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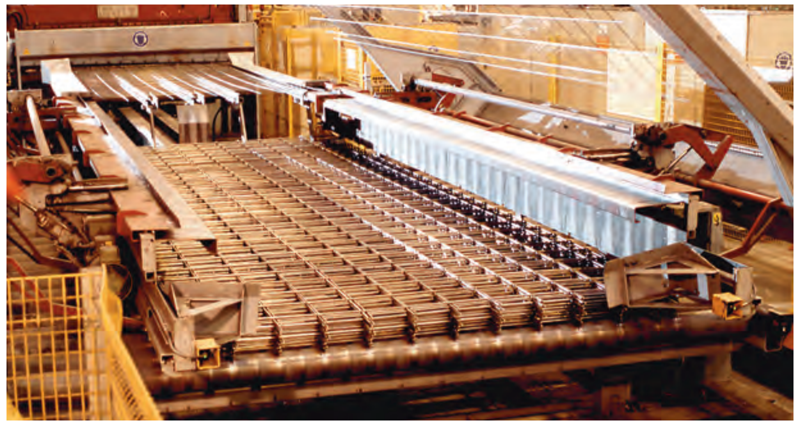

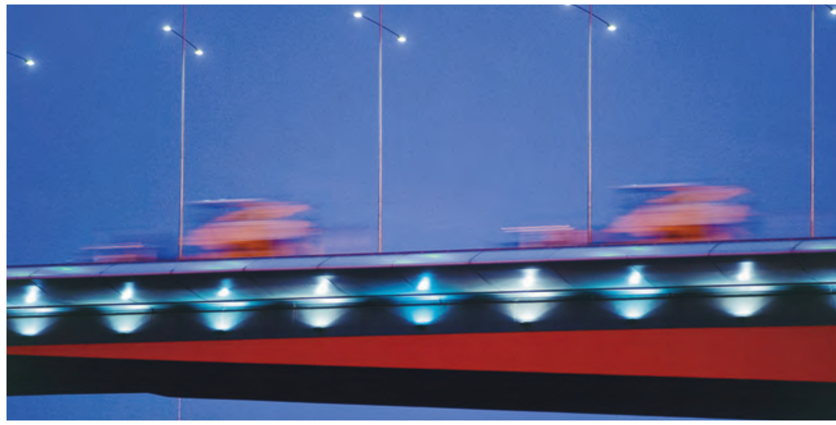

Z6

Concrete Institute of Australia

RECOMMENDED PRACTICE

Reinforcement Detailing Handbook

Z6

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RECOMMENDED PRACTICE

Reinforcement Detailing Handbook

For Reinforced and Prestressed Concrete

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RECOMMENDED PRACTICE

Reinforcement Detailing Handbook

For Reinforced and Prestressed Concrete

Based upon the Australian Concrete Structures Standard – AS 3600:2009

CONCRETE INSTITUTE of AUSTRALIA

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Revised edition produced by Engineers Media for
Concrete Institute of Australia ACN 000 715 453
Z6 First published 1975
Updated and republished 1988
Rewritten and republished 2007
Updated and republished 2012
ISBN 0 909375 69 0

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Preface

The basic requirements of good reinforced concrete detailing are clarity and conciseness. Unfortunately, there has been a steady deterioration in the quality and quantity of drawings supplied for reinforced concrete over the last twenty years. The net result of poor quality drawings is increased costs in the material supply and construction sectors and unacceptable levels of dispute.

Detailing of reinforcement is the interface between the actual design of the concrete structure and what is to be constructed. There is no point in having the most sophisticated analysis and design if it cannot be constructed in the field. Designers must be aware of practical limitations of construction. Detailing is also important for durability, as poor placement of reinforcement leads to insufficient cover and long term problems. Detailing of reinforcement is not taught to designers and yet it is fundamental to the proper design of reinforced concrete.

Unlike some countries (and in particular the United Kingdom) reinforcement is scheduled by the reinforcing suppliers based on the concrete drawings provided. If the drawings are poor, the actual reinforcing provided on site may not match the designer's expectations.

The aim of this manual is to guide designers, draftsmen and other professionals toward a uniform method of communicating the design intention to the construction team so that confusion cannot arise from the misinterpretation of the drawings.

This is the fourth edition of the "Reinforced Concrete Detailing Manual"; first published in 1975; and rewritten in 1988 to match the publication of AS 3600. Substantial sections of this document remain unchanged from the 1988 edition prepared by Mr. Brian Ferguson and his committee. However, the review team has addressed the following issues:

- Progressive revisions of AS 3600 and incorporation of the provisions of AS 3600:2009.
- Introduction of 500 MPa reinforcing steel. The standardisation of steel strength for both mesh and bar and the increased focus on ductility has affected how and where reinforcing steel is used. The increase in strength has also necessitated the revision of bond and anchorage lengths.
- Detailing for seismic response. The 1998 edition was published prior to the Newcastle Earthquake. This edition has taken the opportunity to discuss detailing issues, which affect the safety and ductility of concrete structure under extreme seismic events.
- Update diagrams and drawings to comply with new edition of AS 1100.501.

The Concrete Institute of Australia is pleased to acknowledge the valuable contribution of the following people and organisations:

- Brian Ferguson. As noted above a large proportion of this edition is unaltered from the excellent work of the 1988 edition.
- Smorgon Steel. Humes ARC held the copyright of the previous edition. In order to facilitate this revision, Smorgon Steel has generously assigned copyright to the Concrete Institute of Australia.
- Queensland Branch of the Concrete Institute of Australia. The Branch has provided funds to expedite the typing and publication of this document.
- Steel Reinforcement Institute of Australia. The recommendations on seismic detailing have been drawn from the SRIA's *Reinforced Concrete Digest*, RCD 17.
- David Beal. The project management and finalisation of this substantial rewrite of the original edition would not have been possible without his untiring efforts on behalf of the Concrete Institute of Australia.

Contents

Introduction

Until the mid-1960's, the strength of the structure and its elements were always considered to be the prime design parameter. With the introduction of higher-strength concretes and reinforcing steels, shallower members were adopted. Combined with the effects of internal air-conditioning, this led to situations inside buildings where deflection and cracking became of concern to owners and designers alike. Over this same period, there was a large increase in atmospheric and industrial pollutants which affected the external concrete structures and cladding.

All concrete elements which are reinforced are three dimensional, and designers and detailers must appreciate this concept. Reinforcement on-site is much thicker and heavier than lines on a drawing. There must be sufficient room between the reinforcing to place the concrete.

The Handbook discusses detailing insitu reinforced concrete using reinforcing mesh and bars. Other manuals describe the particular requirements of prestressed concrete and precast concrete. This Handbook deals with only the untensioned conventional reinforcement in prestressed concrete members. Precast concrete detailing can be found in the Precast Concrete Handbook (Z48) although the detailing in this publication most likely is very similar.

The correct position of reinforcement and the maintenance of cover are the major factors controlling the principles of this Handbook.

The Handbook is based on the *Concrete Structures* Standard, AS 3600:2009. There are also references to the differences in the *Bridge Design* Standard AS 5100.

The Handbook follows these guidelines:

- The contents are in no way to be considered as replacing the judgement of a person professionally-qualified in the area of design and/or construction of concrete structures;
- It is not intended for use as a legal document forming part of a building contract;
- The information is provided as a basis upon which individual designers and detailers can obtain ideas to simplify detailing and to reduce design and construction costs;
- It is not intended to exclude alternatives where particular detailing situations occur, nor will it cover the full range of detailing situations;
- As an extension of the scope of AS 3600, the Handbook in many instances sets out more stringent requirements than that standard. This is because the lack of attention to detailing reinforcement is a major cause of "failure" of members used in zones where the durability or serviceability of the structure has been at the greatest risk;
- Examples of "*Standard Details*" for various types of members are presented for adoption as they stand or for adoption within individual offices.

1

Scope and General Principles

1.1 SCOPE

This Handbook illustrates detailing of reinforcement in insitu reinforced concrete and partially-prestressed concrete structures and members. Precast and prestressed concrete detailing is not specifically covered (refer Introduction) Information for design purposes is also provided.

For the proper application of this Handbook, users must have a copy of the Australian Standard AS 3600:2009 and the accompanying Commentary, when it is published.

Also essential is a copy of AS 1100.501:2002, *Technical drawing – Structural engineering drawing*. This sets out methods to be used in structural drawing. Each drawing office should also have the other appropriate parts of AS 1100. This Handbook is prepared under the recommendation of Clause 1.2 of AS 1100.501.

For bridges, the AS 5100.5:2004 *Bridge design – Concrete*, should be followed.

1.2 GENERAL PRINCIPLES

The design of a structure or member to which AS 3600 applies is the responsibility of an engineer, although AS 3600 is not permitted to state this. The Building Code of Australia sets out these responsibilities.

Therefore, the responsibility for the preparation of the drawings, which form part of the documents setting out the work to be executed, lies with an engineer also. These responsibilities should include the checking and co-ordination of the drawings before construction.

The definitions given in AS 3600 also apply here, in particular:

Drawings - the drawings forming part of the documents setting out the work to be executed.

Specification - the specification forming part of the documents setting out the work to be executed.

Conditions of Contract - they also are generally part of the contract documents for a project.

Not mentioned in the standard are:

Detailer - the person, to whom this Handbook is primarily directed, who prepares all details of the design or construction as appropriate to the job. In this broad context “the detailer” could be a draftsman, a design draftsman, a design or construction engineer, a reinforcement scheduler or a steel fixer. The details so prepared may or may not form part of the contract documents but preparation of a drawing or sketch is implied.

