified by the designer
Nominal cover specified by designer (At least 20 or bar size which ever is greater)

75 minimum
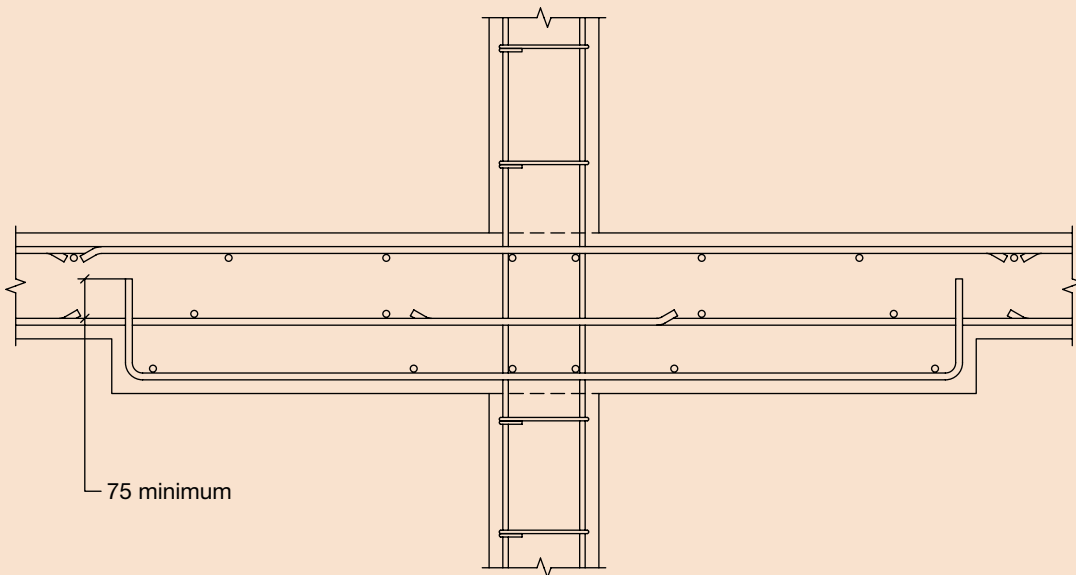
The main bottom bars are carried through
the column drop. Nominal reinforcement is
provided in the bottom of the drop.

12 dia. bars at 300 pitch

SLABS   MS8
Ribbed and coffered slabs

Nominal cover specified by designer (At least 20 or bar size whichever is greater)

Nominal fabric A252 is provided, unless otherwise specified. If greater than nominal mesh used, check lap lengths to EC2, Cl 8.7.5

Special care should be given to ensure sufficient cover where fabric overlaps

300 unless otherwise specified
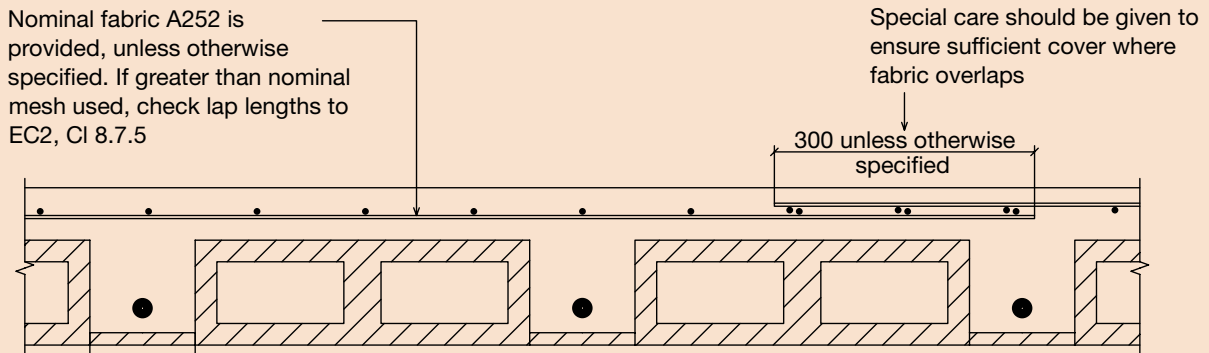
In order to ensure flow of concrete into bottom of ribs the minimum width of rib for:-
i) one bar is 75
ii) two bars side by side is 125

DETAIL 'A'
(Hollow pot)

300 unless otherwise specified

Nominal fabric A252 is provided, unless otherwise specified

Closed links should be provided if required for shear

12 dia. lacing bars are provided if overall depth exceeds 750

12d minimum

If cover exceeds 40 supplementary reinforcement may be required for fire resistance. This is provided by 6mm links as shown (Max. pitch 200) plus nominal lacer bar for coffered slabs

DETAIL 'B'
(Coffered slab)

DETAIL 'C'
(Coffered slab with supplementary reinforcement)

6.3 BEAMS

6.3.1 Scope

The information given relates to specifically to straight suspended beams with defined supports.

Ground beams are considered separately in 6.7 of this manual.

The detailing of holes in beams should not normally be carried out without specific design instructions. They can dramatically affect the structural safety of a beam.

6.3.2 Design and detailing notes

Concrete grade

For reinforced concrete the concrete grade is normally 30/37 MPa (cylinder strength/cube strength) with a maximum aggregate of 20mm.

Nominal cover to all reinforcement (EC2, Clause 4.4)

- Internal use: **30mm** + Δc_{dev} (Concrete inside buildings with low air humidity, XC1)
- External use: **35mm** + Δc_{dev} (Corrosion induced by carbonation, XC3)

See 5.2.1 for values of Δc_{dev}

Note

The cover to grouped bars should be for the equivalent bar size (see 5.8). Top cover may be determined by slab or transverse beam reinforcement.

For the purposes of 4 hour fire resistance, supplementary reinforcement may be required where the nominal cover exceeds 40mm (See EC2: Part 1.2, Clause 4.5.2; axis distance to the link reinforcement exceeds 70mm).

Minimum area of reinforcement (EC2, Clause 9.2.1.1)

Tension reinforcement

For concrete Grade 30/37 and f_{yk} = 500MPa

$A_{s,min} \geqslant 0.0015\ b_t\ d$

where b_t is the mean width of the tension zone

d is the effective depth

Compression reinforcement

$A_{sc,min} \geqslant 0.002\ A_c$

Transverse reinforcement in top flange

$A_{s,min} \geqslant 0.0015\ h_f\ l$

where h_f is depth of flange

l is the span of the beam

Minimum diameter

12mm

Bar spacing

Minimum horizontal pitch

75mm (sufficient space must be allowed for insertion of poker vibrator)

100mm for pairs of bars

Minimum vertical pitch

25mm or bar diameter, whichever is greater

Maximum pitch

The following simplified values may normally be used:

- *Tension bars:* The values given in Table 6.3 may normally be used. Unless otherwise stated it may be assumed that the service stress in the reinforcement is 310 MPa.

Table 6.3 Maximum bar spacing for crack control

Steel stress [MPa]	Maximum bar spacing [mm]		
	w_k=0.4mm	w_k=0.3mm	w_k=0.2mm
160	300	300	200
200	300	250	150
240	250	200	100
280	200	150	50
310	165	115	-
320	150	100	-
360	100	50	-

Note
The values in the table are reproduced from EC2, Table 7.3N

- *Compression bars:* 300mm, provided that all main bars in the compression zone are within 150mm of a restrained bar (see Figure 6.24).

Bars along side of beams (see EC2, Clause 7.3.3)

For beams with a total depth of 1000mm or more additional reinforcement is required to control cracking in the side of faces of the beam. As a simplification bars (16mm) should be placed along the sides inside the links at a maximum pitch of 250mm.

Links

$A_{sw}/s\ b_w \geqslant 0.085\%$

where A_{sw} is the cross-sectional area of the 2 legs of link

b_w is the average breadth of concrete below the upper flange

s spacing of link ($\leqslant$ 15ø of main compression bars)

Preferred minimum diameter 8mm.

Link spacing
Minimum pitch
100mm or [50 + 12.5 (No. of legs)]mm, whichever is greater. This ensures that the space taken up by links along the beam is not overlooked.

(See Model Details MB1 and MB2)

Maximum pitch
300mm or **0.75d** or 12×diameter of compression bar, whichever is least.

Maximum lateral pitch of legs
600mm or **0.75d**. The distance of a tension or compression bar from a vertical leg should not be greater than 150mm.

Anchorage and lapping of bars (EC2, Clauses 8.4 and 8.7)
Minimum anchorage length
Greater of 10ø or 100mm.

For high yield steel, 500 Grade and deformed bars, Table 6.4 gives typical anchorage and lap lengths for 'good' and 'poor' bond conditions (see 5.4).

Curtailment of longitudinal reinforcement in beams (EC2, Clauses 8.4.4 and 9.1.2.3)
Figure 6.14 shows a typical moment envelope.

The tension force, F_E, to be anchored may be determined by the shift rule:

$F_E = |V_{Ed}| \, a_l/z + N_{Ed}$ (See Figure 6.14 and EC2, Expression (9.3))

The required anchorage length, l_{bd}, is taken from the line of contact between beam and support.

Transverse pressure may be taken into account for 'direct' supports (α_5 in Table 8.2 of EC2, Clause 8.4.4).

The Designer should specify the curtailment length $l_{bd} + al$. Where nothing is specified the Detailer should assume that $al = 1.25d$.

Simplified curtailment rules
The following simplified rules with 'flexible detailing' (see Figure 6.15) may be applied to the secondary longitudinal reinforcement and for the main longitudinal reinforcement where:

- the characteristic imposed load, Q_k does not exceed the characteristic dead load, G_k
- the loads are substantially uniformly distributed over three or more spans
- the variation in span length does not exceed 15% of the longest span.

The effective span, L, need not be taken greater than: (the clear span + d).

Hanger bars
At least 20% of maximum support area or sufficient for compression area required, whichever is greater, should be carried to 25mm from each support.
Diameter: 16mm (recommended size).
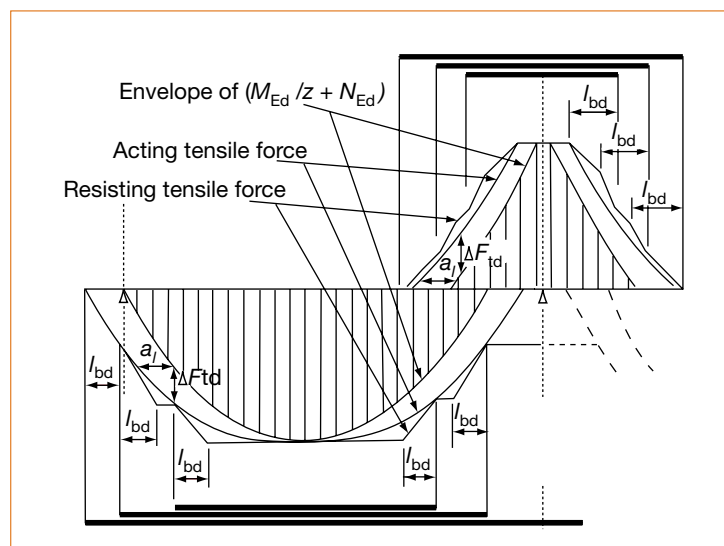
Figure 6.14 Illustration of the curtailment of longitudinal reinforcement

Table 6.4 Typical values of anchorage and lap lengths					
	Bond conditions	**Length in bar diameters**			
		f_{ck}/f_{cu} = 25/30	f_{ck}/f_{cu} = 28/35	f_{ck}/f_{cu} = 30/37	f_{ck}/f_{cu} = 32/40
Full tension and compression anchorage length, $l_{b,rqd}$[1]	good	36	34	32	31
	poor	48	45	43	41
Full tension and compression lap length[2]	good	42	39	37	35
	poor	56	52	49	47

Notes
1 It is assumed that the bar size is not greater than 32mm and α_1, α_2, α_4 and α_5 all equal 1 and that α_3 = 0.9 (λ = 1.35 and K = 0.05).
2 It is assumed α_6 = 1.15 (not more than 33% of the bars are lapped at one place).
For other situations refer to EC2, Clause 8.4.4.
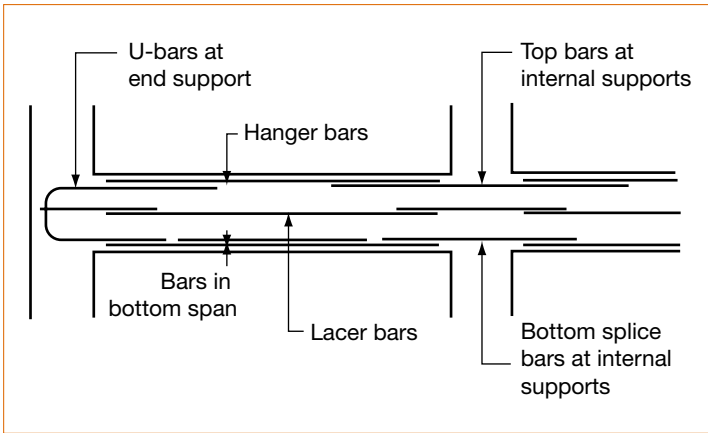
Figure 6.15 Layout of reinforcement for flexible detailing of beams

Top bars at internal support
(Simplified rules)

At least 60% of the maximum support area should continue to a point where the hanger bars are sufficient, plus a tension lap, or to a point of zero moment if the nominal hanger bars do not satisfy the minimum spacing rules for tension reinforcement. Where no information is given concerning curtailment, this reinforcement should extend 0.25L from the support face.

No reinforcement should extend less than 0.15L from the support face, nor 45 times the bar diameter from the support face, whichever is greater, where L is the effective span of beam.

Bottom splice bars at internal support

The area should not be less than the minimum percentage required. At least 30% of the maximum span area should be supplied, if the simplified rules are used. Otherwise it should conform to the bending moment diagram as modified by Figure 6.14.

These bars should extend for a tension lap with the main bottom bars or, if in compression, to a point at which compression bars are no longer required, plus a compression lap.

Bottom bars in span (Simplified rules)

The area should not be less than the minimum percentage required. At least 30% of maximum span area for continuous beams and 50% of maximum span area for simply supported beams, is continued to 25mm from the support. The remainder extends to within 0.15L of internal supports, 0.1L of exterior supports and 0.08L of simply supported beam supports. The point of support may be considered up to $d/2$ inside the face.

U-bars at end of beam

These should provide the tension area required for support moment or 30% of maximum span area (50% for simple supports), if the simplified rules are used, whichever is greater.

The length of the top leg of the bar should be calculated in the same way as for internal support bars.

The bottom leg of the bar extends to the same distance into the span as for internal support splice bars.

Where the design has assumed a simply supported end, sufficient top steel should be provided for crack control. Where this is much less than the bottom reinforcement required, the U-bars should be replaced by L-bars, top and bottom.

The bars should extend for a tension lap from the support, both at the top and bottom.

Lacer bars at sides of beam

As specified above.

Anchorage of bottom reinforcement at end supports
(EC2, Clauses 8.4.4 and 9.2.1.4)

The area of bottom reinforcement provided at supports with little or no end fixity assumed in design should be at least **0.25** that provided in the span.

Partial fixity with monolithic construction
(EC2, Clause 9.2.1.2)

Even when simple supports have been assumed in design the section at supports should be designed for a bending moment arising from partial fixity of at least **0.15** of the maximum moment in the span.

Flanged beams at intermediate supports of continuous beams
(EC2, Clause 9.2.1.2)

The total area of tension reinforcement, A_s, of a flanged cross-section should be spread over the effective width of flange. Part of it may be concentrated over the web width (see Figure 6.16).
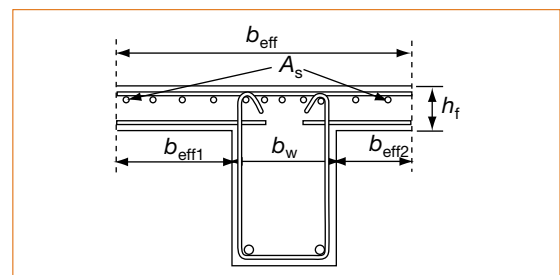
Figure 6.16 Placing of tension reinforcement in a flange cross-section

The effective flange width b_{eff} for a T beam or L beam may be derived as:

$$b_{eff} = \sum b_{eff,i} + b_w \leqslant b$$

where $\qquad b_{eff,i} = 0.2b_i + 0.1l_0 \leqslant 0.2l_0$
and $\qquad b_{eff,i} \leqslant b_i$
(for the notations see Figures 6.17 and 6.18).

Curtailment of longitudinal reinforcement in cantilevers

The curtailment of the main longitudinal reinforcement in cantilevers should always be related to the bending moment diagram.

At least 50% of the maximum area of reinforcement at the support should be continued to the end of the cantilever.

Arrangement of links (EC2, Clause 9.2.2)

Links are arranged such that if more than an enclosing link is required other links are provided at the same section with the preferred arrangements as shown in Figure 6.19.

A pattern which overlaps links makes it difficult to fix the reinforcement and should not be used (see Figure 6.20).

Open links may be used for beam and slab construction using L-hooks where the width of rib is 450mm or more. In such circumstance a top locking link is also used (see Figure 6.21).

Where links are used for torsion they should be shaped as shown in Figure 6.22.

Connection to edge supports

Wherever possible U-bars which can be placed within the depth of beam should be used.

Where a moment connection requires bars to be bent down into the column, refer to 6.4.2 of this manual. Bending top bars up into the column is not recommended.

For narrow edge supports each tension bar should be anchored by one of the following:
- an effective anchorage length equivalent to 12 times the bar size beyond the centre line of the support; no bend or hook should begin before the centre of the support
- an effective anchorage length equivalent to 12 times the bar size plus $d/2$ from the face of the support, where d is the effective depth of member; no bend or hook should begin before $d/2$ from the face of the support.
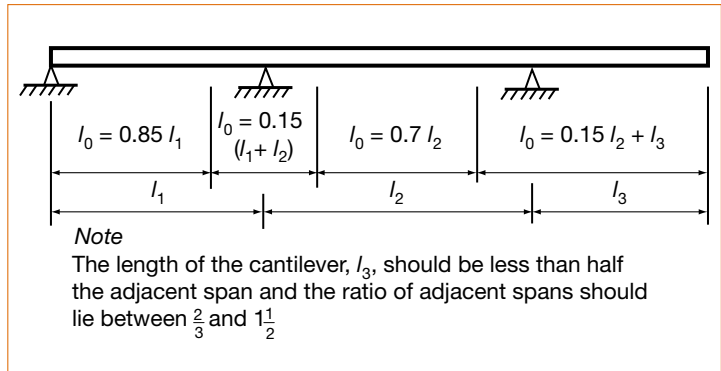
Figure 6.17 Definition of l_0, for calculation of effective flange width
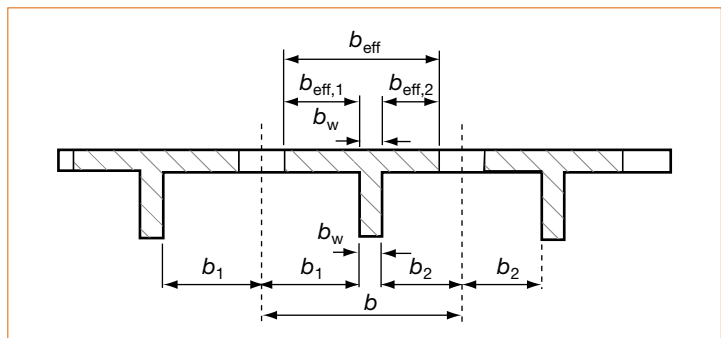
Figure 6.18 Effective flange width parameters
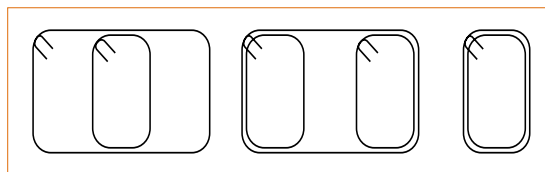
Figure 6.19 Preferred arrangement of links
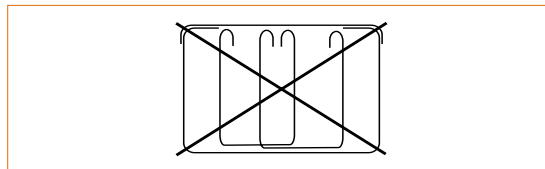
Figure 6.20 Overlapping of links is not recommended
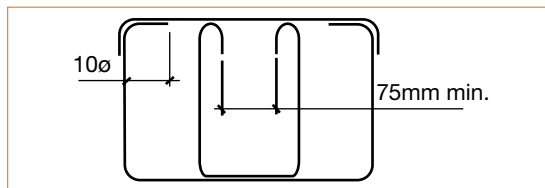
Figure 6.21 Open links with top locking links
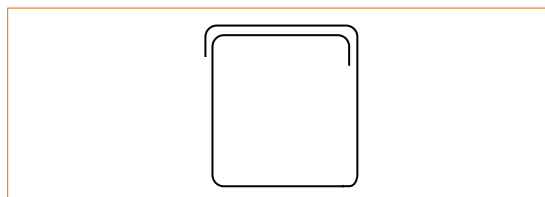
Figure 6.22 Required shape of torsion links

These rules should be adhered to where there is no vertical reinforcement through the support (e.g. brickwork, see Detail MS3). Where vertical reinforcement exists, sufficient anchorage can be achieved by ensuring that some mechanical link occurs between the beam and the vertical element. A typical example is where a beam is supported by a wall. Horizontal bars can be threaded through U-bars as shown in Figure 6.23.
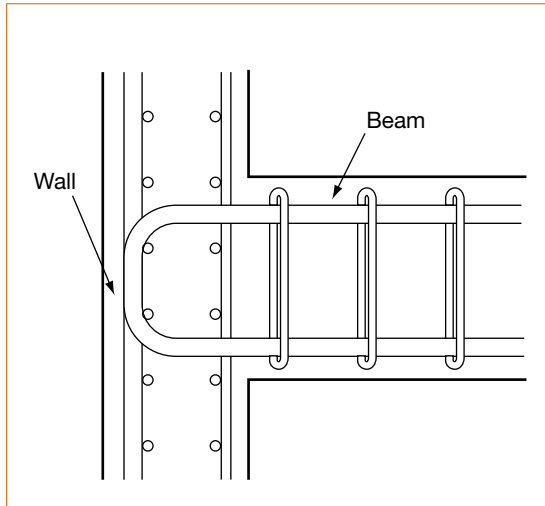
Figure 6.23 Beam to wall connection

Where wide shallow beams are required with narrow columns, it may be necessary to consider the provision of design transverse top steel at the column position, to cater for corbel action, in addition to any links required for shear. This is most likely to occur where precast slabs are used with no transverse beams (note: tying action also to be considered). As a general rule of thumb, this will apply where the beam is wider than the column width plus twice the effective depth.

Deep beams (EC2, Clause 9.7)
Where the span of the beam is less than 3 times the overall section depth it should be considered to be a deep beam. For such elements reference should also be made to CIRIA Guide 2, *The design of deep beams in reinforced concrete*[30].

Minimum area of reinforcement
Deep beams should normally be provided with an orthogonal mesh near each face with a minimum area of **0.001A_c or 150mm^2/m**, whichever is greater, in each face and in each direction.

Maximum spacing of bars
The spacing of the bars in the orthogonal mesh should not exceed 2 times the beam width or 300mm whichever is less.

Main tension reinforcement
The reinforcement corresponding to the ties in the design model, should be fully anchored at the support node, by bending the bars, by using U-bars or by using end anchorage devices, unless there is sufficient length of beam beyond the support for a full anchorage length of bar.

6.3.3 Detailing information
Design information for detailing should include:
- Layout and section drawings including details of nibs and upstands, etc.
- Concrete grade and aggregate size (standard 30/37MPa and 20mm).
- Nominal cover to reinforcement (standard 35 or 40mm), and the criteria governing this (fire resistance or durability). Where nominal cover is more than 40mm further information is required for fire resistance.
- Details of the main reinforcement and links including:
  - bar size and number or pitch
  - type of reinforcement and bond characteristics (standard H)
  - curtailment of bars if other than standard lap length or other than normal tension lap.
- Details of any special moment bar connecting beam to edge columns with sketches at large scale.
- Details of insertion and openings, e.g. conduit, cable ducting, etc., should be given where the placing of reinforcement is affected.

6.3.4 Presentation of working drawings
Traditional method

Individual beams are drawn related to specific grid lines.

This method is normally used where the job has little repetition and it is simpler to show the details of all beams individually.

BEAM ON GRID 1/A – B

1 – 1

2 – 2
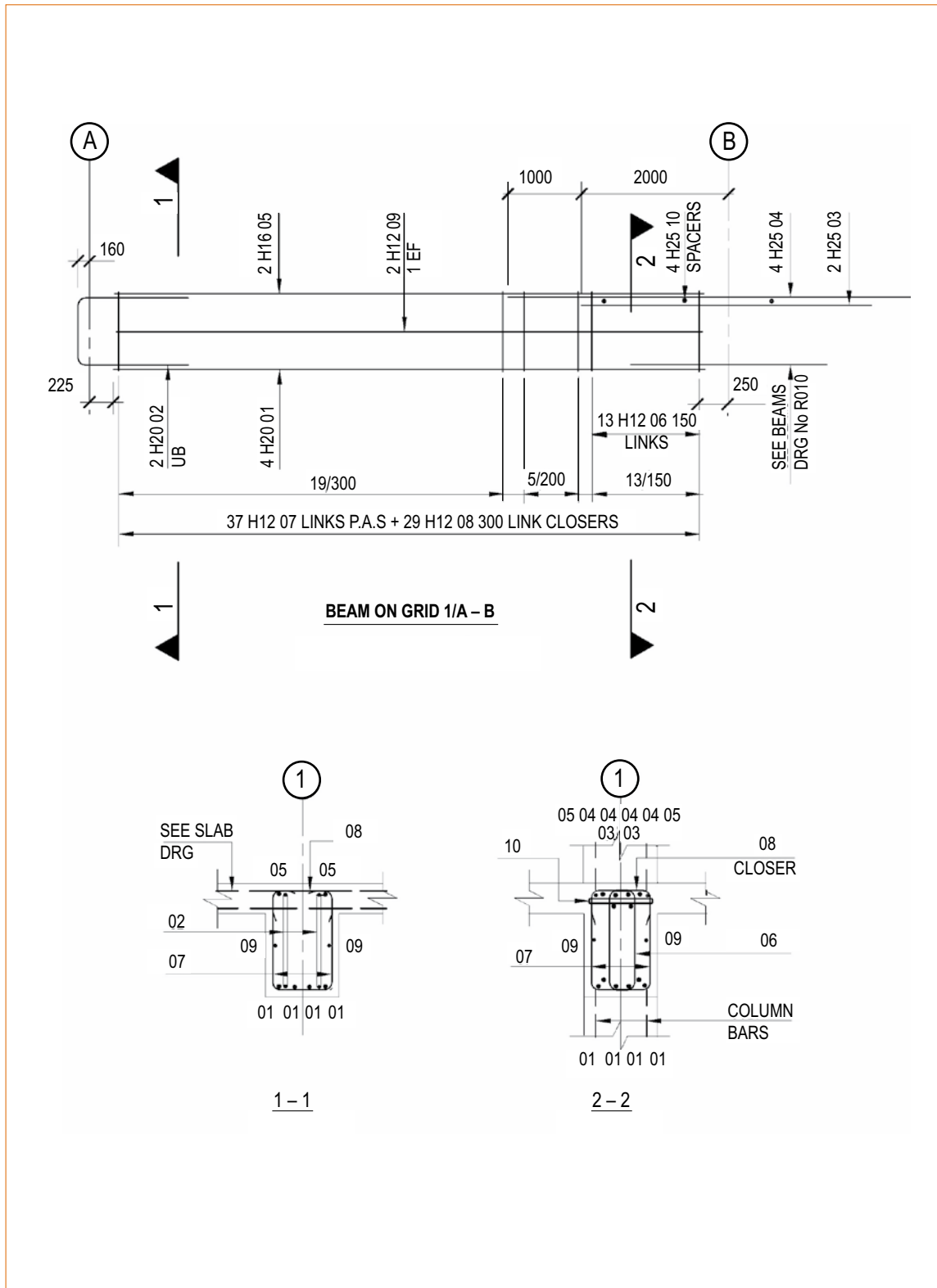
Representational method

The details relate to a general beam elevation and specific cross sections.

Bar location letters are used to cross-reference the reinforcement on the elevations and the table.

Fixing dimension of bars are labelled and cross-referenced from the elevations to the table.

The position of each beam is shown on a key plan which also shows the relevant grid lines.

BEAM	DIM 1	DIM 2	REINFORCEMENT								SECTION	SECTION
			A	B	C	D	E	L1	L2	L3		
A	1500	250	2 H32 01	4 H25 02 (2+2)	2 H20 03	2 H12 04	2 H20 05	7 H10 06 175	10 H10 06 250	7 H10 06 175	1 - 1	4 - 4
B	1400	200	2 H3 07	4 H25 02 (2+2)	2 H20 03	2 H12 08	2 H20 05	7 H10 06 175	8 H10 06 250	7 H10 06 175	2 - 2	5 - 5
C	1100	175	2 H25 09	4 H20 10 (2+2)	2 H20 11	2 H12 12	2 H20 05	6 H10 06 200	5 H10 06 300	6 H10 06 200	3 - 3	6 - 6

22 H10 09 + 44 H10 10 LINKS IN 3s PAS.
PLUS 18 H10 11 300 CLOSERS

BEAM ON GRID LINE 6/E-F

1 - 1

2 - 2

3 - 3

SEE SLAB DRG

BEAMS MB1
Span and support details

Nominal cover to all reinforcement specified by designer (Normally: Internal 35, External 40)

Nominal spacing of links to be 0.75d or 12 x diameter of compression bar, whichever is less

Curtailment bars given by simplified rules in 6.3.2 unless otherwise specified

50

A

B

50

25

A

B

25

Curtailment of bottom bars given by simplified rules in 6.3.2 unless otherwise specified

Tension lap unless otherwise specified
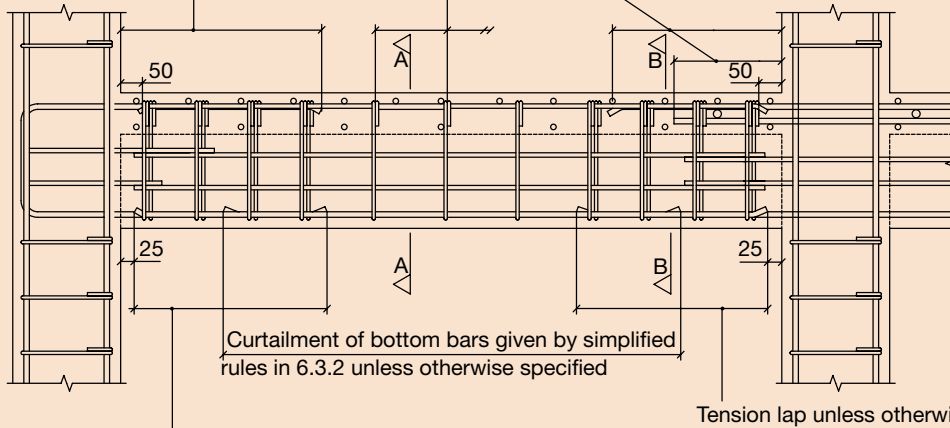
Tension lap unless otherwise specified. Area of 'U' bars equal to that for support moment or 30% of maximum span area (50% for simple supports), whichever is greater. For moment connection between beam and edge columns see 6.4.2
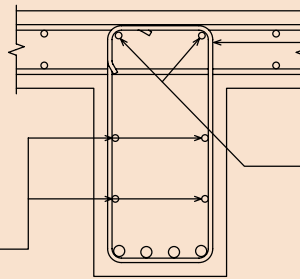
'Closer' bars used with open links for beam width of 300 or more

Hanger bars to be 20% of maximum support area unless otherwise specified. For beams 500 deep or more use minimum 2 H16s

Bars specified by designer. For beam depth of 1000 or more use minimum of H12's at 150

A-A

One space should be left (75mm) sufficient to insert poker vibrator

For sections with more than one layer of main bars spacers are provided. Diameter 25 or main bar diameter whichever is greater

Main top bars placed inside hanger bars

Bottom support splice bars placed inside main bars. Area at least 30% of maximum span area

B-B

Cover should be greater than equivalent bar size
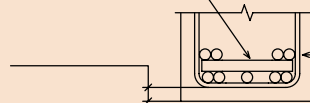
Special care should be given to avoid congestion of reinforcement especially at laps

BEAMS   MB2
Broad shallow sections

For general details see Model Detail MB1

The longitudinal space taken by each set of links shown is 3 x bar size. This should be checked to ensure congestion does not occur

At external supports the anchorage of longitudinal bars should be treated as for slabs

See Model detail MS2

'Closer' bar for overall link (This may not be required where the slab reinforcement is coincident with links.)

Greater of 10ø or 70

75 minimum

Greater of 5ø or 50

Internal links should not overlap

Maximum lateral spacing of link legs is effective beam depth. The distance of a tension bar from a vertical leg should not be greater than 150
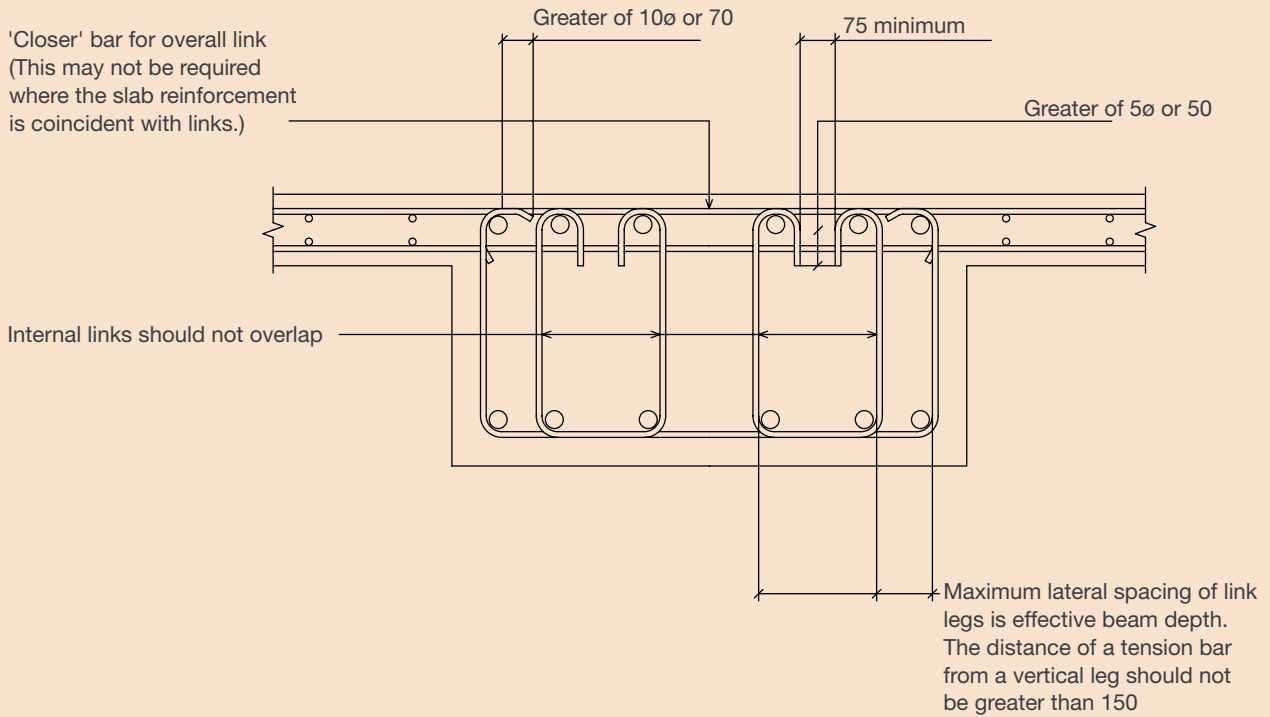
BEAMS   MB3
Cantilever beams

For general details see Model Detail MB1
Curtailment of main cantilever bars as specified by designer

At least 50% of maximum area continues to end of cantilever unless specified otherwise by designer

At least 50% of cantilever bars should be anchored a distance of 1.5 x cantilever. No reinforcement should be stopped less than 0.75 x cantilever unless specified by designer

50

25

Tension lap for 'U' bar

Bottom bars specified by designer. Minimum 2 H16's
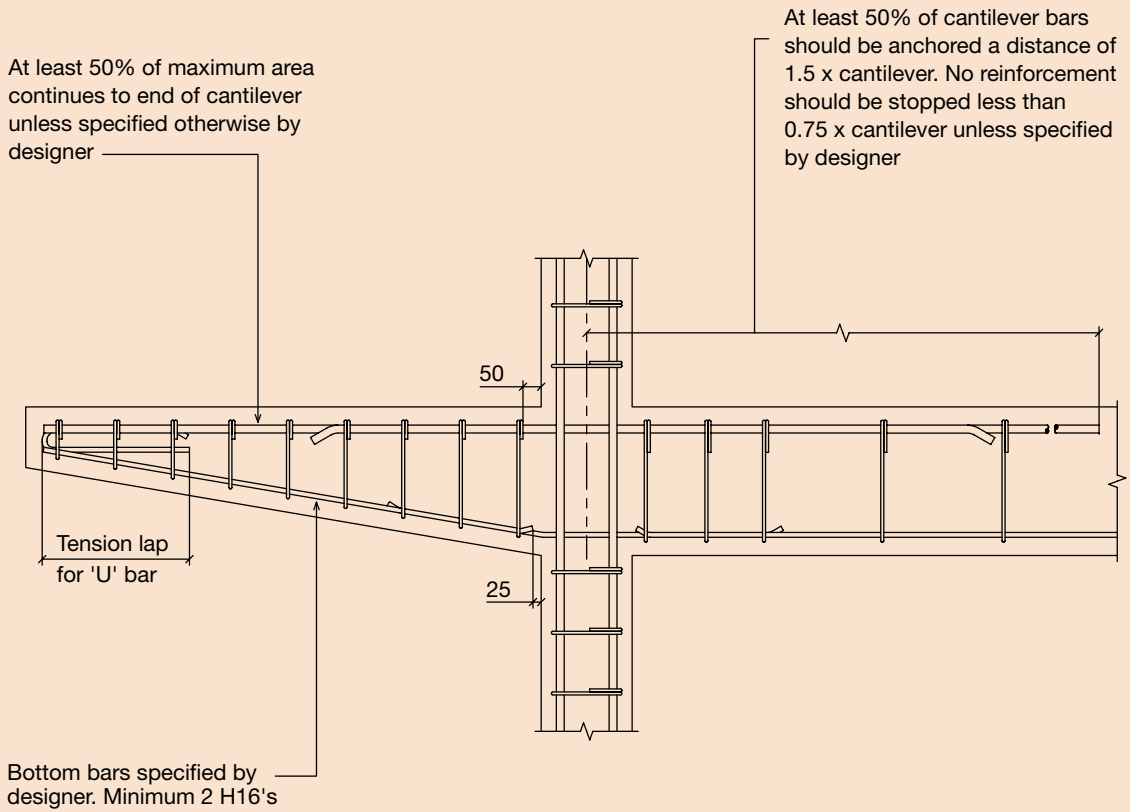
6.4 COLUMNS

6.4.1 Scope

The information given relates specifically to in-situ rectangular and circular columns but in general it also applies to all irregular shaped columns.

The details given are not applicable for earthquake conditions (see BS EN 1998[8]).

Walls, as defined by EC2, with a breadth/thickness ratio greater than 4 are considered in 6.5 of this manual.

6.4.2 Design and detailing notes
Concrete grade

Concrete grades less than 28/35 MPa (cylinder strength/cube strength) are not normally used. Care should be taken to ensure that the design strength of concrete required in a column does not exceed 1.4 times that in the slab or beam intersecting with it unless special measures are taken to resist the bursting forces.

Nominal cover to all reinforcement (EC2, Clause 4.4)

- Internal use 30mm + Δc_{dev} (Concrete inside buildings with low air humidity, XC1)
- External use 35mm + Δc_{dev} (Corrosion induced by carbonation, XC3)
  See 5.2.1 for values of Δc_{dev}

The cover to bundled bars should be the equivalent bar size (see 5.8).

Where nominal cover (i.e. cover to outermost steel) exceeds 40mm (where the axis distance to the main reinforcement is greater than 70mm), there is a danger of concrete spalling in fire, (see EC2, Part 1.2, Clause 4.5.2) and surface reinforcement should be provided. The surface reinforcement mesh should have a spacing not greater than 100mm, and a diameter not less than 4mm.

Minimum area of reinforcement (EC2, Clause 9.5.2)

$0.002A_c$ or $0.10 \, N_{Ed}/f_{yd}$, whichever is greater
where A_c is the area of concrete
          N_{Ed} is the design axial compression force
          f_{yd} is the design yield strength of
               reinforcement

If the percentage of reinforcement is less than $0.002A_c$ it should be considered as a plain column (see EC2, Section 12).

Recommended minimum bar diameter is 16mm (for very small section columns, less than 200mm, the minimum of **8mm** given in EC2, Clause 9.5.2 may apply).

Minimum number of bars for rectangular columns is 4.

Minimum number of bars for circular columns is 6 (for very small diameter columns, less than 200mm, the minimum of 4 given in EC2 may apply).

Maximum area of main reinforcement (EC2, Clause 9.5.2)

Maximum area of reinforcement should not exceed **$0.04 \, A_c$** unless it can be shown that any resulting congestion of reinforcement does not hinder the ease of construction.

At laps the maximum area of reinforcement should not exceed **$0.08 \, A_c$.**

Mechanical splices should be considered where congestion becomes a problem (see 5.5).

Bar spacing (EC2, Clause 9.5.2)
Preferred minimum spacing

- Main bars
  75mm (bars 40mm size and greater: 100mm)
- Pairs of bars
  100mm

When considering the minimum spacing of bars of 32mm size or greater, allowance must be made for lapping of bars.

Preferred maximum spacing

- Compression bars
  300mm, provided that all main bars in the compression zone are within 150mm of a restrained bar (see Figure 6.24)
- Tension bars
  175mm

Anchorage and lapping of bars (EC2, Clauses 8.4 and 8.7)
Minimum anchorage length
Greater of 10ø or 100mm.

For 500 Grade steel Table 6.5 gives typical anchorage and lap lengths for columns. This assumes 'good' bond conditions (see Figure 5.2 for definition of 'good' and 'poor' bond conditions).

Table 6.5 Typical values of anchorage and lap lengths

	Length in bar diameters			
	$f_{ck}/f_{cu} =$ 25/30	$f_{ck}/f_{cu} =$ 28/35	$f_{ck}/f_{cu} =$ 30/37	$f_{ck}/f_{cu} =$ 32/40
Full tension and compression anchorage length, $l_{b,rqd}$[1]	36	34	32	31
Full tension and compression lap length[2]	54	51	48	46

Notes

1 It is assumed that the bar size is not greater than 32mm and α_1, α_2, α_4 and α_5 all equal 1 and that $\alpha_3 = 0.9$ ($\lambda = 1.35$ and $K = 0.05$).

2 It is assumed $\alpha_6 = 1.5$ (more than 50% of the bars are lapped at one place).

For other situations refer to EC2, Clause 8.4.4.

Lapping of bundled bars

When lapping bundled bars, care should be taken to avoid congestion. This may be achieved by staggering the laps of the bars in each bundle (see 5.4.5).

Links

The size of link should be the greater of a quarter the maximum size of longitudinal bar and 8mm (for very small diameter columns, less than 200mm, the minimum of 6mm given in EC2 may apply).

Bundled main bars may be represented by a single bar for the purpose of calculating link size and spacing. This single bar has an equivalent size to give it the same cross section area as the bundle.

An overall enclosing link is required together with additional restraining links for alternate main bars or bundle of bars. Provided that all other main bars in the compression zone are within 150mm of a restrained bar no other links are required (see Figure 6.24). Otherwise additional links should be added to satisfy this requirement. Additional links are not required for circular columns.

Maximum spacing of links

The least of:

• 20 times the size of the longitudinal bars, or
• the lesser dimension of the column, or
• 400mm.

The maximum spacing should be reduced by a factor 0.6 in sections within a distance equal to the larger dimension of the column cross-section above and below a beam or slab.

Where the direction of the longitudinal bars changes (e.g. at laps), the spacing of links should be calculated. The spacing of links should ensure that there is a link close to the cranking positions of the main bars. These effects may be ignored if the change in direction is 1 in 12 or less.

Links to resist bursting at laps

Where the diameter of the longitudinal bars ø $\geqslant$ 20mm, the links required to resist the bursting forces in the lapping zone should have a total area, ΣA_{st}, of not less than the area A_s of one lapped bar ($\Sigma A_{st} \geqslant 1.0 A_s$). These links required for bursting should be positioned at the outer sections of the lap as shown in Figure 6.25.

Figure 6.24 Requirement of links in columns
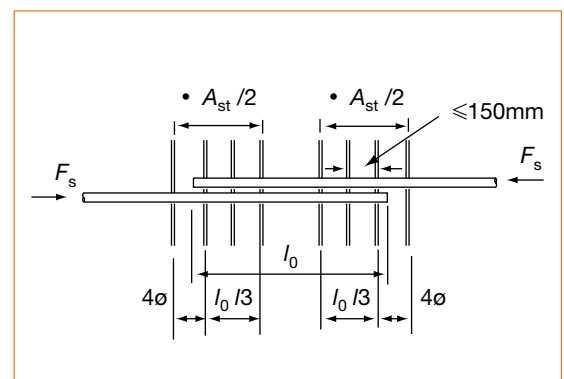
Figure 6.25 Links required for bursting at column laps
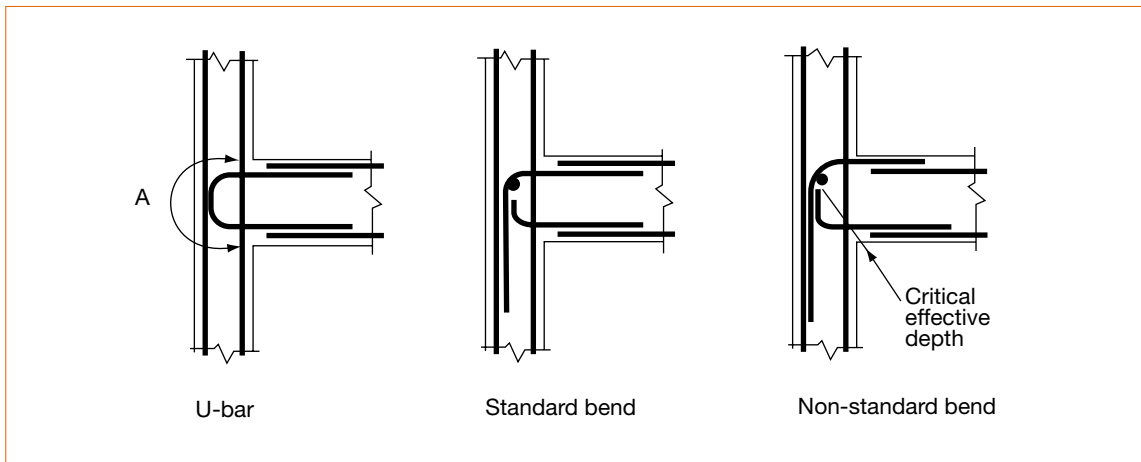
Figure 6.26 Moment connection between beam and edge column
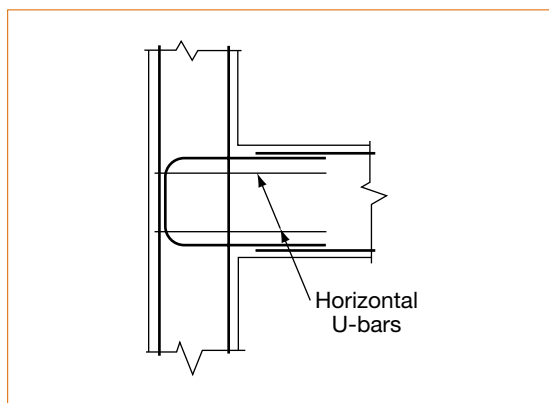
Figure 6.27 Shear enhancement of column

Moment connections between beam and edge column

Wherever possible U-bars which can be placed within the depth of beam should be used. These are fixed in position and concreted with the beam, and thus do not require precise fixing when the column is being concreted. L-bars which penetrate down into the column should be used when the distance 'A' (see Figure 6.26) is less than the anchorage length for that bar diameter. These bars must be fixed accurately at the top of the column lift which is a difficult and unattractive site task. A standard radius to the bend may normally be used provided a bar of the same size or greater is placed inside the corner normal to it.

A non-standard bend may be required if a corner bar is not present. If so, a thorough check should be carried out to ensure that the reinforcement fits and will perform as intended. The critical effective depth may not be obvious, and various locations may need to be assessed.

Special care should be taken by the Designer and Detailer to make sure that this reinforcement does not conflict with any beam reinforcement passing through the column in the other direction.

Shear capacity of column (EC2, Clause 6.2)

The maximum tensile reinforcement in the beam or that part required for the moment connection to the column is also controlled by the shear capacity of the column. (See *The Structural Engineer*, February 1994[31]).

Where there is no edge beam intersecting at approximately the same level as the joint, transverse column reinforcement should be provided within the depth of the beam (See Figure 6.27). This may be in the form of links or horizontal U-bar extending into the beam. Unless specified by the Designer the spacing should be as for the links in the column.

Bursting action

Where a change of column section occurs, particularly at edge and corner locations, links may be required to provide adequate restraint to bursting action (i.e. end block action). These links may occur within the depth of beam or slab, but may extend further down also.

Starter bars

It is important to recognise at the design stage the implications of the construction sequence and the level of foundation on the length of starter bars, e.g. if the foundation reinforcement is placed at a depth lower than specified the consequent lap of the first lift of column bars is likely to be too short. For this reason the length of starter bars from pad footings and pile caps is specified longer than required. (See Model Details MF1 and MF2).

6.4.3 Detailing information

Design information for detailing should include:

- The section dimensions and its position and orientation relative to particular grid lines.
- Outline drawings which show clearly what happens to the column above the lift being considered.
- Kicker height if other than 75mm.
- Concrete grade and aggregate size (standard 30/37MPa and 20mm).
- Nominal cover to all reinforcement (standard 35mm internal, 40mm external). Supplementary mesh reinforcement if required.
- A simple sketch of cross-section of column showing the longitudinal reinforcement in each face of the column, i.e.
  - number and position of bars
  - type of reinforcement and bond characteristics (standard H)
  - diameter of bars
  - lap length if other than normal compression lap the linking reinforcement.
  - type of reinforcement (standard H)
  - diameter of links
  - spacing
  - pattern of links (if special).
- Instructions for lapping of bunched bars if required.
- Special instructions for links within depth of slab or beam.
- If a mechanical or special method of splicing bars is required this must be shown in a sketch, otherwise the method given in the Model Details will be assumed.
- Special instructions and sketches should be given where services are provided within the column.
- Details of insertions, e.g. conduit, cable ducting, cladding fixings, etc., should be given where the placing of reinforcement is affected.

6.4.4 Presentation of working drawings
Traditional method

Individual columns are drawn related to specific grid lines.

Reinforcement is shown in schematic form on the elevations.

Sections are shown with the column outline drawn to scale.

This method is normally used where the job has little repetition and it is simpler to show the details of all columns individually.

COLUMN G7

6 - 6
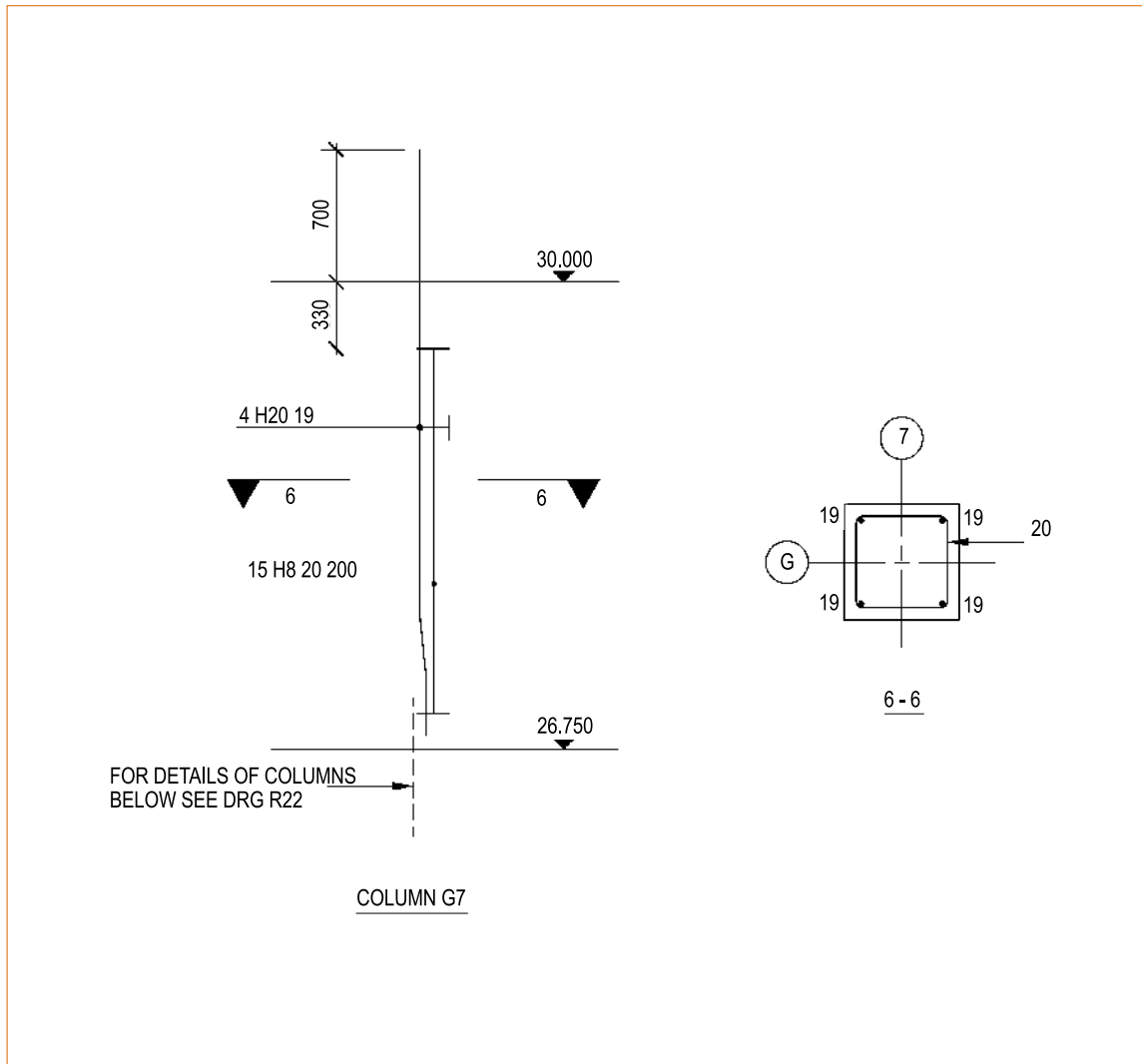
Representational method

The detail relates general column elevations and sections to X and Y directions, together with a table giving details of reinforcement for each type of column. Bar location letters are used to cross-reference the reinforcement on the drawing and in the table.

Column outlines to the elevations are not drawn. The section shapes of each column type are only representative, and may not be drawn to scale.

The following points should be noted:
- The X and Y directions must be related to the general arrangement drawing.
- Each column is related to a reinforcement type, either by a location plan or by tabulating the column grid references (shown below).
- The levels and any relevant fixing dimensions must be specified either on the drawing or in the table.

COLUMN REF.	No OFF	LEVEL A	LEVEL B	DIM C	DIM D	CAGE SECTION	MAIN BARS		LINKS	
							E	F	G	H
G6, H6	2	30.50	33.75	395	850	7 - 7	6 H25 03	———	14 H8 07 200	14 H8 08 200
K8, L8	2	30.50	34.00	395	1050	7 - 7	6 H32 10	———	14 H8 07 200	14 H8 08 200
M9	1	31.50	34.75	425	850	8 - 8	4 H25 03	4 H20 10	14 H8 11 200	28 H8 12 200
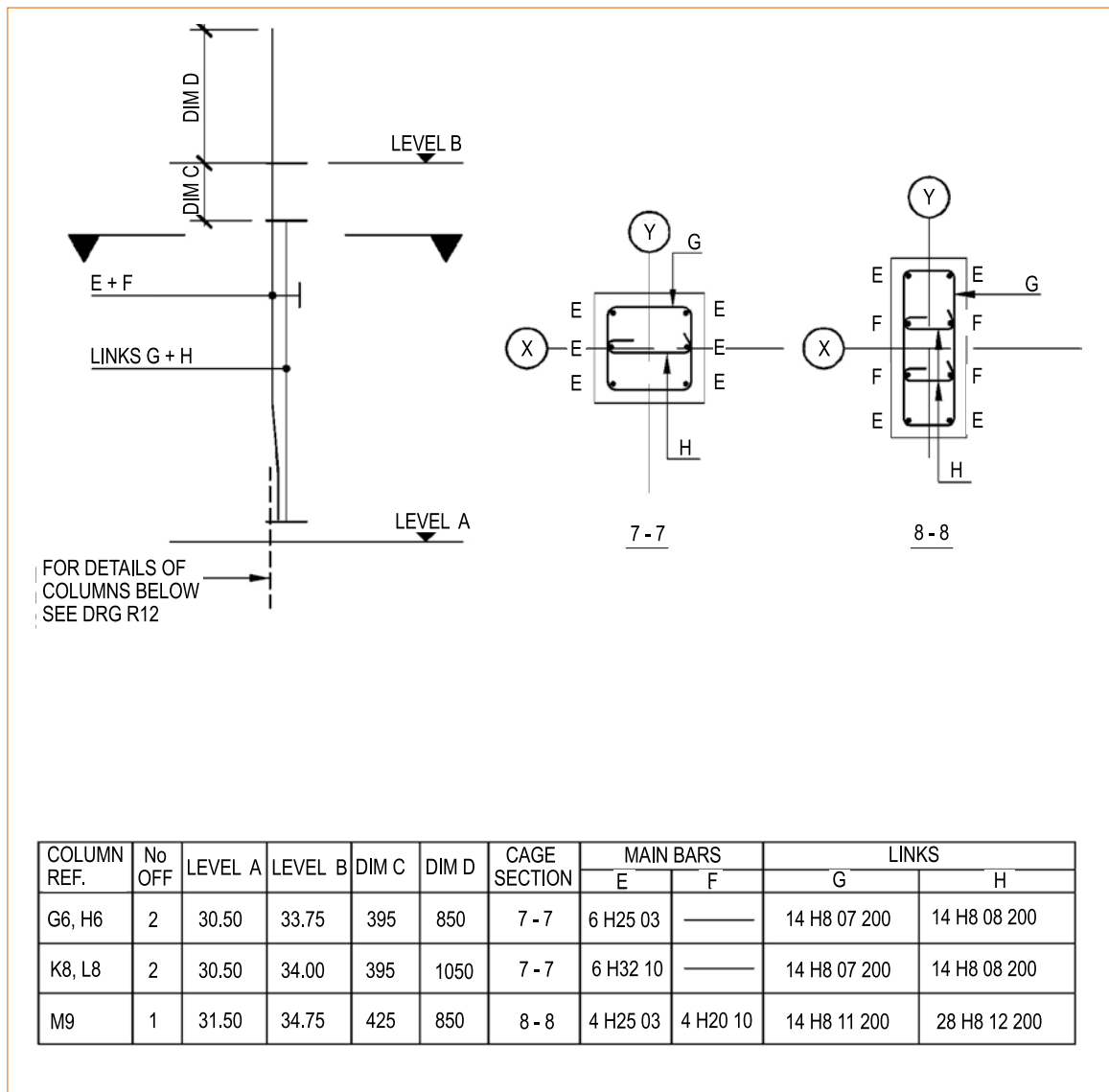
COLUMNS MC1
Bottom detail

Nominal cover to all reinforcement specified by designer (Normally: Internal 35, External 40)

This detail allows bars to be extended easily to give foundation level tolerance

Spacing of links at lap not greater than:
- 12ø of longitudinal bar
- 0.6 x lesser dimension of column
- 240

At least 3 No. links

Top of foundation

Compression lap plus 150 for foundation level tolerance

Kicker: 75 (150 below ground)

450 min.

A-A
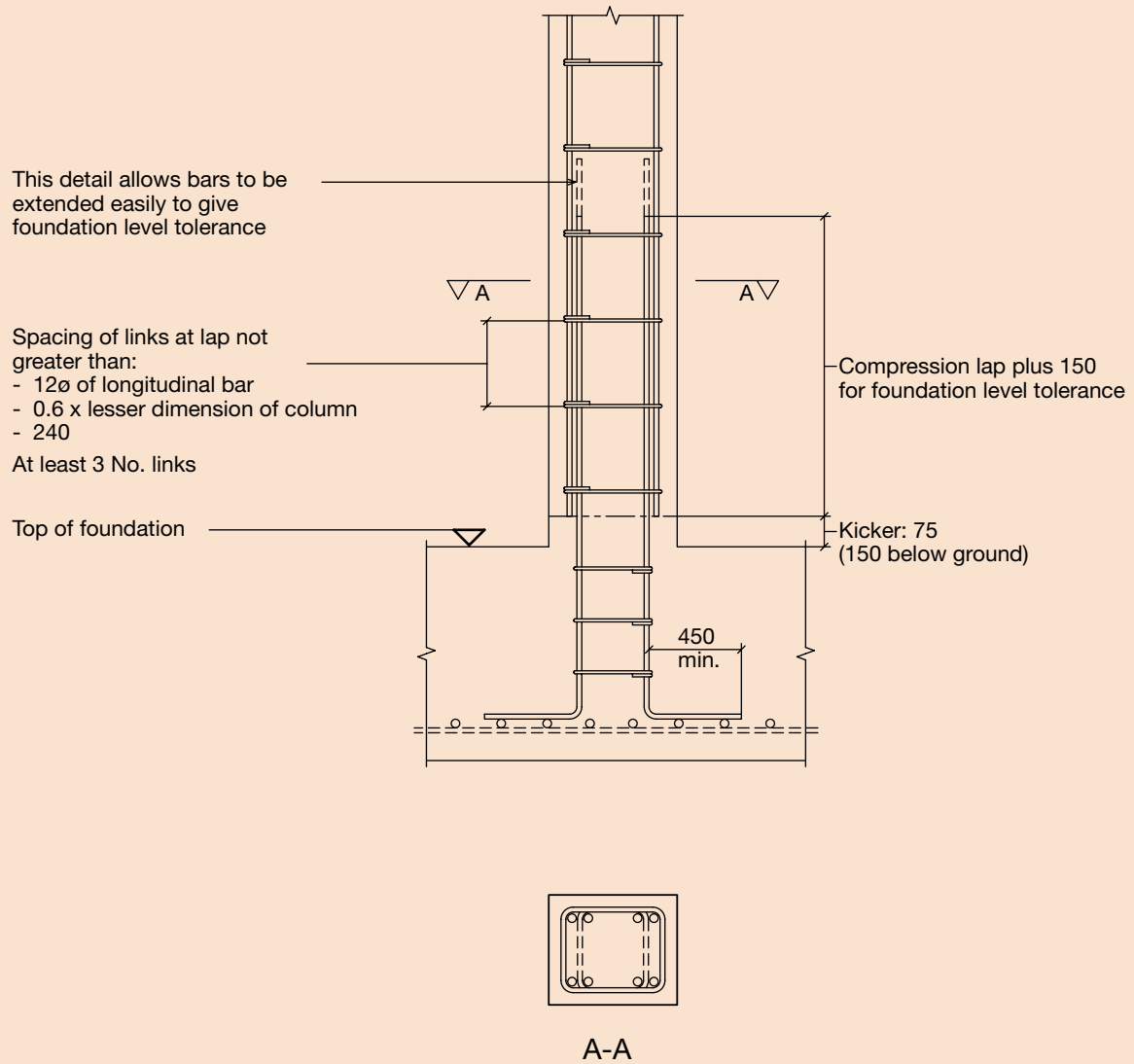
COLUMNS MC2
Intermediate detail

This detail is used where the column is concentric and of the same dimensions as the storey below
Nominal cover to all reinforcement specified by designer (Normally: Internal 35, External 40)

Projection above slab level:
Compression lap + kicker
height - unless specified
otherwise

See 6.4.2 for spacing of links

Nominal floor level

Additional links may be required
See 6.4.3

Slab or beam soffit

Larger dimension of column
Pitch of links not greater than:
- 12ø of longitudinal bar
- 0.6 x lesser dim. of column
- 240
At least 3 No. links

A

A

No special link at crank

Link at knuckle of crank

Crank at bottom of lift
Length of crank is 10 x offset

Spacing of links at lap not
greater than:
- 12ø of longitudinal bar
- 0.6 x lesser dimension of column
- 240

50

At least 3 No. links

50 to start to link run

Nominal floor level

Kicker: 75

Main bars rest on kicker

-Denotes direction of crank

Link not required for face bar if
it is within 150 of restrained bar

12ø minimum

A-A

COLUMNS   MC3
Intermediate detail

This detail applies for stepped or offset columns
For general notes see Model Detail MC2

Where columns are offset or large moments exist these bars should be anchored into floor slab as shown

Nominal floor level

Slab or beam soffit

X

X

75 min.

Y

Y

Spacing of links at lap not greater than:
- 12ø of longitudinal bar
- 0.6 x lesser dim. of column
- 240

At least 3 No. links

Additional links may be required See 6.4.2

Fixing dimension to be compression lap +75 unless specified
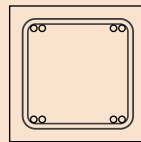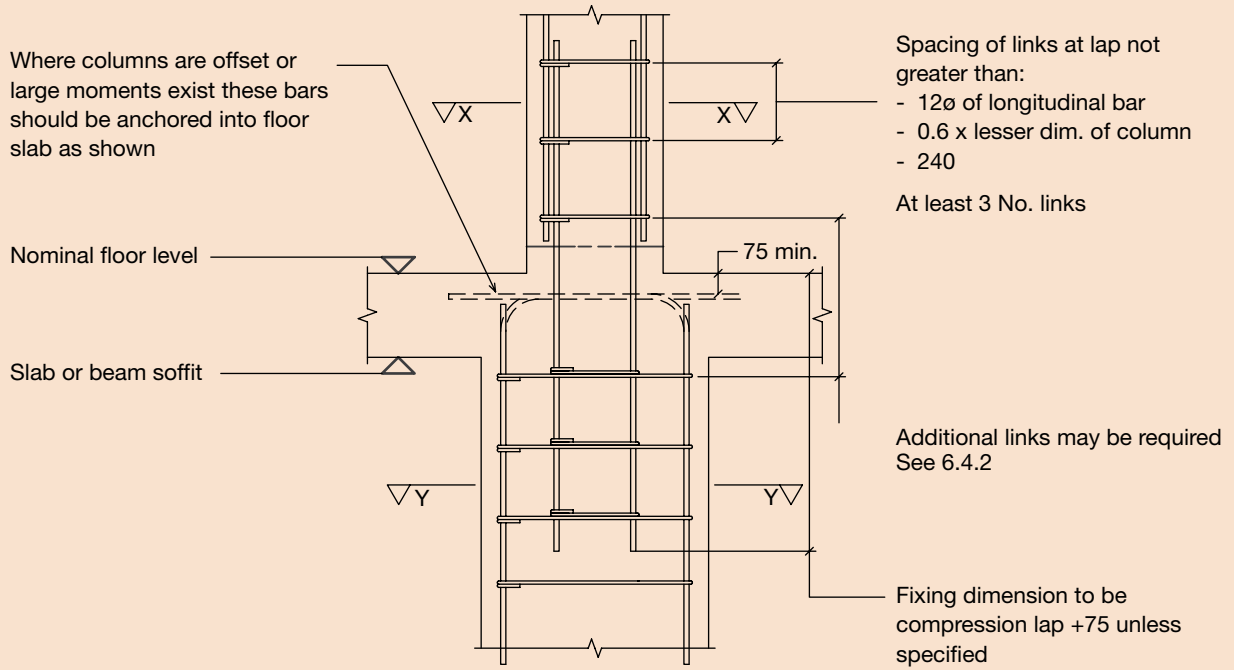
X-X

Splice bars are located by dimensions from face of lower column

Locating links. Minimum 3 set
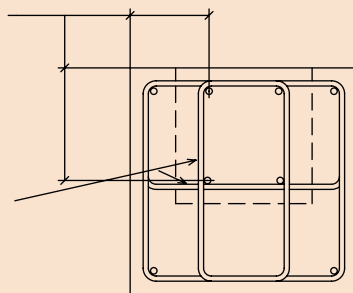
Y-Y

COLUMNS   MC4
Top detail

Detail 'A' applies when slab depth is not less than:
– 200 using 20 size of column bars
– 250 using 25 size of column bars
– 300 using 32 size of column bars
otherwise Detail 'B' applies
For single storey buildings orwhere splice bars have been used at the floor below see MC5
For general details see Model Detail MC2

Nominal roof level

Slab or beam soffit

Tension lap

Spacing of links at lap not
greater than:
- 12ø of longitudinal bar
- 0.6 x lesser dim. of column
- 240

At least 3 No. links

PLAN

DETAIL 'A'

Column bars are positioned in
level from nominal roof level.

Spacing of links at lap not
greater than:
- 12ø of longitudinal bar
- 0.6 x lesser dim. of column
- 240
At least 3 No. links

Tension lap
For edge and corner columns
tension laps should equal
1.4 x anchorage length for
25mm diameter bars and
over, unless otherwise specified

Bars must be positioned to
avoid clashes

PLAN

DETAIL 'B'

COLUMNS MC5
Top detail

This detail is used for single storey buildings and where splice bars have been used at the floor below
For general details see Model Detail MC2

Level of top bar depends on
accuracy of vertical leg length
and height of kicker

Nominal roof level

Slab or beam soffit

These bars should be turned as
shown in Model Detail MC4 B in
accordance with the table given
in MC4

Spacing of links at lap not
greater than:
- 12ø of longitudinal bar
- 0.6 x lesser dim. of column
- 240
At least 3 No. links

Kicker: 75

For detail of splice see MC3
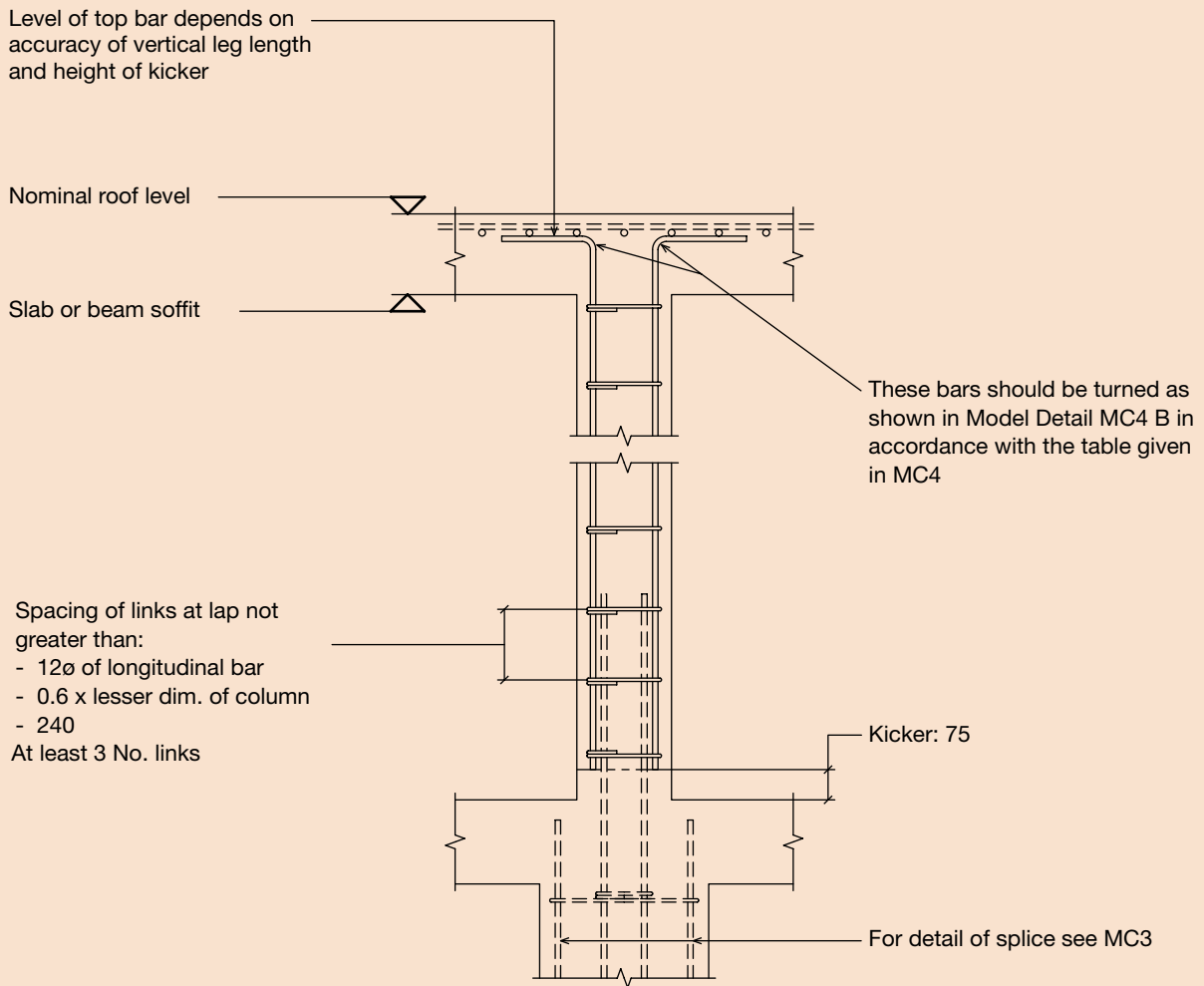
COLUMNS MC6
Circular columns

For general details see Model Detail MC2

Helical binders are used unless circular links are specified by designer

Main bars scheduled straight. Cage is rotated to lap with cage below

Helical binders scheduled in 12m lengths. Tension lap length is required between helical binders

p=pitch of helix

p

0.5p

Kicker: 75
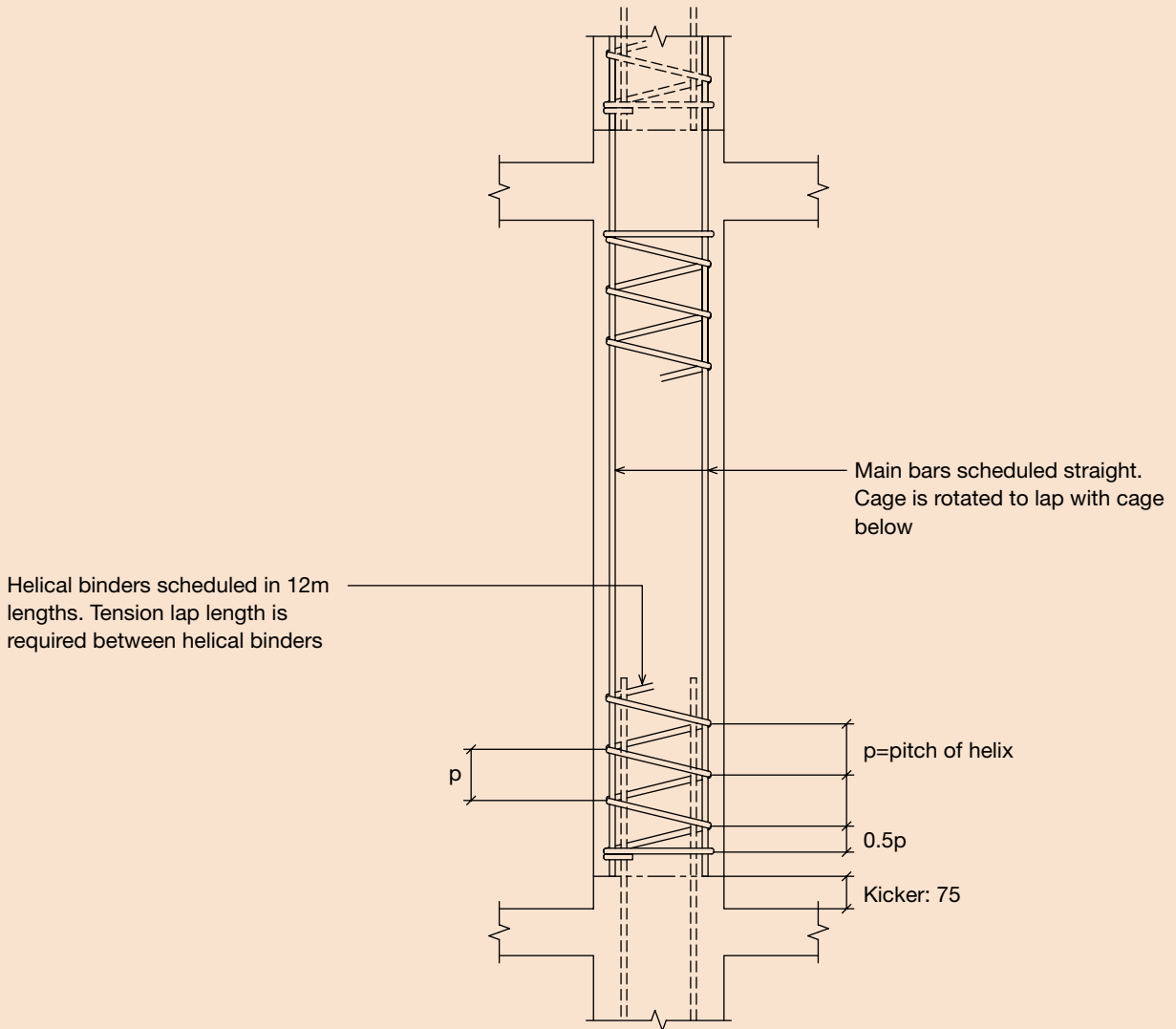
6.5   Walls

6.5.1   Scope

The information given relates specifically to walls which are vertical loadbearing members. It includes for plain concrete walls as defined in EC2.

Columns, as defined by EC2, with a breadth/thickness ratio of not greater than four are considered separately in 6.4 of this manual.

Walls thinner than 150mm are not recommended.

Basement retaining walls are considered separately in 6.6 of this manual.

Deep beams are covered in 6.3 of this manual.

6.5.2   Design and detailing notes
Concrete grade

Concrete grades lower than 28/35 MPa (cylinder strength/cube strength) are not normally used.

Nominal cover to all reinforcement (EC2, Clause 4.4)

Horizontal bars are placed outside the vertical bars and cover is measured to these.

- Internal use (15mm or bar diameter) + Δc_{dev} (Concrete inside buildings with low air humidity, XC1) whichever is greater
- External use 35mm + Δc_{dev} (Corrosion induced by carbonation, XC3)
  See 5.2.1 for values of Δc_{dev}

Minimum area of reinforcement (EC2, Clause 9.6.2)
Vertical reinforcement

0.002 A_c (half placed in each face)
Minimum bar diameter to ensure robust cage: 12mm

Horizontal reinforcement (in each face)

25% of the vertical reinforcement or **0.001 A_c** whichever is greater

Preferred minimum bar diameter: ¼ × diameter of vertical bars.

Links

Diameter to be not less than a quarter of the size of the largest compression bar.

Plain concrete walls

Where reinforcement is required for the purpose of controlling shrinkage or temperature (also applies to reinforced concrete walls), it should comply with the following.

Minimum steel area for both vertical and horizontal reinforcement 0.0025A_c.
This reinforcement should consist of small diameter bars closely spaced and placed (with adequate cover) near the exposed surface. This reinforcement should be distributed half near each face.

Maximum area of vertical reinforcement (EC2, Clause 9.6.2)

Maximum percentage of gross cross section: **0.04 A_c**

Bar spacing (EC2, Clause 9.6.3)
Minimum spacing
75mm (bars 40mm size and greater: 100mm).

Pairs of bars
100mm. When considering the minimum spacing of bars of 32mm size or greater, allowance must be made for lapping of bars.

Maximum spacing
Vertical and horizontal bars. The lesser of
- 3 times the wall thickness
- 400mm.

Links

Where the total area of the vertical reinforcement in the two faces exceeds 0.02 A_c links should be provided (see 6.4.2. The larger dimension referred to need not be taken larger than 4 times thickness of wall).

Vertical spacing
The lesser of
- 16 times the size of the vertical bar size or
- twice the wall thickness.

Any vertical compression bar not enclosed by a link should be within 200mm of a restrained bar.

Horizontal spacing
Maximum spacing should not exceed twice the wall thickness.

Table 6.6 Typical values of anchorage and lap lengths

	Length in bar diameters			
	$f_{ck}/f_{cu} =$ 25/30	$f_{ck}/f_{cu} =$ 28/35	$f_{ck}/f_{cu} =$ 30/37	$f_{ck}/f_{cu} =$ 32/40
Full tension and compression anchorage length, l_{bd}[1]	40	37	36	34
Full tension and compression lap length l_0[2]	61	56	54	51

Notes
1   It is assumed that the bar size is not greater than 32mm and α_1, α_2, α_4 and α_5 all equal 1.
2   It is assumed that no more than 50% of the bars are lapped at one place $\alpha_6 = 1.5$.
For other situations refer to EC2, Clause 8.4.4.

Anchorage and lapping of bars (EC2, Clauses 8.4 and 8.7)

For high yield steel, 500 Grade Table 6.6 gives typical anchorage and lap lengths for 'good' bond conditions.

Lap lengths provided (for nominal bars, etc.) should not be less than 15 times the bar size or 200mm, whichever is greater.

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:
• abbreviation for near face   N
• abbreviation for far face   F

F – far face   N – near face
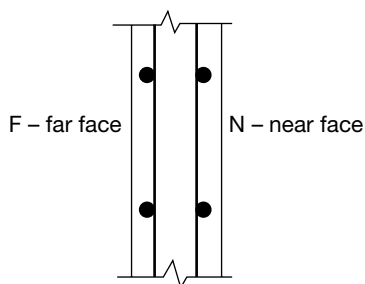
Typical bar and indicator line

The convention for illustrating and 'calling up' bars on walls follows closely to that for slabs (see 6.2.2)
A zone of similar bars in one face

20H10-63-150N1
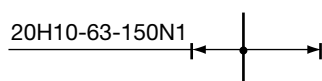
A zone of similar bars in two faces

40H10-63-150
(20N1-20F2)
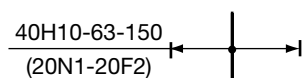
A zone of dissimilar bars in two faces

20H10-63-150N1   63   64
20H10-64-150F2
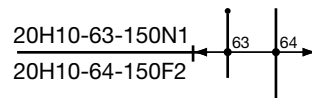
Identical bars appearing on different faces are itemised separately.

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

Corner details

For most conditions of applied moment, Model Detail MW2 is suitable. For situations where the opening applied moment requires more than 1.5% tensile reinforcement, consideration should be given to introducing a splay and diagonal reinforcement (see also EC2, Annex J: UK National Annex).

Openings in walls

Isolated openings which are smaller than the pitch of the reinforcement need not be trimmed. Where an opening does affect the structural integrity, consideration should be given to the use of diagonal bars at the corners of the hole, to provide better crack control. Where an opening occurs in a wall which does not affect the structural integrity, it should be trimmed with bars of diameter one size larger than that used in the surrounding wall. For such situations the minimum wall thickness should be increased to 175mm. U-bars of the same size as the horizontal bars should be placed around the opening enclosing the trimmer bars. See Model Detail MW4.