Scheduler - the person who extracts from the structural drawings all necessary information about the reinforcement to enable it to be manufactured, labelled, delivered and located in its correct position in the formwork.

1.2.1 General

Drawings provide the means for the engineer to communicate the design requirements through the detailer to the contractor’s site operators in a clear and concise manner. Adequate drawings will eliminate the need for contractors to ask the designer for additional information.

1.2.2 **Quality of Drawings and Prints**

Building site conditions are very different from those in an air-conditioned drawing office, and drawing preparation must allow for this. Details which appear to be easily read in an office can be obscured on site by dirt, oil or clay. Drawings can get wet or be folded and unfolded many times so that they become illegible. Therefore for site use, drawings must be to a reasonable scale with the line thicknesses recommended in this Handbook. Prints of drawings should be on good quality paper. Also, the trend of using A3 copies of larger drawings on site, means the details must be clear and concise.

1.2.3 **Information on Drawings**

AS 1100.501 gives general guidelines.

AS 3600 clause 1.4 is quite specific on the design details to be given on drawings and, because they are so important, they are quoted here with additional comments. There are minor differences in the AS 5100.5 clauses 1.6.1 and 1.6.2. (Author's comments are given in parentheses).

AS3600 CLAUSE 1.4 DOCUMENTATION

The drawings or specification for concrete structures and members shall include, as appropriate, the following:

(a) Reference number and date of issue of applicable design Standards.
(Material properties may need to be checked sometime in the distant future, say for renovations or demolition).

(b) Imposed actions (live loads) *used in design.*

(c) The appropriate earthquake design category determined from AS1170.4.

(d) Any constraint on construction assumed in the design.
(There is not much point in preparing an innovative design if its special features are not clear to the tenderers. In other situations, the construction techniques to be used by the contractor will not be known to the design engineer at the planning stage. The earlier the construction team can be brought together, the better it will be for all parties).

(e) Exposure classification for durability.

(f) Fire-resistance level (FRL), if applicable.

(g) Class and, where appropriate, grade designation of concrete.

(h) Any required properties of the concrete.
(See Specification and Supply of Concrete AS1379 Clauses 1.5.3 and 1.5.4).
AS 5100.5 Clause 1.6.2h. The minimum strength the concrete has to obtain before the application of prestressing forces.
(This requirement should be given in all prestressed concrete jobs).

(i) The curing procedure.

(j) Grade, Ductility Class and type of reinforcement and grade and type of tendons.

(k) The size, quantity and location of all reinforcement, tendons and structural fixings and the cover to each.
(This Handbook is written to explain how to specify all these items including tolerances, techniques for proper chairing for strength and durability; supervision of construction, and many other items).

(l) The location, and details of any splices, mechanical connections and welding of any reinforcement or tendon.

(m) The maximum jacking force to be applied in each tendon, and the order in which tendons are to be stressed.

(n) The shape and size of each member.
(Because these drawings will be the basis of the formwork drawings, the concrete outline must be clearly defined and dimensioned. The author of this Handbook questions the omission of valuable information from structural drawings of buildings by leaving this work to the architect. It is the designer's responsibility to control strength and serviceability of the structure and omission of critical dimensions of structural elements can no longer be justified as a minimum structural depth and width must be shown even if the plan dimensions for the gridlines are shown by the architect).

(o) The finish and method of control for unformed surfaces.
(Reference should be made to AS 3610. There are also many excellent publications on these topics issued by Cement Concrete & Aggregates Australia).

(p) Class of formwork in accordance with AS 3610 for the surface finish specified.
(Detailing of formwork is beyond the scope of this Handbook).

(q) *The minimum period of time after placing the concrete and before stripping of forms and removal of shores.*

(r) *The location and details of planned construction and movement joints, and the method to be used for their protection.*
(This has considerable relevance for designers. It requires them to specify every joint in both concrete and steel, and to state how laps are to be made, their length, and so on. Unfortunately, many designs do not show the construction joints often resulting in argument and cost on these matters).

1.2.4 Information in the Specification

In most large contracts, the materials to be used will be fully described in a separate Specification and subsequent reference in the drawings to concrete or other materials will be in abbreviated form.

From a contractual point of view, information given in both drawings and Specification must be consistent and not in conflict.

However, the Specification is not always made available to men in the working areas or to every subcontractor. Information which is critical for day-to-day construction should not be confined solely to the Specification.

1.2.5 General Notes

Requirements common to many parts of the structure can be stated in a set of *General Notes*, often printed as the first sheet of a set of drawings. Examples of General Notes are given in **Appendix B** of this Handbook.

Notes are instructions to the contractor and should therefore always be written in the imperative.

1.2.6 "Standard Details"

The term "standard" means a standard method of detailing produced by a particular design office, not an Australian Standard detail.

In some cases, there may be advantages in presenting "standard details" in a set of drawings. Where they bear little relevance to the actual situation, they should not be used because confusion and loss of time will result.

Possible uses for standard details are the layout of main column bars and their associated ties in columns having a common shape, the predominant grid of bars in flat slab floors, staircase details and footings.

1.3 CERTIFICATION OF REINFORCING STEEL

In the last few years, reinforcing steel in Australia has been sourced from around the world, not just from local mills and processors. Designers should satisfy themselves that the reinforcing steel used in their projects complies with AS/NZS 4671 and is processed to the requirements of AS 3600 or AS 5100 as appropriate. This includes the requirements of ensuring long-term quality statistics.

Third party product certification is a cost effective means of demonstrating compliance. The Australian Certification Authority for Reinforcing Steels, ACRS, has been established in Australia to provide this service. The certification program offered by ACRS covers steel mills, reinforcement processors and mesh manufacturers. ACRS-certified steel can be identified by the ACRS mark attached to all supporting documentation for the steel.

Figure 1.1 *The ACRS Mark*

Specifiers should ensure that both the manufacturer and processor of reinforcing steel are ACRS certified. Research conducted by ACRS has shown that the mechanical properties of steel can be significantly altered through uncontrolled processing. More details of ACRS certification and a current list of Certificate holders and products can be obtained from *www.acrs.net.au*.

Appropriate specifications are provided below:

SUGGESTED ACRS SPECIFICATION

Steel reinforcement for concrete shall comply with AS/NZS 4671. It shall be cut and bent in accordance with AS 3600. Acceptable manufacturers and processors of steel reinforcement must hold a valid certificate of approval, issued by the Australian Certification Authority for Reinforcing Steel (ACRS) or to an equivalent certification system as may be approved in writing by the specifier. Evidence of compliance with this clause must be obtained when contract bids are received.

SUGGESTED WORDING FOR STEEL NOT COVERED BY LONG-TERM QUALITY LEVEL

Should the Contractor wish to use reinforcing steel that is not covered by long-term quality levels of AS/NZS 4671, approval must be obtained in writing prior to such use. In seeking such approval, the Contractor shall nominate the members in which each individual batch of reinforcing steel is to be used and shall also state the country, mill of origin and the specification to which the reinforcing steel for that member is produced, and clearly demonstrate how it is equivalent to that specified by AS/NZS 4671. Certificates from a NATA laboratory of chemical composition and physical properties of all reinforcing steel will be required. All testing will be in compliance with Clause B7 of AS/NZS 4671-2001, including frequency of sampling and testing. Reinforcing steel not covered by the long-term quality level of AS/NZS 4671 shall not be ordered or placed before written approval has been obtained.

2

Reinforcement Detailing

2.1 TECHNICAL DEFINITIONS

These definitions are from AS 3600 Clause 1.6.3 with extra comment to show the intentional differences between various terms.

Reinforcement, reinforcing steel. Steel bar, or mesh but not prestressing tendons.

In AS/NZS 4671, reinforcing steel is described by its strength and ductility class rather than by type of manufacture.

Reinforcing steel bars are often referred to as "rebar" or "reo", or in the case of deformed bars, "debar". Although bars are sometimes called "rods", this name can be most misleading and should not be used. Bars are usually hot-rolled at the steel merchant-mill and then cut into straight "stock lengths" with a traditional maximum of 12 metres. Bars up to 16 mm diameter are also obtained from a coil by straightening and cutting it to length. The coil can be several hundred metres long and is formed whilst red-hot in a rod mill – hence the term "rod". But as the straightened and cut length of rod is almost indistinguishable from a hot-rolled bar, it is recommended that the term "bar", and not "rod", be used in structural detailing. Rebars and coiled-rebar must comply with AS/NZS 4671.

Wire (AS/NZS 4671 also describes this as reinforcing bar) is a material manufactured also from rod in coils of mass between 700 to 1300 kg; but in this case the rod is additionally cold-worked by drawing or rolling to increase its strength. Typically, this steel is low ductility and is classified as grade 500L steel. Grade 500L bars must comply with AS/NZS 4671.
AS 3600 has placed some limitations on the use of Grade 500L reinforcement.

Welded Mesh is often called just "fabric" or "mesh". It is manufactured from Grade 500L bars by a process of resistance welding every intersection of a series of longitudinal and cross bars. Some Grade 500N mesh can be manufactured to special order. The difference between "longitudinal" and "cross" bars is important; they refer to the direction in which the bars proceed through the mesh machine. The length of the cross-bars determines the width of a mesh sheet (2.4 m is a common maximum) whilst the length of the longitudinal bars determines the sheet length, which is generally supplied in 6-m lengths. The resulting product of a mesh machine resembles continuous computer paper. Like paper, it can be cut to any desired length, limited only by handling capability and the configuration of the machine itself. Mesh can be cut off the machine to a range of lengths between, say 2 to 10 m, or to produce a roll up to 60 m. A width range from 100 mm (2 longitudinal bars as for trench mesh) up to 2400 mm or more (with various numbers of longitudinal bar/ spacing combinations) is possible depending on the machinery. Mesh must comply with AS/NZS 4671.

Fitment. A unit of reinforcement commonly known as a tie, stirrup, ligature or helix.

Fitments may be made from individual Grade N or L bars, cut to length and then bent to shape, or from mesh by bending a flat sheet into the desired shape. Fitments are often assumed to have a shape resembling the surrounding concrete surface; however, unless care is taken in detailing, the shape can be so complex that the bars inside the fitment cannot be placed.

Tendon (prestressing steel). A wire, strand or bar or any discrete group of such wires, strands or bars, which is intended to be pretensioned or post-tensioned.

The method of manufacture and the resulting properties of tendons are best obtained from manufacturers' literature.

Prestressing steel must comply with AS/NZS 4672, and prestressing anchorages with AS/NZS 1314. If prestressing steel is imported, engineers should satisfy themselves such steel complies with the Australian Standard.

Plain concrete member. A member either unreinforced or containing reinforcement but assumed to be unreinforced.

While many plain concrete members are designed for strength and durability without reinforcement, steel is often included for crack control purposes, or for added continuity or for aesthetic reasons. The principles of this Handbook still apply in these cases.

Construction joint. A joint, including a joint between precast segments, that is located in a part of a structure for convenience of construction and made so that the load-carrying capacity and serviceability of the structure will be unimpaired by the inclusion of the joint. A typical location of a construction joint is at the top of slabs at walls and columns. The joints between precast segments may be treated differently to joints between insitu cast segments of the structure.

Movement joint. A joint which is made in or between portions of a structure for the specific purpose of permitting relative movement between the parts of the structure on either side of the joint.

2.2 BASIC CONSIDERATIONS FOR DETAILING REINFORCEMENT

Since reinforcement is generally to be encased by concrete, the first step in structural design is to define the proportions of the structure as a whole and the concrete outline for each member from the architectural and structural requirements. To a large extent, this will have been done during the planning and analysis stages. After this, the appropriate forces and stresses can be calculated.

The next step is to define the quantity of reinforcing steel in each face of the member and to determine how that steel can be fixed there (using fitments, tie wire, chairs and spacers) until the concrete is placed and has hardened.

Then it is necessary to ensure that the whole structure can be built using the assembly of the reinforcing steel and concrete as designed. This is done by dividing the structure into small placing zones comprising one or more of the individual members.

Let us use a small building with a single level basement as an example. Firstly the foundation is prepared and the footings constructed within a horizontal zone taken over the whole site. Of course, these may not be at exactly the same level but it is the principle we are concerned about. The next division would be a vertical zone consisting of the basement walls and columns, stairs and lift shaft walls if they are of concrete – these are built as a number of individual vertical elements.

Then the lowest suspended floor would be taken as one horizontal zone – although in practice the floor area is often subdivided into several zones by construction joints. After the floor is cast, the walls and columns supporting the next floor are constructed. Their outlines have been defined by their size and shape and their upper and lower limits (horizontal construction joints this time) are the top of the lower floor and the soffit of the floor above.

This concept continues to the roof.

Thus reinforced concrete construction consists of being able to subdivide the whole structure into manageable blocks which are built almost individually. It really does not matter whether the structure is of insitu concrete entirely, or of prestressed concrete, or of steel frame with concrete floors, or of fully precast concrete.

This Handbook explains detailing the reinforcement of individual concrete elements so that they can be economically connected with their adjoining elements by using insitu concrete.

3

Material and Construction Requirements

3.1 SOURCE

Section 17 of AS 3600 sets out the requirements for reinforcing steel, ducts, anchorages and tendons, joints and embedded items, and tolerances for structures and members. For bridges, the equivalent section is AS 5100 Part 5 Section 16 for materials and construction requirements. In this chapter, similar clauses exist to those referred to in AS 3600 Section 17.

Users of this Handbook should familiarise themselves with these clauses. Some will be referred to directly because they are very important to detailing procedures, whilst other clauses may not even be discussed.

3.1.1 Reinforcement

Materials. Reinforcement shall be deformed Class N bars or Class L or Class N welded wire mesh (plain or deformed), with a yield strength of up to 500 MPa, except that fitments may be manufactured from Class L wire or bar (plain or deformed), or plain Class N bar. Fitments can also be manufactured from plain Class 250N bar which is commonly designated as R bar. All reinforcement shall comply with AS/NZS 4671. All rules related to development and anchorage are based on this requirement.

Protective coatings such as galvanising or epoxy are allowed but bars so coated are not allowed to have reduced cover. (Refer AS 3600 Clause 17.2.1.2).

Bending. The term “bending” includes hooks and cogs at the ends of bars.

Throughout AS 3600, the term “standard hook” defines the dimensions required to provide additional anchorage for a bar when sufficient embedment length in concrete is not available. Hook and cog lengths depend solely on the bar diameter and the bending pin diameter; by Australian Standards, the physical length of steel required is independent of the angle of bend, ie 180°, 135° or 90°. Details are given in **Clause 6.2.4** of this Handbook.

3.1.2 Prestressing Ducts, Anchorages and Tendons

The main points in AS 3600 Clause 17.3 which concern the detailer of prestressed concrete are the specification of the tendon or duct profile and the methods to be used to maintain the profile. Of critical importance to the prestressing contractor are the jacking forces to be applied during the stressing operation. Determination of these is a matter of design and beyond the scope of this book, but the appropriate forces and the times for stressing must be given in the drawings.

3.1.3 Fixing

The “catch-all” clause in AS 3600 Clause 17.2.5, when read in conjunction with AS 3600 Clause 1.4, clearly indicates that all reinforcement and tendons required for whatever purpose must be shown in the drawings. Provision for tie-bars and so on may be made in the form of *General Notes* in the drawings. It is also implied that the chairs should also be specified but by whom is not clear. Plastic-tipped wire chairs should not be used in B2 or more severe environments due to the potential for corrosion and subsequent staining of concrete surfaces. Plastic bar chairs should be used in these severe environments. **Chapter 5** describes how to select the appropriate concrete cover. Further guidance on spacers and chairs for fixing of reinforcement in its correct position can be obtained from British Standard BS 7973 Parts 1 and 2.

3.2 TOLERANCES FOR REINFORCEMENT

3.2.1 Introduction to Tolerances for Reinforcement

AS 3600 tolerances for fabrication (Clause 17.2.2) and fixing (Clause 17.5.3) provide structurally reasonable and commercially realistic values bearing in mind traditional industrial practices. Reinforcement cannot be bent to tighter tolerances without an increase in costs; fixing tolerances are considered reasonable to ensure adequate strength. Designers must be aware that bending and fixing of reinforcement is not precision engineering.

Tolerances in engineering work are an allowance for variations in manufacturing operations. Cutting and bending rebars is not a precision operation. Nevertheless, in some jobs it may be necessary to specify tolerances tighter than given in the AS 3600 despite a significantly higher cost. As an alternative, specifying a higher cover with normal tolerances may be an easier solution.

No special allowance is made in the AS 3600 for precast concrete. Although a smaller cover is permitted (see Clause 4.10.3.3) it does not require reinforcement to be fabricated to smaller tolerances than given in Clause 17.5.3 for insitu concrete.

Cutting and bending. The reinforcement fabrication tolerances (AS 3600 Clause 17.2.2) are put in a "+0, -t mm" format so as to avoid a reduction in cover. These tolerances must be considered in conjunction with the cover specification for durability and fire resistance (refer **Chapter 5**).

Bar bending dimensions are nearly always controlled by the nearest concrete surfaces.

The scheduled length of reinforcement required to fit inside a concrete shape is obtained by subtracting the specified cover or covers from the concrete dimension. The negative tolerance on length should then ensure proper cover at each end of the bar.

Placing. It is important to understand that when a specification says "*Cover must not be not less than 'c' mm*", this should be interpreted as meaning cover to the ends of the bar as well as cover to the nearest parallel surface. This cover 'c' is the design or actual cover derived in **Chapter 5**.

Placing tolerances (AS 3600 Clause 17.5.3) are of the "+t, -t" type, that is the bar may be so placed that a small reduction or small increase in cover is permissible. Because of this, the cover required for corrosion resistance (AS 3600 Clause 4.10.3) includes an allowance of +5 mm (which is not specifically stated in the standard but implied from Clause 17.5.3) should placing inadvertently reduce the cover.

However, combinations of tolerances will require the designer to use a reduced effective depth for top steel than is theoretically required. This would normally only be a problem in thin slabs and the like or top steel in beams.

In critical situations, support heights should be calculated and specified on the original drawings. In some cases, a height greater than theoretically assumed may be desirable to allow for deviations in formwork and for the mass of the supported steel.

3.2.2 Application of Fabrication Tolerances

Shape Codes for reinforcement are described in **Chapter 9 Clause 2.1**.

Figure 3.1(a) shows a bar in the bottom of a slab. The slab length is "a" and the cover is specified as "c" without other explanation. Thus the bottom cover, end cover and face cover are all assumed to be "c".

The bar dimension A is calculated as follows:

A = a – 2c

Based on this calculated length, applying the cutting tolerances in AS 3600 Clause 17.2.2(a), the fabricated length varies from:

a – 2c + 0 to a – 2c – 40 mm,
for A more than 600 mm, or
a – 2c + 0 to a – 2c – 25 mm,
for A less than 600 mm.