Edge wall connections to slabs

This method for detailing slab to edge walls is described in section 6.2.2. This is similar to that for beam to edge columns which is described in 6.3.2. Model detail MS2 shows the reinforcement detail for such a joint. Where slab starter bars are required and can not be inserted through holes left in the wall Model detail MW3 is used.

Half landings

Where starter bars are required for half landings these may be inserted in the walls. Mechanical shear dowels and couplers may be considered as alternatives to half joints so avoiding the use of nibs.

6.5.3 Detailing information

Design information for detailing should include:
- Layout and section drawings including details of slab intersections and holes, and details of the construction system if known.
- Concrete grade and aggregate size (standard 30/37MPa and 20mm).

- Nominal cover to reinforcement and controlling design consideration, fire or durability (standard 20mm for internal conditions, 40mm for external conditions).
- Details of any design reinforcement required including:
  - type of reinforcement (standard H)
  - bar diameter
  - pitch or number
  - where it is required
  - lap length if other than normal compression lap.

  Otherwise bar size and pitch given in Model Detail MW1 is assumed.
- Details of proprietary reinforcement, insertions and openings, e.g. conduit, cable ducting, etc., should be given where the placing of reinforcement is affected. Provide this information at an early stage.

14 H10 05 200
(7NF 7FF)

10 H12 03 200
(UB'S in pairs)

2 H16 06

20 H10 04 200 UB

4 H16 02 (2 NF 2 FF)

52 H12 01 200 (25 FF 27 NF)

12 H10 04 200 UB

12 H10 07 200 UB

40 H10 08 200
(20 NF 20 FF)

20 H10 07 200 UB

16.675

20 H10 09
(200 links)

600

75

12.675

WALL ON LINE 'A'

A

03

0303

05 — — 05

03

06 06

1 - 1

07

01

01

08   07

08

09

A   A

01

02

02

01

04   04 04

2 - 2

3 - 3
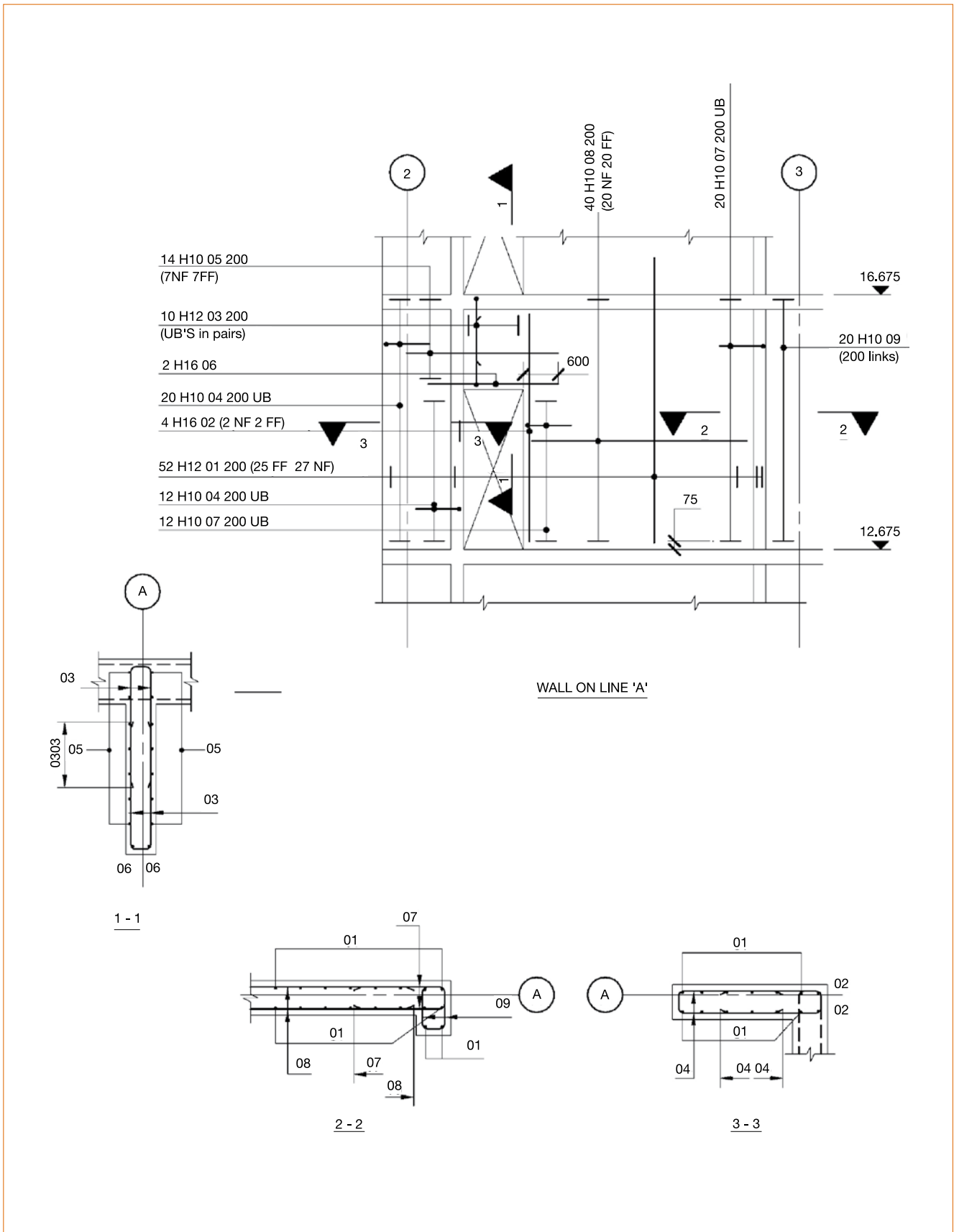
WALLS MW1
General details

Horizontal bars are laid outside vertical bars
Nominal cover specified by designer (At least 20 or bar size whichever is greater)
Where there is no specific design requirement the bar size and pitch given below may be used

'U' bars provided at top

Compression lap unless
specified otherwise

Projection above floor level:-
Compression lap + kicker height
unless specified otherwise

Structural floor level

Kicker: 75

Wall thickness	Vertical bars		Horizontal bars	
	Dia.	Pitch	Dia.	Pitch
150-175	12	300	10	200
175-200	12	250	10	200
200-250	12	200	10	200
250-300	16	300	10	200
300-400	16	250	12	200
400-500	16	200	12	150
500-600	20	250	16	200
600-700	20	200	16	200
700-800	20	200	16	200

Compression lap + 150 for
foundation level tolerance

For edge walls the starter bars
for slabs shown on Model Detail
MS2 B and C should be detailed
with the wall drawings wherever
possible. Otherwise they must be
clearly cross referenced

Kicker: 75
(150 below ground)

Vertical bars rest on kicker

'L' bars provided at bottom

450

WALLS   MW2
Corner details

For cover, size and pitch of main bars see Model Detail MW1 unless specified otherwise
U-bars to be same size and pitch as horizontal bars

Two bars should be placed within loop for wall thickness 300 and less. For wall thickness over 300 four bars should be included as shown

Tension lap
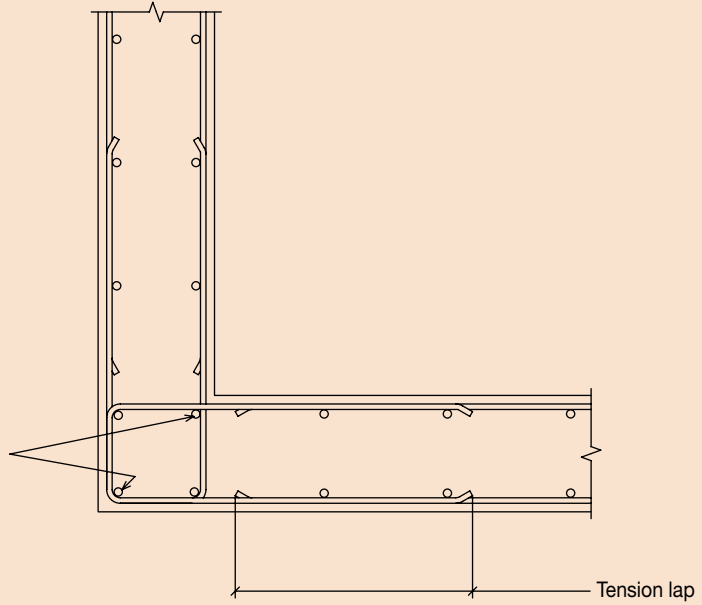
DETAIL 'A'

Two bars should be placed within loop for wall thickness 300 and less. For wall thickness over 300 four bars should be included as shown

Tension lap
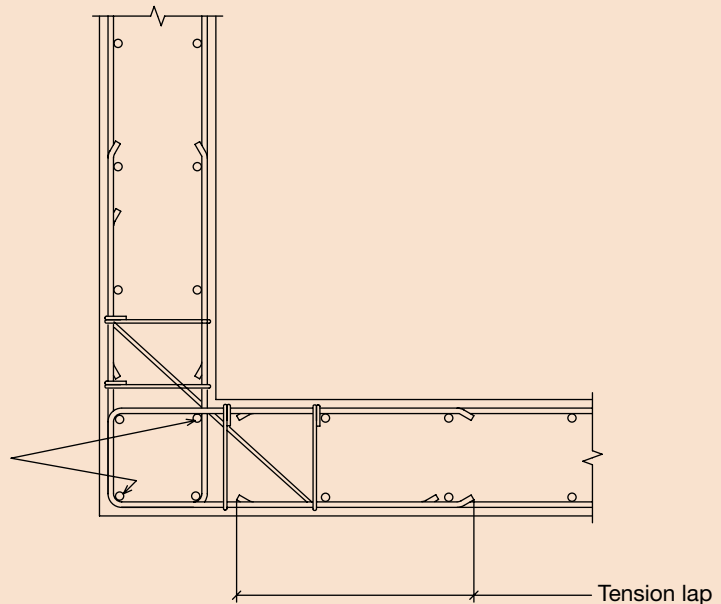
DETAIL 'B'   (for large opening moments)

WALLS   MW3
Half landing detail

For cover, size and pitch of wall bars see Model Detail MW1

For details of slab bars see Model Detail MS2, but 'U' bars to be Class B or C steel and of size not greater than 12

For details of staircases see Model Details MST1 and MST2

Horizontal wall reinforcement
not shown for clarity

Bars are pre-bent to fit flush
with the shutter

Two fixing bars are
placed inside 'U' bars

35

Tension lap
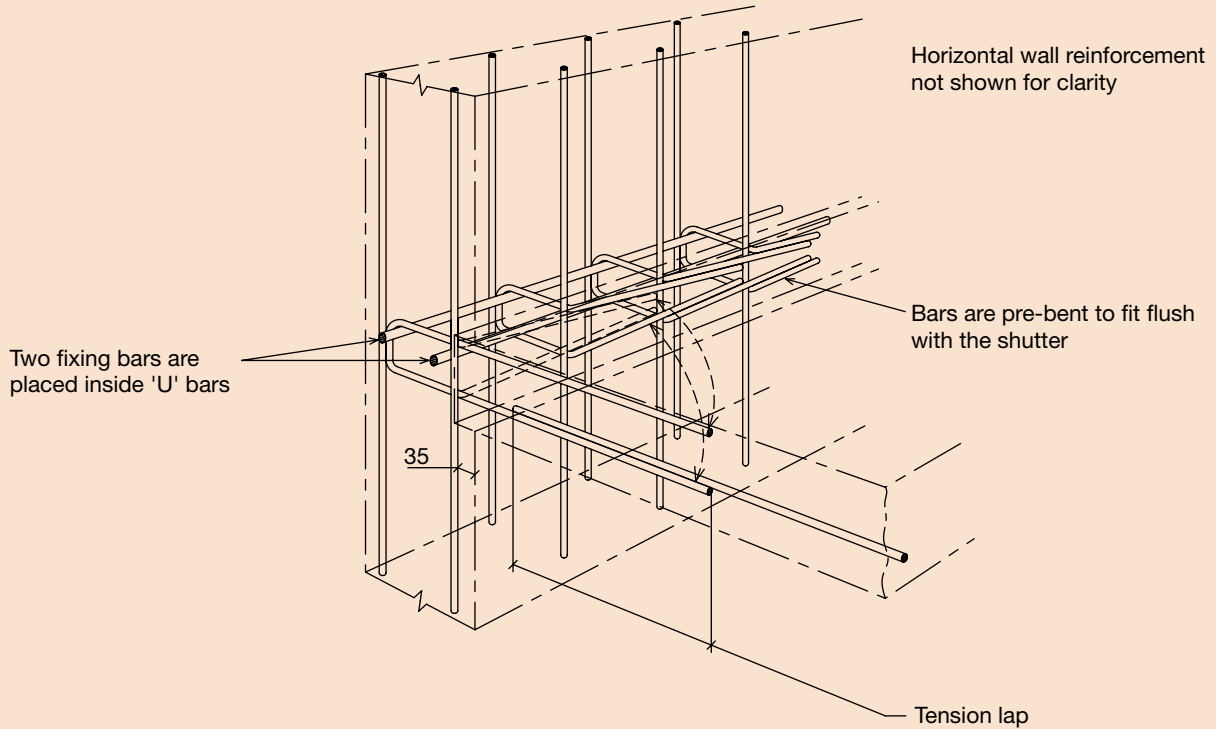
WALLS   MW4
Hole details

For cover, size and pitch of main bars see Model Detail MW1

Tension anchorage length beyond trimmer bars

Compression lap unless specified otherwise

Diameter of trimmer bars is one size larger than vertical bars. For walls less than 250 thick only one trimmer bar of equivalent area is used

Trimmer bars at side of opening

Hole
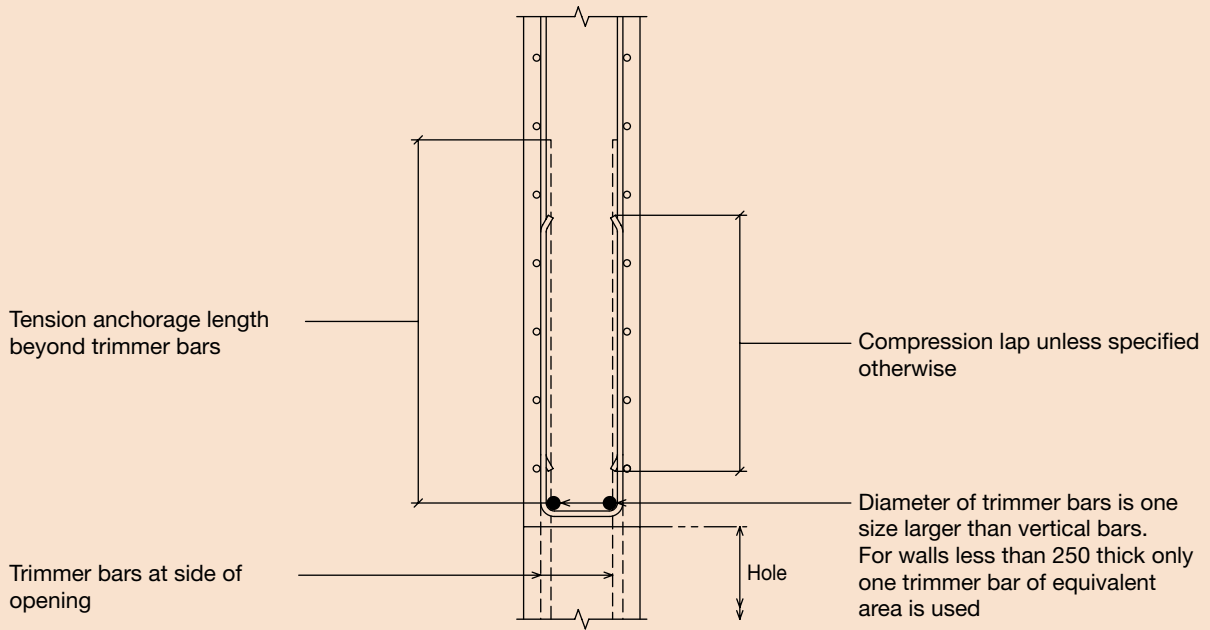
DETAIL 'A'

Section through top of opening
Section through bottom similar

Tension anchorage length beyond trimmer bars

Hole

Trimmer bars above and below

Tension lap

Diameter of trimmer bars is one size larger than vertical bars. For wall thickness of 200 or less only one trimmer bar on each side of the hole is used
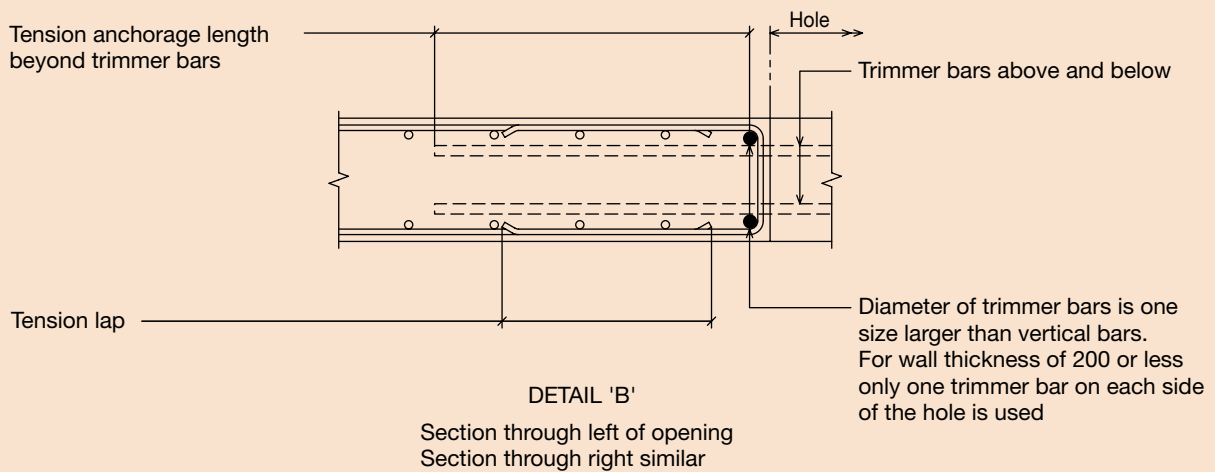
DETAIL 'B'

Section through left of opening
Section through right similar

6.6 Retaining Walls

6.6.1 Scope

The information given relates specifically to retaining walls with two layers of reinforcement. The requirements for water retaining structures given in Chapter 9 may also be relevant (e.g. basement walls).

The specification of joints and water-bars for water resistant structures is not covered by this manual. Reference should also be made to EN 1992-3[4], BS 8007[32] and CIRIA Report 139, *Water-resisting basements*[11]. Reinforced and plain concrete walls are considered separately in 6.5 of this manual.

Foundations are considered separately in 6.7 of this manual. Diaphragm walls are not considered in this manual.

6.6.2 Design and detailing notes
Concrete grade

Concrete grades lower than 28/35 MPa (cylinder strength/cube strength) are not normally used.

Note

There may be particular requirements for concrete grade/mix in contaminated ground.

*Nominal cover to all reinforcement
(EC2, Clause 4.4)*

Cover is measured to the outer layer of reinforcement.

- Internal face
  (20mm or bar size) + Δc_{dev}, whichever is greater. (Concrete inside buildings with low air humidity, XC1).This may be modified by particular internal environment.
- External face
  35mm + Δc_{dev} (Corrosion induced by carbonation, XC3)
- Earth face
  45mm + Δc_{dev} (see Model Detail MRW1)

See 5.2.1 for values of Δc_{dev}

*Minimum area of reinforcement
(EC2, Clause 9.6.2, pr EN 1992-3)*
Simple earth retaining walls

Retaining walls which provide means for the water to drain, e.g. weep holes, and for which minor seeping problems do not create problems.

- Vertical reinforcement
  0.002 A_{c} (half in each face). Minimum bar size 12mm
- Horizontal reinforcement
  the greater of 25% of vertical reinforcement or 0.001A_{c} (in each face)

Water resisting retaining walls or retaining walls which are required to prevent water seepage, e.g. basements

Restraints can cause cracking to occur in any direction and hence the minimum steel provided should equal $A_{\mathrm{c}} f_{\mathrm{ct}} / f_{\mathrm{y}}$ in both directions and the crack widths checked accordingly.

See also EC2, Part 3 and CIRIA Report 139, *Water-resisting basements*[11].

*Maximum area of vertical reinforcement
(EC2, Clause 9.6.2)*

- Maximum percentage of gross cross section: 4%.

Bar spacing (EC2, Clause 9.6.3 and EC2, Part 3 Clause 7.3.3)

- Minimum spacing
  75mm (bars 40mm size and greater:100mm)
- Pairs of bars
  100mm
  When considering the minimum spacing of bars of 32mm size or greater, allowance must be made for lapping of bars.
- Maximum spacing
  200mm

*Anchorage and lapping of bars
(EC2, Clauses 5.2.2, 5.2.3 and 5.2.4)*

For high yield steel, 500 Grade Table 6.7 gives typical anchorage and lap lengths for 'good' bond conditions.

Lap lengths provided (for nominal bars, etc.) should not be less than 15 times the bar size or 200mm, whichever is greater.

Table 6.7 Typical values of anchorage and lap lengths

	Length in bar diameters			
	$f_{\mathrm{ck}}/f_{\mathrm{cu}}$ = 25/30	$f_{\mathrm{ck}}/f_{\mathrm{cu}}$ = 28/35	$f_{\mathrm{ck}}/f_{\mathrm{cu}}$ = 30/37	$f_{\mathrm{ck}}/f_{\mathrm{cu}}$ = 32/40
Full tension and compression anchorage length, l_{bd}[1]	40	37	36	34
Full tension and compression lap length, L_0[2]	61	56	54	51

Notes
1. It is assumed that the bar size is not greater than 32mm and α_1, α_2, α_4 and α_5 all equal 1.
2. It is assumed that not more than 50% of the bars are lapped at one place. α_6 = 1.5.

For other situations refer to EC2, Clause 8.4.4

Edge wall connection to slabs

The method for detailing slab to edge walls is described in 6.2. This is similar to that for beam to edge columns which is described in 6.4. Model Detail MS2 shows the reinforcement details for such a joint.

Mechanical shear dowels and couplers may be considered as alternatives and are described in 6.2.2.

Corner details

For most conditions of applied moment Model Detail MW2 is suitable. However for thin sections with a high applied opening moment a special detail may be required (see EC2, Annex J, UK National Annex).

Construction joints

Kicker height for walls below ground level should be a minimum of 150mm and cast integral with the foundations.

Full contraction joints should only be used when it is predicted that shortening along the full length of the wall will be cumulative. Where necessary they should be detailed at 30m centres. See Model Detail MRW3B.

Liquid retaining structures should only be provided with movement joints if effective and economic means cannot otherwise be taken to minimise cracking.

There are two main options available (see Table 6.8).

A   Design for full restraint. In this case, no movement joints are provided and the crack widths and spacings are controlled by the provision of appropriate reinforcement according to the provisions of EC2, Clause 7.3.

B   Design for free movement (see Model Detail MRW3C). Cracking is controlled by the proximity of joints. A moderate amount of reinforcement is provided sufficient to transmit any movements to the adjacent joint. Significant cracking between the joints should not occur. Where restraint is provided by concrete below the member considered, a sliding joint may be used to remove or reduce the restraint.

Wall starters

Wall starter bars should always be specified with the base slab reinforcement and care taken to define them relative to the wall section, or at least refer to their location on drawing and schedule.

Links in walls

Where the total area of the vertical reinforcement in the two faces exceeds 0.02 A_c links should be provided.

6.6.3   Detailing information

Design information for detailing should include:
- Layout and section drawings, which include plan dimensions, depths and levels.
- Dimensions and positions of kickers (standard kicker height below ground 150mm, above ground 75mm).
- Concrete grade and aggregate size (standard 30/37MPa and 20mm).
- Cover to reinforcement:
  - standard:
    50mm to earth face of walls
    40mm to external exposed faces of walls
    75mm to bottom and side cover to base
    25mm to internal faces.
- Detail of design reinforcement required including:
  - type of reinforcement (standard H)
  - bar diameter
  - pitch or number
  - position.
- Details of construction joints.
- Details of any services fittings where placing of reinforcement may be affected, e.g. large openings, puddle flanges.

Table 6.8 Design of joints for the control of cracking			
Option	Method of control	Movement joint spacing	Reinforcement
A	Continuous – full restraint	Generally no joints, though some widely spaced joints may be desirable where a substantial temperature range is expected	Reinforcement in accordance with EC2, Clauses 6 and 7.3
B	Close movement joints – maximum freedom from restraint	Complete joints at greater of 5m or 1.5 times wall height	Reinforcement in accordance with EC2, Clauses 6 but not less than minimum given in Clauses 9.6.2 to 9.6.4.

PANEL B

16 H12 03 250
8H 8B

8 H16 04 250 T
8 H12 05 250 B

A

SEE PANEL D

47 H16 01 150 T
47 H12 02 150 B

PLAN PANEL C

14

10   10   4.300

08 14

08   09

07

08 06   09

03   10   10   03   1.800

03   02   03

07   06   02

1 – 1

PANEL B

54 H10 14 150 UB

22 H12 11 250 NF
11 H12 12 250 FF

4.300

75   500   52   2   54 H12 08 150 NF
54 H16 09 150 FF

1.800   3   3   06   07   2   52   2   54 H12 06 150 NF
54 H16 07 150 FF

150

11 H10 13 (a-k) 250 (UB)

22 H12 10 250 11NF 11FF

22 H12 10 250 11NF 11FF

ELEVATION PANEL C
(1 No OFF)

12
10
11

1

SEE PANEL B

10   13

09   09

08   08

10

3 – 3

09   09

08   12
08   11

11

2 – 2

PANEL A   B   B   B   C

1

A

WALL A
KEY PLAN

PLAN WALL A

8 H16 02 4B 4T
2 H12 03 SIDE
8 H16 01 4B 4T
2 H12 03 SIDE
8 H16 02 4B 4T

03 03

05
04 06

50 50

29 H12 04 300 T
29 H12 05 300 B
29 H12 06 300 B

SEE SLAB DRG

10.300

13 13

09 10

09 10

40 CVR 50 CVR

DETAILED WITH WALL B

05 09 07 10 08

01 13 13 01

03 03 05 04

500 01 01

08 07 75 CVR

06 05

ELEVATION WALL A

34 H12 13 150 17NF 18FF
34 H12 14 150 17NF 18FF
34 H12 13 150 17NF 18FF
65 H12 11 150 UB

10.300
(2)
17 H12 12 150 UB
(2)
6.800

50 50
3 (61)
3 17 H12 12 150 UB
2 550 2 (61)
(2) 65 H12 09 150 NF
65 H16 10 150 FF
07 08 150 (61)
65 H12 07 150 NF
65 H16 08 150 FF

2 – 2

14 13 13 14
10 10
13 09 14 13 09

3 – 3

13 12 13 12
10 10
09 09 09

SEE WALL B DRG

KEY PLAN

A B
WALL B WALL A WALL B
1

RETAINING WALLS   MRW1
External cantilever wall

Vertical bars placed on outside for earth faces
Horizontal bars placed on outside for exposed faces

Tension lap

Bar size and pitch for earth face as specified by designer

40 for externally exposed faces

50 for buried faces

Bar size and pitch for exposed face (based on minimum wall thickness) given in table of Model Detail MW1 unless stated otherwise

Granular fill

Tension laps

Bar size and pitch as specified by designer

Kicker:150

50

75

Tension lap

75

Nominal reinforcement, see Model Detail MS1, unless stated otherwise

Tension lap

Key added if and where required

Large radius of bend specified by designer if necessary

RETAINING WALLS   MRW2
Basement retaining wall

Tension lap

50 for buried faces

Tension lap

50

Wall placed centrally on
ground beam

75

300 minimum
overlap

Tension lap

Tension lap

Details of waterbars as specified

Vertical reinforcement fixed
first for ease of construction

25 for internal faces
40 for external exposed faces

Reinforcement not specified by
designer is given by nominal steel
table for Model Detail MW1

Kicker: 150

75

75

Large radius of bend specified by
designer if necessary

Cavity drain slot

Kicker: 150

50

75

300 minimum
overlap

Tension lap

Tension lap

75

Floor to falls

75

75

Large radius of bend specified by
designer if necessary

Tension lap

RETAINING WALLS   MRW3
Vertical construction joints

25 for internal faces
40 for external exposed faces

Splice bars of the same
size and pitch as main bars

50 for buried faces

Tension lap

Tension lap

50   50

DETAIL 'A'
Simple construction joint

If dowel bar specified see
Model Detail MF5 B

Spacing of joints should be
30m maximum

500   500

H10 'U' bars

75   75

If internal water bar is
required 'U' bars are
displaced to avoid clash

DETAIL 'B'
Full contraction joint

For details of waterbars and
expansion joints see CIRIA Report 139
'Water-resisting basements'

500   500

75   75

DETAIL 'C'
Movement joint

6.7　Foundations

6.7.1　Scope

The information given relates to:
- rectangular pad footings and multi-column bases
- piled foundations
- rafts
- ground beams and slabs.

The specification of joints and waterbars for water resistant structures is not covered by this manual. Reference should be made to CIRIA Report 139, *Water-resisting basements*[11].

Retaining walls are considered separately in 6.6 of this manual.

Details for holding down bolts are not included.

6.7.2　Design and detailing notes
Concrete grade

Concrete grades lower than 28/35 MPa (cylinder strength/cube strength) are not normally used, unless there is a specific durability requirements (e.g. for concrete grade/mix in contaminated ground).

Nominal cover to all reinforcement (EC2, Clause 4.4.1.3)

- Large foundations, pile caps, pad and wall footings: **75mm**
- Bottom cover for piled foundations: 100mm
  The extra cover recognises that piles project into the cap and the reinforcement mat is laid on them.
- Earth face: 45mm + Δc_{dev}
- External exposed face: 35mm + Δc_{dev} (other than earth faces)
- Internal face: (25mm or bar size) + Δc_{dev}, whichever is the larger. This refers to the top of ground slabs, inside trenches, etc.

See 5.2.1 for values of Δc_{dev}

Note

There may be particular requirements for concrete grade/mix in contaminated ground.

Minimum area of reinforcement (EC2, Clause 9.2.1.1)

- Tension reinforcement:
  $$A_{s,min} = 0.26\, b_t\, d\, f_{ctm}\, /f_{yk} \geqslant 0.0013\, b_t\, d$$
  where b_t is the mean width of the tension zone
  　　　d is the effective depth
  　　　f_{ctm} is determined from Table 3.2 of EC2
  　　　f_{yk} is the characteristic yield strength

- For concrete Grade 28/35 and f_{yk} = 500 MPa
  $$A_{s,min} = 0.0014\, b_t\, d$$
  This also applies for nominal reinforcement.
- Bar diameters less than 16mm should not be used except for lacers.

Bar spacing (EC2, Clause 9.8)

- Minimum spacing
  75mm (bars 40mm sizes and greater: 100mm)
- Pairs of bars:100mm
  When considering the minimum spacing of bars of 32mm size or greater, allowance must be made for lapping of bars.
- Maximum spacing:　200mm
- Minimum spacing:　100mm
- Maximum spacing
  When A_{st} is 0.5% or less – 300mm
  Between 0.5% and 1.0% – 225mm
  1.0% A_{st} or greater – 175mm

Anchorage and lapping of bars (EC2, Clauses 5.2.2, 5.2.3 and 5.2.4)

For 500 Grade steel Table 6.9 gives typical anchorage and lap lengths for 'good' and 'poor' bond conditions.

Table 6.9 Typical values of anchorage and lap lengths						
	Bond conditions	**Length in bar diameters**				
		f_{ck} /f_{cu} = 25/30	f_{ck} /f_{cu} = 28/35	f_{ck} /f_{cu} = 30/37	f_{ck} /f_{cu} = 32/40	
Full tension and compression anchorage length, l_{bd}[1]	good	40	37	36	34	
	poor	48	45	43	41	
Full tension and compression lap length l_0[2]	good	46	43	42	39	
	poor	66	61	59	56	

Notes
1　It is assumed that the bar size is not greater than 32mm and α_1, α_2, α_4 and α_5 all equal 1.
2　It is assumed that not more than 33% of the bars are lapped at one place, α_6 = 1.15.
For other situations refer to EC2, Clause 8.4.4.

Lap lengths provided (for nominal bars, etc.) should not be less than 15 times the bar size or 200mm, whichever is greater.

Starter bars for columns should have a minimum horizontal leg of 450mm to ensure that the compression forces can be transmitted to the foundation, unless it can be shown that the column is lightly loaded and that the design compressive stress in the bars is less than 50% of its maximum capacity.

Figure 6.28 Detailing of pad footings and column strips

Pad footings and column strips

Straight bars are normally used without curtailment, and should be detailed if nothing else is specified (see Figure 6.28). However, an anchorage length should be provided from the face of the wall or column to the end of the bars. This may require bobs to be bent at the ends of bars.

If $l_x > 1.5$ $(c_x + 3d)$, at least two-thirds of the reinforcement parallel to l_y should be concentrated in a band width $(c_x + 3d)$ centred at the column, where d is the effective depth, l_x and c_x are the footing and column dimensions in the x-direction and l_y and c_y are

the footing and column dimensions in the y-direction. The same applies in the transverse direction with suffixes x and y transposed.

Pile caps

A full tension anchorage length should be provided from the centre line of the edge pile to the end of the bar.

Standard pile caps

The configuration of reinforcement that is normally adopted for standard pile caps is shown in Table 6.10.

Table 6.10 Layout of reinforcement for standard pile caps

No. of Piles	Bar Ref.	Shape Code	Size and Type	
2	1	21*	Design H20, H25, H32 or H40 (Easy bends)	
	2	12	Nominal H16, H20 or H25	
	3	21	Nominal H16	
3	1	21*	Nominal H16	
	2	21*	Design H20, H25, H32 or H40 (Easy bends)	
	3	21	Nominal H16 @ 200	
	4	21	Design H20, H25, H32 or H40	
	5	27	Nominal H16	
	6	25	Nominal H16	
4, 6 5, 8 or 9	1	21* }	Design H20, H25, H32 or H40	
	2	21		
	3	12	Nominal H16	
7	1	21 }	Design H20, H25, H32	
	2	21		
	3	21 }		
	4	15	Nominal H16	

Note
* Where the design requires a large mandrel size the Shape Code will be 99
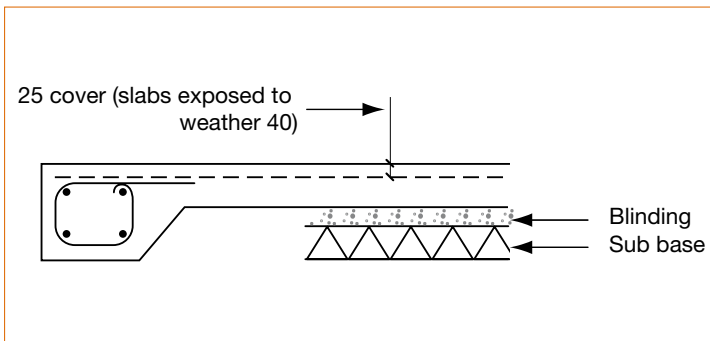
Figure 6.29 Detailing of ground slab cast directly onto ground
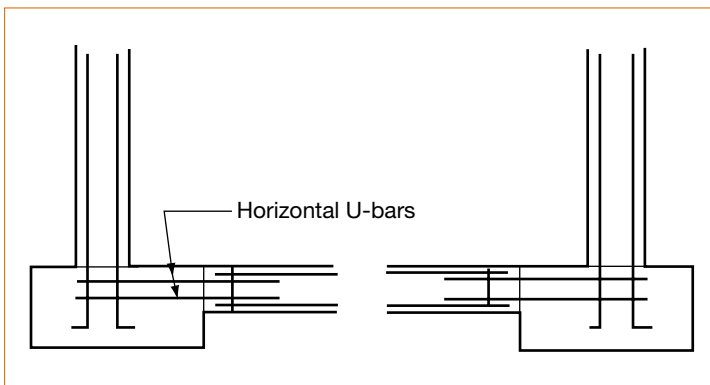
Figure 6.30 The beam between two foundations
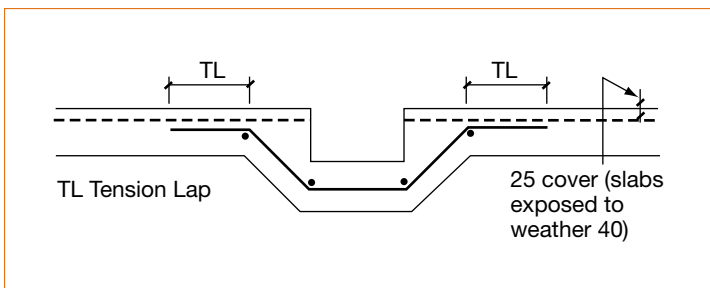
Figure 6.31 Nominal reinforcement for ducts and trenches
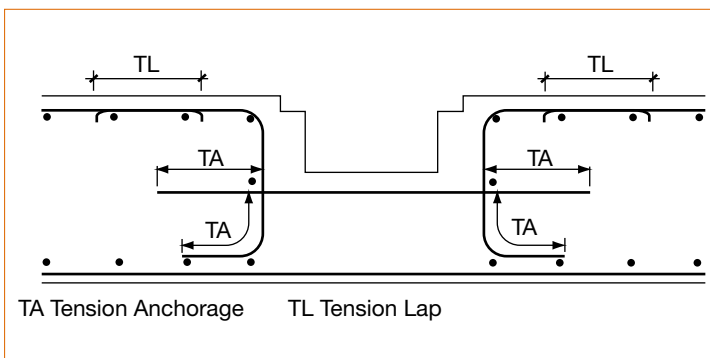
Figure 6.32 Continuity reinforcement across trenches in foundations

Ground slabs

(See the Concrete Society Technical Report No. 34, *Concrete industrial ground floors*[9])

This clause refers only to lightly loaded ground slabs, typically in buildings. Where such slabs are cast directly onto the ground they should be reinforced to control cracking. Square mesh fabric (A193) is suitable for this purpose. Laps of 300mm minimum should be used (see Figure 6.29). Details for fully reinforced slabs are given separately in 6.2 of this manual.

Ground beams

Detailing of ground beams is dealt with in 6.3 of this manual, except that the cover to reinforcement should be increased to 75mm where formwork is not used.

Where ground beams span on to pad footings or pile caps which otherwise would not require top steel, the main beam reinforcement should be continued right across the foundation.

When the ground beam is used as a tie between foundations, the main beam reinforcement should pass around the column or wall starter bars and be fully anchored (see Figure 6.30).

Rafts

Detailing reinforcement in rafts is dependent on the construction method and sequence. The designer should give clear instructions which relate to a possible solution. These instructions should be confirmed with the contractor before detail drawings are produced and should include:

- position of construction joints for lapping of reinforcement
- position, width and depth of movement joints
- position of water bar joints.

In order to avoid congestion of reinforcement, consideration should be given to adding splice bars at lapping points and placing them in a separate layer.

Ducts and trenches

Where ducts and trenches occur in ground slabs (see Ground slabs), if there is no requirement for design reinforcement, nominal reinforcement should be placed around them (see Figure 6.31).

Where they occur in rafts or multi-column foundations, special attention should be given to detailing continuity top reinforcement, where moment transfer is required (see Figure 6.32).

Normally walls for small trenches and manhole chambers should be detailed with a single layer of reinforcement in each direction.

Column and wall starters

Wherever possible column and wall starter bars should be specified with the footing reinforcement and care taken to define their position relative to the column section or wall.

Chairs (BS 7973[19])

Where top reinforcement is required in multi-column foundations and rafts, consideration should be given to the method of supporting this with chairs and edge U-bars. This should take into account the construction sequence, the weight of top reinforcement and depth of foundation, which affect the size and number of chairs required. The concrete may be poured in more than one layer, and it may thus be possible to sit the chairs on an intermediate level.

6.7.3 Detailing information

Design information for detailing should include:

- Layout drawings including column and wall outlines.
- Plan dimensions including depth and level.
- Dimensions and positions of kickers (standard kicker height below ground 150mm, above ground 75mm).
- Concrete grade and aggregate size (standard 30/37MPa and 20mm).

- Cover to reinforcement (standard 75mm; bottom cover for piled foundations 100mm). Position in plan of starter bars.
- Reinforcement parallel to x axis and parallel to y axis, clearly relating to layout drawings. This should include:
  - Number and pitch of bars
  - Type of reinforcement and bond characteristics (standard H)
  - Diameter of bars and direction of bottom bars
  If standard pile cap number of piles (see standard arrangements in 6.7.2).
- Reinforcement for starter bars and links. This should include:
  - Number and position of bars
  - Type of reinforcement and bond characteristics.
- Band width details of reinforcement when required.
- Details of L-bends. These are only required if anchorage length necessary exceeds the length between the face of the column or wall and the edge of foundation.
  - Details of construction joints
  - Details of gullies etc. which affect slab detail.

6.7.4 Presentation of working drawings
Traditional method

Individual pad footings or pile caps are drawn related to specific grid lines.

This method is normally used where the job has little repetition and it is simpler to show the details of all footings individually.

Details of column starter bars are shown with the footing drawings wherever possible. The position of these must take into account the position of the main column bars which are spliced to them.