Figure 3.1(b) can be considered as a slab with the left edge turned up. In this member the cover "c" applies to all slab faces and also to the ends of the bar in the upstand and the right edge.

Two dimensions 'A' and 'B' are required for cutting and bending the bar. They are calculated and shown on the schedule as follows:

Dimension 'A' = a – c – c = a – 2c,
Dimension 'B' = b – c –c = b – 2c, so that
The scheduled length 'L' = A + B

If we assume that dimension 'A' is less than 600 mm, and dimension 'B' is more than 600 mm, then the permissible range of fabricated dimensions are:

'A' ranging from a – 2c + 0 to a – 2c – 25 mm,
'B' ranging from b – 2c + 0 to b – 2c – 40 mm, and
'L' ranging from L + 0 to L – 40 mm.

Obviously, if the length 'L' is cut within tolerance, the individual dimensions 'A' and 'B' should also be within tolerance.

Figure 3.1(c) can be regarded as a cross-section through either a column or a beam. In practice, the cover is usually specified only once and is assumed to apply to all surfaces of the member. It is unwise to specify more than one cover value for a concrete element such as a wall, beam or slab.

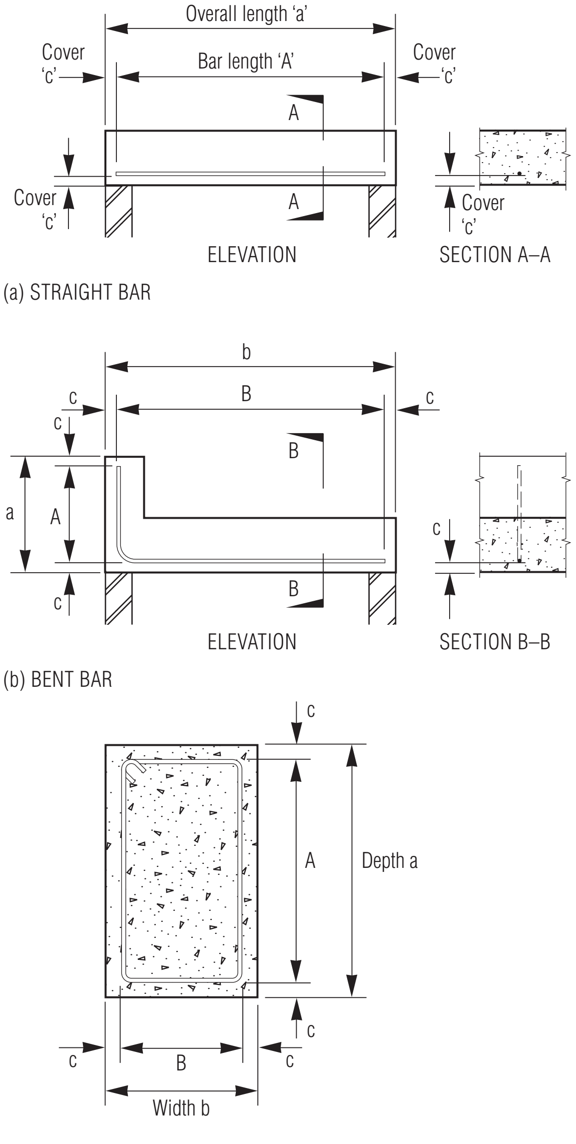
The scheduled dimensions for bending the fitment are:

Dimension 'A' = a –2c,
Dimension 'B' = b – 2c,
Scheduled Length 'L' = 2(A + B) + two 135° hooks

The scheduled length does not depend on

the size of the bar used to make the fitment, but we will assume it is a N12 deformed bar. Allowing for fabricating tolerances, for each leg of the fitment the fabricated dimensions are:

'A' ranging from a – 2c + 0 to a – 2c – 15mm, and



'B' ranging from b – 2c + 0 to b – 2c – 15mm.

Figure 3.1 *Fabrication Tolerances*

3.2.3 Fixing Tolerances for Reinforcement

As said earlier, the designer and detailer rarely need to take account of fabricating tolerances. Fixing tolerances are another matter – not because the tolerances are given in the drawings but because awareness is critical if design accuracy is to be understood. An excessive expectation of placing accuracy is unwise. When designing thin elements with small effective depths for design in bending, the theoretical effective depth may not be the actual one achieved on site.

AS 3600 Clause 17.5.3 refers to deviation from the "specified position", and this is very important because the detailer's job is to define this "specified position" (see Clause 1.4(k), **Clause 1.2.3** this Handbook).

However, to understand the relationship between specified position and the possible location of the bar in the actual member, a placing envelope can be calculated. This is illustrated in the following Figures. Note again, that the cover at the ends of the bar are usually not specified directly, but they are assumed to be the same as the face cover.

Figure 3.2(a). The placing envelope of a straight bar is defined by the placing tolerances and the cover to each end and to any surface of the slab. By comparing the scheduled length in **Figure 3.1(a)** with the placing-envelope in this example, it can be seen that maintaining bottom cover requires adequate chairing; to maintain the end cover depends on the cutting tolerance.

In practice, it is possible that an excessive cover will occur at the ends; this has no effect on the strength and in fact could lead to improved durability.

Figure 3.2(b) illustrates the placing-envelope within which a fabricated L-shaped bar should fit.

When the bar is fixed, its position in the formwork can be checked by measuring the cover at each end. The placing tolerance occurs twice – once at each end. Therefore, it can be seen from **Figure 3.2(b)** that, where the bar's position is controlled by cover at each end, then the fabrication tolerances will always assist in providing the design cover. In fact, if the bar is fabricated to the exact length then the bar will always fit into the placing-tolerance envelope of "cover – 5" mm to "cover + 10" mm.

However, if the fabricated dimensions have maximum undersize tolerances of –25 mm and –40 mm respectively, then the end covers would be greater than "cover + 10" mm.

Since it can be expected that the length 'L' after cutting will range from L + 0 to L – 40 mm, then the fabricated bent bar should fit inside the placing envelope.

The major concern here is that chairs must be specified to provide the appropriate cover on the soffit of the slab and along the upturned edge on the left. Care must be taken during construction to prevent the bar ends from touching the formwork.

Figure 3.2(c) describes the placing-envelope of a fitment within a beam cross-section.

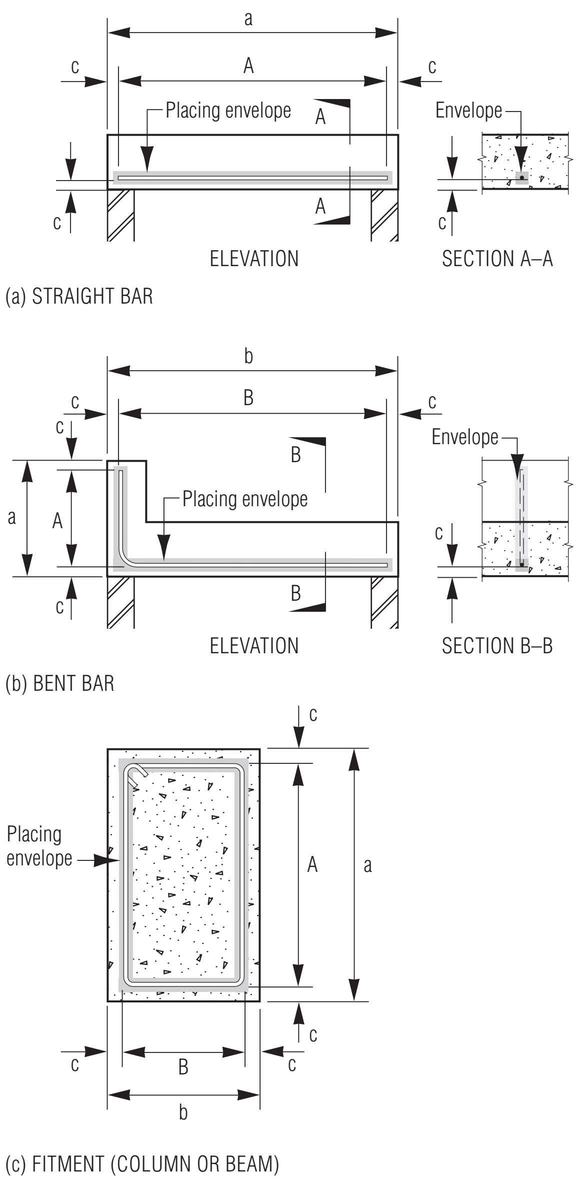


Figure 3.2 *FixingTolerances*

3.2.4 Fixing Tolerances for Footing Reinforcement

These are given in AS 3600 Clause 17.5.3(a). Fabrication tolerances are unchanged but the fixing tolerances are increased to allow for considerable unevenness of the foundation profile, consequently chair heights may need to be greater than specified cover. This is a case where specifying a greater cover than AS 3600 may assist construction on site.

3.2.5 Fixing Reinforcement not Controlled by Cover

At ends of reinforcement. **Figure 3.3** gives cases controlled by AS 3600 Clause 17.5.3(b)(ii). In general, splice locations do not need to be constructed to an accuracy any greater than 50 mm.

Fixing bars to comply with spacing. The tolerance on "position" given in AS 3600 Clause 17.5.3(b)(iii) again refers to "specified position". **Figure 3.4** illustrates how an unexpected hole in a slab could require that a bar be moved sideways during fixing. This displacement (of 60 mm say) may exceed the permitted tolerance range of "+/- 10% of the specified spacing or 15 mm, whichever is greater", but it is certainly preferable to cutting the bar.

If the hole is large, trimmer bars each side perpendicular to span of slab will be required.

There will also be cases where an extra bar must be used. Provided the correct total area of steel is embedded, it does not matter greatly if the individual spacing varies from bar to bar. The AS 3600 tolerance on spacing is there to control excessively bad steel fixing, not to force unrealistic demands on a simple process.

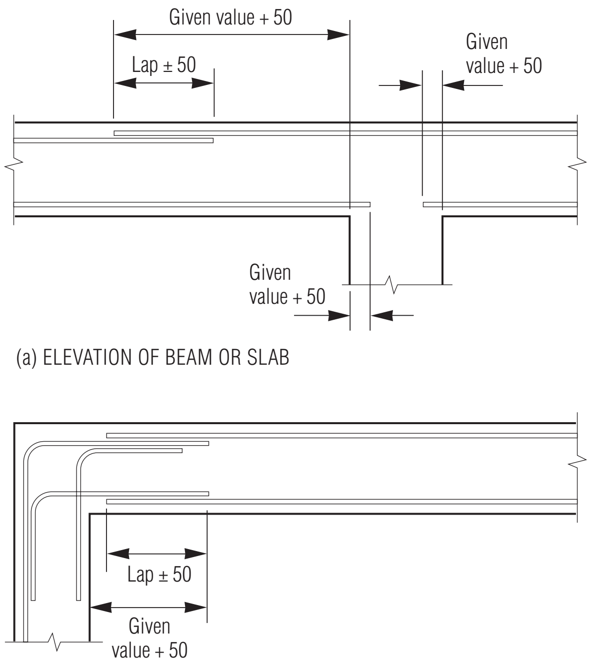
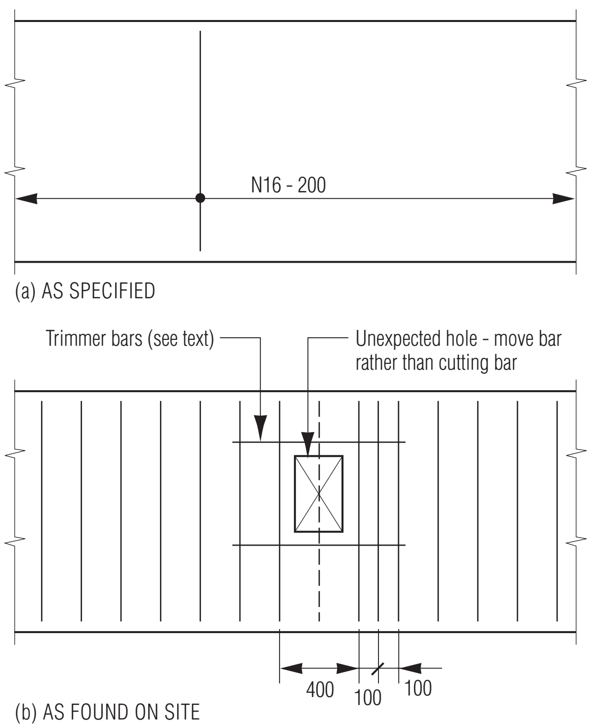


Figure 3.3 *SplicingTolerances*

Figure 3.4 *SpacingTolerances*



3.3 PRESTRESSING DUCTS, ANCHORAGES AND TENDONS

3.3.1 Continuity

At some stage of its life, a prestressing tendon will be expected to impose a very large force on its anchorage. The detailer must therefore show exactly where the anchorages are to be located and how they will be reinforced if extra steel is required.

If the tendon profile is curved as with most post-tensioned work, or deflected in a series of straight lines as for some pre-tensioned designs, it must be defined before any additional reinforcing steel is detailed around it.

Rebars can be cut or bent to fit around tendons which must be continuous from anchor to anchor and have as smooth a line as possible.

As a result, good detailing should allow for some of the reinforcing steel to be fixed before the ducts and tendons as a means of securing the latter, and the remainder should be in smaller pieces fitted later around the profile. As an example, “open top” fitments of bent mesh can be used in the soffit of band beams; a short bar resting on and tied to the horizontal cross-wires will provide vertical support for the tendon profile and for any slab top-steel placed after the tendons are secured.

3.3.2 Fabrication and Fixing

These are specialist tasks and will not be discussed further, other than to say that for post-tensioned tendons the tolerance for fixing is based on the final location of the tendons, not on the surface of the duct. Obviously, the stressed tendon will follow the shortest path through the member, and extensions should be based on this length. When multiple strands form the cable, they will be forced to bunch together on the inside of every curve of the duct.

The specified tolerances of “+/- 5” mm can only be maintained by adequate, correctly-placed supports or tie bars whose location in elevation and cross-section are accurately defined in simple, clear details by the designer.

3.4 JOINTS AND EMBEDDED ITEMS

AS 3600 draws a distinction between joints which are "detailed", that is they are defined by the designer, and those which occur unexpectedly during construction. To comply with Clause 17.4.1(b), the prudent detailer will show in the drawings how construction joints are to be made – whether or not these are likely to occur.

It should be noted that the detail is very dependent on the location and that approval must be sought from the designer as to where and when the detail must be used.

Obviously not every situation can be included so it is possible that alternative joint details will be required if amendments are made at short notice during the job's progress.

In reinforced concrete, a joint generally implies that splicing will be needed. By far the most common joint occurs in columns and walls at the junctions below and above beams or slabs. Splices have considerable effect on construction techniques. See **Chapter 6**.

Some fixtures and other items can be embedded during construction and need not be referred back to the designer. The drawings or Specification should contain clear instructions on the procedures to be taken in these cases. All embedded items which are manufactured from metals which are dissimilar to reinforcing steel must be isolated from the reinforcement to stop galvanic cells forming.

The design of fixings is covered by AS 3600 Section 14.3; particular care is required in detailing fixings used for lifting purposes. Under no circumstances should reinforcing bar or strand loops be used as the lifting hook. These materials are not meant for this purpose and can fail unexpectedly. For lifting concrete, there are proprietary cast in lifters with clutches for lifting. If the fixing is for later support, then a purpose designed fixing must be cast into the concrete section which is correctly load tested.

3.5 STRUCTURAL ROBUSTNESS

The commentary to AS 1170.0 gives the following advice:

"A structure should be designed and constructed in such a way that it will not be damaged by events like fire, explosion, impact or consequences of human errors, to an extent disproportionate to the original cause. The potential damage may be avoided or limited by use of the following:

(a) Avoiding, eliminating or reducing the hazards which the structure may sustain.

(b) Selecting a structural form that has a low sensitivity to the hazards considered.

(c) Selecting a structural form and design that can survive adequately the accidental removal of an individual element or a limited part of the structure or the occurrence of acceptable localised damage.

(d) Avoiding as far as possible structural systems that may collapse without warning.

The design should provide alternate load paths so that the damage is absorbed and sufficient local strength to resist failure of critical members so that major collapse is averted. The materials design Standards usually contain implicit consideration of resistance to local collapse by including such provisions as minimum levels of strength, continuity, and ductility. Connections for example should be designed to be ductile and have a capacity for large deformation and energy absorption under the effect of abnormal conditions".

Reinforcement detailing for robustness should address the issues raised above. The guidance given later in this Handbook on detailing for seismic resistance gives some examples of how robustness can be achieved.

4

Properties of Reinforcement for Detailing Purposes

4.1 GENERAL – AUSTRALIAN STANDARDS

There are a number of Australian standards which specify the mechanical and design properties of reinforcement. These are listed in **Table 4.1** and should be referred to for further information.

Table 4.1 *Australian Standards which Relate to Reinforcement and Tendons*

Reference number	Short title	Comments
AS/NZS 4671:2001	Steel reinforcing materials	All types of untensioned reinforcement
AS/NZS 4672:2007	Prestressing steel	All types of tendons for prestress
AS/NZS 1314:2003	Prestressing anchorages	For tendons only
AS/NZS 1554.3:2008	Welding of reinforcing steel	Permissible arrangements

For bar, wire and mesh, the design strength is the “characteristic yield strength” and this is called the “Grade” of the steel. It is measured in megapascals (MPa)

The strength of prestressing tendons is given in several ways and AS/NZS 4672 should be used to avoid mistakes. This standard also highlights the commonly-available prestressing steels.

Other standards and regulations which cross-reference the reinforcing steel and tendons Standards are given in **Table 4.2**.

Table 4.2 *Regulations and Design Standards*

Reference number	Short title	Comments
–	Building Code of Australia (BCA)	Basis of state building regulations
AS 1170.4:2007	Structural design actions - Earthquake actions in Australia	
AS 2783:1992	Concrete for small swimming pools	
AS 2870:1996	Residential slabs and footings	
AS 3600:2009	Concrete structures	
AS 5100:2004	Bridge design	Part 5 Concrete
AS/NZS 1100.501:2002	Structural engineering drawing	
AS 1379:2007	Specification and supply of concrete	

Note: A design or detail prepared under one standard cannot be expected to comply retrospectively with a standard published after the design is prepared. Dating the drawings should ensure that designs can be checked for future renovations, safety after fire, demolition, etc.

4.2 DEFORMED BARS, GRADE 500N

Physical properties are given in **Table 4.3** while design properties are given in **Tables 4.4** and **4.5**.

Suggested specification. *Reinforcing bars shall be hot-rolled deformed bars of grade 500N complying with AS/NZS 4671 + year*[Note 1]

Note:

1 “Year” must be that of the current version.