BASE K/12

65 COVER TO 03

2 - 2

1 - 1
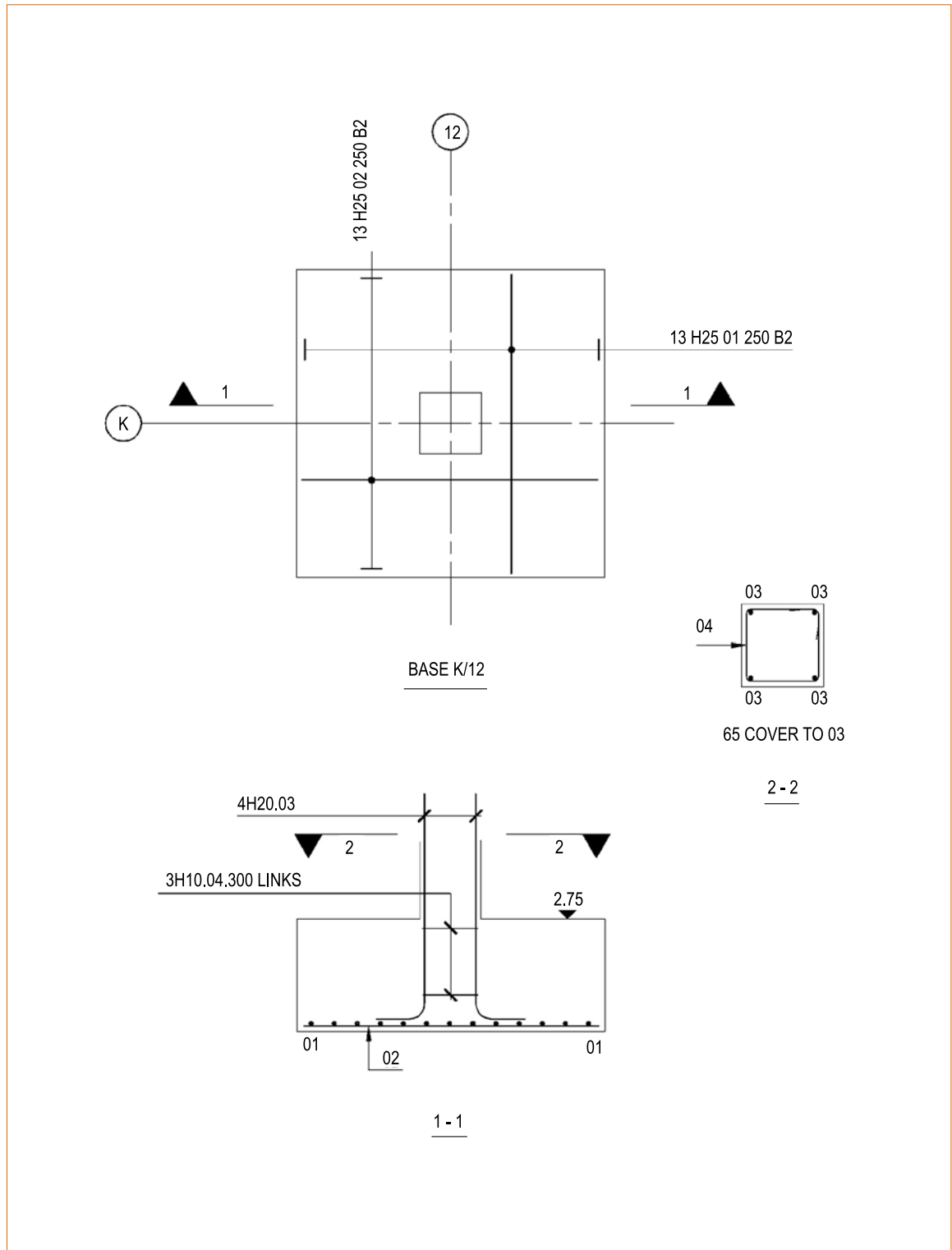
Representational method

The detail relates a general pad footing or pile cap to X and Y directions, together with a table giving details of reinforcement for each type of footing, and, where possible, column starters.

The plan shape of each footing type is only representative and not drawn to scale. Rectangular footings are divided into those with and without banded reinforcement.

The following points should be noted:

• The X and Y directions must be related to the general arrangement drawing.

• Each footing is related to a reinforcement type, either by a location plan or by tabulating the column grid references (shown below).

• Column starters are shown, wherever possible, in the same table. Where column starters are not shown on the same drawing, comprehensive cross referencing of drawings is an essential requirement.
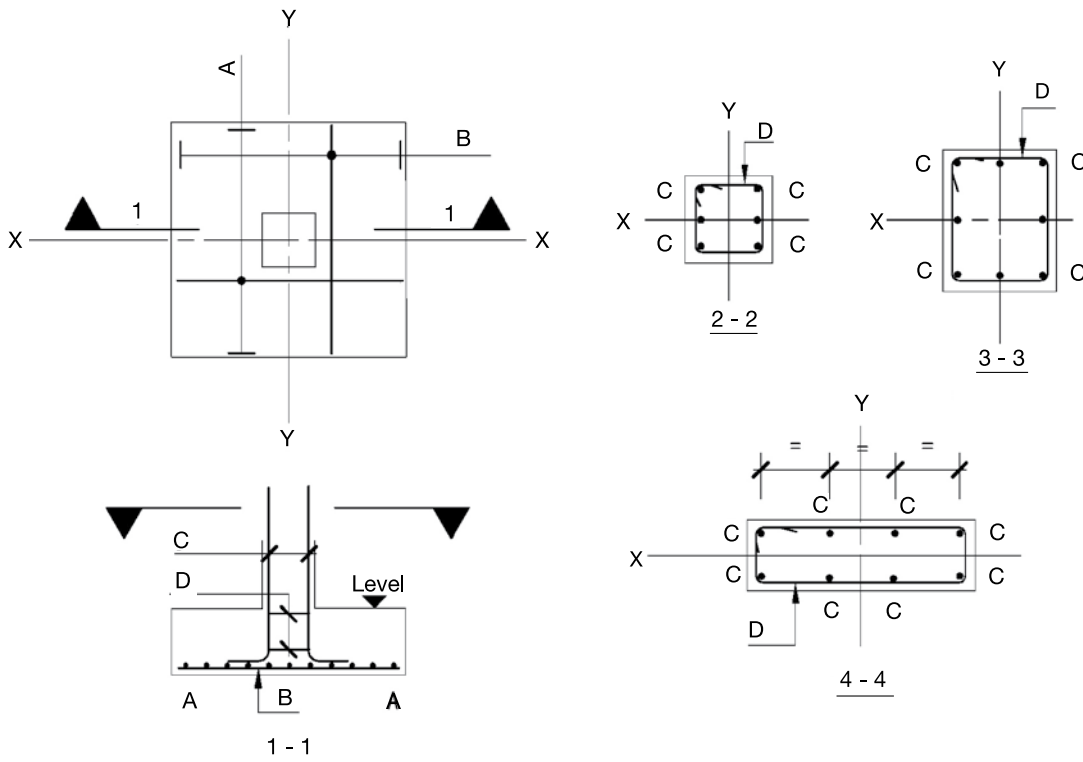
X - X Relates to lettered grids
Y - Y Relates to numbered grids

Column Reference	No off	Base Level	Base Steel		Cage Sect.	Starters	
			MK A	MK B		MK C	MK D
A1, A3, A5, A7, F1, F3, F7	7	2.75	15 H25 01 200	15 H25 01 200	2-2	6 H32 10	3 H10 12 300
F5	1	2.75	15 H25 02 200	18 H25 02 200	3-3	8 H25 13	3 H10 14 300
C2, C4, C6	3	3.90	18 H25 06 225	18 H25 06 200	2-2	6 H40 16	3 H10 17 300
C5	1	4.20	12 H20 08 250	12 H20 08 250	4-4	8 H20 21	3 H10 22 300

PAD FOOTINGS   MF1

For details of column splice see Model Detail MC1

Compression lap plus 150 for
foundation level tolerance

Kicker: 75
(150 below ground)

Footing level

Unless specified
by design, use
H10-300 (3 No. min.)

Sufficient cover
to ensure no
problems of fit

75

450
min.

75

Main bars normally straight.
Bars may be bobbed if
required by design

Cover to starter bars is given
from column faces
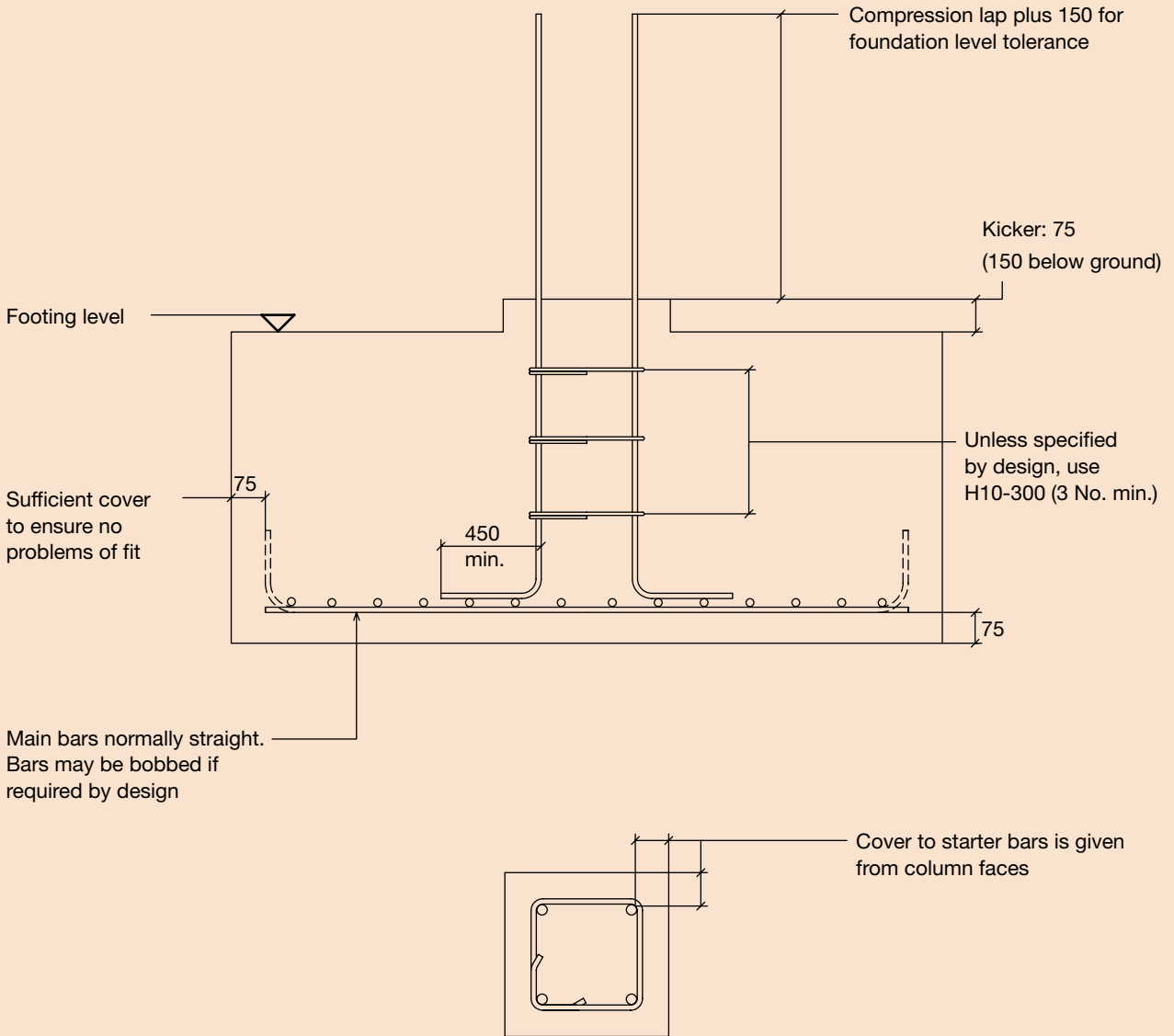
PILE CAPS MF2

For details of column splice see Model Detail MC1

Cover to starter bars is specified from column faces

Compression lap plus 150 for foundation level tolerance

Kicker: 75 (150 below ground)

Pile cap level

75

Length of bob specified by design

Sufficient cover to ensure no problems of fit

450 min.

2 layers of lacers, H12

The main bars are bent at both ends

100 (allows for pile head)

Bars normally rest on top of piles - bottom cover allows for this

If large radius of bend specified corner bar shifted accordingly

Unless specified by design use H10-300 (3 No. min.)

FOUNDATIONS   MF3
Multi-column Base

For details of column starter bars see Model Detail MF
For details of column splice see Model Detail MC1

A

40 for exposed concrete
50 for buried concrete

Foundation level

75

300 min. overlap

A

A

Distribution bars H16s at 300 centres

75

Two layers of lacers, H12s

300 min. overlap

A-A
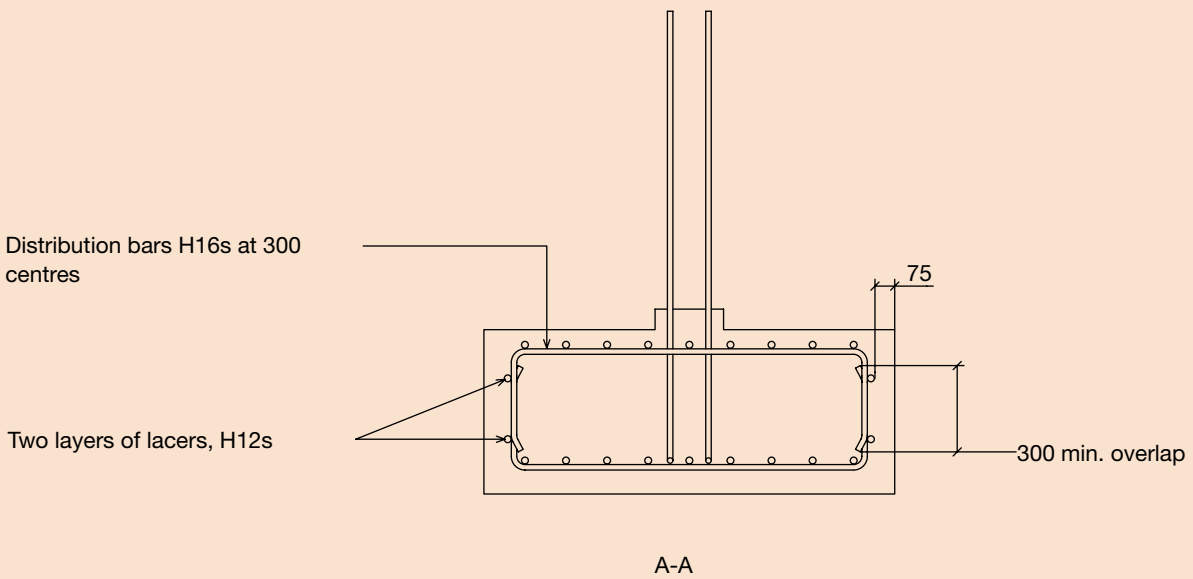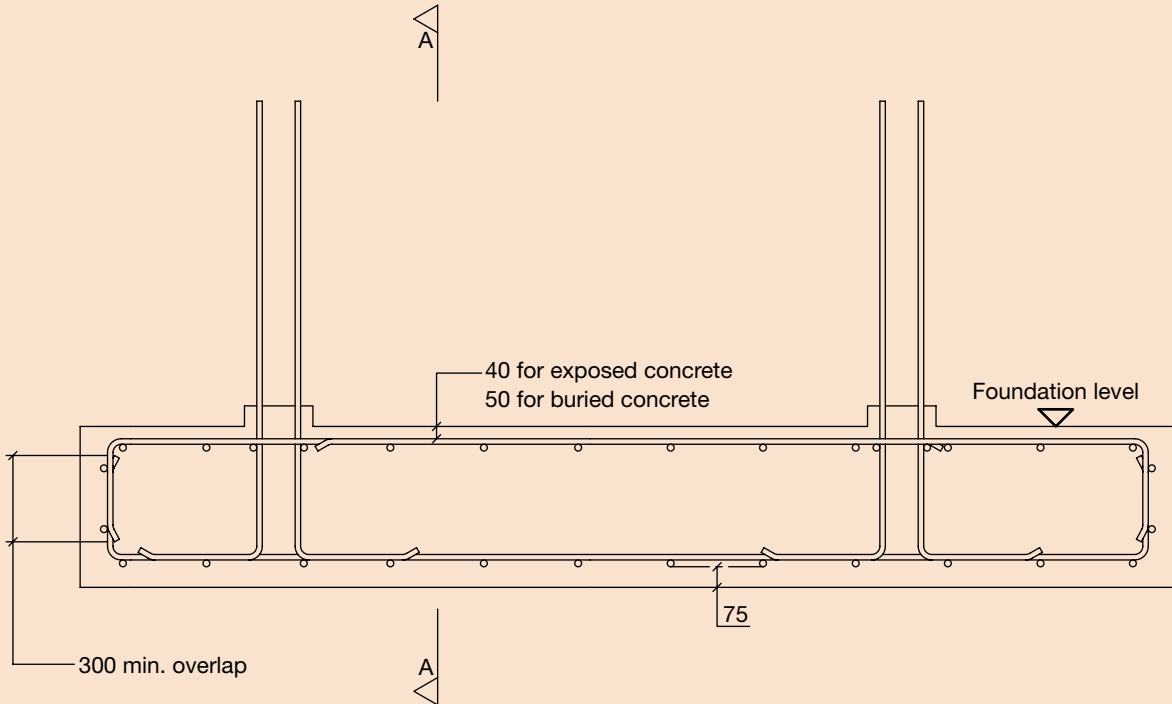
FOUNDATIONS   MF4
Ground slab and beam

For retaining wall details see Model Details MRW1 or MRW2

40 for exposed concrete
50 for buried concrete

Mesh fabric – A193 unless specified otherwise

Tension lap

75

75

Extension to link not required if width of link is 300 or more
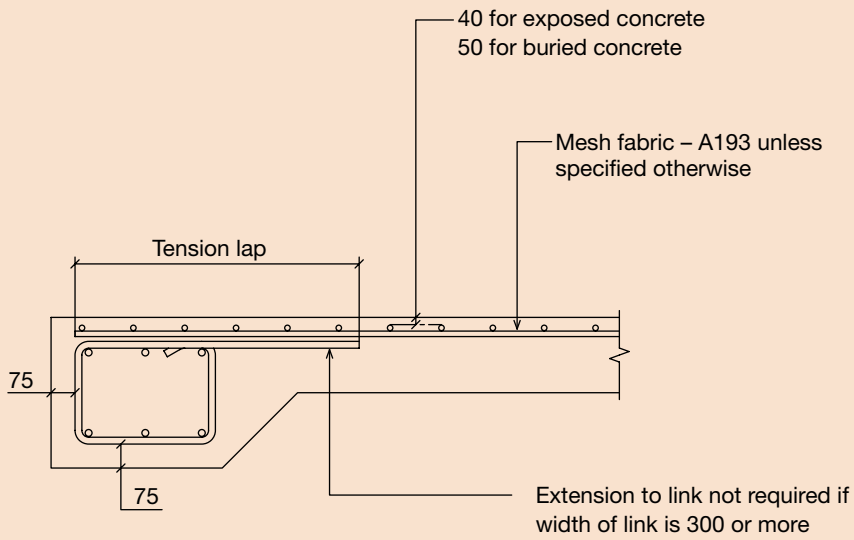
FOUNDATIONS   MF5
Trenches

For retaining wall details see Model Details MRW1 or MRW2

Tension lap

Tension lap

50

25 for internal faces
40 for external exposed faces
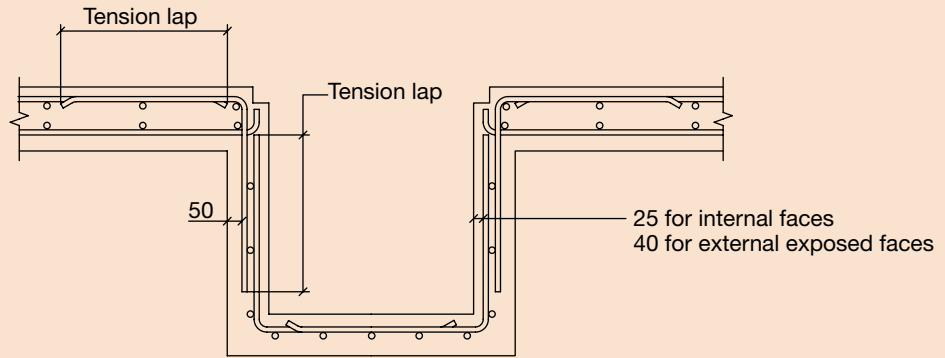
DETAIL 'A'
Wall thickness 150 or less

Tension lap (=1.4
x Anchorage length)

Tension lap

Splay bars used when design
moment specified

50

Tension lap (=1.4
x Anchorage length)
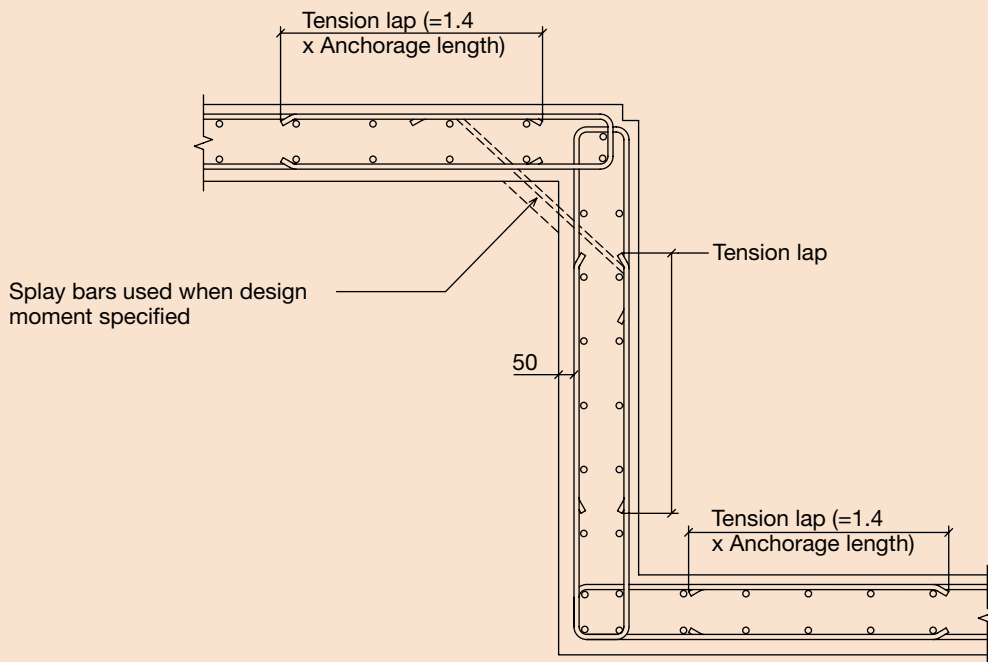
DETAIL 'B'
Wall thickness more than 150

6.8 Staircases

6.8.1 Scope

The information given relates specifically to suspended in-situ reinforced concrete stair flights and related half landings.

Precast concrete stair flights with half joints are not covered in this manual.

6.8.2 Design and detailing notes

Concrete grade

For reinforced concrete the concrete grade is normally 30/37 MPa (cylinder strength/cube strength) with a maximum aggregate of 20mm

Nominal cover (EC2, Clause 4.4)

Solid slabs

- Internal use: (15mm or bar size) + Δc_{dev}, (Concrete inside buildings with low air humidity, XC1) whichever is greater
- External use: 35mm + Δc_{dev} (Corrosion induced by carbonation, XC3) See 5.2.1 for values of Δc_{dev}

The top cover also applies at the throat of the stairway. Where there will be no applied finish, allow an extra 10mm on the top wearing surface.

Minimum area of reinforcement (EC2, Clauses 9.3.1.1, 9.3.1.2 and 9.2.1.1)

- Tension reinforcement:
  $A_{s,min} = 0.26\ b_t\ d\ f_{ctm}\ /f_{yk} \geqslant 0.0013\ b_t\ d$
  where

b_t	is the mean width of the tension zone
d	is the effective depth
f_{ctm}	is determined from Table 3.2 of EC2
f_{yk}	is the characteristic yield strength

  For concrete Grade 30/37 and f_{yk} = 500 MPa
  $A_{s,min} = 0.0015\ b_t\ d$

Bar spacing (EC2, Clauses 8.2 and 9.3.1.1)

- Recommended minimum pitch of reinforcing bars: 75mm (100mm for laps)
- Maximum pitch of bars:
- Main bars: $3h \leqslant 400mm$ (in areas of concentrated loads $2h \leqslant 250mm$)
- Secondary bars: $3.5h \leqslant 450mm$ (in areas of concentrated loads $3h \leqslant 400mm$)

Anchorage and lapping of bars (EC2, Clauses 8.4 and 8.7):

For 500 Grade steel Table 6.11 gives typical anchorage and lap lengths for 'good' and 'poor' bond conditions.

End supported stair flights

Model Detail MST1 shows the arrangement of reinforcement and curtailment details for end supported Stair flights.

An alternative is for the landings to support the stair flight and to have a simple concrete recess at the end as shown in Figure 6.33. This method avoids congestion of starter bars at the corners of the landings.

Where there is an in-situ wall at the edge of the stairs, the recess should be continued up the flight as shown in Figure 6.33 to avoid cracking.

Cantilever stair flights

Stair flights which are cantilevered from the side of a wall should be detailed as shown in Model Detail MST2.

Connection to walls

This method for detailing connections of half landings to walls is described in 6.5.2 of this manual.

Table 6.11 Typical values of anchorage and lap lengths					
	Bond conditions	**Length in bar diameters**			
		$f_{ck}\ /f_{cu} =$ 25/30	$f_{ck}\ /f_{cu} =$ 28/35	$f_{ck}\ /f_{cu} =$ 30/37	$f_{ck}\ /f_{cu} =$ 32/40
Full tension and compression anchorage length, l_{bd}[1]	good	40	37	36	34
	poor	58	53	51	49
Full tension and compression lap length l_0[2]	good	46	43	42	39
	poor	66	61	59	56

Notes
1 It is assumed that the bar size is not greater than 32mm and α_1, α_2, α_4 and α_5 all equal 1.
2 It is assumed that not more than 33% of the bars are lapped at one place, α_6 = 1.15.
For other situations refer to EC2, Clause 8.4.4.

Figure 6.33 Detail for stair flight landing

Bottom connection of stair flights to ground floor or foundations

The following methods are recommended for the bottom of stair flights:

- Starter bars projecting from a prepared concrete surface. This is suitable when the position and height of the starter bars is closely controlled.
- Pocket left in the ground floor or foundations of sufficient size to ensure fitting the end of the stair flight reinforcement cage.

Handrail supports

The Designer should make sure that adequate consideration is given to the reinforcement detail for handrail supports.

If pockets are left in the concrete into which the handrail posts are later concreted, reinforcement must pass around the pockets and be anchored into the main body of the concrete.

If inserts are set into the concrete these should have reinforcement bars passing around them or have sufficient anchorage ties built in.

6.8.3   Detailing information

Design information for detailing should include:

- Layout and section drawings of staircase and landings. The setting out of the soffit should be clearly shown.
- Concrete grade and aggregate size (standard 30/37MPa and 20mm).
- Nominal cover to reinforcement and controlling design consideration, fire or durability (standard 20mm for internal conditions/40mm for external conditions).
- Details of design reinforcement required including:
    - type of reinforcement
    - bar diameter
    - pitch or number
    - where it is required.

  Otherwise bar size and pitch given in Model Detail MST1 is assumed.
- Details of cast in inserts or pocket details, and associated reinforcement details.

6.8.4 Presentation of working drawings
End supported stair flights

5 H10 10 200
(UB)

1 H10 12 UB

12.102 (First floor)
15.642 (2nd Floor)

12 H10 01 200

12 H10 09 200

6T. 6B

1

15 H10 11 200 B
6 H10 11 200 T

1

50

25

5 H10 10 200
(UB)

6 sets of bars at 200 each set
(H10 02 B. H10 03 B. H10 04 B.
H10 05 B. H10 06 B. H10 07 T. H10 C8 T)

FLIGHT B WITH LANDING
2 No THUS

05   08

08

15.642
12.102

08

11

11

05

11

06

SLAB REINF'T

04

05   04

2

07   01

03

11

07   04   02

03   02

1 - 1

01

07

09

09
09

09

02

03

02

WALL REINF'T
See drg. R021

2

Flight B   2nd Floor
Flight C
                 1st Floor
Flight B

Flight A
                 Gnd Floor

STAIR S1
KEY PLAN

Cantilever stair flights

6 H8 04 200 links per tread
10 No treads

See landing drg R012

▲ 1

1 ▲

11 H8 03 UB
1 per tread

20 H10 01. 2 per tread
11 H10 02 B

6 sets of bars at 200 each set
(H10 05 B. H10 06 B. H10 07 B. H10 08 B.
H10 09 T. H10 10 T. H10 11 T)

FLIGHT B
2 No THUS

SPINE WALL
See drg R010

04
(typ.)

11

08

07

11

02

07

01 01

08

06

06

10

10

Position of
03's in tread

09

10

02

06 05

2

09

05

10

1 - 1

01

03 01

04

04

03

01

02

03

06

06

02

02

2 - 2

Flight B

Flight C
Flight A

STAIR S2
KEY PLAN

STAIRCASES MST1
End supported with landings

Distribution bars as for Model Detail MS1

'U' bars for both landings to be 50% of the area of the main bottom reinforcement

'A' to be the greatest of 0.1 x design span, tension anchorage length or 500

For detail where landing reinforcement spans in other direction see design notes 6.5.2

See also Model Detail MW3

Nominal cover specified by designer (Minimum 20 or bar size whichever is greater)

See also design notes 6.8.2
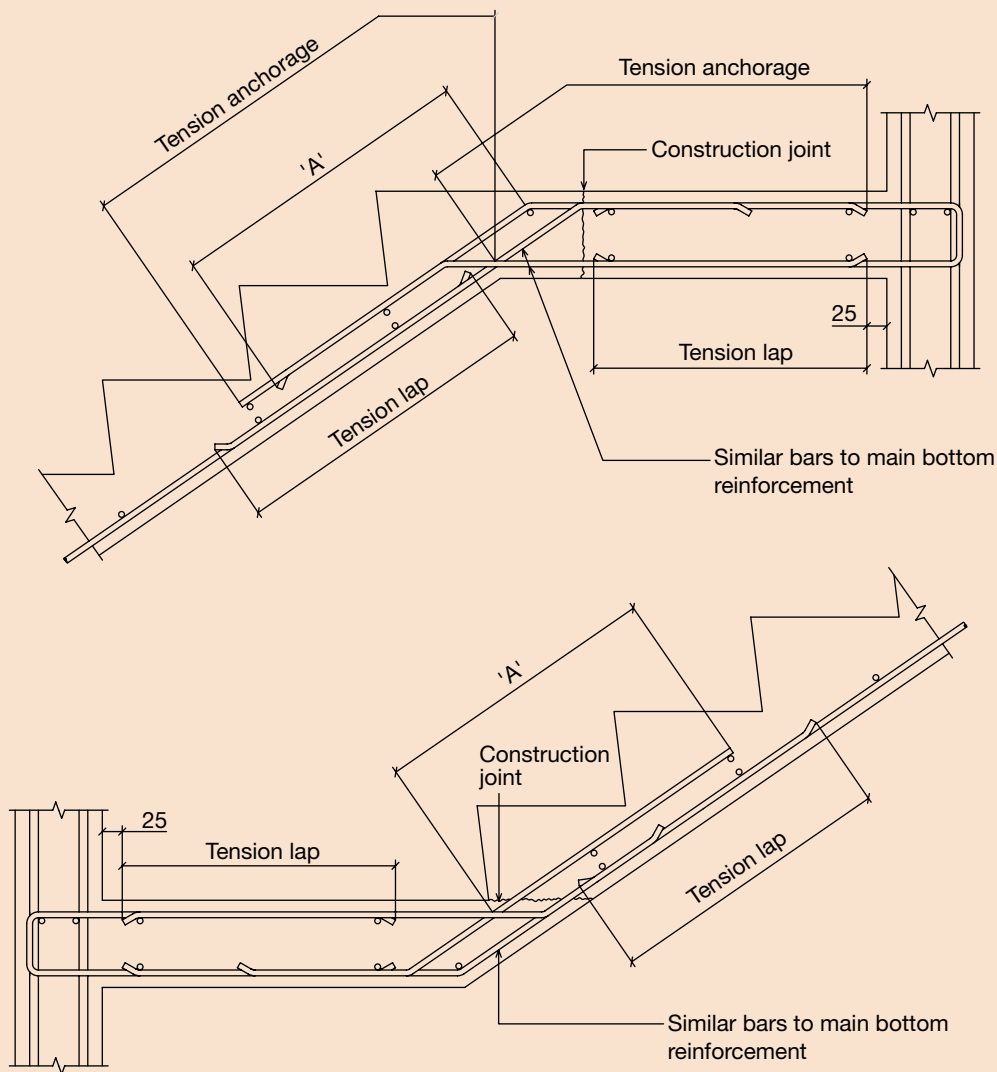
STAIRCASES MST2
Cantilever from wall or edge beam

Main cantilever bars must be mild steel if they areto be rebent. See Model Detail MW3
Nominal cover specified by designer (Minimum 20 or barsize whichever is greater)
See also design notes 6.8.2

Linking to be H8s at 300
unless otherwise specified.
N.B. Bends to be adjusted
to suit on site

Position of H8 'U' bar

Specified by designer

Distribution bars to be H10s at
300 unless otherwise specified

Corner bar detailed
with wall

Nominal H8 'U' bar

Design reinforcement

Tension anchorage

A-A
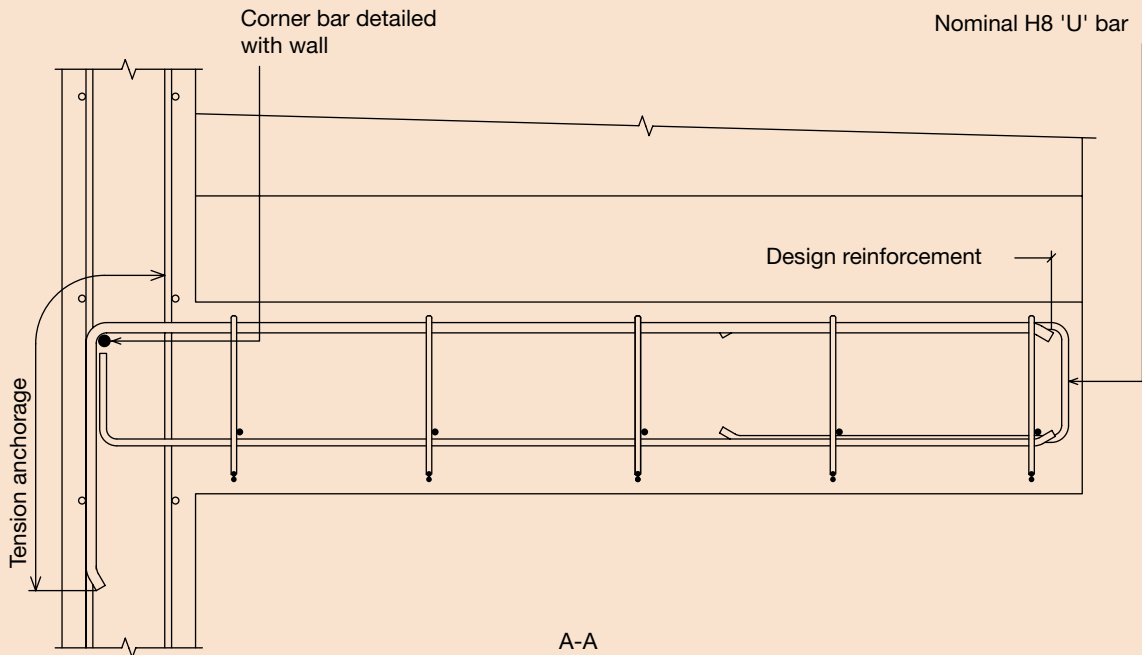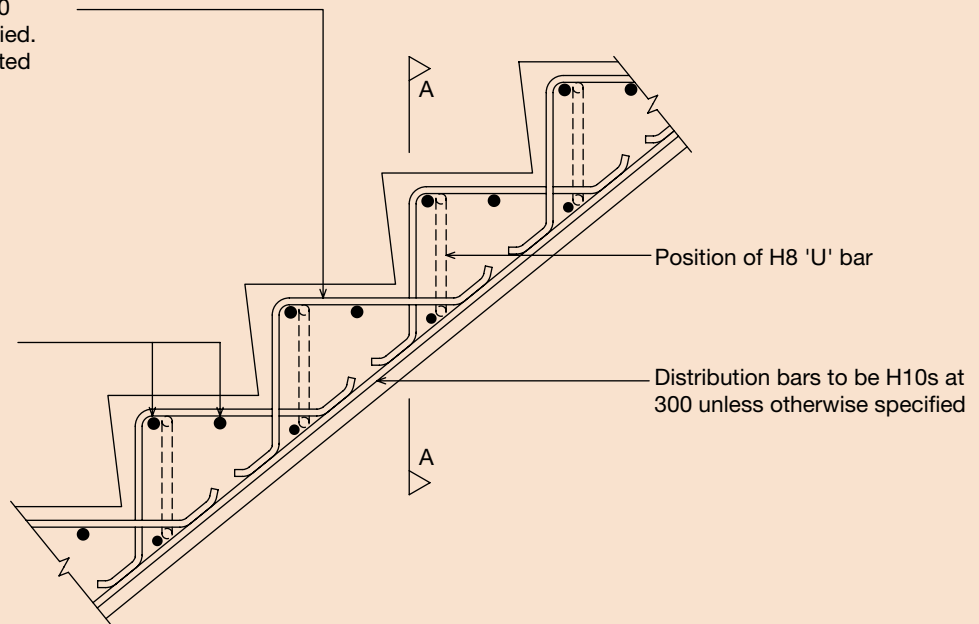
6.9   Corbels, half joints and nibs

6.9.1   Scope

This section covers the detailing of in-situ corbels, beam half joints and continuous nibs. The detailing for these elements is very closely related to the joint, and the designer must, in all circumstances, ensure that the detail design is clearly specified.

Details given in this section are not intended to cover all aspects of precast concrete corbels, half joints and nibs.

Detailed information concerning the design of bearing pads is not included, for more information see specific proprietary literature.

6.9.2   Design and detailing notes

Concrete grades lower than 28/35 MPa (cylinder strength/cube strength) are not normally used.

*Nominal cover to all reinforcement
(EC2, Clause 4.4)*
Corbels
- Internal use: 25mm + Δc_{dev} (Concrete inside buildings with low air humidity, XC1)
- External use: 35mm + Δc_{dev} (Corrosion induced by carbonation, XC3) See 5.2.1 for values of Δc_{dev}

Note
The cover to grouped bars should be for the equivalent bar size (see 5.8). For the purposes of 4 hour fire resistance, supplementary reinforcement may be required where the nominal cover exceeds 40mm (See EC2: Part 1.2, Clause 4.5.2; axis distance to main reinforcement exceeds 70mm).

Continuous nibs and slab half joints
- Internal use: 20mm or bar size whichever is greater (Concrete inside buildings with low air humidity, XC1)
- External use: 40mm (Corrosion induced by carbonation, XC3)

*Minimum area of reinforcement
(EC2, Clauses 9.2.1.1, 9.3.1.1 and 9.3.1.2)*
Corbels
For concrete grades 28/35 and f_{yk} = 500 MPa
- Tension reinforcement:
    $A_{s,min} \geqslant 0.0014\, b_t\, d$
    where b_t is the mean width of the tension zone
                d is the effective depth
- Compression reinforcement:
    $A_{sc,min} \geqslant 0.002\, A_c$

Half joints and continuous nibs
- Tension reinforcement:
    $A_{s,min} = 0.26\, b_t\, d\, f_{ctm}\, /f_{yk} \geqslant 0.0013\, b_t d$
    where b_t is the mean width of the tension zone
                d is the effective depth
                f_{ctm} is determined from Table 3.2 of EC2
                f_{yk} is the characteristic yield strength
    For concrete Grade 28/35 and f_{yk} = 500 MPa
    $A_{s,min} = 0.0014\, b_t d$
- Preferred minimum bar diameter: 10mm

Bar spacing (EC2, Clauses 8.2 and 9.3.1.1)
- Minimum pitch of bars: 75mm (Sufficient space must be allowed for insertion of poker vibrator)
- Minimum vertical space between individual bars: 25mm or bar size, whichever is greater

Continuous nibs
- Maximum pitch of bars
    – Main bars:
        $3h \leqslant 400mm$ (in areas of concentrated loads $2h \leqslant 250mm$)
    – Secondary bars:
        $3.5h \leqslant 450mm$ (in areas of concentrated loads $3h \leqslant 400mm$)

*Anchorage and lapping of bars
(EC2, Clauses 8.4 and 8.7)*
Minimum anchorage length
Greater of 10ø or 100mm.

For high yield steel, 500 Grade and deformed bars, Table 6.12 gives typical anchorage and lap lengths for 'good' and 'poor' bond conditions (see 5.4).

Arrangement of reinforcement
The arrangement of reinforcement is very closely related to the design of corbels, half joints and nibs, and the Designer must ensure that the detail design is clearly specified.

In general small bar diameters, i.e. not larger than 16mm, should be used when detailing such elements. If larger diameter bars are used, it is likely that welding will be required. This should normally be carried out off-site under factory conditions (see 5.6).