Table 4.3 *Physical Properties of Deformed Bars D500N*

Bar size, d_b (mm)	Design area[Note 1] (mm^2)	Theoretical area[Note 2] (mm^2)	Calculated mass[Note 3] (kg/m)	Nominal mass[Note 4] (kg/m)
10	80	78.5	0.6162	0.6316
12	110	113.1	0.8878	0.9100
16	200	201.1	1.5783	1.6178
20	310	314.2	2.4662	2.5278
24	450	452.4	3.5513	3.6400
28	620	615.8	4.8337	4.9545
32	800	804.2	6.3133	6.4712
36	1020	1017.9	7.9903	8.1901
40	1260	1256.6	9.8646	10.1112
50	1960	1963.5	15.4131	15.7984

NOTES:

1 The design area of a deformed bar is the theoretical area, rounded to two significant places.

2 The theoretical area of a deformed bar is calculated from the bar size as if it was a circle.

3 The calculated mass is the theoretical area multiplied by 0.00785 kg/mm^2/m.

4 The nominal mass includes the rolling margin of 2.5% based on the calculated mass.

Table 4.4 *Design Area by Number of Deformed Bars (mm^2)*

Number of bars	D500N bar size (mm)						
	12	16	20	24	28	32	36
1	110	200	310	450	620	800	1020
2	220	400	620	900	1240	1600	2040
3	330	600	930	1350	1860	2400	3060
4	440	800	1240	1800	2480	3200	4080
5	550	1000	1550	2250	3100	4000	5100
6	660	1200	1860	2700	3720	4800	6120
7	770	1400	2170	3150	4340	5600	7140
8	880	1600	2480	3600	4960	6400	8160
9	990	1800	2790	4050	5580	7200	9180
10	1100	2000	3100	4500	6200	8000	10 200

NOTE:

Before selecting the number of bars in one layer of a beam or column, check **Clause 4.3.1** for minimum beam and column widths.

Table 4.5 *Design Area for Distributed Deformed Bars (mm^2/m)*

Spacing of bars (mm)	D500N bar size (mm)						
	12	16	20	24	28	32	36
60	1833	3333	*	*	*	*	*
80	1375	2500	3875	*	*	*	*
100	1100	2000	3100	4500	*	*	*
120	917	1667	2583	3750	5167	*	*
140	786	1429	2214	3214	4429	5714	*
160	688	1250	1938	2813	3875	5000	6375
180	611	1111	1722	2500	3444	4444	5667
200	550	1000	1550	2250	3100	4000	5100
220	500	909	1409	2045	2818	3636	4636
240	458	833	1292	1875	2583	3333	4250
260	423	769	1192	1731	2385	3077	3923
280	393	714	1107	1607	2214	2857	3643
300	367	667	1033	1500	2067	2667	3400
320	344	625	969	1406	1938	2500	3188
340	324	588	912	1324	1824	2353	3000
360	306	556	861	1250	1722	2222	2833
380	289	526	816	1184	1632	2105	2684
400	275	500	775	1125	1550	2000	2550
450	244	444	689	1000	1378	1778	2267
500	220	400	620	900	1240	1600	2040

* A centre-to-centre spacing of less than $4d_b$ is not provided because concrete is difficult to place and splitting can occur along this plane.

4.3 SELECTION OF MEMBER SIZE

Check that beam and column sizes are adequate for fire resistance and concrete compaction purposes before selecting the number of bars in a layer.

4.3.1 Minimum Beam and Column Sizes for Fire Resistance

Table 4.6 is derived from AS 3600 Section 5 using the minimum thicknesses for various fire resistance periods. Exposure classifications other than A1 and B1 for buildings are unlikely to be exposed to fire and are not included.

Rectangular beams which may be exposed to fire on all sides must also have a depth not less than the width required for fire resistance. T-beams and L-beams need only comply for the web width because the top surface is protected by the slab, see **Figure 4.1**.

Table 4.6 *Minimum Beam Web Width for Fire Resistance, $b_{w.fire}$ (mm) Assuming Fitments to be 10 mm or Larger*

Exposure Class	Cover c_{exp} (mm)	Main-bar cover,*	Fire Resistance Period (FRP) in minutes					
			30	60	90	120	180	240
SIMPLY-SUPPORTED BEAMS								
A1	20	30	80	200	N/A	N/A	N/A	N/A
	25	35	80	160	400	N/A	N/A	N/A
	30	40	80	120	300	N/A	N/A	N/A
B1	40	50	80	120	175	500	N/A	N/A
	45	55	80	120	150	300	N/A	N/A
CONTINUOUS BEAMS								
A1	20	30	80	120	200	≥ 500	N/A	N/A
	25	35	80	120	150	300	N/A	N/A
	30	40	80	120	150	250	≥ 600	N/A
B1	40	50	80	120	150	200	400	≥ 700

* Assuming 10-mm fitments, $c_{fire} = c_{exp} + 10$

Example 4.1

A continuous beam has an exposure classification of A1, which leads to a cover to the fitment of 20 mm for corrosion protection (**Clause 5.5**).

Enter **Table 4.6** at the A1 classification. Assume the fitment is R10, so that the side-cover and soffit-cover to the main steel is 30 mm. This is the value of c_{fire}. For an FRP of 120 minutes, the minimum continuous-beam width $b_{w.fire}$ is read as 500 mm. If the beam is exposed to fire on all sides then this is also the minimum overall depth, D.

However if the required FRP is 240 minutes, then a side cover of 30 mm will never be adequate regardless of the beam width.

To obtain an FRP of 240 minutes, the continuous-beam width must be at least 700 mm with 50 mm main-bar cover. Thus for an FRP of 240 minutes, continuous band-beams with banded slabs require 50 mm cover to the soffit and sides provided they are over 700 mm wide.

For columns (**Figure 4.2**) the minimum dimension for fire should be obtained from AS 3600 Table 5.6.3 or Table 5.6.4, depending on whether the column is braced or unbraced. The value also changes depending on the ratio of actual load to the load capacity of the column and the reinforcement percentage.

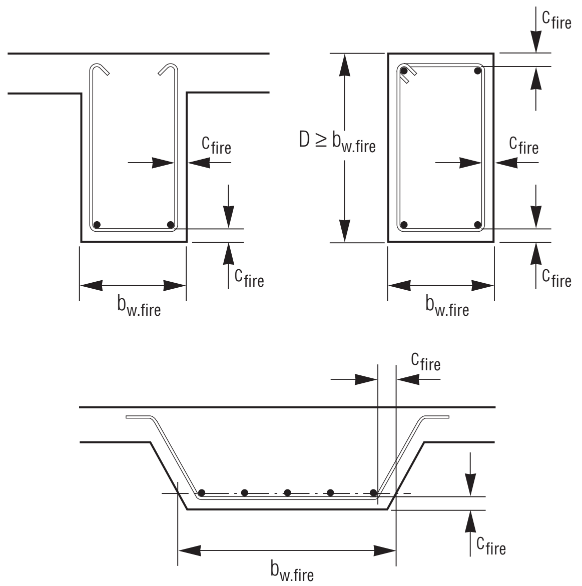


Figure 4.1 *Minimum Beam Widths for Fire*

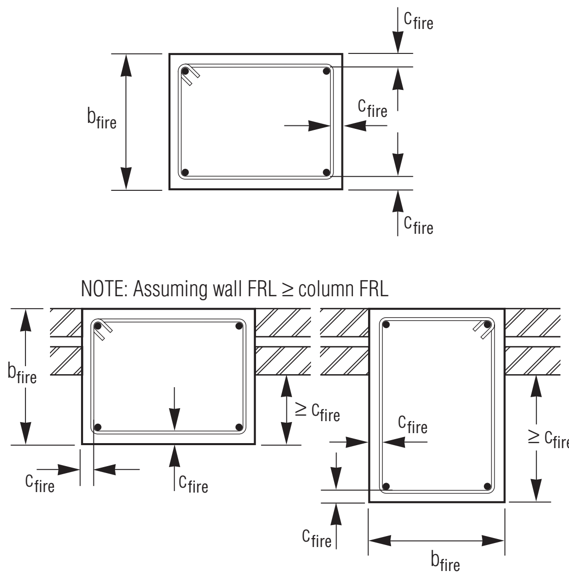


Figure 4.2 *Minimum Column Widths for Fire*

4.3.2 **Band-Beam and Slab Systems, and Blade Columns**

There is no distinction for flexural-strength calculations between beams and slabs. For fire resistance, the cover to the longitudinal bars of a wide beam is the same as that for a slab when the web width is at least 700 mm for a simply-supported member, or continuous member.

In each case, there is a reduced cover requirement for shorter FRP's. For further details on fire resistance of slabs including flat slabs, flat plates and ribbed slabs, refer to AS 3600 Clause 5.5.

For fire resistance of walls, AS 3600 Clause 5.7 should be used for obtaining full details.

4.3.3 **Minimum Beam Web Width and Column Sizes for Concrete Compaction Purposes**

Table 4.7 gives the minimum web width of beams and minimum width of a column. They are based on a clear distance between bars of twice the size of the main bar ($2d_{b.main}$), that is the centre to centre spacing is $3d_b$.

These limitations are related to AS 3600 Clause 13.1.2.1 for tensile stress development. One of the factors is that the cover to the main bar ($c_{main} = c_{fitment}+d_{b.fitment}$) must not be less than one-half the clear distance between parallel bars (clear distance = $2d_{b.main}$ in this Table). It is assumed that the member has properly designed fitments to control longitudinal splitting.