Corbels (EC2, Clauses 6.2, 6.5 and Annex J)
The use of small bar diameters, horizontal U-bars or links with easy bends is preferred, as shown in Model Detail MCB1. However, where the loading is high and the geometry restrictive, large bar diameters may be necessary, in which case welding them to a cross bar

Table 6.12 Typical values of anchorage and lap lengths

	Bond conditions	Length in bar diameters			
		$f_{ck}/f_{cu} =$ 25/30	$f_{ck}/f_{cu} =$ 28/35	f_{ck}/f_{cu} =30/37	f_{ck}/f_{cu} =32/40
Full tension and compression anchorage length, l_{bd}[1]	good	36	34	32	31
	poor	48	45	43	41
Full tension and compression lap length l_0[2]	good	55	51	37	48
	poor	73	68	64	62

Notes
1   It is assumed that the bar size is not greater than 32mm and α_1, α_2, α_4 and α_5 of Table 8.2 of EC2 all equal 1 and that $\alpha_3 = 0.9$ ($\lambda = 1.35$ and K = 0.05).
2   It is assumed that $\alpha_6 = 1.5$ (more than 50% of the bars are lapped at one place).
For other situations refer to EC2, Clause 8.4.4.

or plate may be the only solution. The size of this may be governed by the strength of weld (see also 5.6). This is shown in Model Detail MCB2.

It is essential that the main tensile reinforcement is extended as close to the outer face of the corbel as possible, and that it extends beyond the load bearing area by a minimum of the distance shown on the Model Details.

Where large horizontal forces are required to be transmitted into the corbel, a welded joint may be the only suitable solution (see *Reinforced concrete structures*[33]).

Half joints in beams
(EC2, Clauses 6.2, 6.5 and Annex J)

The use of inclined bars in half joints provides better control of cracking than other arrangements of reinforcement (see *Serviceability behaviour of reinforced concrete half joints*[34]). However such bars are often difficult to fix correctly and can cause congestion of reinforcement. Great care is needed to

ensure the use of practical details with inclined links or bent bars, especially when large bar diameters are required and a welded solution is adopted.

Continuous nibs
(EC2, Clauses 6.2 and 6.5)

The arrangement of reinforcement for continuous nibs may control the depth of nib. Vertical U-bars or links should be used wherever possible, as shown in Model Detail MN1. However, where a shallow nib is required, e.g. for supporting brickwork, horizontal U-bars should be used, as shown in Model Detail MN2. The vertical leg of the links in the supporting beam must be designed to carry the loads from the nibs (see Figure 6.34). The Designer should note that it is necessary to reduce the value of *d* as the concrete in the nib below the vertical beam link does not contribute to the resistance.

In situations where horizontal movement may occur between the nib and the supported member, the outer edge of the nib should be given a 20mm chamfer.

6.9.3   Detailing information

Design information for detailing should include:
- Detail and section drawings at half full scale, giving all relevant dimensions.
- Concrete grade and aggregate size (standard 30/37MPa and 20mm).
- Nominal cover to reinforcement and controlling design consideration, fire or durability (standard 35mm for internal conditions, 40mm for external conditions).
- Details of reinforcement required including:
  – type of reinforcement
  – bar diameter
  – number and position of bars (the exact position of the main bars should be given).

Figure 6.34 Design and detailing of shallow nibs

CORBELS MCB1
Without welds

This detail is suitable when using 16mm bar size or smaller for the main tensile reinforcement
Nominal cover specified by designer

Two column links should be
placed close to corbel top

Distance between edge of bearing and inside of
bar to be a minimum of the bar diameter
or 0.75 x cover, whichever is greater

A

A

Main tensile
reinforcement.
Large radius of
bend is required

Tension lap

Secondary horizontal reinforcement.
Total area of this should not be less
than 0.50 of area of main tensile
reinforcement

Compression bars. Total area of
this should not be less than
1000mm²/metre width of corbel

Compression anchorage

Outer compression bars angled to
pass inside links

Main tension bars

A-A

CORBELS MCB2
With welds

This detail is suitable when using 20mm bar size or smaller for the main tensile reinforcement
Nominal cover specified by designer

Two column links should be placed close to corbel top

Large radius of bend required

Tension lap

Compression anchorage

Distance between edge of bearing and outside of plate or bar should not be less than the vertical cover to the plate or bar

Main tensile bars welded to a cross bar, or plate, and to the vertical compression bars

Horizontal links. Total area should not be less than 0.50 of area of the main tensile reinforcement

Compression bars. Total area of which should not be less than 1000mm²/metre width of corbel

A-A

HALF JOINTS MHJ

Special design information must be given concerning the bearing pads
Nominal cover specified by designer. (Normally to ensure 40mm to the main steel)

Full length links sufficient to resist total reaction equally spaced

Tension anchorage

h_h

h_h

A

A

Distance between edge of bearing and inside of bar to be a minimum of the bar diameter or 0.75 x cover, whichever is greater

Horizontal 'U' bar to be the same diameter as main bottom bars

Nominal hanger links at 450

Cranked bars if necessary for crack control

Tension lap for cranked bar

Horizontal 'U' bar with standard radius of bend

Tension lap

A-A

Nominal links at 150

NIBS MN1
This detail is also suitable for half joints in slabs

Minimum nominal overlap of reinforcement in nib and reinforcement in supported member to be 60
Nominal cover specified by designer

Tension anchorage length if 'U' bars are used

Links to be specified by designer to take load on nib

Closed links or 'U' bars may be used

Not less than bar diameter or 0.75 x nominal cover, whichever is greater

Diameter of links to be not more than 12
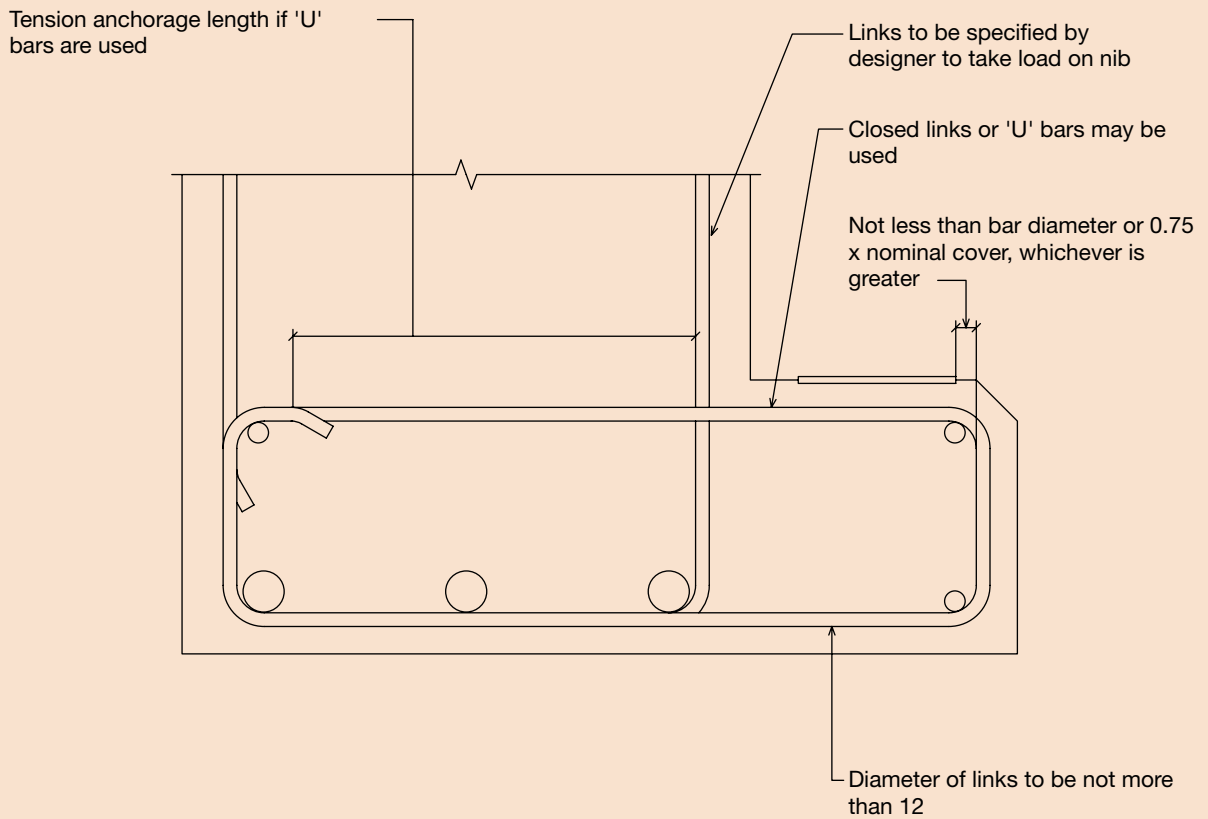
NIBS MN2
Shallow nibs (suitable for light loads)

Nominal cover specified by designer. (Normally to ensure 40mm to the main steel)

Links to be specified by designer to take load on nib

Horizontal 'U' bars. Diameter to be not more than 16

Tension anchorage length

A

A

Wired to at least two main longitudinal bars

Depth of nib to be not less than 140. See also 6.9.2 for strut and tie model

Lacer bar to be same diameter as 'U' bars

A-A

Pitch of 'U' bars to be not more than 250
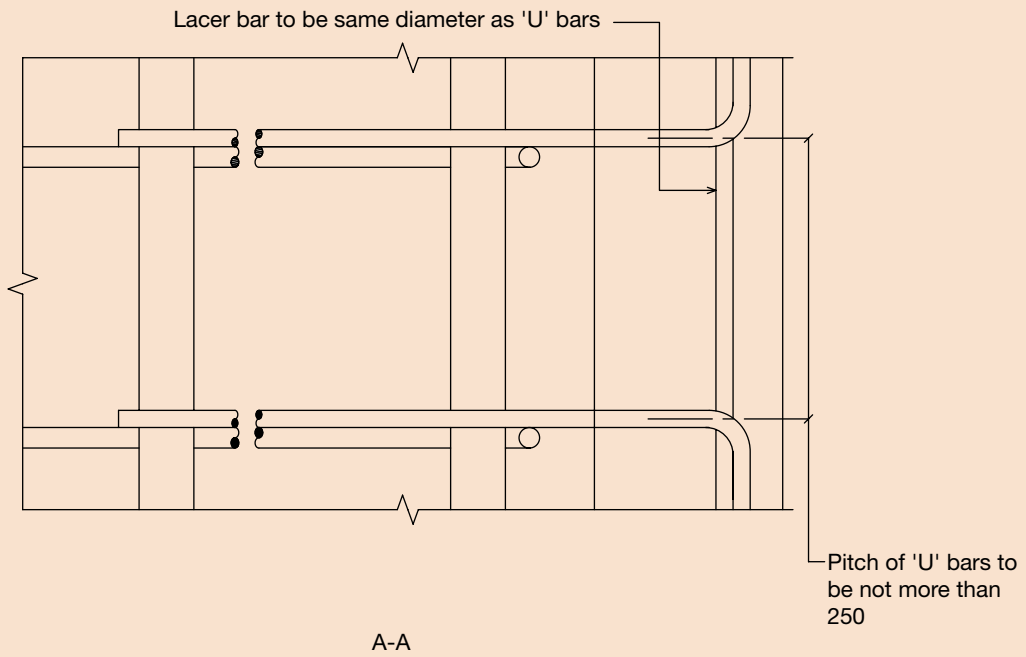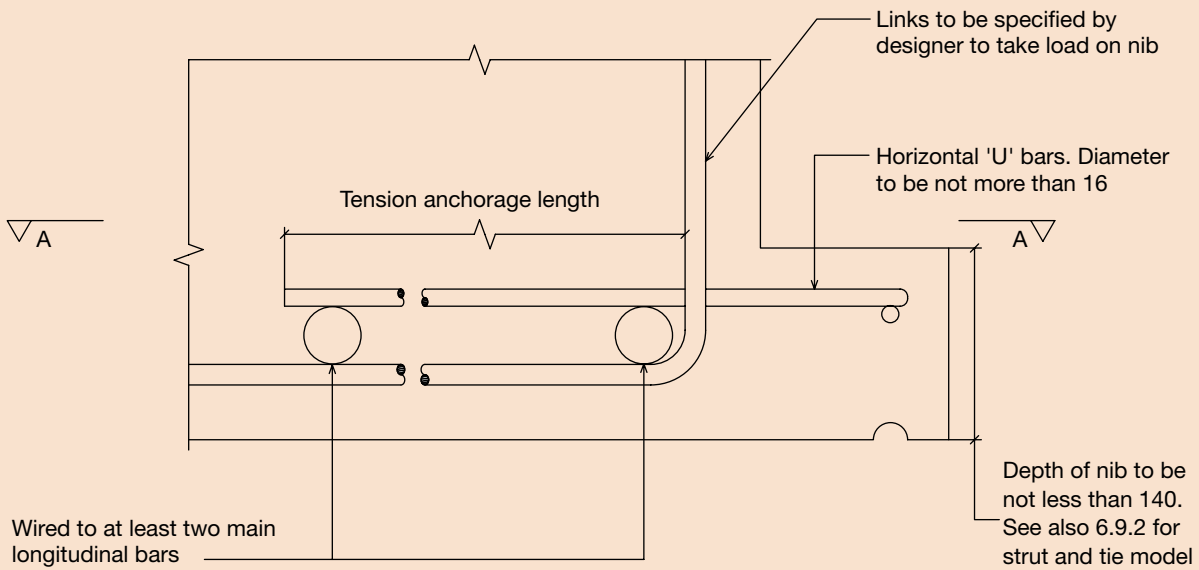
7.1 General

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 elements that are commonly used in buildings (flat slabs, banded beams, and trough/waffle slabs, transfer structures etc.) are reviewed, although the principles are applicable to other prestressed concrete structures such as bridges.
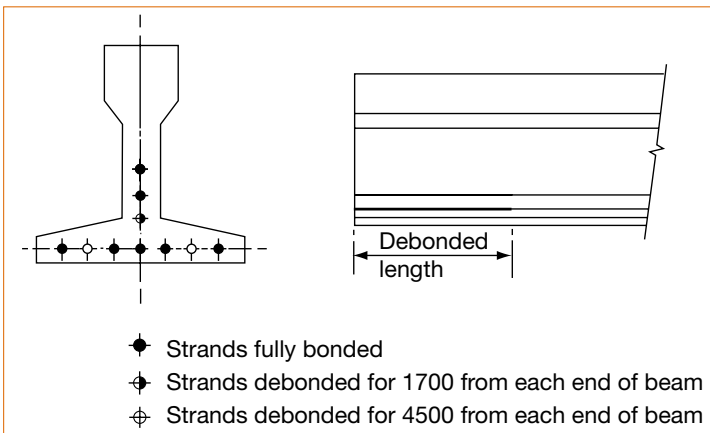

♦ Strands fully bonded
⊕ Strands debonded for 1700 from each end of beam
⊕ Strands debonded for 4500 from each end of beam

Figure 7.1 Debonding tendons for pre-tensioned elements

♦ Straight strands
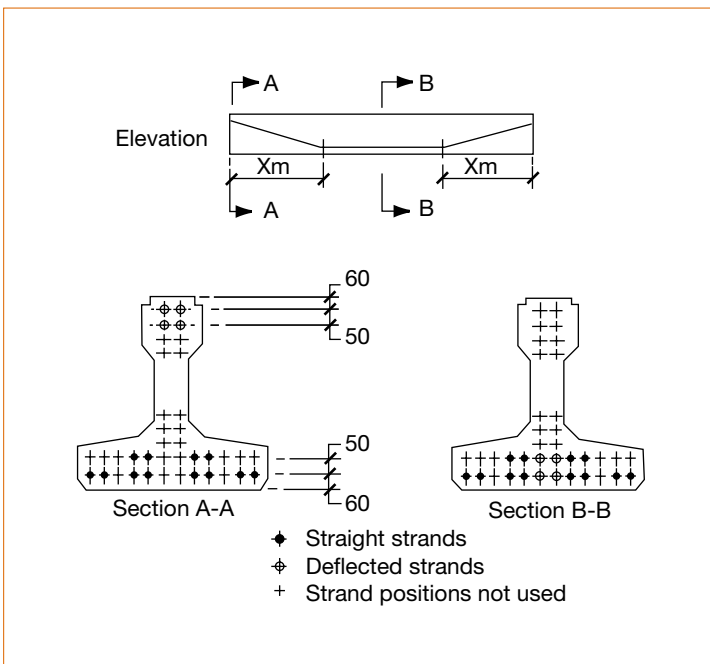⊕ Deflected strands
+ Strand positions not used

Figure 7.2 Pre-tensioned element with deflected etendons

There are two methods of prestressing: pre-tensioning and post-tensioning. Pre-tensioning consists of stressing the reinforcement between large steel buttresses, and then casting the concrete around the reinforcement. This process is generally carried out in a factory environment and is commonly used for precast prestressed units that are delivered to the construction site. Post-tensioning involves stressing of steel in a duct installed in concrete when the concrete reaches the specified strength. This latter process is used for in-situ concrete frames and is considered in more detail in this section of the manual. Due to their nature the two are invariably similar in principle and therefore the term 'prestressed' is used in the chapter in introducing the principles of both pre-tensioning and post-tensioning.

7.2 Drawings

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

- layout and arrangement of tendons, including spacing of tendons
- minimum cover to tendons
- setting out data for each tendon, profile and tolerances both in vertical and horizontal direction
- tendon and duct types and sizes
- anchorage recess dimensions if any
- the prestressing system that is detailed if any
- forces to be applied to each tendon and tensioning sequence
- location of grouting points and vents
- grouting pressure in the ducts and grout specifications
- infill strips (size and location)
- connection detail consideration with shear walls and other strong bracing points in the structure
- any tendons to be debonded marked on sections and elevations and the method and length of debonding specified as illustrated in Figure 7.1
- deflection of tendons to be clearly indicated and dimensioned both horizontally and vertically as shown in Figure 7.2 (radius of curvature to comply with the recommendations of the manufacturer)
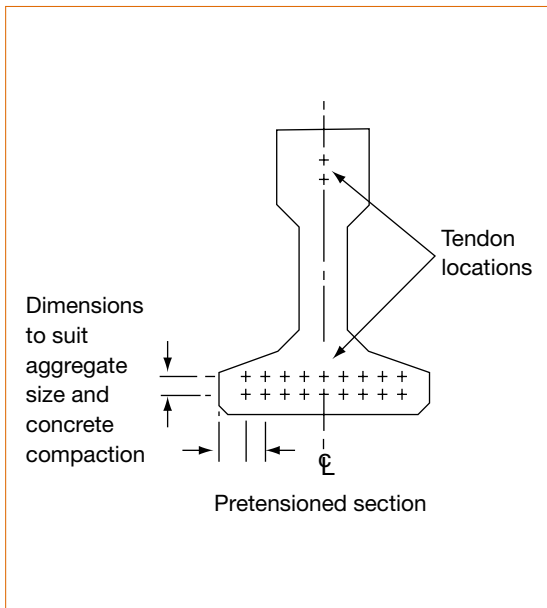
Figure 7.3 Symmetrical arrangement of tendons for pre-tensioned units

Note
Where ø is the diameter of pre-tensioned tendon and d_g is the maximum size of aggregate
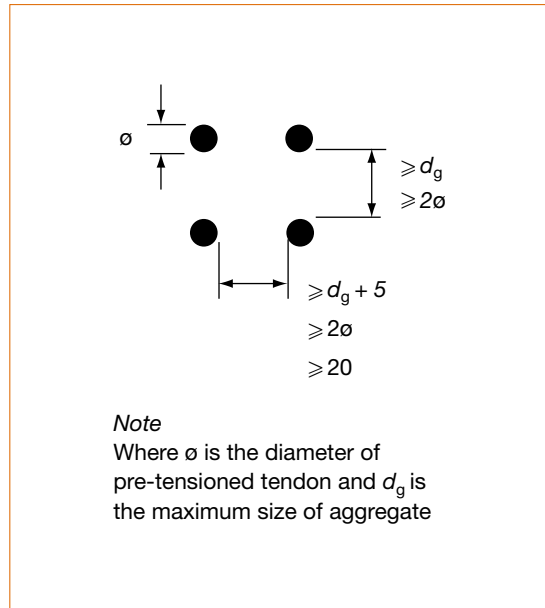
Figure 7.4 Minimum clear spacing between pre-tensioned tendons

- concrete grade and minimum strength required at transfer of prestress
- relevant parameters assumed in design
  - relaxation of prestressing steel
  - duct friction and wobble factors
  - anchorage draw-in
  - modulus of elasticity of steel and expected tendon extensions
  - movement of permanent structure at stressing
  - variations in camber
- method of marking the tendons on the soffit of the slab
- demolition sequence where required (as per CDM guidelines).

It should be clearly stated that the choice of prestressing is left to the specialist 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 the original Detailer/Designer should check any alternative proposed by the contractor, particularly any reinforcement modifications that may be required.

It should also be stated where clashes occur with reinforcement bars (links or main steel), or inserts, or pipes, the tendons should take priority.

It should be stated that the use of harmful additives such as calcium chloride have corrosive effects on the tendons and must not be used.

7.3 Components

7.3.1 Pre-tensioned units

Pre-tensioned units should be suitable for precasting. Apart from the common forms of floor slabs (e.g. hollowcore and double tee units), pre-tensioned beams are used for transfer structures in buildings. Bearing plates or similar should be designed to allow elastic shortening of the element to take place.

Tendons should be in vertical rows with spacing and edge dimensions compatible with the maximum size of aggregates 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 Figure 7.3).

The minimum permissible clear spacing of pre-tensioned bonded tendons is shown in Figure 7.4.

7.3.2 Post-tensioned units

Tendons and anchorages

- Tendons generally consist of wires, strands or bars, produced in accordance with BS EN 10138[35]. 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 avoid errors during installation. Prestressing strands are available in several diameters. Some commonly used sizes are given in Table 7.1. For the full available range refer to BS EN 10138, Table 4.

Table 7.1 Prestressing strands commonly used in buildings								
Strand type	Steel Number	Nominal tensile strength (MPa)	Nominal diameter (mm)	Cross-sectional area (mm²)	Nominal mass (kg/m)	Characteristic value of maximum force (kN)	Maximum value of maximum force (kN)	Characteristic value of 0.1% proof force (kN)
12.9 Super	1.1373	1860	12.9	100	0.781	186	213	160
12.7 Super	1.1372	1860	12.7	112	0.875	209	238	180
15.7 Super	1.1375	1770	15.7	150	1.17	265	302	228
15.7 Euro	1.1373	1860	15.7	150	1.17	279	319	240
15.2 Drawn	1.1371	1820	15.2	165	1.290	300	342	258

The designation of the type of strand may include the steel grade, number and size of strand, e.g. EN 10138-3-1..373-12.9, or the full description, e.g. EN 10138-3-Y1860S7-12.9 (where 'Y' means prestressing steel and 'S' means strand).

- Post-tensioning anchorages should be of proprietary manufacture and meet the requirements of BS 4447[36] and ETAG 013[37]. They may be either live (stressing), dead-end or passive anchorages or anchorage couplings. Each manufacturer produces a range of suitable anchorages.

- Couplers for tendons should be located away from intermediate supports. The placing of the couplers on 50% or more of the tendons at one cross-section should be avoided.

Note
Where ø is the diameter of post-tension duct and d_g is the maximum size of aggregate

Figure 7.5 Minimum clear spacing between ducts

Tendon ducts

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.

- Ducts may be formed in several ways, most commonly by using semi-rigid corrugated steel or plastic sheathing (see Concrete Society Technical Report No 43[38]), which may be bent to suit the tendon profile. Rigid steel sheathing is occasionally used on special projects, sometimes pre-bent to radius.

- External diameter of sheathing may vary, depending on the type and depth of corrugations, for which due allowance should be made when considering spacing, clearances and reinforcement details.

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

- Designed tendon deviations up to an angle of 0.01 radians may be permitted without using a deviator. The forces developed by the change of angle using a deviator in accordance with the relevant European technical Approval should be taken into account in the design calculations.

- The radius of curvature of the tendon in a deviation zone shall be in accordance with EN 10138[35] and appropriate European Technical Approvals.

Duct spacing and cover, EC2, Clause 8.10.1

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. The minimum permissible clear spacing of post-tensioned bonded tendons is shown in Figure 7.5.

Nominal cover requirements

The nominal cover, c_{nom}, is the minimum cover c_{min} plus an allowance for deviation, Δc_{dev}.

The minimum cover with regard to bond, $c_{min,b}$, for post-tensioned circular and rectangular ducts for bonded tendons is:

- for circular ducts: diameter
- for rectangular ducts: greater of the smaller dimension or half the greater dimension.

There is no requirement for more than 80mm for either circular or rectangular ducts.

The minimum cover with regard to bond, $c_{min,b}$, for pre-tensioned tendons is:

- 1.5 × diameter of strand or plain wire
- 2.5 × diameter of indented wire.

For prestressing tendons, the minimum cover of the anchorage should be provided in accordance with the appropriate European Technical Approval.

The value of Δc_{dev} should be taken as 10mm. This may be reduced to 5mm if special control measures are in place.

The nominal cover with regard to durability, $c_{min,dur} + \Delta c_{dev}$ for prestressing tendons is as for reinforced concrete (see 6.2 for slabs and 6.3 for beams).

For unbonded tendons the cover should be provided in accordance with the European Technical Approval.

Deviation in duct position

Allowable deviation in the position of ducts should be specified. The recommended values for maximum deviation are given in Table 7.2.

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 sheathing (See Figure 7.6).

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

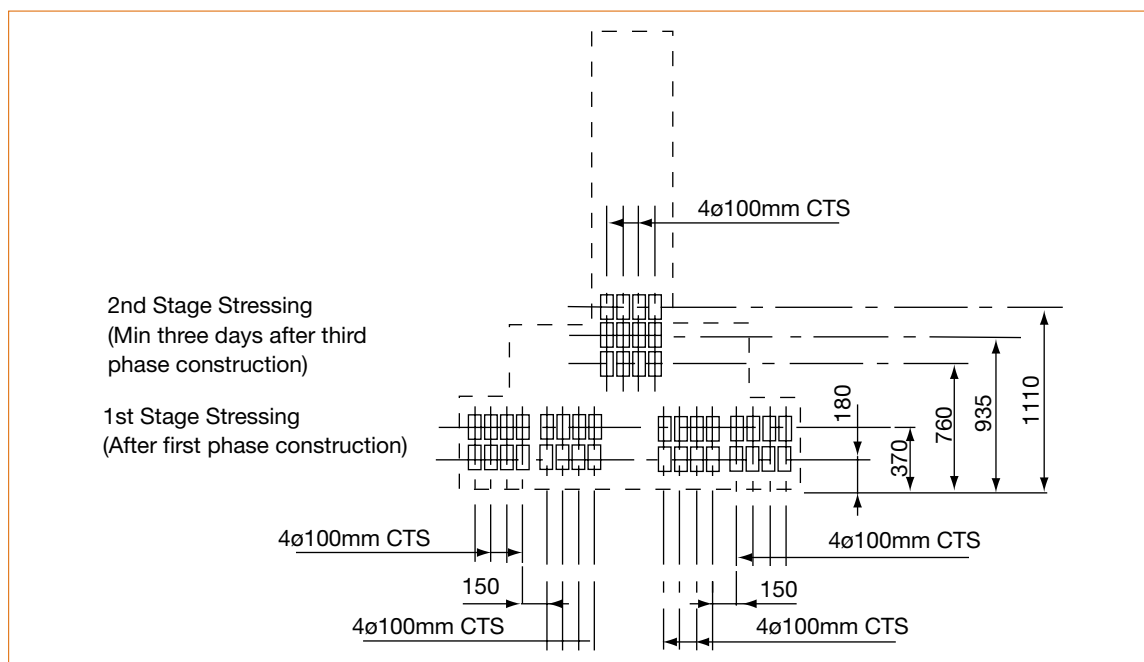| Table 7.2 Permissible deviation in position of post-tensioned ducts		
Slab thickness, h	Permissible deviation	
	Vertical	Horizontal
h < 200mm	+ or − $h/40$	+ or − 20mm
h > 200mm	+ 5mm or -5mm	+20mm or -20mm

Figure 7.6 Symmetrical layout of multiple layer of tendons

comply with Codes of Practice. The radial stresses on the insides of curves of small radius are considerable. Increased duct spacing and tensile reinforcement are normally required.

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 Figure 7.7).

Grouting points and vents

Grouting points (see Figure 7.8) 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
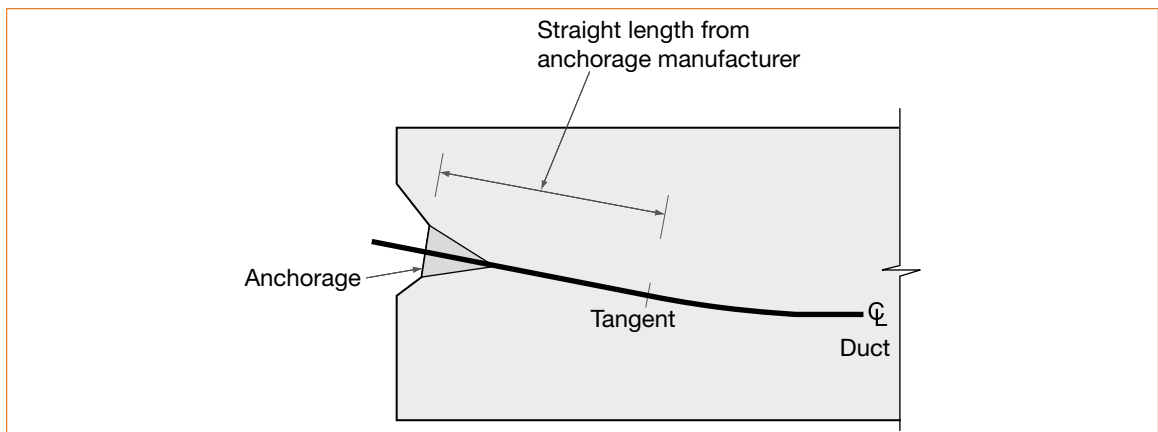

Figure 7.7 Minimum straight length of bonded tendon in a post-tensioned system
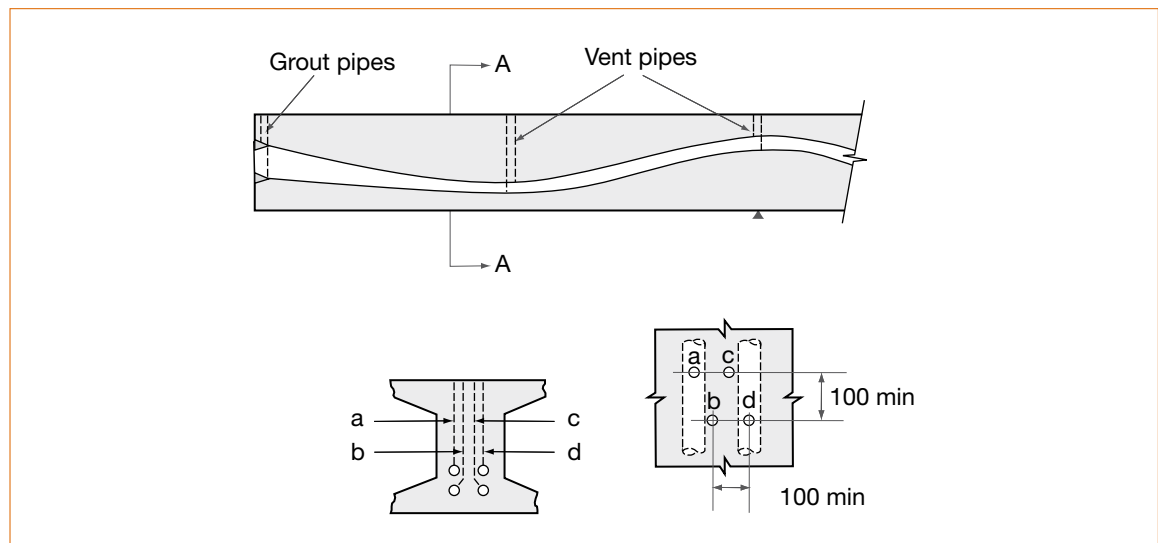

Figure 7.8 Grouting points and vents

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.

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

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 Figure 7.9)

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

Anchorages

If the structure is detailed for a particular prestressing system, an outline of the anchorage should be shown (see Figure 7.10); it should be axially in line with the last straight length of tendon.

	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

Figure 7.9 Duct setting-out profiles

* Key dimensions required
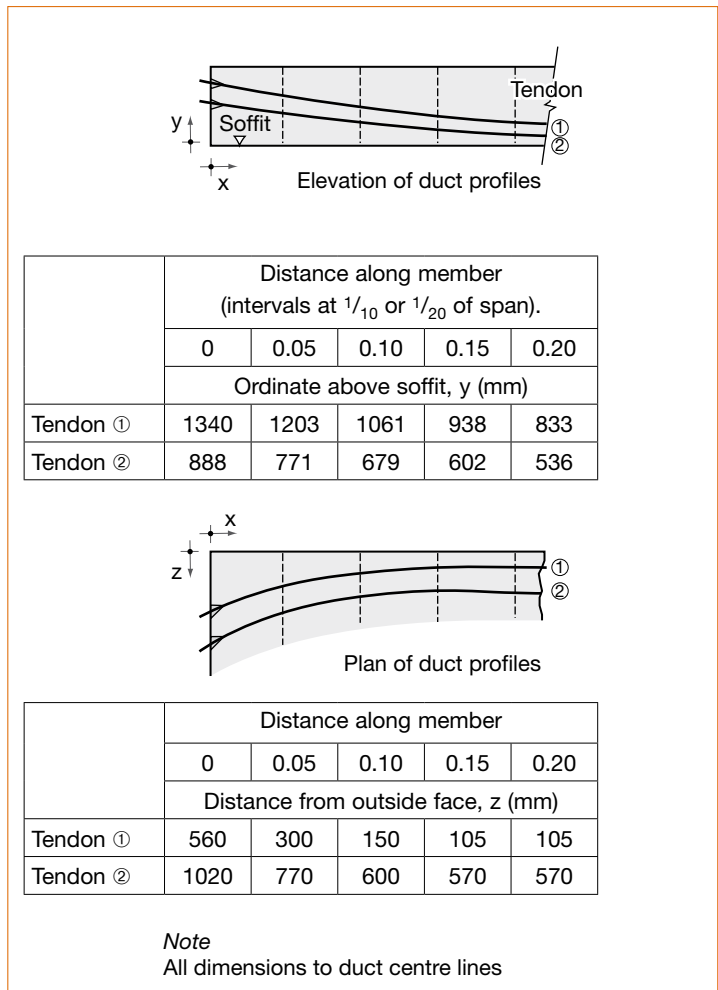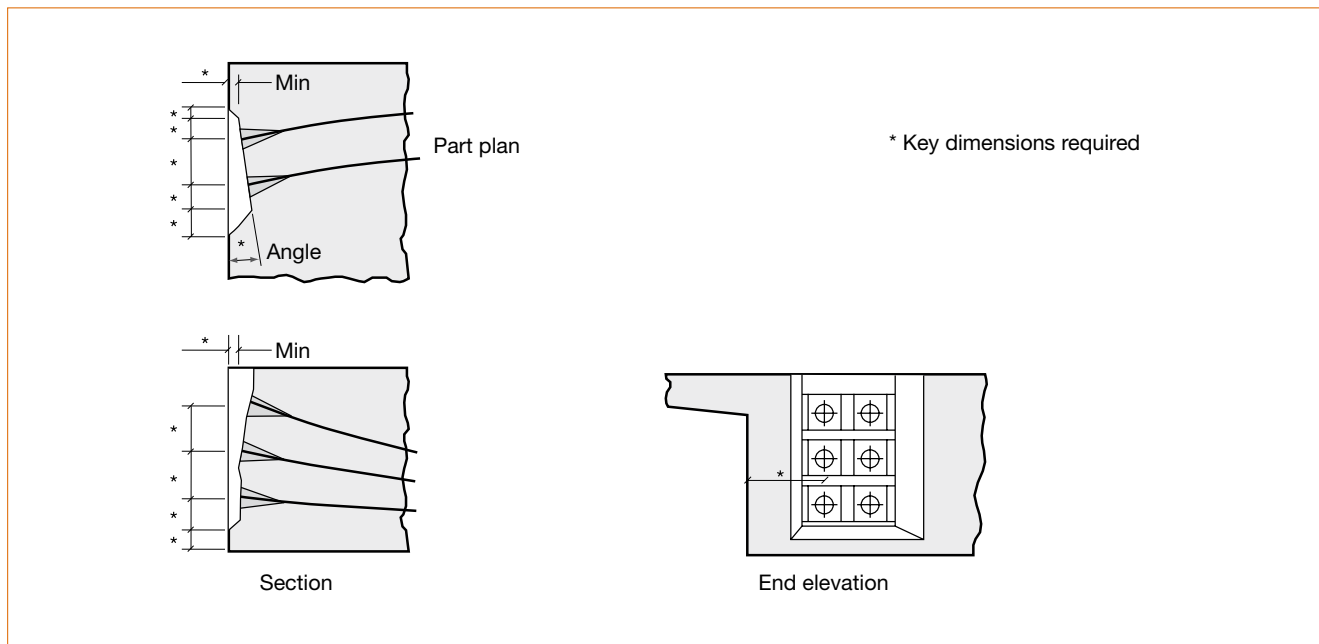
Figure 7.10 Anchorage recess in end block

Key dimensions and photographs of typical live end and dead end anchorages are shown in Figures 7.11a and 7.11b respectively. Reference should be made to suppliers' information.

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 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.
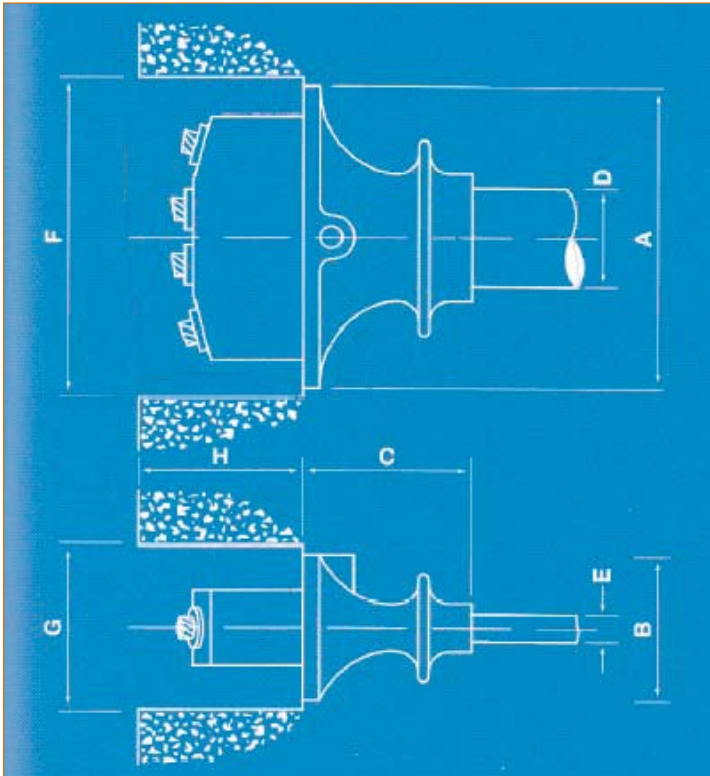

Figure 7.11a) Key dimensions of typical live end and dead end anchorages
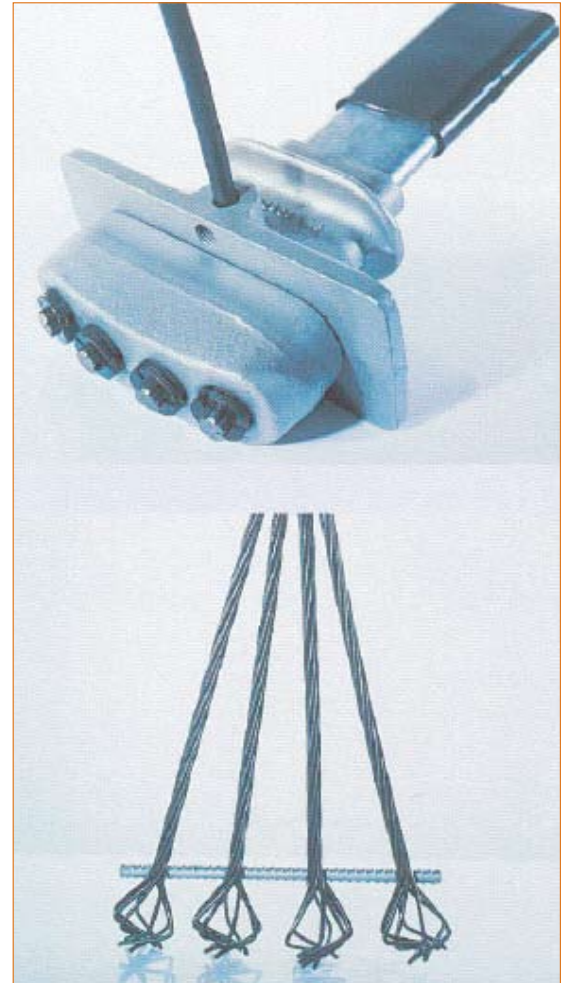

Figure 7.11b) Typical live end and dead end anchorages

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 inline with the tendon and to be removed after stressing (see Figure 7.12).

There must be 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 fencing walls.
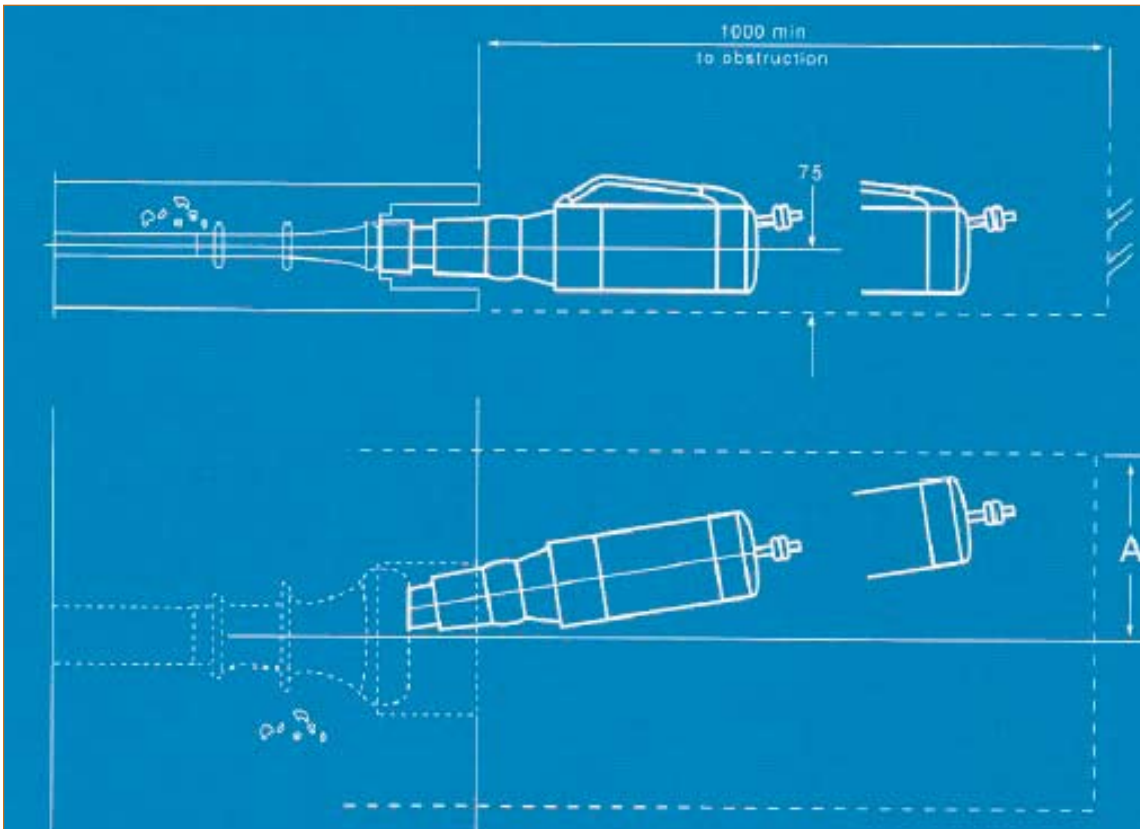
a) Flat ducts commonly used in buildings

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
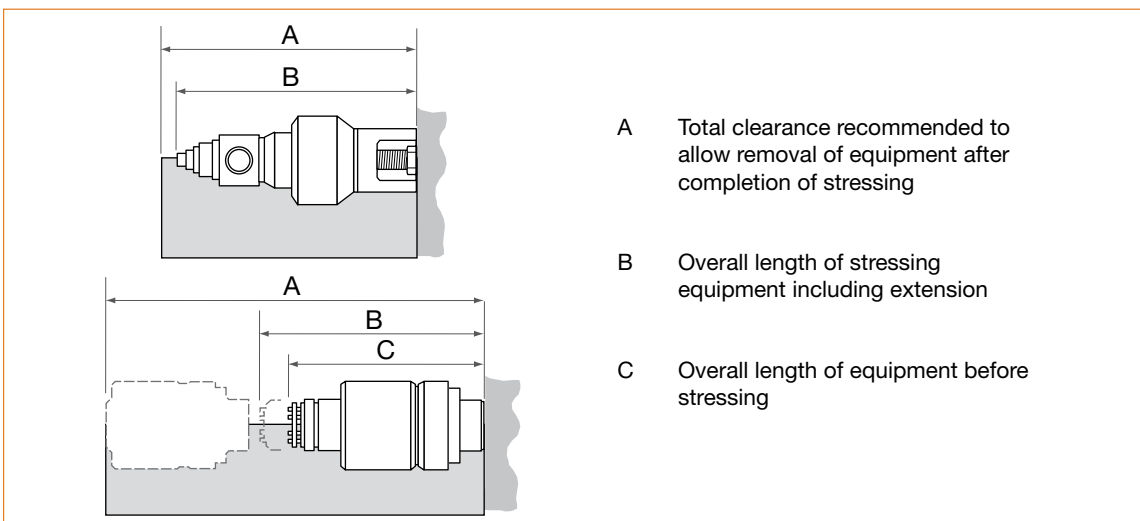
b) Jack clearances for circular ducts (refer to suppliers for the dimensions)

Figure 7.12 Jack clearance dimensions

7.4 Reinforcement detailing

7.4.1 Minimum reinforcement

Where fire ratings of greater than 2 hours are required, it is recommended that anti-spalling reinforcement be placed in the soffit when no other reinforcement is provided.

One-way spanning floors
Bonded tendons

There are no minimum un-tensioned reinforcement requirements for one-way spanning floors with bonded tendons. It is considered that these floors have sufficient tendon-to-concrete bond to distribute flexural cracking. Care should be taken to ensure sufficient reinforcement is provided to guard against cracking before stressing, if early phased stressing is not employed.

Unbonded tendons

One-way spanning floors with unbonded tendons should have minimum reinforcement in accordance with EC2, Section 9. This reinforcement should be spread evenly across the full width of slab in accordance with the spacing rules given in EC2, Sections 8 and 9.

Flat slabs (two-way spanning on discrete column supports)

All flat slabs should have minimum un-tensioned reinforcement at column positions to distribute cracking. The cross-sectional area of such reinforcement should be at least 0.075% of the gross concrete cross-section 0.00075 A_c, and should be concentrated between lines that are 1.5 times the slab depth either side of the width of the column. The reinforcement should be placed as near as practical to the top of the floor, with due regard for cover and tendon location, and should extend at least an anchorage length beyond $0.2 \times L$ into the span or as far as necessary by calculation (see 5.8.1 and 5.8.2). The maximum pitch of the reinforcement should be 300mm.

In the span zone, there are no minimum requirements. However, when unbonded tendons are used it would normally be necessary to provide designed un-tensioned reinforcement in the bottom of the slab (see 5.8.1). This reinforcement should extend at least to within a distance of $0.2 \times L$ (plus an anchorage length), measured from the centre of the support. It should be placed at a spacing of $3 \times$ slab thickness or 500mm, whichever is the lesser.

Minimum reinforcement (or bonded tendons) of 0.1% should be provided in the hogging regions of a slab. The spacing of this should not exceed 500mm.

7.4.2 End blocks in post-tensioned elements

An 'end block' is that zone of a prestressed concrete element 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.

Overall internal equilibrium of the end block

Both vertical and horizontal equilibrium should be considered and reinforcement provided to resist the tensile forces induced .

Tensile bursting forces behind the anchorages

These forces act normally to the line of the prestressing force in all lateral planes. The distribution is influenced by the geometry of the element. The reinforcement to resist these forces is normally provided as closed hoops or spirals (see Figure 7.13). 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 and with large radius bends to avoid crushing the concrete.

Simple equilibrium calculations including strut and tie models can be used to estimate the bursting forces. Table 7.3 may be used to estimate the bursting forces behind the anchorages where y_{po} is the half side of the loaded area, y_o is the half side of the end block, P_o is the tendon jacking force, and F_{bst} is the bursting force.

Table 7.3 Design bursting tensile forces in end blocks

y_{po}/y_o	0.2	0.3	0.4	0.5	0.6	0.7
F_{bst}/P_o	0.20	0.18	0.15	0.13	0.10	0.08

This force is distributed in a region from $0.2y_o$ to $2y_o$ from the loaded face and should be resisted by reinforcement in the form of spirals or closed links, uniformly distributed throughout this region, and acting at a stress of 200N/mm².

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.
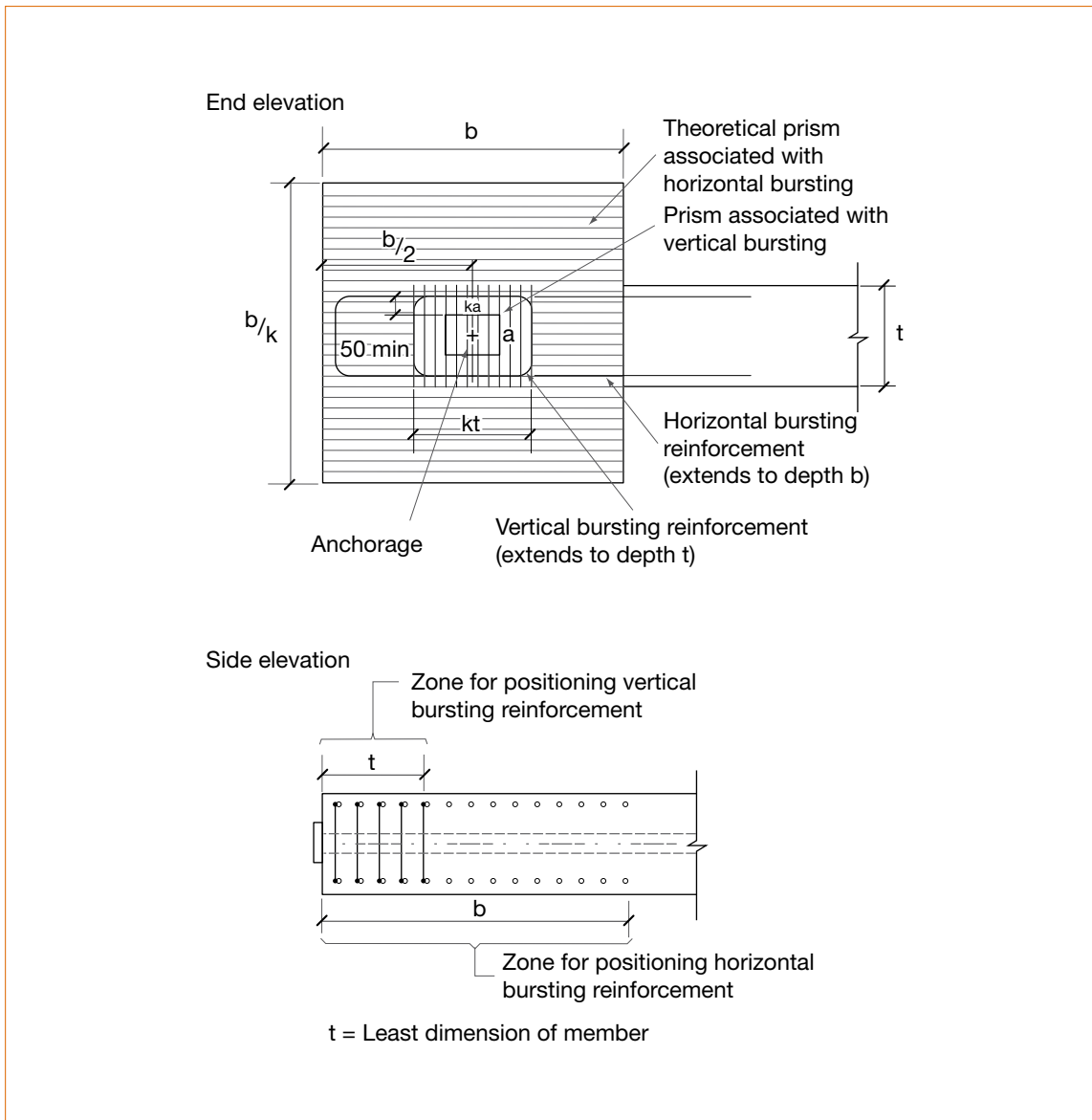
Figure 7.13 Location of bursting reinforcement

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.

Tensile stresses occurring on the faces of end block, 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:

* 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.

* 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 and to allow ease of fixing.

Curved stressing chairs may be used to reduce required stressing pocket dimensions

Note
Check pocket dimensions to ensure that there is sufficient clearance for the stressing jack

Note
Trimmer bars require proper anchorage

Nominal trimmer bars

Total area of longitudinal bars to equal area of prestressing steel being anchored at pocket

Recessed stressing pocket or full blockout

Figure 7.14 Local reinforcement design near stressing pockets

Stressing pockets are used in some cases in buildings where there is no scope for access to the anchorages. Figure 7.14 demonstrates the compatibility forces behind the anchorage. A pragmatic approach to analyse such situations should be to provide a certain minimum amount of well distributed reinforcement to control cracking.

Anchorage blisters are used in some cases either to stop the tendons at intermediate points to avoid congestion at the ends of the elements or where the access is restricted.
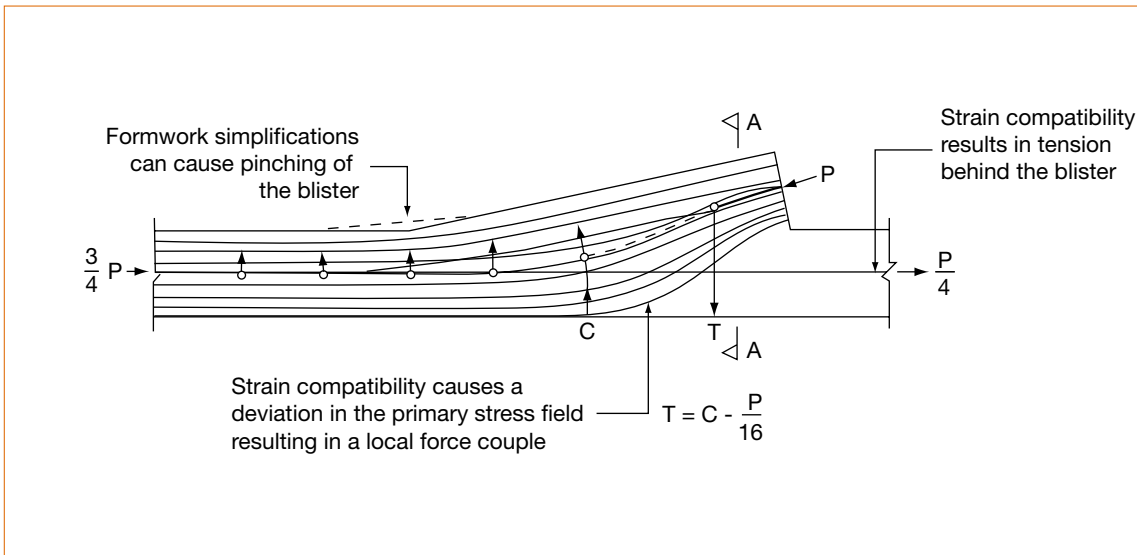
Figure 7.15 Typical blisters in slabs or diaphragms (stress trajectories shown)
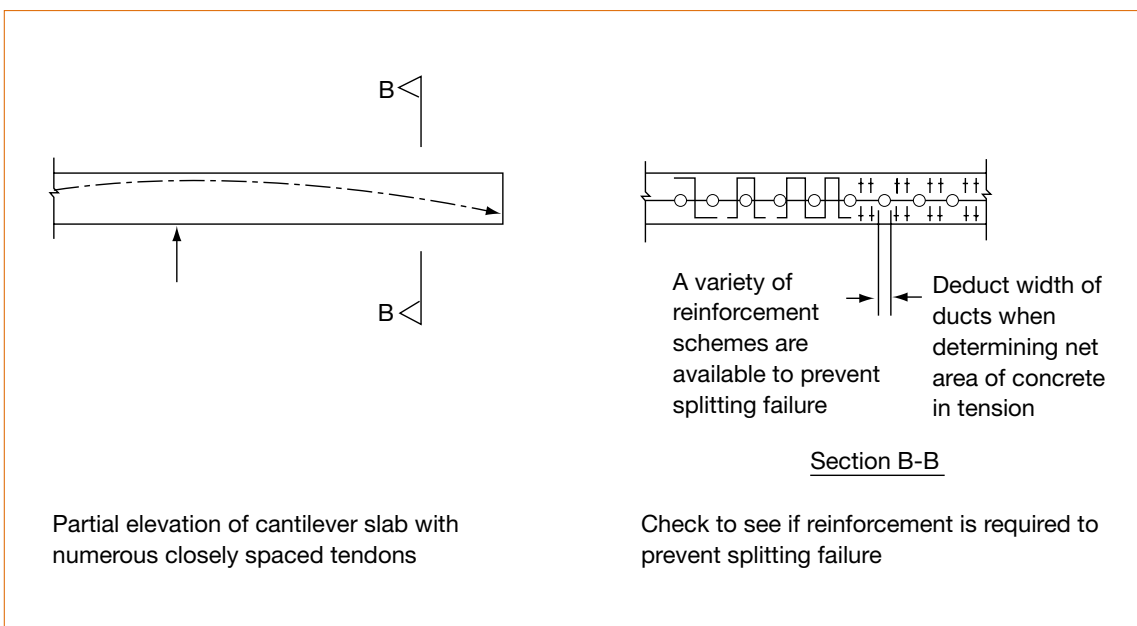
Figure 7.16 Example of slab splitting

Blisters, as far as is reasonably practical, should be located at stiffer points in the structure. Local strut and tie models should be used to determine the amount of reinforcement. A typical model is shown in Figure 7.15.

In cases where tendons are spaced closely, as in a slab, splitting along the plane of the tendon may be likely. To avoid cracking, reinforcement may be required as shown in the Figure 7.16.

Figure 7.17 Shear reinforcement

Figure 7.18 Stress distribution and additional reinforcement around circular holes

Figure 7.19 Forces acting on anchorage blisters
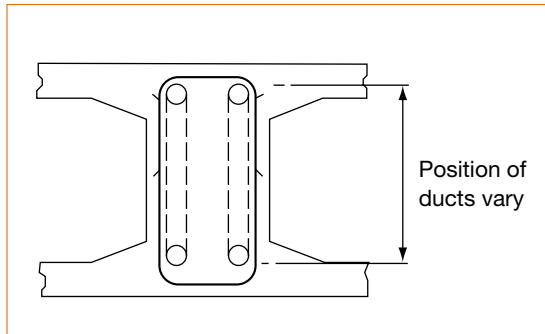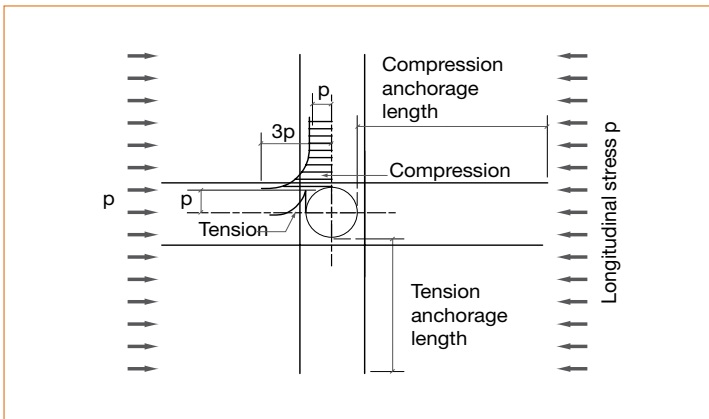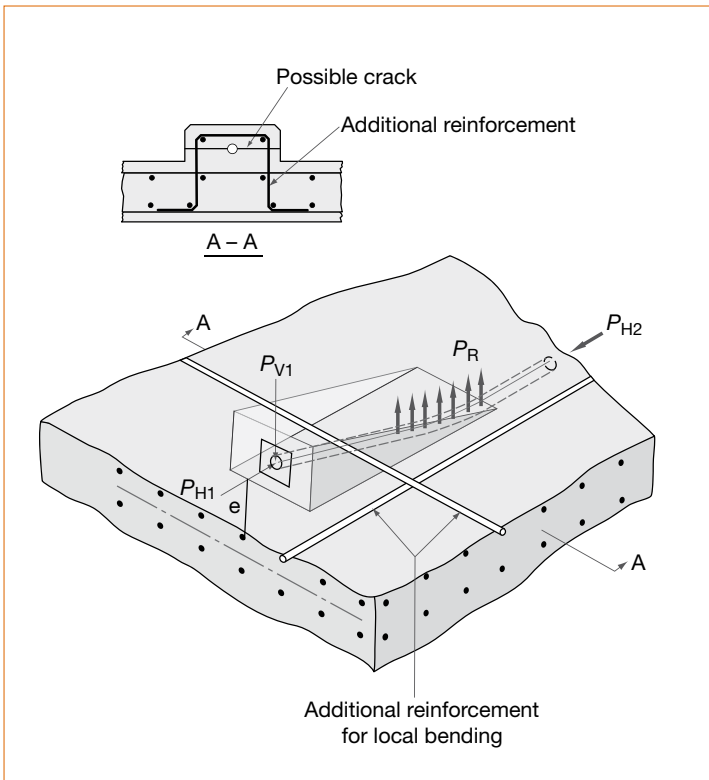
7.4.3 Secondary reinforcement

While prestress is normally introduced into an element 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 may consist of open links or pairs of lapping U-bars so that the tendons can be easily positioned (see Figure 7.17).

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

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

7.4.4 Additional reinforcement around holes

When holes occur in prestressed concrete elements, the compressive stresses in the direction parallel to the line of action of the prestress may be significantly increased (see Figure 7.18). 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.

7.4.5 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 element is considered as a whole, local shear forces and moments are induced, and these may need to be resisted by reinforcement.

As an example consider an anchorage blister on the flange of a box girder (see Figure 7.19). The radial component of the prestress force (P_R) is applied to the concrete along the curved length of the tendon and is balanced by the forces at the end of the tendon (P_{V1}, P_{H1} and P_{H2}). Reinforcement should be provided to resist the forces and moments induced.
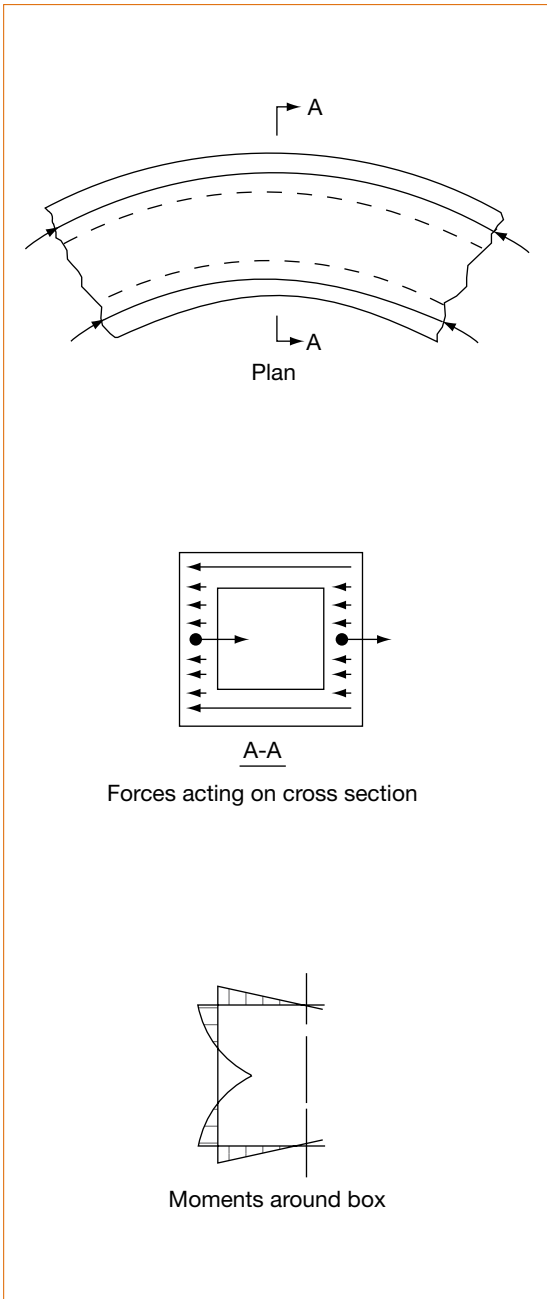
Figure 7.20 Forces in box girder in plan

Figure 7.21 Forces at looped anchorages

Where the radial prestress component P_R 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.

When tendons are located in the webs of beams that are curved in plan (see Figure 7.20),

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 forces 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 Figure 7.21).
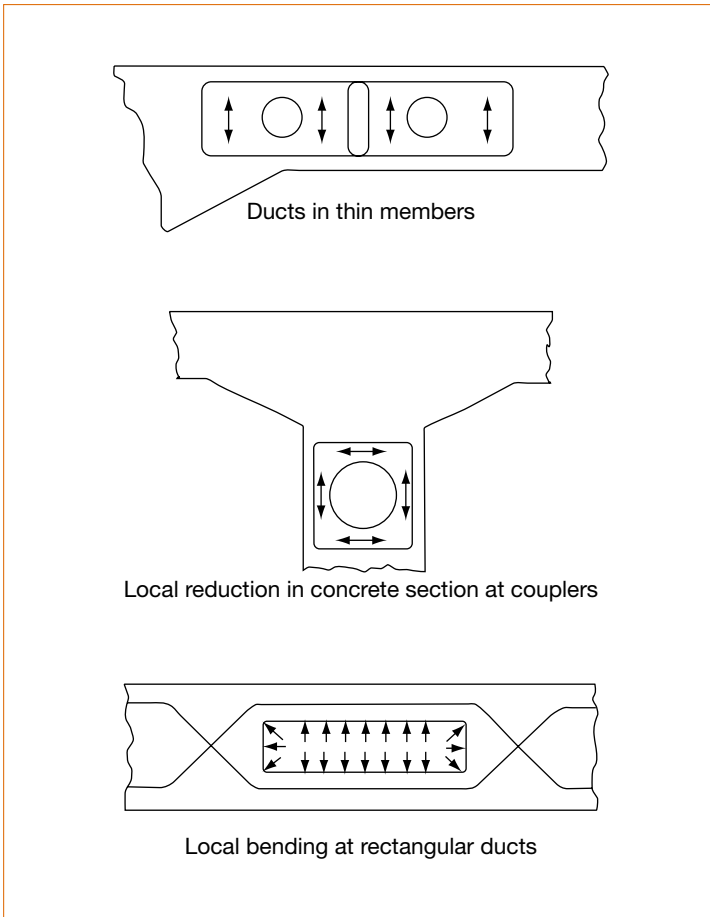
Figure 7.22 Tensile forces from grouting pressure

7.4.6 Reinforcement against grouting pressure

It is usually specified that tendon ducts should be grouted to a pressure of 0.1 MPa for slabs and for beams according to the Concrete Society Technical Report No. 47[39]. In all circumstances, the grout pressure must be sufficient to penetrate around the strands and must also expel the air and any water in the duct. In some circumstances, higher pressure may be used in order to force grout through the duct. Sheathings, anchorages and couplers are not designed to resist grouting pressure, which is consequently transmitted to the concrete where it can induce tensile stresses.

Figure 7.22 shows areas where tensile stresses are induced when the ducts are grouted. It may be necessary to provide reinforcement links around the ducts.

7.4.7 Intermediate anchorages

Figure 7.23 shows an anchorage within the body of a concrete element. 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 element from, for example, other prestressing tendons.

Reinforcement fully anchored into the surrounding concrete should be provided each side of the anchorage parallel to the prestressing tendon.
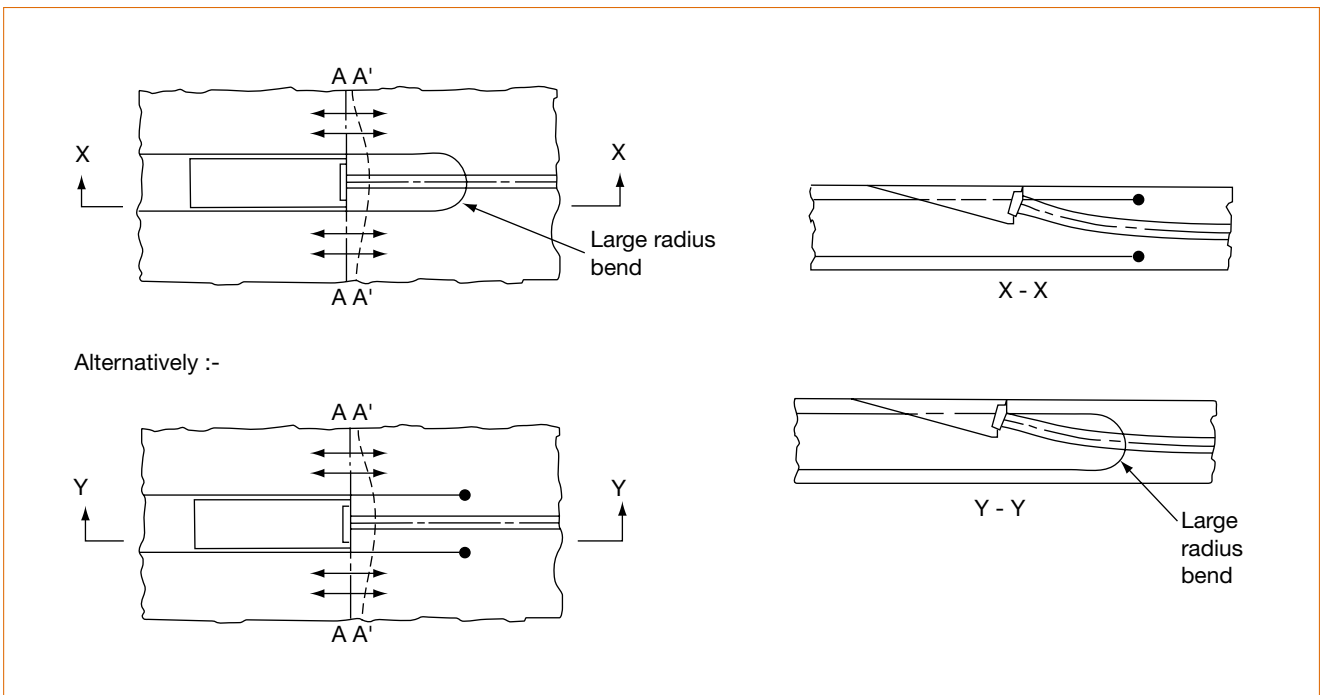
Figure 7.23 Tensile forces and additional reinforcement at intermediate anchorages

Local tensile forces can also occur at anchorage couplings (see Figure 7.24). 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.

7.4.8 Reinforcement in unstressed areas in slabs

Reinforcement may be required in the unstressed areas of the slabs. Figure 7.25 shows part of a typical floor slab with equally spaced tendons and the hatched areas show the unstressed zones of slab.

The area of reinforcement placed perpendicular to the slab edge should be the greater of 0.13% bh, or a quarter of the reinforcement provided parallel to the edge. It should be placed evenly between anchorages, and extend the greater of l_a or $0.7l_a$ plus a full anchorage length into the slab.

7.4.9 Reinforcement infill strips

Infill strips required in prestressed elements should be designed as reinforced concrete elements and be suitably reinforced. The drawings should clearly specify the minimum time to elapse before the infill strip is concreted.

Stage 1

Stage 2

Figure 7.24 Tensile forces at anchorage coupling

Figure 7.25 Unstressed zones near the edges of post tensioned floor slabs

Length of debonding
(see schedule)

Debonded tendon

Bonded tendon

Transmission zone
of bonded tendon

Transmission zone
of debonded tendon

Figure 7.26 Transmission zones in pre-tensioned elements

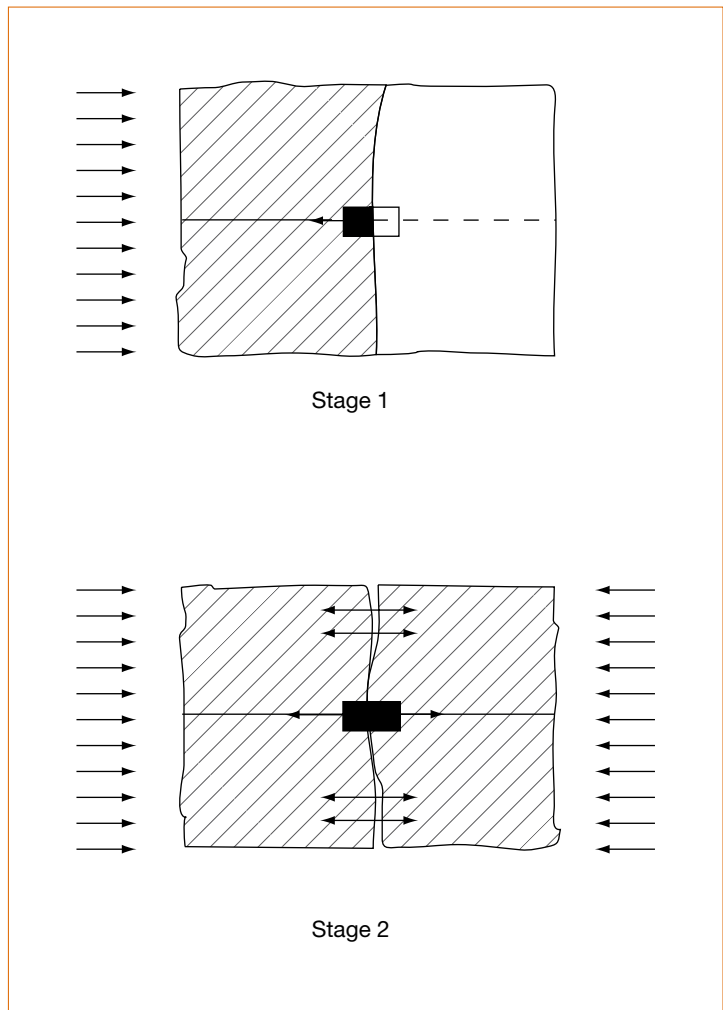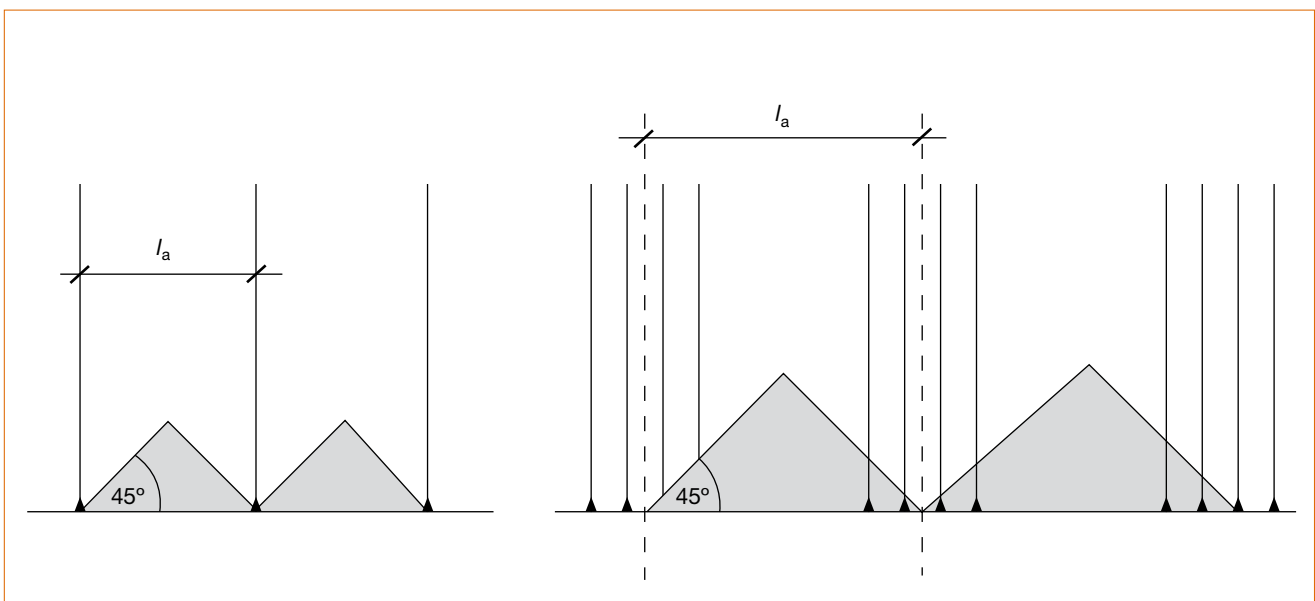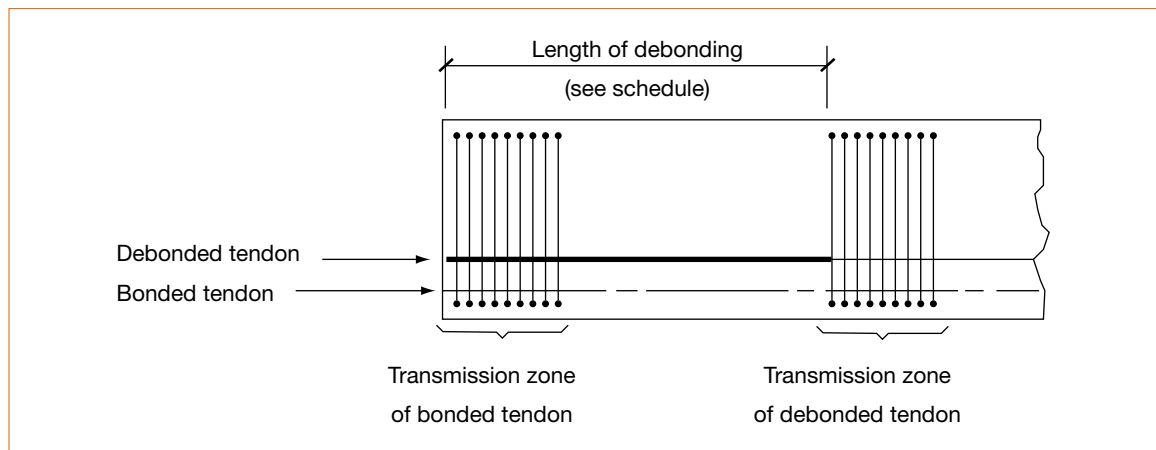### 7.4.10 Reinforcement near stiff points

Additional reinforcement may be required near stiff points such as core walls in the floors to account for shrinkage cracking. This should be shown on the reinforcement drawings.

7.4.11 Movement joints

The movements in a post-tensioned concrete slab or frame system are generally larger than that anticipated in similar reinforced concrete. The drawings should specify the long term movements at the movement joints taking into account the long term creep and shrinkage.

7.4.12 Pre-tensioned elements

In pre-tensioned elements 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. Transmission zones occur where tendons are debonded as well as at end of elements. 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 as necessary (see Figure 7.26).

It is recommended that the end zone of a beam is designed and detailed as a reinforced concrete element with longitudinal and shear reinforcement as necessary. It is normal practice to provide sets of standard stirrups at a closer spacing (e.g. 75mm) in transmission. This reinforcement is usually sufficient to resist the Poisson effect and equilibrium forces, as well as providing adequate shear capacity (see Figure 7.26).

7.4.13 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.

7.5   Other effects of prestressing

Information relating to the points addressed in this section 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 elements 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 either permanent or 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 Figures 7.27 and 7.28).

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.

7.5.2 Variation in camber

In defining the dimensional tolerances of prestressed concrete elements, variations in the modulus of elasticity and elastic shortening of the concrete should be considered.

The effects of variations in camber are of great significance 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.

7.5.3 Drilling and demolition

In order to avoid drilling into tendons during the 'life' of the building, the detailer must specify the specialist techniques required for drilling into post-tensioned structures. The drawing should specify the drilling techniques and measures to prevent drilling into tendons. Release of high energy, particularly with unbonded tendons due to drilling or demolition poses a direct risk of personal injury as well as posing a structural safety hazard and hence should be addressed by the designer/detailer.

Structures with bonded tendons can be demolished using similar techniques and methods to reinforced concrete. However structures with unbonded tendons may require a method of de-stressing prior to demolition due to sudden release of high energy and could pose a safety hazard. Therefore the Designer/Detailer should specify a safe method and sequence of demolition in accordance with the current CDM (Construction Design and Management) regulations.

It is helpful for later reference to specify that the soffit of slabs be marked to show the positions of the tendons.
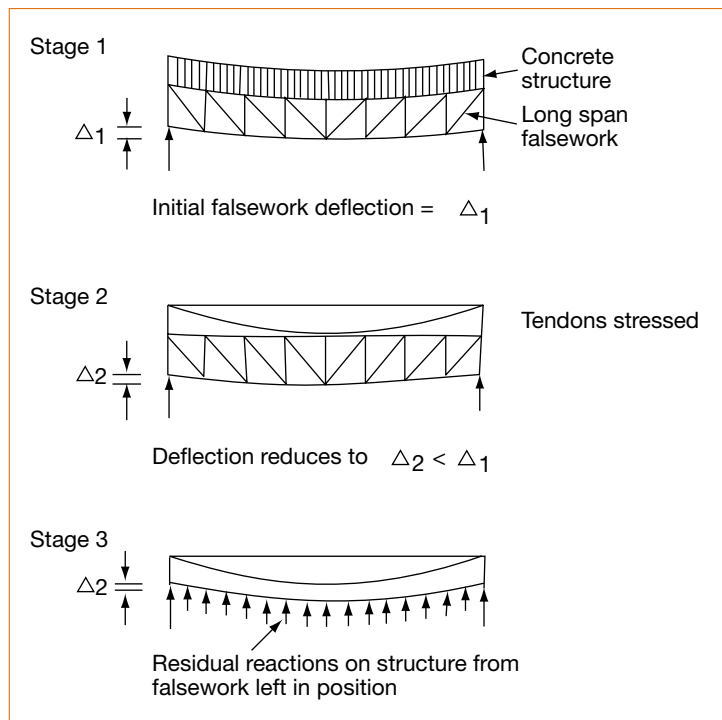
Figure 7.27 Effect of leaving falsework in position – Case A
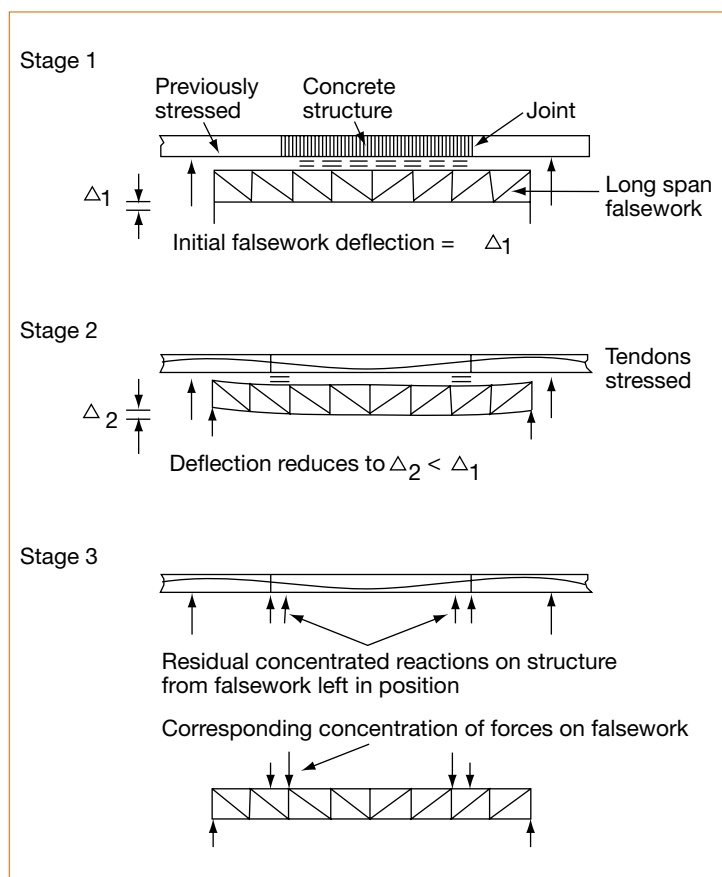
Figure 7.28 Effect of leaving falsework in position – Case B

7.6 Typical details of post-tensioned floor slabs

Figures 7.29 to 7.40 show typical methods of detailing post-tensioned elements in which the tendon layout, the tendon support bars and additional bonded reinforcement are shown separately.