There are minimum values – generally columns less than 200 mm x 200 mm are difficult to build. Wherever possible, wider members should be selected.

NOTE: While the beam widths in **Table 4.7** may meet the requirements of AS 3600, generally a gap of 60–75 mm is required between top bars to allow the use of a thin poker vibrator. This means a beam may have to be wider, especially for narrow beams. Hence sections less than 200 mm thick may be difficult to construct, and place and compact the concrete.

Table 4.7 *Beam Web Widths and Column Sizes (mm) for $2d_b$ Clear Distance Between Bars*

Cover to main bars (mm)	No. of bars	Main-bar size (mm) 12	16	20	24	28	32	36
30 (20-mm cover +10-mm fitment)	2	110	130	140	160	180	190	N/A
	3	150	180	200	230	260	290	N/A
	4	180	220	260	300	340	380	N/A
	5	220	270	320	380	430	480	N/A
	6	260	320	380	450	510	580	N/A
	7	290	370	440	520	600	670	N/A
	8	330	420	500	590	680	770	N/A
	9	360	460	560	660	760	860	N/A
	10	400	510	620	740	850	960	N/A
	Extra	36	48	60	72	84	96	N/A
40 (30-mm cover +10-mm fitment)	2	130	150	160	180	200	210	230
	3	170	200	220	250	280	310	340
	4	200	240	280	320	360	400	440
	5	240	290	340	400	450	500	550
	6	280	340	400	470	530	600	660
	7	310	390	460	540	620	690	770
	8	350	440	520	610	700	790	880
	9	380	480	580	680	780	880	980
	10	420	530	640	760	870	980	1090
	Extra	36	48	60	72	84	96	108
50 (40-mm cover +10-mm fitment)	2	150	170	180	200	220	230	250
	3	190	220	240	270	300	330	360
	4	220	260	300	340	380	420	460
	5	260	310	360	420	470	520	570
	6	300	360	420	490	550	620	680
	7	330	410	480	560	640	710	790
	8	370	460	540	630	720	810	900
	9	400	500	600	700	800	900	1000
	10	440	550	660	780	890	1000	1110
	Extra	36	48	60	72	84	96	108
60 (50-mm cover +10-mm fitment)	2	170	190	200	220	240	250	270
	3	210	240	260	290	320	350	380
	4	240	280	320	360	400	440	480
	5	280	330	380	440	490	540	590
	6	320	380	440	510	570	640	700
	7	350	430	500	580	660	730	810
	8	390	480	560	650	740	830	920
	9	420	520	620	720	820	920	1020
	10	460	570	680	800	910	1020	1130
	Extra	36	48	60	72	84	96	108

See Note in text (**Clause 4.3.3**).

4.4 PLAIN ROUND BARS, GRADE 250N

Physical properties of plain round bars for fitments are given in **Table 4.8**.

Suggested specification. *Plain round reinforcing bars for fitments shall be hot-rolled bars of grade 250N*

Table 4.8 *Physical properties of plain round bars for fitments, Grade 250N*

Bar size, d_b (mm)	Design area (mm^2)	Theoretical area (mm^2)	Calculated mass (kg/m)	Nominal mass (kg/m)
6.5	30	33.2	0.2605	0.2670
10.0	80	78.5	0.6165	0.6320

NOTE:

1. Availability of these sizes can depend on local practice throughout Australia. They may in fact be available only as coiled rod (see **Clause 2.1**) of grade 250N.
2. Plain round bars for dowel bars are available in larger sizes.

4.5 LOW DUCTILITY DEFORMED BARS, GRADE 500L

There is a greater range of D500L bar sizes available as shown in **Table 4.9**. If the designer's calculations use 250 MPa as the design strength for fitments, then either R250N or D500L can be specified; if 500 MPa is used as the design strength, only the appropriate D500L bar size should be detailed. D500L bar can only be used for fitments or for making of mesh in accordance with AS 3600.

Table 4.9 *Physical Properties of Low Ductility Deformed Bars for Mesh or Fitments, Grade 500L*

Bar size, d_b (mm)	Design area (mm^2)	Nominal mass (kg/m)
6.00	28.3	0.222
6.75	35.8	0.281
7.60	45.4	0.356
8.60	58.1	0.456
9.50	70.9	0.556
10.70	89.9	0.706
11.90	111.2	0.873

NOTE:

1. For bar, the design area and nominal mass are calculated from the actual bar size.

Table 4.10 *Mesh Specification for Preferred-Size Mesh to AS/NZS 4671 Using D500L Bars*

	Longitudinal bars		Cross bars		Mass (6 x 2.4 m sheets)		Cross-sectional area	
Mesh ref. No.	No. x dia. (mm).	Pitch (mm)	No. x dia. (mm)	Pitch (mm)	Unit area (kg/m^2)	Sheet (kg)	Longitudinal (mm^2/m) UNO	Cross (mm^2/m)
Rectangular								
RL1218	25 x 11.9	100	30 x 7.6	200	10.5	157	1112	227
RL1018	25 x 9.5	100	30 x 7.6	200	7.3	109	709	227
RL818	25 x 7.6	100	30 x 7.6	200	5.3	79	454	227
Square, with edge side-lapping bars								
SL102	10 x 9.5 + 4 x 6.75	200 100	30 x 9.5	200	5.6	80	354	354
SL92	10 x 8.6 + 4 x 6.0	200 100	30 x 8.6	200	4.6	66	290	290
SL82	10 x 7.6 + 4 x 6.0	200 100	30 x 7.6	200	3.6	52	227	227
SL72	10 x 6.75 + 4 x 5.0	200 100	30 x6.75	200	2.8	41	179	179
SL62	10 x 6.0 + 4 x 5.0	200 100	30 x 6.0	200	2.2	33	141	141
Square, without edge side-lapping bars								
SL81	25 x 7.6	100	60 x 7.6	100	7.1	105	454	454
Trench Meshes								
L12TM	N x 11.9	100	20 x 5.0	300	N/A	N/A	N x 111.2 (mm^2)	65
L11TM	N x 10.7	100	20 x 5.0	300	N/A	N/A	N x 89.9 (mm^2)	65
L8TM	N x 7.6	100	20 x 5.0	300	N/A	N/A	N x 45.4 (mm^2)	65

NOTES:

1. The edge bars on SL meshes may be replaced by smaller edge bars of equal or greater cross-sectional area, in total, that the main longitudinal bars being replaced provided the smaller bars meet the minimum ductility requirements of the bar or bars to be replaced.
2. Mass of mesh is based on a piece cut from a full sheet and being one metre square with equal overhangs on opposite sides.
3. Trench mesh is normally specified by the number (N) of bars used in either the top and/or bottom of the footing so that the cross-sectional areas are not often utilised. Common strip widths are 200 mm (3 bars), 300 mm (4 bars), and 400 mm (5 bars). See AS 2870 for applications.
4. Mesh configurations are not limited to those shown in the **Table 4.10**. Mesh main bar spacings are the most critical factor for special meshes, and detailers should check with mesh manufacturers before finalising a design.
5. The design characteristic yield strength of mesh is 500 MPa but at low ductility.

5

Cover

5.1 INTRODUCTION

According to AS 3600:2009, "*cover is the distance between the outside of the reinforcing steel or tendons and the nearest permanent surface of the member, excluding any surface finish. Unless otherwise noted, the tolerances on cover given in Clause 17.5.3 apply*". It should be noted that AS 3600 only sets minimum standards, including cover. Designers may choose a larger cover if they consider it warranted.

The two primary purposes of cover are for durability and for fire resistance. As a general rule, cover is selected from an appropriate Table but there are several cases where additional cross-checks are required. A secondary reason for adequate cover is to ensure that the stresses in steel and concrete can be transferred, one to another, by bond. These actions are called stress development and anchorage. The "cover" required for these purposes is measured not to the "nearest bar" but to the bar whose stress is being developed. An example is the "cover" to a longitudinal bar in a beam which is enclosed by a fitment – the latter piece of steel is therefore the "nearest" surface. Anchorage is dealt with in **Chapter 6** of this Handbook.

Fortunately, in practice, designers and detailers recognise the different meanings of the word "cover", but in a Handbook such as this, clear distinctions may be necessary at various times.

Selection of cover is a design decision for the engineer as it influences the mathematics of design. However, the detailer should also have a clear understanding of the method of selection of cover. (See **Clause 1.2.3** in this Handbook).

For bridges, whilst the general principles are the same, the details are different from this chapter. See **Chapter 19**.

5.2 GENERAL COMMENTS

5.2.1 Cover Selection for Durability

In AS 3600, durability of the structure is very much related to individual surfaces of a member and to the compressive strength of the concrete and its exposure to elements that may affect its durability.

For one member having the same durability resistance as another member, AS 3600 requires the same cover, but the method of selecting the exposure classification and the appropriate concrete strength requires a number of factors to be considered.

The following information should be derived from **Clause 5.3**, before cover for corrosion protection is calculated by **Clause 5.5**.

(a) The most severe Exposure Classification for durability (A1 to U);
(b) the characteristic compressive strength of the concrete (f'_c) for the most severe situation for use in strength, serviceability and durability design, allowing for abrasion and freeze/thaw conditions;
(c) the degree of compaction; and
(d) the type of formwork.

5.2.2 Cover Selection for Fire-Resistance

Design for fire resistance by AS 3600 is based on overseas and Australian information. Details are given in **Clause 5.6**.