Typical examples of the legend for bonded and unbonded systems showing groups of tendons and anchorage types are given in Figures 7.29 and 7.30.

Tendon quantity, colour code
Intermediate stressing anchor
Intermediate anchor
Placing sequence
Dimension between tendon group centres

Live End
Weave

One tendon
Two tendons
Three tendons
Four tendons
Five tendons

Dead end
Add tendons
Edge of slab

Will be marked with a number symbol

Tendon stressing reference numbers

Note
When more than one symbol appears on a tendon group, the number of tendons will equal the sum of the symbols

a) Unbonded tendons

Tendon quantity, length, colour code and elongation

Placing sequence (where required)

Dimensions from reference line to ₵ of tendon group

Symbol defining numbers of tendons in group

One strand
Two strands
Three strands
Four strands
Five strands
Fixed end
Additional
strands

24 x 31.850
Green □ = 84

1 x 12.500 (thru')
Red Δ = 130

3 x 10.500 (added)
Blue Δ = 75

Edge of slab

Stressed
ends

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

b) Bonded tendons

Figure 7.29 Typical legends
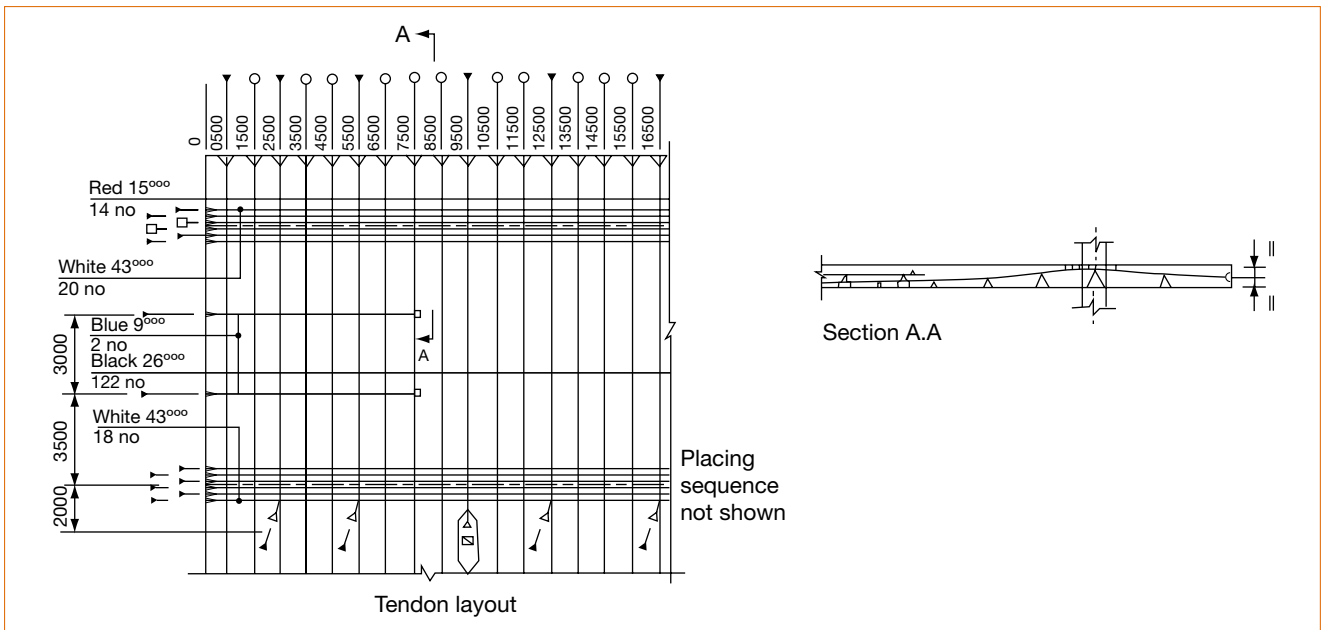
Figure 7.30 Typical unbonded tendon layout and placing sequence

It is always necessary to prepare the reinforcement drawings separately from the post-tensioning profile drawings. An example of untensioned reinforcement layout for an unbonded tendon system is shown in Figure 7.31. Reinforcement is always required in the top of the slab at columns and at prestressing anchorages. It is also sometimes required in the bottom of the slab at mid-span.
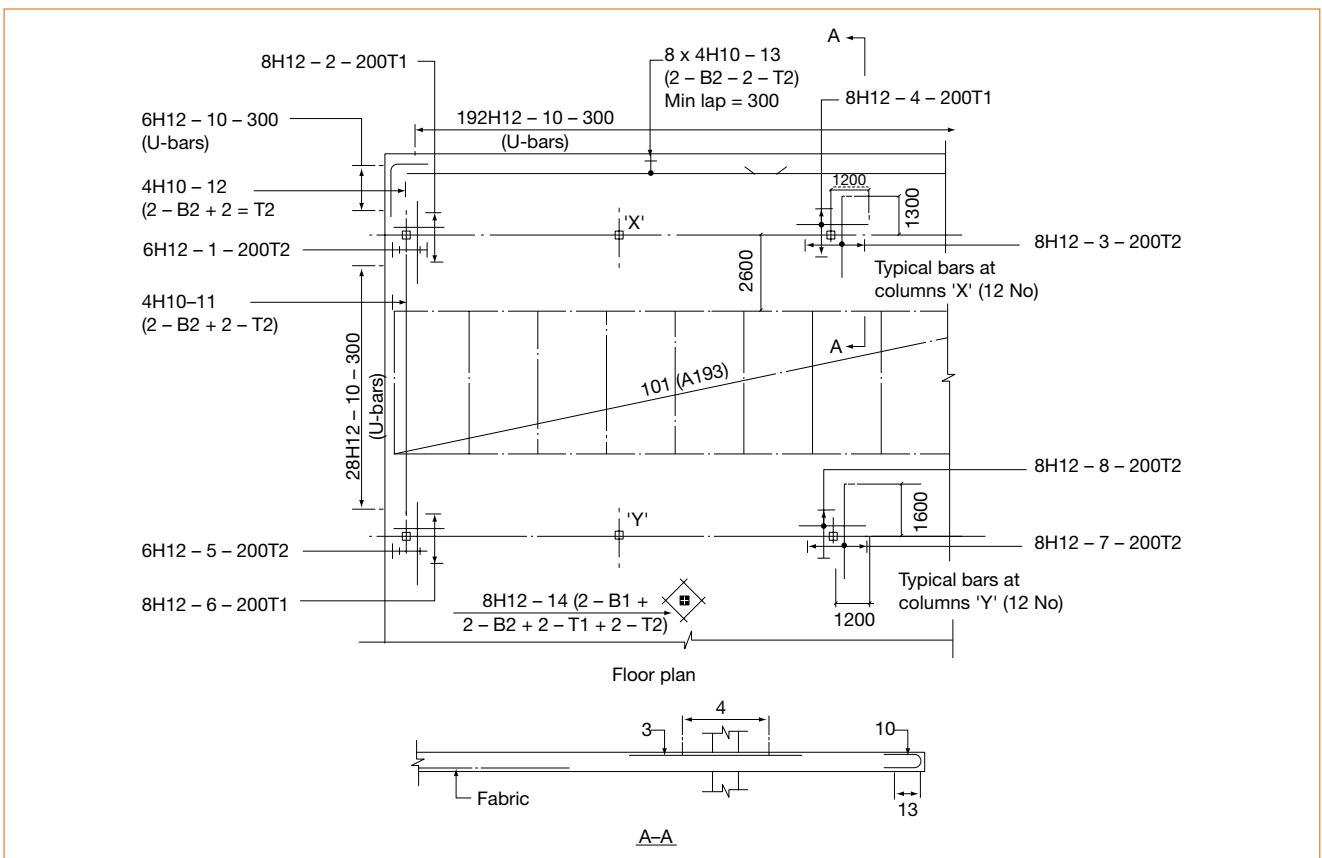
Figure 7.31 Example of untensioned reinforcement layout for an unbonded system

Figures 7.32 and 7.33 show layouts for a post-tensioned band beam and slab with bonded tendons.
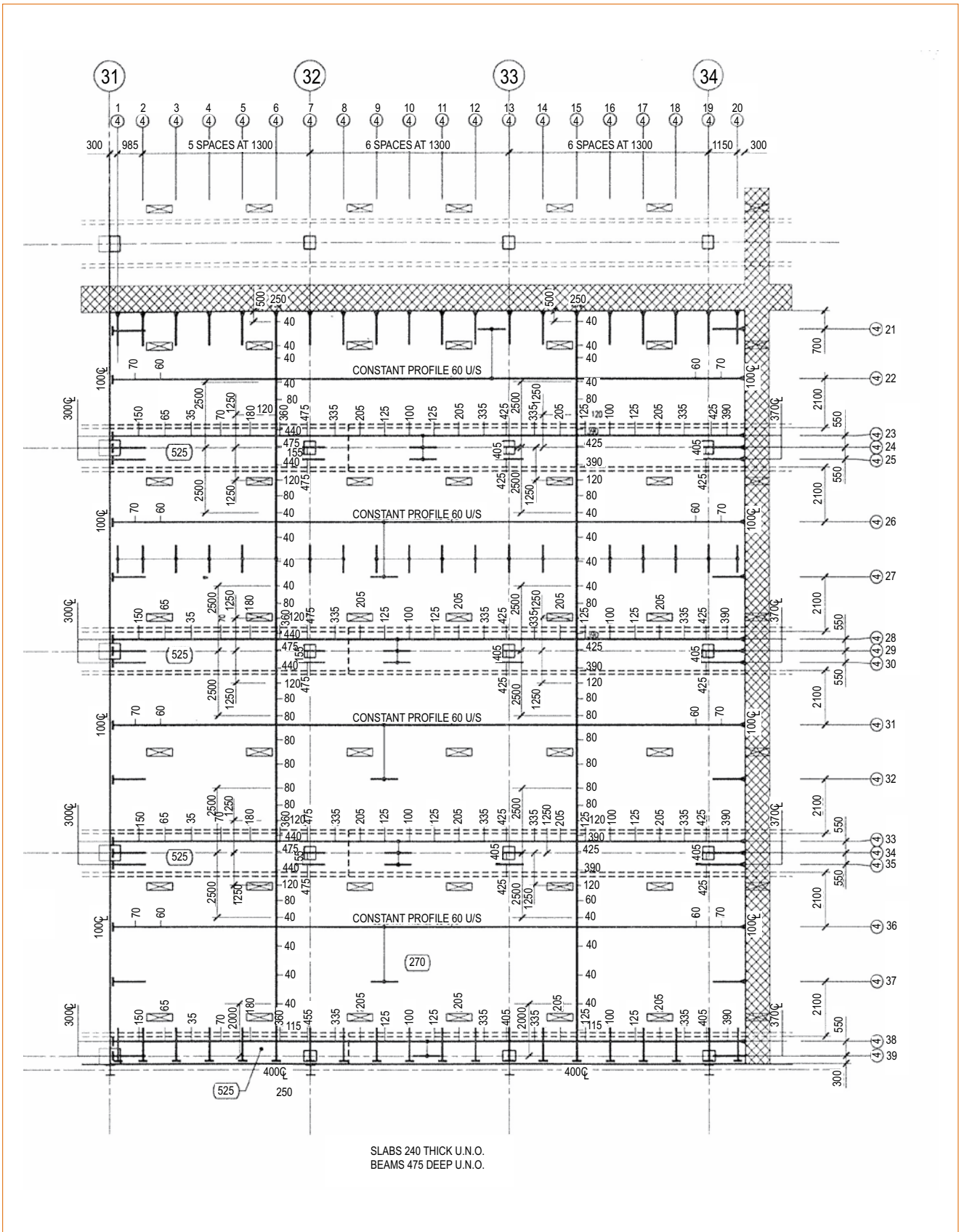
Figure 7.32 a) Typical tendon profile in a post-tensioned band beam and slab (plan)
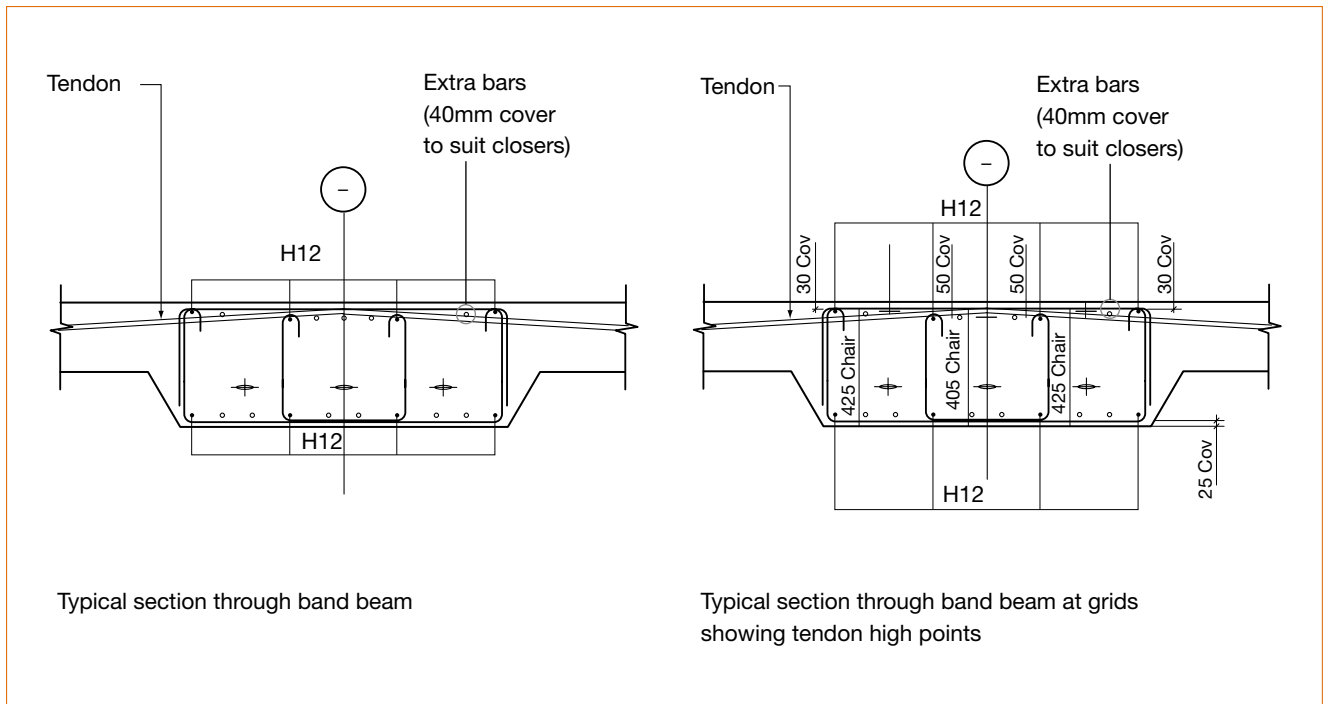
Figure 7.32 b) Typical tendon profile in a post-tensioned band beam and slab (typical sections)

Figure 7.33 Slab and beam tendons in post tensioned slab (courtesy of Sir Robert McAlpine Ltd)

Figures 7.34 and 7.35 show typical infill strip details
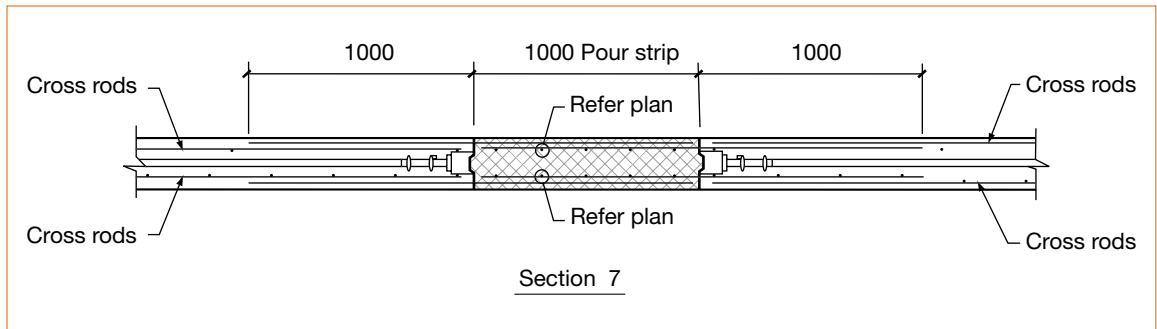
Figure 7.34 Infill strip detail

Figure 7.35 Typical pour strip (infill strip) (courtesy of Sir Robert McAlpine Ltd)
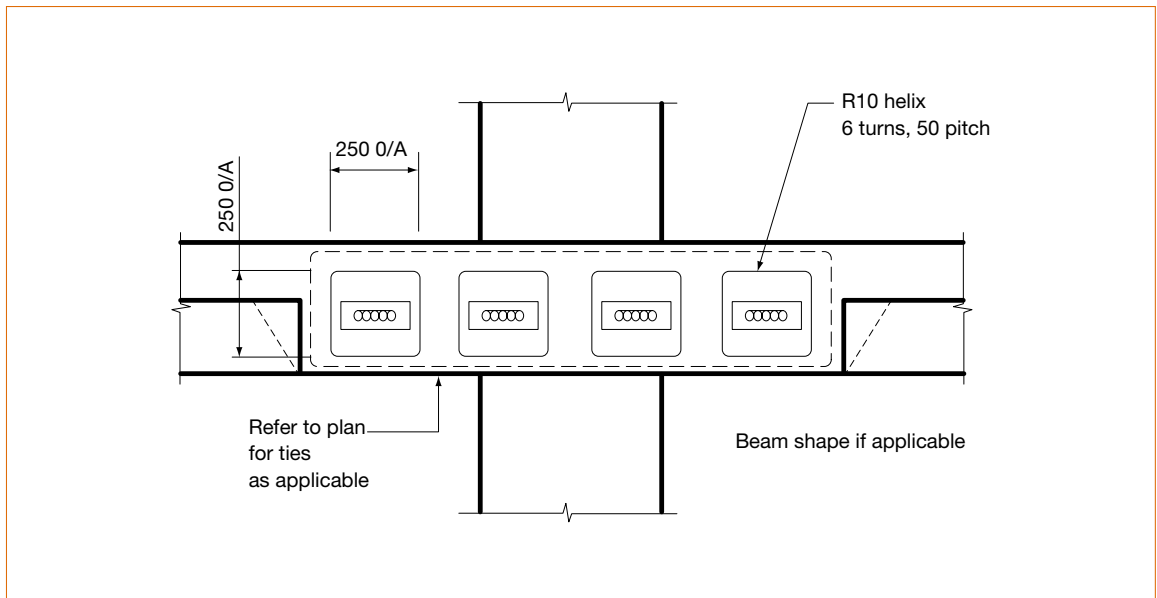
Figure 7.36 Section through a band strip over a column
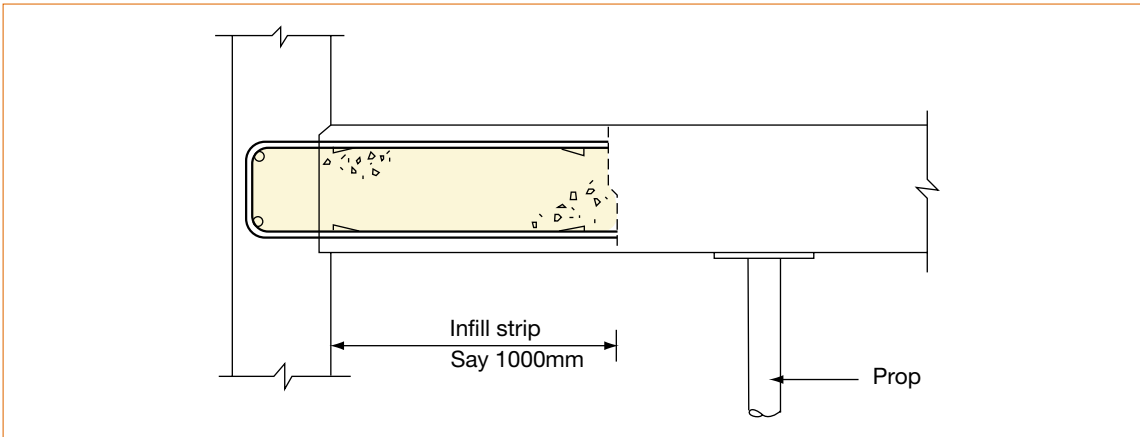
Figure 7.37 Typical infill detail near core wall

Figure 7.38 Bursting reinforcement for a typical live end in a post-tensioned slab
(courtesy of Sir Robert McAlpine Ltd)

Figure 7.39 Typical dead end anchorage showing the grout tube and bursting helix
(courtesy of Sir Robert McAlpine Ltd)

Figure 7.40 Typical ducts in transfer beams (courtesy of Sir Robert McAlpine Ltd)

8.1 General

Detailing of precast concrete work requires special disciplines that do not occur with in-situ concrete. The reasons 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.

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 (police notification required if over 18.3m)

        > 27.4m special dispensation required from Department for Transport

Height   < 4.88m (standard height of motorways is 5.03m)

        > 4.88m two days notice to traffic authorities, concerning route, required

Width   < 2.9m no restriction

        2.9 up to 3.5m possible with notification to police

        3.5 up to 5m special dispensation required from the Department for Transport

Weight   < 26 tonne no restriction on normal 32/36/42 tonne trucks

        where weight of vehicle and load exceeds 44 tonnes Special Types vehicle is required:

        STGO 1 Up to 80 tonnes gross (2 day police notification required)

        STGO Over 80 tonnes gross (5 day police notification required)

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 the weight of the whole number of units approaches but does not exceed 30 tonne, i.e. 2 number 9.8 tonne per load as against 1 number 10.2 tonne unit.

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.

Reinforcement is considered generally 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 an assessment of 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, ways should be sought to isolate the fixings so that only the correct forces may be applied.

Where a drawing 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 and 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 de-moulding 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 Engineers report *Structural joints in precast concrete*, 1978[40].

Where in-situ concrete is placed adjacent to precast units, e.g. an infill slab, the precast units should have a key joint cast in the mutual face for mechanical anchorage or shear purposes. Where a precast concrete face is to receive in-situ concrete placed against it, that face of the precast unit should be properly prepared (e.g. scabbled when the concrete is 'green').

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.

8.2 Particular durability problems

In bridge and car park construction where there is a risk of chloride exposure, the joints between precast units require special attention in order to protect the reinforcement from corrosion. Figure 8.1 illustrates an example where severe exposure, XD3, conditions exist.

Reference should be made to the following reports:

Enhancing the whole life structural performance of multi-storey car parks[41]

Design recommendations for multi-storey and underground car parks[42]

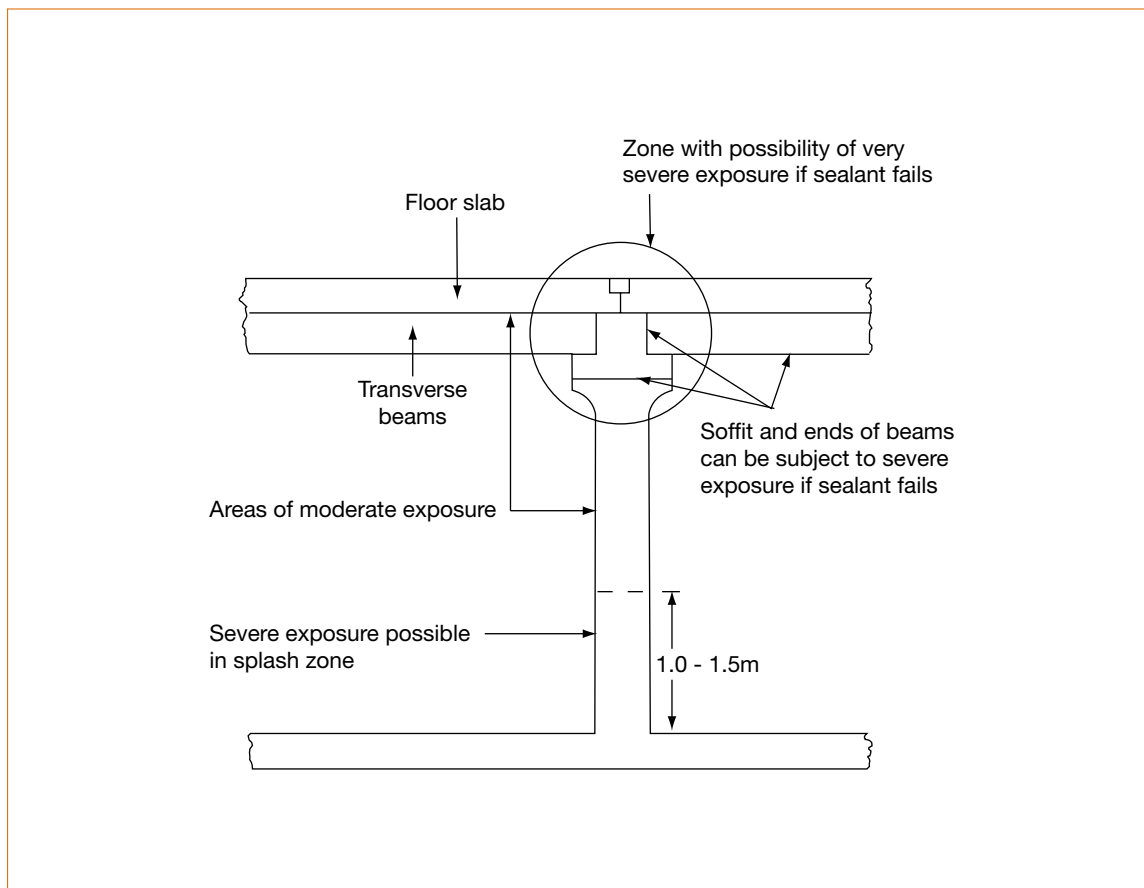*Recommendations for the inspection, maintenance and management of car park structures*[43].

Figure 8.1 Example of severe exposure, XD3, positions for precast car parks and bridges

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 EN 1992-3 (EC2, Part 3)[4] deals with the design of reinforced concrete liquid retaining and containing structures. 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 serviceability limit state of cracking may therefore control the design and in many cases exceed that required for strength.

Water-retaining structures designed to EC2, Part 3 require reinforcement to resist tensile forces caused by

- structural actions due to applied loads and
- 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 each cause.

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. Typical joints are given in 9.4. Partial joints are not covered in EC2, Part 3.

It is the responsibility of the Designer 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 Durability and crack control

9.2.1 General (EC2, Part 3, Clause 7)

The Designer should specify the cover and the size and spacing of the reinforcement necessary for crack control and durability.

Where the aesthetic appearance is critical the crack width should be limited to 0.1mm.

Crack control also affects tightness (e.g. water-tightness). Table 9.1 gives the classification of tightness. It should be noted that all concrete will permit the passage of small quantities of liquids and gasses by diffusion.

Table 9.1 Classification of tightness

Tightness Class	Requirements for leakage
0	Some degree of leakage acceptable, or leakage of liquids irrelevant.
1	Leakage to be limited to a small amount. Some surface staining or damp patches acceptable.
2	Leakage to be minimal. Appearance not to be impaired by staining.
3	No leakage permitted.

Tightness Class 0

The same provisions as for retaining walls are appropriate (EC2, Clause 7.3.1). The minimum thickness of wall is 120mm.

Tightness Class 1

Any cracks which can be expected to pass through the full thickness of the section should be limited to wk1 The minimum thickness of wall is 150mm.

w_{k1} is defined as a function of the ratio of the hydrostatic pressure, h_D to the wall thickness of the containing structure, h_w. For $h_D/h_w \leqslant 5$, $w_{k1} = 0.2$mm while for $h_D/h_w \geqslant 25$, $w_{k1} = 0.05$mm. For intermediate values of h_D/h_w, linear interpolation between 0.2 and 0.05 may be used. Limitation of the crack widths to these values should result in the effective healing of the cracks within a relatively short time (see also EC2, Part 3, Clause 7.3.1 (112) and (113).

Tightness Class 2

Cracks which may be expected to pass through the full thickness of the section should generally be avoided unless appropriate measures such as liners or water bars have been incorporated. The minimum thickness of wall is 150mm.

Tightness Class 3

Generally, special measures such as liners or prestress will be required to ensure water-tightness.

Prestressed walls

A minimum amount of passive reinforcement of 300mm²/m or $0.001A_c$ should be provided in each direction and in each face.

9.2.2 Cover

The nominal cover given should not be less than 40mm. A greater cover may be necessary at a face in contact with aggressive soils or subject to erosion or abrasion.

9.2.3 Spacing of reinforcement

For tensile reinforcement where the stress in the bar does not exceed 150 MPa the bar spacing should not exceed 250mm. The spacing of distribution bars should not exceed 150mm (preferably closer). For higher stresses the pitch reduces rapidly (see EC2, Part 3, Clause 7.3.3).

9.3 Other design and detailing information/requirements

9.3.1 Circular tanks

In circular tanks the centroid of horizontal prestressing tendons should generally lie in the outer third of the wall. Where cover makes this impossible this may be relaxed providing the tendon duct remains in the outer half of the wall. The diameter of ducts should not exceed 20% of the wall thickness.

9.3.2 Opening corners

At an opening corner the detailing of the reinforcement should ensure that the diagonal tension faces are adequately catered for. A strut and tie system as covered in EC2, Clause 5.6.4 provides an appropriate design approach.

9.4 Typical details

Construction joints

Movement joint
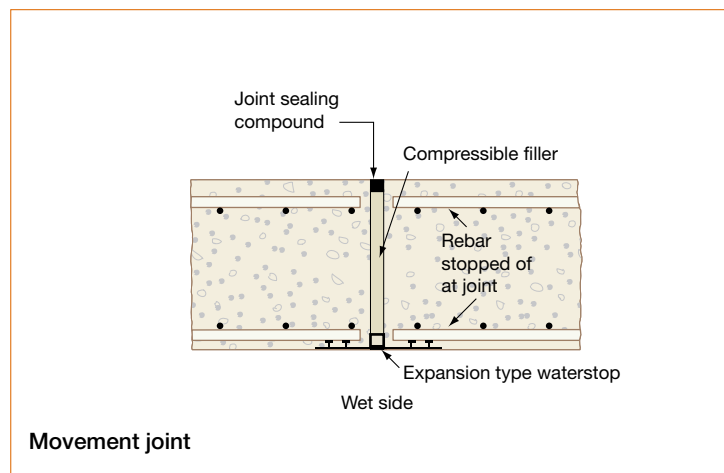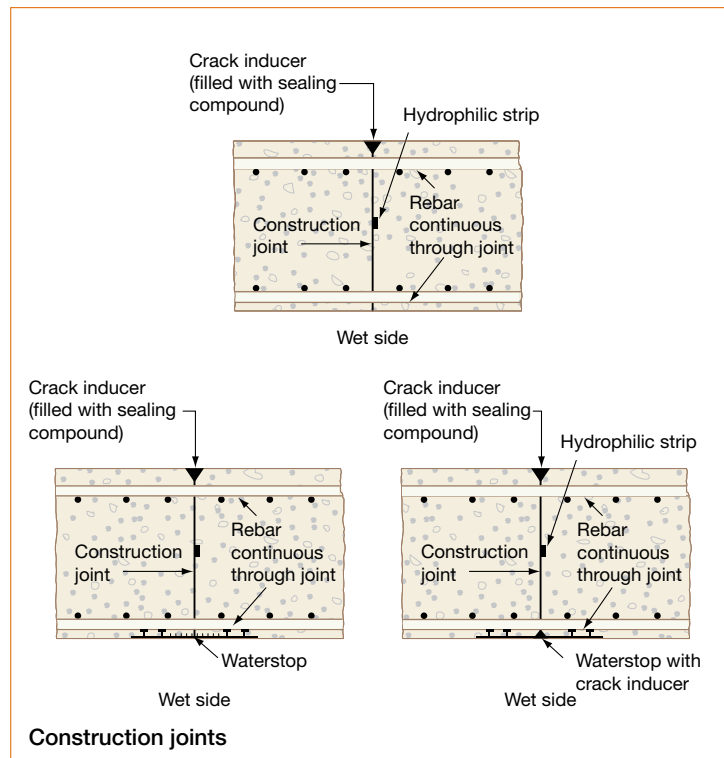
10 REFERENCES

1 British Standards Institution. *BS EN 1992-1-1: Eurocode 2: Design of concrete structures. General rules and rules for buildings*. London, BSI, 2004.

2 British Standards Institution. *BS EN 1992-1-2: Eurocode 2: Design of concrete structures. General rules. Structural fire design*. London, BSI, 2004.

3 British Standards Institution. *BS EN 1992-2: Eurocode 2. Design of concrete structures. Bridges*. London, BSI, 2004.

4 British Standards Institution. *BS EN 1992-3: Eurocode 2: Design of concrete structures, Part 3: Liquid retaining and containing structures*. London, BSI, 2004.

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A.1   Approximate period 1948-1957

CP 114   *Code of practice for reinforced concrete.* London, British Standards Institution, 1948: revised 1957 and 1965. Metric version, 1969.

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Refers to **BS 785**:   *Rolled steel bars and hard drawn steel wire for concrete reinforcement.* London, British Standards Institution, 1938.

and **BS 1144:**   *Cold twisted steel bars for concrete reinforcement.* London, British Standards Institution, 1943.

Material properties	Symbol used drawing	lb/in² (MPa)
BS 785: 1938		
Mild steel:	R	62,720 (432)
Minimum tensile strength		
Medium tensile steel:	M	
Minimum tensile strength		73,920 (510)
Minimum yield stress		
Size: up to 2 in		39,200 (270)
up to 1½ in		41,440 (286)
1 in or less		43,680 (301)
High tensile steel:	H	
Minimum tensile strength		82,880 (571)
Minimum yield stress		
Size: up to 2 in		47,040 (324)
up to 1½ in		49,280 (340)
1 in or less		51,520 (355)
BS 1144: 1943		
Twin twisted bars:	I	
Minimum tensile strength		63,000 (434)
Minimum yield stress		54,000 (372)
Square twisted bars:	S	
Minimum tensile strength		
Size: 3/8 in and over		70,000 (483)
under 3/8 in		80,000 (552)
Minimum yield stress		
Size: 3/8 in and over		60,000 (414)
under 3/8 in		70,000 (483)

A.2   Approximate period 1957-1965

Material properties	Symbol used drawing	lb/in² (MPa)

CP 114: 1957
Mild steel (Permissible stress):
   Tension:
      Size: 1½ in and under
      over 1½ in
   Compression:
      Size: 1½ in and under
      over 1½ in
Other steels (Permissible stress):
   Tension: ½ × minimum yield stress but not greater than
   Compression: ½ × min. yield stress but not greater than
   Shear:
		
		20,000 (138)
		18,000 (124)
		
		18,000 (124)
		16,000 (110)
		
		30,000 (207)
		23,000 (159)
		20,000 (138)

London By-Laws: 1952
Mild steel (Permissible stress):
   Tension/compression:
Other steels (Permissible stress):
   Tension: ½ × minimum yield stress but not greater than
   Compression: ½ × min. yield stress but not greater than
Tentor bars (round 'high yield' deformed bars):
   Stress as for square twisted bars
Symbols used on drawings otherwise as for 1948-1957
	
	T
		
		18,000 (124)
		
		27,000 (186)
		20,000 (138)

A.3   Approximate period 1965-1972
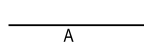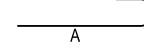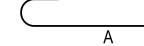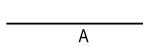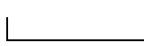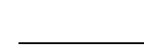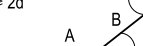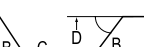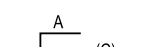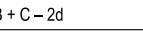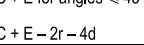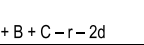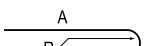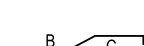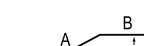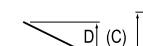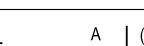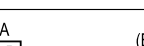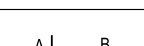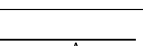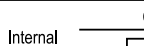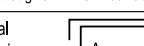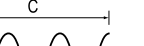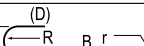
Material properties	Symbol used drawing	lb/in² (MPa)

CP 114: 1965
High yield bars (Permissible stress):
   Tension: 0.55 × min. yield stress
      Size: 7/8 in and under
        over 7/8in
   Compression and shear:
		
		33,000 (227)
		30,000 (207)
		25,000 (172)

CP 114: 1969 (Metric)
High yield bars (Permissible stress):
   Tension:
      Size: 20mm and under
        over 20mm
   Compression and shear:
		
		230
		210
		175

BS 4466: *Specification for scheduling, dimensioning, bending and cutting of steel reinforcement for concrete.* London, British Standards Institution, 1969. Round mild steel High yield bars No specification concerning deformed properties Not covered by R or Y *Before 1969 symbols as for 1948-1965*	 R Y X	

A.4   Approximate period 1972-1980

Material properties	Symbol used drawing	MPa
CP 110: *Code of practice for the structural use of concrete, Part 1: Design, materials and workmanship.* London, British Standards Institution, 1972. (Characteristic strength)		
Hot rolled bars		410
Cold worked bars		
16mm and under		460
over 16mm		425
Design tensile strength = (0.87 × Characteristic strength)		
Design compression strength = $\dfrac{\text{design tensile strength}}{1 + \dfrac{\text{design tensile strength}}{2000}}$		

A.5 Approximate period 1980-1983

Material properties	Symbol used drawing	MPa
BS 4466: 1981 Plain or deformed bars grade 250 Type 2 deformed bars grade 460/425 Not covered by R or T	R T X	

20 A L = A	**32** A L = A + h	**33** A L = A + 2h	**34** A L = A + n
35 A L = A + 2n	**37** A (B) L = A + B − 1/2 r − d	**38** A B (C) A B (C) L = A + B + C − r − 2d	**41** D ⩾ 2d B D A L = A + B + C for angles ⩽ 45 else L = A + B + C − 2d
43 A D (E) B C B L = A + 2B + C + E for angles ⩽ 45 else L = A + 2B + C + E − 2r − 4d	**51** R A B L = A + B − 1/2 R − d		**60** A B Internal dimensions L = 2 (A + B) + 20d Grade 460, 425, 485 A or B ⩾ 10d or 125mm for sizes ⩽ 20mm Grade 460, 425 A or B ⩾ 12d for sizes ⩾ 25mm
62 A B (C) L = A + B for angles ⩽ 45 else L = A + C − 1/2 r − d	**81** A B Internal dimensions L = 2A + 3B + 22d	**83** C B A B (D) L = A + 2B + C + D − 2r − 4d if A and/or B and/or C are not external, see shape code 99	
39 A R B (C) L = A + 0.57B + C − 1.57d	**42** B C D A L = A + B + C + n for angles ⩽ 45	**45** B A D (C) L = A + B + C − 1/2 r − d	**49** D (C) E B L = A + B + C for angles ⩽ 45 else L = A + B + C − r − 2D
52 A A (D) B (D) B C C L = A + B + C + D − 1 1/2r − 3d	**53** A (E) B C D L = A + B + C + D + E − 2r − 4d	**54** A B (C) L = A + B + C − r − 2d	**55** (E) A B D B A (E) C C D A (E) B C D L = A + B + C + D + E − 2r − 4d
65 A R L = A These bars will be supplied straight when the radius exceeds that given in BS 4466 Table 5	**72** Internal dimensions A B L = 2A + B + 25d	**73** C Internal dimensions B A L = 2A + B + C + 10d	
74 Internal dimensions A B L = 2A + 3B + 20d **85** (D) C R B r A L = A + B + 0.57C + D − 1/2 r − 0.257d	**86** C Helix B B A A = Internal diameter (mm) B = Helix pitch (mm) C = Helix overall height (mm) L = C/Bπ (A + d) when B ⩽ A/5	**99** ALL OTHER SHAPES A dimensioned sketch shall be drawn out over the schedule columns A to E. Every dimension shall be specified and the dimension that is free to take up tolerances shall be indicated in parentheses, otherwise the fabricator is free to choose which dimension shall take up the tolerances. If the standard shape is required but a different dimension is to take up the tolerance, the shape code shall be drawn out as a 99 and the free dimension indicated in parentheses.	
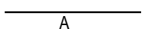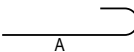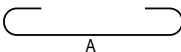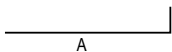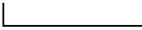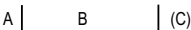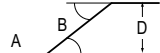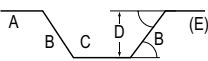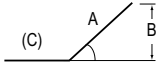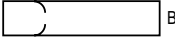
CP 110: Amendment (1980) (Characteristic strength)		
Hot rolled and cold worked bars Size: up to 16mm over 16mm		460 425

A.6 Approximate period 1983-1985

Material properties	Symbol used drawing	MPa
CP 110: Amendment (1983) (Characteristic strength) All sizes		460

A.7 Approximate period 1985 – 2004
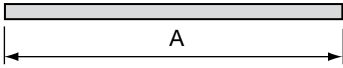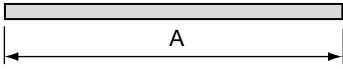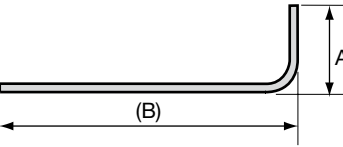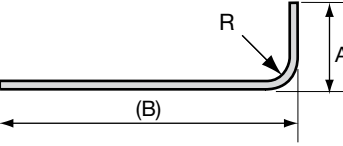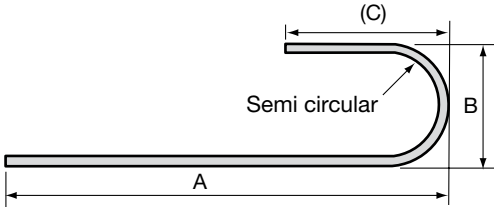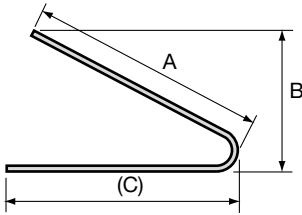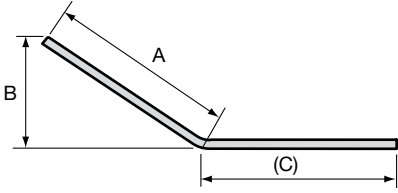
Material properties	Symbol used drawing	MPa
BS 8110: *Structural use of concrete, Part 1: Code of practice for design and construction.* London, British Standards Institution, 1985. Design compressive strength made equal to Design tensile strength which is (0.87 × Characteristic strength)		
BS 4466: 1989		
Plain or deformed	R	250
Type 2 deformed bars or fabric	T	460
Stainless reinforcement	S	
Plain reinforcement to BS 4482	W	460
Type 1 deformed reinforcement to BS 4482	D	460
Not covered by others	X	
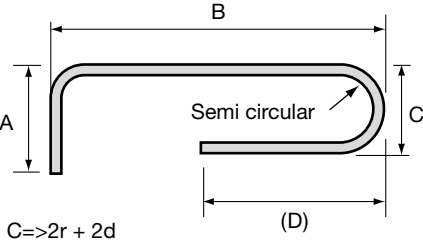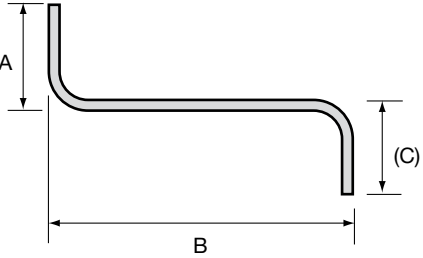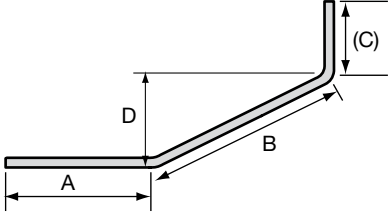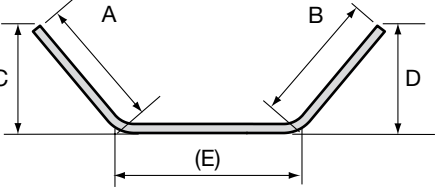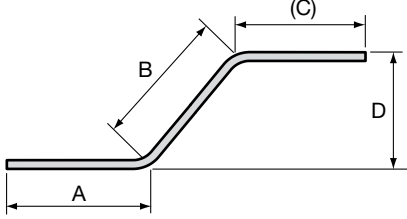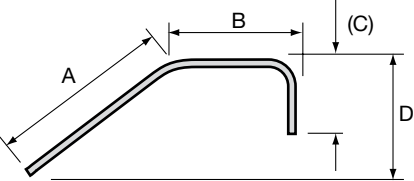
20
$L = A$

32
$L = A + h$

33
$L = A + 2h$

34
$L = A + n$

35
$L = A + 2n$

37
$L = A + B - 1/2 \, r - d$

38
$L = A + B + C - r - 2d$

41
$L = A + B + C$ for angles $\leqslant 45$
else
$L = A + B + C - 2d$

43
$L = A + 2B + C + E$ for angles $\leqslant 45$
else
$L = A + 2B + C + E - 2r - 4d$

51
$L = A + B - 1/2 \, R - d$

62
$L = A + B$ for angles $\leqslant 45$
else
$L = A + C - 1/2 \, r - d$

82
$L = 2A + 3B + 18d$
External dimensions
If B > 350mm see BS 4466 clause 10.2

61
$L = 2 (A + B) + 12d$
External dimensions
Grade 460
A or B $\geqslant$ 12d or 150mm for sizes $\leqslant$ 20
A or B $\geqslant$ 14d for sizes $\geqslant$ 25
Grade 250, with 100mm minimum
A or B $\geqslant$ 10d for sizes $\leqslant$ 20
A or B $\geqslant$ 12d for sizes $\geqslant$ 25
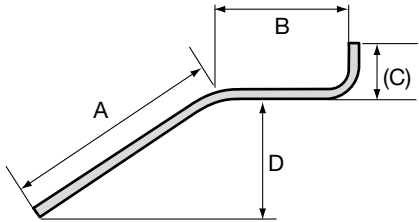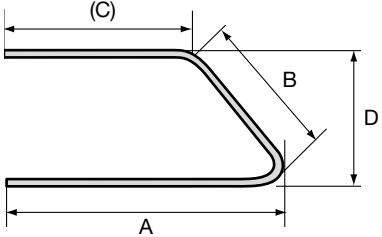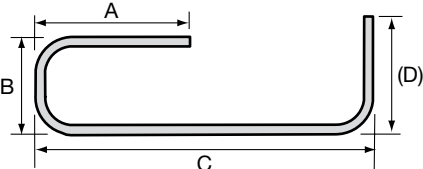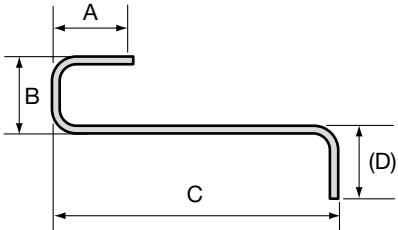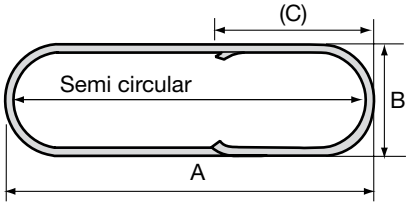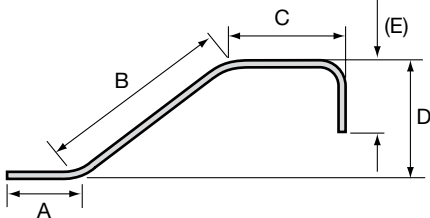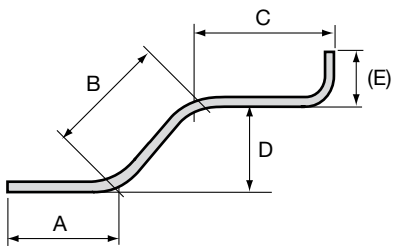
Material properties	Symbol used drawing	MPa

BS 8110: 1997
    Design strength increased to:
    Characteristic strength/1.05		

BS 8666: *Specification for scheduling, dimensioning,* *bending and cutting of steel reinforcement for concrete.* London, British Standards Institution, 2000 (replaced BS 4466*)*. Conformed with new ISO and European standards Conforming to BS 4449	R	250
Deformed Type 1 conforming to BS 4482 (and for fabric conforming to BS 4483)	F	460
Deformed Type 2 conforming to BS 4482 or Ductility A of BS4449 (and for fabric conforming to BS 4483)	D	460
Plain round conforming to BS 4482 (and for fabric conforming to BS 4483)	W	460
Ductility A or B deformed Type 2 conforming to BS 4449	T	460
Ductility B deformed Type 2 conforming to BS 4449 (for bar or fabric conforming to BS 4483)	B	460
A specified grade and type of stainless steel conforming to BS 6744	S	
Reinforcement of a type not included in the above list having material properties that are defined in the design or contract specification	X	
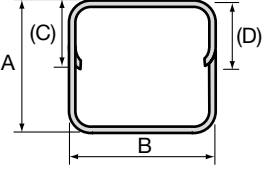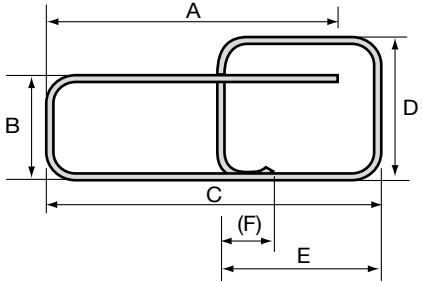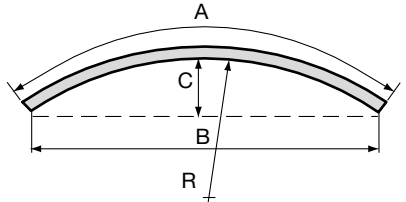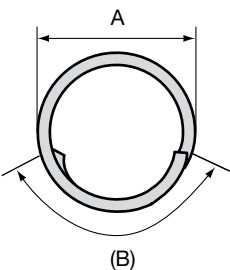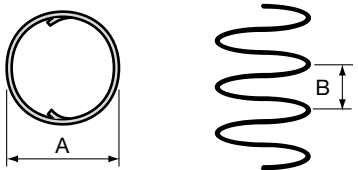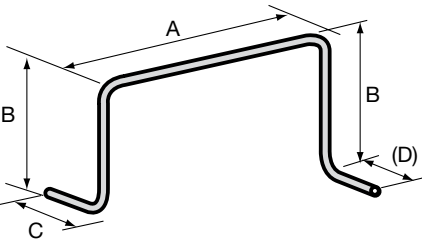
Bar shapes

Shape code	Shape	Total length of bar (*L*) measured along centre line
00	A	A
01	A	A Stock lengths See Note 4
11	A (B)	$A + (B) - 0.5r - d$ Neither A nor B shall be less than P in Table B.1
12	R A (B)	$A + (B) - 0.43R - 1.2d$ Neither A nor B shall be less than P in Table B.1 nor less than (R + 6d)
13	(C) Semi circular B A	$A + 0.57B + (C) - 1.6d$ B shall not be less than 2(r + d). Neither A nor C shall be less than P in Table B.1 nor less than (½B + 5d). See note 3
14	A B (C)	$A + (C) - 4d$ Neither A nor (C) shall be less than P in Table B.1. See note 1
15	A B (C)	$A + (C)$ Neither A nor (C) shall be less than P in Table B.1. See note 1
21	A B (C)	$A + B + (C) - r - 2d$ Neither A nor (C) shall be less than P in Table B.1

Shape code	Shape	Total length of bar (*L*) measured along centre line
22	B, A, Semi circular, C, (D), C=>2r + 2d	A + B + C + (D) - 1.5r - 3d C shall not be less than 2(r + d). Neither A nor (D) shall be less than P in Table B.1. (D) shall not be less than C/2 + 5d
23	A, (C), B	A + B + (C) – r – 2d Neither A nor (C) shall be less than P in Table B.1
24	(C), D, B, A	A + B + (C) A and (C) are at 90° to one another
25	A, B, C, D, (E)	A + B + (E) Neither A nor B shall be less than P in Table B.1. If E is the critical dimension, schedule a 99 and specify A or B as the free dimension. See note 1
26	(C), B, D, A	A + B + (C) Neither A nor (C) shall be less than P in Table B.1. See note 1
27	B, (C), A, D	A + B + (C) – 0.5r-d Neither A nor (C) shall be less than P in Table B.1. See note 1

Shape code	Shape	Total length of bar (*L*) measured along centre line
28		A + B + (C) – 0.5r-d Neither A nor (C) shall be less than P in Table B.1. See note 1
29		A + B + (C) – r – 2d Neither A nor (C) shall be less than P in Table B.1. See note 1
31		A + B + C + (D) – 1.5r – 3d Neither A nor (D) shall be less than P in Table B.1
32		A + B + C + (D) – 1.5r – 3d Neither A nor (D) shall be less than P in Table B.1
33		2A + 1.7B + 2(C) – 4d A shall not be less than 12d + 30mm. B shall not be less than 2(r + d). (C) shall not be less than P in Table B.1, nor less than B/2 + 5d. See note 3
34		A + B + C + (E) – 0.5r - d Neither A nor (E) shall be less than P in Table B.1. See note 1
35		A + B + C + (E) – 0.5r - d Neither A nor (E) shall be less than P in Table B.1. See note 1

Shape code	Shape	Total length of bar (L) measured along centre line
36		A + B + C + (D) – r - 2d Neither A nor (D) shall be less than P in Table B.1. See note 1
41		A + B + C + D + (E) - 2r - 4d Neither A nor (E) shall be less than P in Table B.1 May also be used for flag link viz:
44		A + B + C + D + (E) - 2r - 4d Neither A nor (E) shall be less than P in Table B.1
46		A + 2B + C + (E) Neither A nor (E) shall be less than P in Table B.1. See note 1
47		2A + B + 2(C) +1.5r - 3d (C) and (D) shall be equal and not more than A nor less than P in Table B.1. Where (C) and (D) are to be minimized the following formula may be used: L = 2A + B + max (21d, 240)
51		2 (A + B + (C)) – 2.5r – 5d (C) and (D) shall be equal and not more than A or B nor less than P for links in Table B.1. Where (C) and (D) are to be minimized the following formula may be used: L = 2 A + 2B + max (16d, 160)
56		A + B + C + (D)+ 2(E) – 2.5r – 5d (E) and (F) shall be equal and not more than B or C nor less than P in Table B.1. See notes 1 and 2

Shape code	Shape	Total length of bar (L) measured along centre line
63		2A + 3B + 2(C) - 3r - 6d (C) and (D) shall be equal and not more than A or B nor less than P for links in Table B.1. Where (C) and (D) are to be minimized the following formula may be used: L = 2A + 3B + max(14d, 150)
64		A + B + C + 2D + E + (F) - 3r - 6d Neither A and (F) shall be less than P in Table B.1. See note 2
67		A See BS8666 Clause 10
75		π (A-d) + B Where B is the lap
77	 C = number of turns	C π (A –d) Where B is greater than A/5 this equation no longer applied, in which case the following formula may be used: L = C $((\pi(A-d))^2 + B2)^{1/2}$
98		A + 2B + C + (D) – 2r – 4d Isometric sketch. Neither C nor (D) shall be less than P in Table B.1

Shape code	Shape	Total length of bar (*L*) measured along centre line
99	All other shapes where standard shapes cannot be used. No other shape code number, form of designation or abbreviation shall be used in scheduling. A dimensioned sketch shall be drawn over the dimension columns A to E. Every dimension shall be specified and the dimension that is to allow for permissible deviations shall be indicated in parenthesis, otherwise the fabricator is free to choose which dimension shall allow for tolerance.	To be calculated See note 2

General Notes

The values for minimum radius and end dimensions, r and A respectively, as specified in Table B.1, shall apply to all shape codes.

The dimensions in parentheses are the free dimensions. If a shape given in this table is required but a different dimension is to allow for the possible deviations, the shape shall be drawn out and given the shape code 99 and the free dimension shall be indicated in parentheses.

The length of straight between two bends shall be at least 4d, (see Figure 6 BS 8666[6]).

BS 8666[6], Figures 4, 5 and 6 should be used in the interpretation of bending dimensions.

Notes

1   The length equations for shapes 14, 15, 25, 26, 27, 28, 29, 34, 35, 36 and 46 are approximate and where the bend angle is greater than 45°, the length should be calculated more accurately allowing for the difference between the specified overall dimensions and the true length measured along the central axis of the bar. When the bending angles approach 90°, it is preferable to specify shape code 99 with a fully dimensioned sketch.

2   5 bends or more may be impractical within permitted tolerances.

3   For shapes with straight and curved lengths (e.g. shape codes 12, 13, 22, 33 and 47) the largest practical mandrel size for the production of a continuous curve is 400 mm. See also BS 8666[6] Clause 10.

4   Stock lengths are available in a limited number of lengths (e.g. 6m, 12m). Dimension A for shape code 01 should be regarded as indicative and used for the purpose of calculating total length. Actual delivery lengths should be by agreement with the supplier. Tolerances for shape code 01, stock lengths, shall be subject to the relevant product standard, e.g. BS 449:2005.

Table B1 Minimum scheduling radius, former diameter and bend allowances
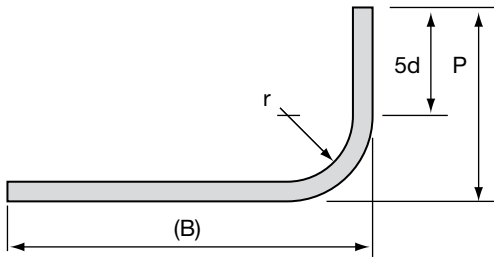
Nominal size of bar, d (mm)	Minimum radius for scheduling, r (mm)	Minimum diameter of bending former, M (mm)	Minimum end projection, P	
			General (min 5d straight), including links where bend ⩾150° (mm)	Links where bend <150° (min 10d straight) (mm)
6	12	24	110ª	110ª
8	16	32	115ª	115ª
10	20	40	120ª	130
12	24	48	125ª	160
16	32	64	130	210
20	70	140	190	290
25	87	175	240	365
32	112	224	305	465
40	140	280	380	580
50	175	350	475	725

Notes

ª   The minimum end projections for smaller bars is governed by the practicalities of bending bars.

1   Due to 'spring back' the actual radius of bend will be slightly greater than half the diameter of former.

2   BS 4449:2005 grade B500A in sizes below 8 mm does not conform to BS EN 1992-1.1:2004.

Bar areas number

Number	Sectional Area (mm²)									
	Size (mm)									
	6	8	10	12	16	20	25	32	40	50
1	28	50	79	113	201	314	491	804	1257	1963
2	57	101	157	226	402	628	982	1608	2513	3927
3	85	151	236	339	603	942	1473	2413	3770	5890
4	113	201	314	452	804	1257	1963	3217	5027	7854
5	141	251	393	565	1005	1571	2454	4021	6283	9817
6	170	302	471	679	1206	1885	2945	4825	7540	11781
7	198	352	550	792	1407	2199	3436	5630	8796	13744
8	226	402	628	905	1608	2513	3927	6434	10053	15708
9	254	452	707	1018	1810	2827	4418	7238	11310	17671
10	283	503	785	1131	2011	3142	4909	8042	12566	19635
11	311	553	864	1244	2212	3456	5400	8847	13823	21598
12	339	603	942	1357	2413	3770	5890	9651	15080	23562
Perimeter (mm)	18.85	25.13	31.42	37.70	50.27	62.83	78.54	100.53	125.66	157.08
Weight (kg/m)	0.222	0.395	0.616	0.888	1.579	2.466	3.854	6.313	9.864	15.413
Number	6	8	10	12	16	20	25	32	40	50

Bar areas pitch

Pitch (mm)	Sectional Area (mm²)									
	Size (mm)									
	6	8	10	12	16	20	25	32	40	50
50	565	1005	1571	2262	4021	-	-	-	-	-
75	377	670	1047	1508	2681	4189	6545	-	-	-
100	283	503	785	1131	2011	3142	4909	8042	-	-
125	226	402	628	905	1608	2513	3927	6434	10053	-
150	188	335	524	754	1340	2094	3272	5362	8378	13090
175	162	287	449	646	1149	1795	2805	4596	7181	11220
200	141	251	393	565	1005	1571	2454	4021	6283	9817
250	113	201	314	452	804	1257	1963	3217	5027	7854
300	94	168	262	377	670	1047	1636	2681	4189	6545
	6	8	10	12	16	20	25	32	40	50

Bar weights pitch

Pitch (mm)	Weight (kg/m²) Size (mm)									
	6	8	10	12	16	20	25	32	40	50
50	4.44	7.89	12.33	17.76	31.57	49.32	-	-	-	-
75	2.96	5.26	8.22	11.84	21.04	32.88	51.38	84.18	-	-
100	2.22	3.95	6.17	8.88	15.78	24.66	38.53	63.13	-	-
125	1.78	3.16	4.93	7.10	12.63	19.73	30.83	50.51	78.92	-
150	1.48	2.63	4.11	5.92	10.52	16.44	25.69	42.09	65.76	102.76
175	1.27	2.25	3.52	5.07	9.02	14.09	22.02	36.08	56.37	88.08
200	1.11	1.97	3.08	4.44	7.89	12.33	19.27	31.57	49.32	77.07
250	0.89	1.58	2.47	3.55	6.31	9.86	15.41	25.25	39.46	61.65
300	0.74	1.32	2.06	2.96	5.26	8.22	12.84	21.04	32.88	51.38
	6	8	10	12	16	20	25	32	40	50

Fabric types

Preferred types of steel fabric are defined in BS 4483 : 1985

British Standard Fabric Reference		Longitudinal Wires			Cross Wires			Nominal Mass (kg/m²)
		Nominal wire size (mm)	Pitch (mm)	Area (mm²)	Nominal wire size (mm)	Pitch (mm)	Area (mm²)	
Square Mesh	A 393	10	200	393	10	200	393	6.16
	A 252	8	200	252	8	200	252	3.95
	A 193	7	200	193	7	200	193	3.02
	A 142	6	200	142	6	200	142	2.22
	A 98	5	200	98	5	200	98	1.54
Structural Mesh	B 1131	12	100	1131	8	200	252	10.9
	B 785	10	100	785	8	200	252	8.14
	B 503	8	100	503	8	200	252	5.93
	B 385	7	100	385	7	200	193	4.53
	B 283	6	100	283	7	200	193	3.73
	B 196	5	100	196	7	200	193	3.05
Long Mesh	C 785	10	100	785	6	400	70.8	6.72
	C 636	9	100	636	6	400	70.8	5.55
	C 503	8	100	503	5	400	49	4.34
	C 385	7	100	385	5	400	49	3.41
	C 283	6	100	283	5	400	49	2.61
Wrapping Mesh	D 98	5	200	98	5	200	98	1.54
	D 49	2.5	100	49	2.5	100	49	0.77
Stock Sheet Size	Length 4.8m Width 2.4m Sheet Area 11.52m²							

Notes

Wire of Grade 500 complying with BS 4449 or BS 4482 shall be used except that wire of grade 250 shall be permitted for wrapping fabric.

5mm size is available in hard drawn wire only

The 6, 7, 8, 10 and 12 mm sizes are available in either hard drawn wire or bar form.

The 7 mm size is not a preferred size of cold worked bar.

Effective anchorage length

L-bars
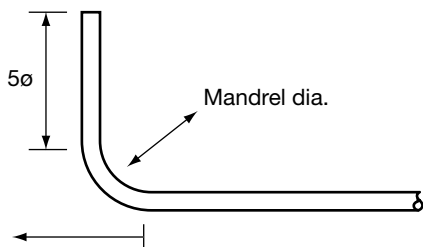
Effective anchorage length = (π (mandrel dia. + ø)/4 + 5ø)/0.7

Mandrel size/Bar dia	Effective anchorage length from start of bend (mm)							
	Bar Sizes							
	8	10	12	16	20	25	32	40
4	102	128	153	204	255	319	408	510
5	78	139	166	222	277	347	444	555
6	84	150	180	240	300	375	480	600
7	90	161	193	258	322	403	516	645
8	97	172	207	276	345	431	552	690
9	103	184	220	294	367	459	588	735
10	109	195	234	312	390	487	624	779
11	115	206	247	330	412	515	659	824
12	122	217	261	348	435	543	695	869
13	128	229	274	366	457	571	731	914
14	134	240	288	384	479	599	767	959

U-bars
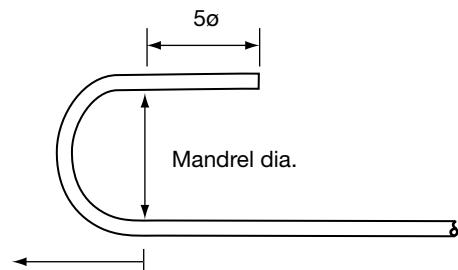
Effective anchorage length = (π (mandrel dia. + ø)/2 + 5ø)/0.7

Mandrel size/Bar dia	Effective anchorage length from start of bend (mm)							
	Bar Sizes							
	8	10	12	16	20	25	32	40
4	147	184	220	294	367	459	588	735
5	165	206	247	330	412	515	659	824
6	183	229	274	366	457	571	731	914
7	201	251	301	402	502	627	803	1004
8	219	273	328	437	547	683	875	1094
9	237	296	355	473	592	740	947	1183
10	255	318	382	509	637	796	1018	1273
11	273	341	409	545	681	852	1090	1363
12	291	363	436	581	726	908	1162	1453
13	308	386	463	617	771	964	1234	1542
14	326	408	490	653	816	1020	1306	1632

Minimum overall depth of various U-bars
Hook
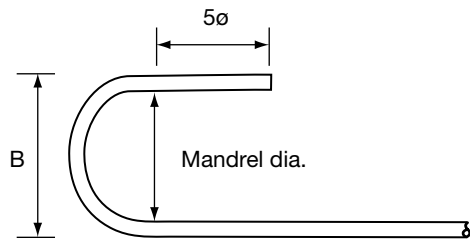
f_y = 500 MPa
Minimum mandrel diameter:
for ø ≤16mm   Mandrel dia. = 4ø
for ø ≤16mm   Mandrel dia. = 7ø

Bar Size	6	8	10	12	16	20	25	32	40
B	40	50	60	75	100	180	225	290	360

Trombone
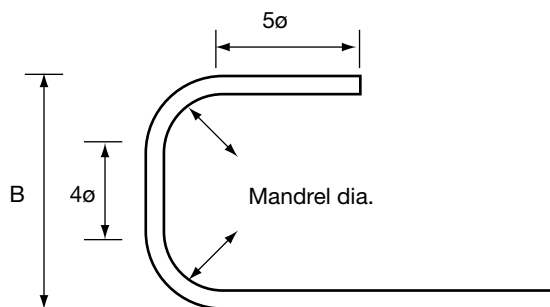
f_y = 500 MPa
Minimum mandrel diameter:
for ø ≤16mm   Mandrel dia. = 4ø
for ø ≤16mm   Mandrel dia. = 7ø

Bar Size	6	8	10	12	16	20	25	32	40
B	60	80	100	120	160	260	325	420	520

Large diameter bends
Concrete strength class (f_{ck}/f_{cu}) 20/25
Minimum mandrel size, $ø_{m,min}$ (mm)

$ø_{m,min} = F_{bt}\,((1/a_b) + 1/(2ø))/f_{cd}$ where F_{bt} is the tensile force from ultimate loads (N)

            $ø$ is the size of bar (mm)

            a_b is half the pitch of bars or nominal cover + $ø/2$ (mm)

            f_{cd} is the design concrete strength = $\alpha_{cc} f_{ck}/\gamma_c$ (MPa)

Internal diameter of bend (mm)

a_b (mm)	Actual Ult. stress in bar (MPa)	Bar diameter ø (mm)						
		10	12	16	20	25	32	40
25	100	60	80	125	180	255		
	150	90	120	185	270	385		
	200	120	160	250	360	515		
	250	155	200	315	450	645		
	300	185	240	375	540	775		
	350	215	285	440	630	905		
	400	245	325	505	720	1035		
	450	280	365	565	810	1165		
50	100	45	60	90	120	170	250	360
	150	70	90	135	185	255	375	540
	200	95	120	180	245	345	505	720
	250	120	150	225	310	430	630	900
	300	145	180	270	370	515	755	1080
	350	165	215	315	435	605	880	1260
	400	190	245	360	495	690	1010	1440
	450	215	275	405	560	775	1135	1620
75	100	40	50	75	105	140	205	285
	150	65	80	115	155	215	305	425
	200	85	105	155	210	285	410	570
	250	105	135	195	265	360	510	715
	300	130	160	235	315	430	615	855
	350	150	190	275	370	505	715	1000
	400	175	215	315	425	575	820	1145
	450	195	245	355	475	645	920	1285
100	100	40	50	70	95	125	180	245
	150	60	75	105	145	190	270	370
	200	80	100	145	190	255	360	495
	250	100	125	180	240	320	450	620
	300	120	150	215	290	385	545	745
	350	145	180	255	335	450	635	870
	400	165	205	290	385	515	725	995
	450	185	230	325	435	580	815	1120
150 and over	100	35	45	65	85	115	155	210
	150	55	70	100	130	170	235	315
	200	75	95	130	175	230	315	425
	250	95	120	165	215	285	395	530
	300	115	140	200	260	345	470	635
	350	135	165	235	305	400	550	740
	400	155	190	265	350	460	630	850
	450	175	215	300	395	515	710	955

Notes

1   Maximum design stress = Characteristic yield stress / 1.15 = 435 MPa

2   Minimum mandrel size may govern: for bar size: < 20   4ø mandrel size

                                             ⩾ 20   7ø mandrel size

Large diameter bends

Concrete strength class (f_{ck}/f_{cu}) 25/30

Minimum mandrel size, $ø_{m,min}$ (mm)

$ø_{m,min} = F_{bt} ((1/a_b) + 1/(2ø)/f_{cd}$ where F_{bt} is the tensile force from ultimate loads (N)

$ø$ is the size of bar (mm)

a_b is half the pitch of bars or nominal cover + $ø/2$ (mm)

f_{cd} is the design concrete strength = $\alpha_{cc}f_{ck}/\gamma_c$ (MPa)

Internal diameter of bend (mm)

a_b (mm)	Actual Ult. stress in bar (MPa)	Bar diameter $ø$ (mm)						
		10	12	16	20	25	32	40
25	100	45	65	100	140	205		
	150	70	95	150	215	310		
	200	95	130	200	285	415		
	250	120	160	250	360	515		
	300	145	195	300	430	620		
	350	170	225	350	500	725		
	400	195	260	400	575	830		
	450	220	290	455	645	935		
50	100	35	45	70	95	135	200	285
	150	55	70	105	145	205	300	430
	200	75	95	145	195	275	400	575
	250	95	120	180	245	345	505	720
	300	115	145	215	295	415	605	860
	350	135	170	250	345	485	705	1005
	400	155	195	290	395	550	805	1150
	450	170	220	325	445	620	910	1295
75	100	35	40	60	85	115	160	225
	150	50	65	90	125	170	245	340
	200	70	85	125	170	230	325	455
	250	85	105	155	210	285	410	570
	300	105	130	185	255	345	490	685
	350	120	150	220	295	400	575	800
	400	140	175	250	340	460	655	915
	450	155	195	280	380	515	735	1030
100	100	30	40	55	75	100	145	195
	150	45	60	85	115	155	215	295
	200	65	80	115	155	205	290	395
	250	80	100	145	190	255	360	495
	300	95	120	175	230	310	435	595
	350	115	140	200	270	360	505	695
	400	130	160	230	310	415	580	795
	450	145	185	260	345	465	650	895
150 and over	100	30	35	50	70	90	125	170
	150	45	55	80	105	135	185	255
	200	60	75	105	140	180	250	340
	250	75	95	130	175	230	315	425
	300	90	115	160	210	275	375	510
	350	105	135	185	245	320	440	595
	400	125	150	215	280	365	505	680
	450	140	170	240	315	415	565	765

Notes

1   Maximum design stress = Characteristic yield stress / 1.15 = 435 MPa

2   Minimum mandrel size may govern: for bar size: < 20   4ø mandrel size

$\geqslant$ 20   7ø mandrel size

Large diameter bends

Concrete strength class (f_{ck}/f_{cu}) 28/35

Minimum mandrel size, $ø_{m,min}$ (mm)

$ø_{m,min} = F_{bt} ((1/a_b) + 1/(2ø)/f_{cd}$ where F_{bt} is the tensile force from ultimate loads (N)

$ø$ is the size of bar (mm)

a_b is half the pitch of bars or nominal cover + ø/2 (mm)

f_{cd} is the design concrete strength = $\alpha_{cc} f_{ck}/\gamma_c$ (MPa)

Internal diameter of bend (mm)

a_b (mm)	Actual Ult. stress in bar (MPa)	Bar diameter ø (mm)						
		10	12	16	20	25	32	40
25	100	40	55	90	125	185		
	150	65	85	135	190	275		
	200	85	115	180	255	370		
	250	110	145	225	320	460		
	300	130	170	270	385	555		
	350	155	200	315	450	645		
	400	175	230	360	510	740		
	450	200	260	405	575	835		
50	100	30	40	60	85	120	180	255
	150	50	65	95	130	185	270	385
	200	65	85	125	175	245	360	510
	250	85	105	160	220	305	450	640
	300	100	130	190	265	370	540	770
	350	120	150	225	310	430	630	900
	400	135	175	255	355	490	720	1025
	450	155	195	290	400	555	810	1155
75	100	30	35	55	75	100	145	200
	150	45	55	80	110	150	220	305
	200	60	75	110	150	205	290	405
	250	75	95	140	185	255	365	510
	300	90	115	165	225	305	440	610
	350	105	135	195	265	360	510	715
	400	125	155	225	300	410	585	815
	450	140	175	250	340	460	660	920
100	100	25	35	50	65	90	125	175
	150	40	55	75	100	135	190	265
	200	55	70	100	135	185	255	355
	250	70	90	130	170	230	320	445
	300	85	110	155	205	275	385	530
	350	100	125	180	240	320	450	620
	400	115	145	205	275	370	515	710
	450	130	165	235	310	415	580	800
150 and over	100	25	30	45	60	80	110	150
	150	40	50	70	90	120	165	225
	200	55	65	95	125	160	225	300
	250	70	85	120	155	205	280	375
	300	80	100	140	185	245	335	455
	350	95	120	165	215	285	395	530
	400	110	135	190	250	325	450	605
	450	125	155	215	280	370	505	680

Notes

1   Maximum design stress = Characteristic yield stress / 1.15 = 435 MPa

2   Minimum mandrel size may govern: for bar size: < 20   4ø mandrel size

$\geqslant$ 20   7ø mandrel size

Large diameter bends
Concrete strength class (f_{ck}/f_{cu}) 30/37

Minimum mandrel size, $ø_{m,min}$ (mm)

$ø_{m,min} = F_{bt} ((1/a_b) + 1/(2ø)/f_{cd}$ where

F_{bt}	is the tensile force from ultimate loads (N)
$ø$	is the size of bar (mm)
a_b	is half the pitch of bars or nominal cover + ø/2 (mm)
f_{cd}	is the design concrete strength = $\alpha_{cc} f_{ck}/\gamma_c$ (MPa)

Internal diameter of bend (mm)

a_b (mm)	Actual Ult. stress in bar (MPa)	Bar diameter ø (mm)						
		10	12	16	20	25	32	40
25	100	40	50	80	120	170		
	150	60	80	125	180	255		
	200	80	105	165	240	345		
	250	100	135	210	300	430		
	300	120	160	250	360	515		
	350	145	190	290	420	605		
	400	165	215	335	480	690		
	450	185	240	375	540	775		
50	100	30	40	60	80	115	165	240
	150	45	60	90	120	170	250	360
	200	60	80	120	165	230	335	480
	250	80	100	150	205	285	420	600
	300	95	120	180	245	345	505	720
	350	110	140	210	290	400	585	840
	400	125	160	240	330	460	670	960
	450	145	180	270	370	515	755	1080
75	100	25	35	50	70	95	135	190
	150	40	50	75	105	140	205	285
	200	55	70	105	140	190	270	380
	250	70	90	130	175	240	340	475
	300	85	105	155	210	285	410	570
	350	100	125	180	245	335	475	665
	400	115	145	210	280	380	545	760
	450	130	160	235	315	430	614	855
100	100	25	30	45	60	85	120	165
	150	40	50	70	95	125	180	245
	200	55	65	95	125	170	240	330
	250	65	85	120	160	215	300	415
	300	80	100	145	190	255	360	495
	350	95	120	170	225	300	420	580
	400	110	135	195	255	345	480	665
	450	120	150	215	290	385	545	745
150 and over	100	25	30	40	55	75	105	140
	150	35	45	65	85	115	155	210
	200	50	60	85	115	150	210	280
	250	65	80	110	145	190	260	350
	300	75	95	130	175	230	315	425
	350	90	110	155	200	265	365	495
	400	100	125	175	230	305	420	565
	450	115	140	200	260	345	470	635

Notes

1   Maximum design stress = Characteristic yield stress / 1.15 = 435 MPa
2   Minimum mandrel size may govern: for bar size: < 20   4ø mandrel size
                                                      ≥ 20   7ø mandrel size

Large diameter bends
Concrete strength class (f_{ck}/f_{cu}) 32/40

Minimum mandrel size, $\emptyset_{m,min}$ (mm)

$\emptyset_{m,min} = F_{bt}((1/a_b) + 1/(2\emptyset)/f_{cd}$ where

F_{bt}	is the tensile force from ultimate loads (N)
$\emptyset$	is the size of bar (mm)
a_b	is half the pitch of bars or nominal cover + $\emptyset/2$ (mm)
f_{cd}	is the design concrete strength = $\alpha_{cc}f_{ck}/\gamma_c$ (MPa)

Internal diameter of bend (mm)

a_b (mm)	Actual Ult. stress in bar (MPa)	Bar diameter ø (mm)						
		10	12	16	20	25	32	40
25	100	35	50	75	110	160		
	150	55	75	115	165	240		
	200	75	100	155	225	320		
	250	95	125	195	280	405		
	300	115	150	235	335	485		
	350	135	175	275	390	565		
	400	155	200	315	450	645		
	450	175	225	355	505	730		
50	100	30	35	55	75	105	155	225
	150	45	55	85	115	160	235	335
	200	60	75	110	155	215	315	450
	250	75	95	140	190	270	395	560
	300	90	115	170	230	320	470	675
	350	105	130	195	270	375	550	785
	400	120	150	225	310	430	630	900
	450	135	170	255	350	485	710	1010
75	100	25	30	45	65	90	125	175
	150	40	50	70	95	135	190	265
	200	50	65	95	130	180	255	355
	250	65	85	120	165	225	320	445
	300	80	100	145	195	270	385	535
	350	95	120	170	230	315	445	625
	400	105	135	195	265	360	510	715
	450	120	150	220	295	405	575	805
100	100	25	30	45	60	80	110	155
	150	35	45	65	90	120	170	230
	200	50	60	90	120	160	225	310
	250	60	80	110	150	200	280	385
	300	75	95	135	180	240	340	465
	350	90	110	1660	210	280	395	545
	400	100	125	180	240	320	450	620
	450	115	145	205	270	365	510	700
150 and over	100	20	30	40	50	70	95	130
	150	35	45	60	80	105	145	195
	200	45	60	80	105	140	195	265
	250	60	75	105	135	180	245	330
	300	70	90	125	160	215	295	395
	350	85	105	145	190	250	345	460
	400	95	120	165	215	285	395	530
	450	110	135	185	245	320	440	595

Notes

1   Maximum design stress = Characteristic yield stress / 1.15 = 435 MPa

2   Minimum mandrel size may govern: for bar size: < 20   4ø mandrel size
                                                      $\geqslant$ 20   7ø mandrel size

Large diameter bends

Concrete strength class (f_{ck}/f_{cu}) 35/45

Minimum mandrel size, $ø_{m,min}$ (mm)

$ø_{m,min} = F_{bt}((1/a_b) + 1/(2ø)/f_{cd}$ where

F_{bt}	is the tensile force from ultimate loads (N)
$ø$	is the size of bar (mm)
a_b	is half the pitch of bars or nominal cover + $ø/2$ (mm)
f_{cd}	is the design concrete strength = $\alpha_{cc} f_{ck}/\gamma_c$ (MPa)

Internal diameter of bend (mm)

a_b (mm)	Actual Ult. stress in bar (MPa)	Bar diameter $ø$ (mm)						
		10	12	16	20	25	32	40
25	100	35	45	70	100	145		
	150	50	65	105	150	220		
	200	70	90	140	205	295		
	250	85	115	180	255	370		
	300	105	135	215	305	445		
	350	120	160	250	360	515		
	400	140	185	285	410	590		
	450	160	205	325	460	665		
50	100	25	35	50	70	95	140	205
	150	40	50	75	105	145	215	305
	200	55	70	100	140	195	285	410
	250	65	85	125	175	245	360	510
	300	80	105	155	210	295	430	615
	350	95	120	180	245	345	505	720
	400	110	140	205	285	395	575	820
	450	120	155	230	320	445	650	925
75	100	25	30	45	60	80	115	160
	150	35	45	65	90	120	175	245
	200	50	60	90	120	160	230	325
	250	60	75	110	150	205	290	405
	300	75	90	135	180	245	350	490
	350	85	105	155	210	285	410	570
	400	100	125	180	240	325	465	650
	450	110	140	200	270	370	525	735
100	100	20	25	40	55	70	100	140
	150	35	40	60	80	110	155	210
	200	45	55	80	110	145	205	285
	250	55	70	100	135	185	255	355
	300	70	85	125	165	220	310	425
	350	80	100	145	190	255	360	495
	400	95	115	165	220	295	415	570
	450	105	130	185	245	330	465	640
150 and over	100	20	25	35	50	65	90	120
	150	30	40	55	75	95	135	180
	200	40	55	75	100	130	180	240
	250	55	65	95	125	160	225	300
	300	65	80	115	150	195	270	360
	350	75	95	130	175	230	315	425
	400	85	110	150	200	260	360	485
	450	100	120	170	225	295	405	545

Notes

1 Maximum design stress = Characteristic yield stress / 1.15 = 435 MPa

2 Minimum mandrel size may govern: for bar size: < 20   4ø mandrel size
                                                      ≥ 20   7ø mandrel size