5.3 **STEP-BY-STEP SELECTION OF EXPOSURE CLASSIFICATION AND CONCRETE STRENGTH FOR DURABILITY RESISTANCE**

Users of this Handbook are advised that the following flowchart is illustrative only, and must be verified from the applicable published edition of AS 3600 before being applied to an actual design.

1 ***Select the member to be designed and refer to AS 3600 Table 4.3 (Step 2)***
Record member:

2 ***Determine Exposure Classification from Table 4.3. Refer AS 3600 for notes on Exposure Classification***	
Surface of the member and its exposure environment	Classification reinforced & prestressed members
1. In contact with the ground	
(a) Members protected by damp-proof membrane	A1
(b) Residential footing in non-aggressive soil	A1
(c) Other members in non-aggressive soils	A2
(d) Members in aggressive soils (refer to AS 3600 Clause 4.8 and Clause 4.5)	U
2. In interior environments	
(a) Member fully enclosed within a building except for brief period of weather exposure during construction	
(i) Residential	A1
(ii) Non-residential	A2
(b) Member in (industrial) building and being subjected to repeated wetting and drying	B1
3. In above-ground exterior environment, in areas which are:	
(a) Inland (> 50km from coastline) –	
(i) Non-industrial and arid climatic zone	A1
(ii) Non-industrial and temperate climatic zone	A2
(iii) Non-industrial and tropical climatic zone	B1
(iv) Industrial and any climatic zone	B1
(b) Near-coastal (1km to 50km from coastline) – Any climatic zone	B1
(c) Coastal (up to 1km from coastline but excluding tidal and splash zones) – Any climatic zone	B2
4. In water	
(a) In fresh water	B1
(b) In sea-water –	
(i) permanently submerged	B2
(ii) in spray zone	C1
(iii) in tidal or splash zones	C2
(c) In soft or running water	U
5. In other environments	
Any exposure not otherwise described above	U
Record Exposure Classification:	

3 ***Select concrete strength for Exposure Classification***		
Exposure Classification (AS 3600 Table 4.3)	For details see AS 3600 Clause…	Select concrete strength (MPa)
A1	4.4	20
A2	4.4	25
B1	4.4	32
B2	4.4	40
C1 C2	4.4	50
U	4.5	Designer specifies
Record strength as $f_{c.xc}$:		

4 ***Is surface subject to abrasion action?*** ***No: Go to AS 3600 Clause 4.7 (Step 5)*** ***Yes: Go to AS 3600 Clause 4.6 (below)***	
Type of abrasion	Minimum strength (MPa)
1. Footpath or residential driveway	20
2. Commercial and non-trafficked industrial floor	25
3 (a) Pneumatic-tyred traffic	32
(b) Non-pneumatic tyred traffic	40
(c) Steel-wheeled traffic. Designer to assess, but not to be less than	40
Record worst case as $f_{c.abrasion}$:	

5 ***Is part of member subject to freeze/thaw?*** ***No: Go to summary (Step 6)*** ***Yes: Go to AS 3600 Clause 4.7 (below)***		
Number of cycles per year	For details see AS 3600 Clause…	Minimum strength (MPa)
< 25	4.7a(i)	32
≥ 25	4.7a(ii)	40
Record as $f_{c.freeze/thaw}$:		

6 ***Summary***
For exposure conditions, take the highest value of $f_{c.cx}$, $f_{c.abrasion}$ and $f_{c.freeze/thaw}$, then… Record this as $f_{c.exposure}$:
For various structural reasons, such as strength or serviceability, the designer may require a compressive strength different from the value of $f_{c.exposure}$… Record this as $f_{c.structural}$:
For design purposes, select the higher value of $f_{c.exposure}$ or $f_{c.structural}$ and call this the *28-day characteristic compressive strength of the concrete…* Record this as f'_c :
Check AS 3600 Clause 4.3.2 (see **Clause 5.5** this Handbook) for any concession on $f_{c.exposure}$ for a member with only one exterior surface exposed to a worst situation… For this member, record previous $f_{c.structural}$ as f'_c :

In the drawings, for every member, you must specify in some way:

- Exposure Classification for durability; ie A1 to U.
- Class of concrete (normal or special) and its strength grade or characteristic strength, ie the final value of f'_c.
- Any other required properties of the concrete.

5.4 OTHER FACTORS AFFECTING SELECTION OF COVER FOR CORROSION PROTECTION

5.4.1 Formwork and Compaction Effects

AS 3600 Clause 4.10.3 allows the concrete to be placed in various types of formwork:

- Forms which comply with AS 3610 (See AS 3600 Section 17.6).
- Against the ground.
- In the ground with a suitable separating membrane.
- For precast concrete, using rigid forms.

For each formwork situation, AS 3600 Clause 4.10.3 has an associated compaction method:

Standard compaction which implies that at least a hand held vibrator is used correctly and that there is sufficient room for it to penetrate the reinforcement cages (see AS 3600 Clauses 4.10.3.2 and 17.1.3), and

Intense compaction of precast concrete only with rigid formwork, which implies that intense external vibration, perhaps from vibrators attached to the forms, will be applied.

Because of its importance for corrosion protection, formwork and methods of compaction are required to be given in the drawings as an instruction.

5.4.2 A Reminder

In any one member it is impossible to provide concrete with more than one specified strength. One exception is floor slabs in high rise buildings where the section of the slab at the column may need a higher strength than the floor and a higher strength is used. (Refer Section 10.8 of AS 3600). However it is quite possible for one member to have different exposure conditions on various faces. For example, an external wall or a roof would be subjected to the weather on its outside face and to a protected environment inside; that is, there can be a combination of A1/B1 or A1/B2 with these members. It is permissible to specify different cover on these faces, but beware of the high risk of error.

In the case of beams and columns, however, different covers on different faces must not be specified.

5.4.3 Interpretation of the Relevant Value of "$c_{corrosion}$"

Tables 5.1 to **5.4** give the cover to the nearest steel as required for corrosion protection. We shall call this "$c_{corrosion}$".

For slabs, walls, footings, etc "$c_{corrosion}$" applies to the steel nearest the appropriate surface. Cover from both surfaces of thin members must be checked, even if there is only one layer of steel.

For beams and columns which have fitments, "$c_{corrosion}$" from the tables applies initially to the fitments. The actual depth to the main bars will be greater than the tabulated values by the bar diameter of the fitments and this increased value is effectively "$c_{corrosion}$" for the main bars.

The negative tolerances on position (equals reduced cover) given in AS 3600 Clause 17.5.3(a) are included already in the values for "$c_{corrosion}$" shown in **Tables 5.1** to **5.4**. This means that to select the appropriate cover to the nearest steel, read the values direct and do not select a higher cover.

The resulting cover for corrosion protection to the appropriate fitment, main bar or tendon is recorded as "$c_{corrosion}$".

Example 5.1

For exposure class A2, 25 mm cover with 25 MPa concrete was considered adequate by the AS 3600's committee. To allow for the tolerance of – 5 mm, the cover specification in Table 4.10.3.2 was set at 30 mm.

5.4.4 **Additional Check on Minimum Cover for Concrete Placement and Compaction (AS 3600 Clause 4.10.2)**

- The actual cover to any fitment, bar or tendon, must not be less than the maximum nominal aggregate size "$c_{aggregate}$". See **Chapter 19** for bridges.
- The actual cover must not be less than the diameter "$d_{b.fitment}$" of any fitment being covered.
- The actual cover must not be less than the diameter "$d_{b.main}$" of any main steel being covered. Because the diameter of any fitment provides an effective cover to the main bars of "$c_{corrosion.fit} + d_{b.fitment}$", this value should be used when checking cover.
- Additional Clauses are given for bridges which will affect tendon and reinforcement layouts.
- If a blinding layer has been previously placed, it can act as a formed surface for cover requirements.

In any member, each layer of steel will have its own cover for durability and the designer must take this into account.

The cover for durability design "$c_{durability}$" for each steel item is the largest of the covers for corrosion protection, the cover for placement of concrete based on aggregate size, and its own diameter.

Example 5.2

Assume the fitment is R10 with a corrosion cover of 20 mm.

This would be satisfactory for the fitment. However, if the main bar diameter was greater than 30 mm, an increased cover to that bar must be specified in the drawings, usually by increasing the cover to the fitment to 25 or 30 mm. Generally these can be checked mentally without need for calculation.

5.5 SELECTING COVER TO REINFORCEMENT AND TENDONS FOR CORROSION PROTECTION

Tables 5.1 to **5.4** apply to the steel nearest the surface.

Users of this Handbook should verify that the values in these Tables apply to the current edition of AS 3600. They are based on AS 3600:2009.

In **Table 5.1** and **Table 5.4** only, the covers shown in parentheses are those appropriate to the concession given in AS 3600 Clause 4.3.2. This permits the concrete strength grade for exposure condition ($f_{c.exposure}$) to be reduced by one grade (eg N32 to N25) when one face of a member has a higher exposure classification than the other faces and the concrete strength for other reasons ($f_{c.structural}$) is also one grade less than $f_{c.exposure}$.

Example 5.3

The exposure classification is B1 for the outer face of an external column. The internal faces are protected and have classification A1. The two combinations for the column as a whole are (from **Table 5.1**):

(i) Concrete grade 32 MPa with 40 mm cover to fitments, or

(ii) Concrete grade 25 MPa with 60 mm cover to fitments.

The fact that, for classification A1, grade 20 could apply to the other surfaces has no influence on the decision.

Table 5.1 *Required Cover (mm) for Corrosion Protection, $c_{corrosion}$, where Standard Formwork and Compaction Used.* [Based on AS 3600 Table 4.10.3.2]

Exposure Classification	Compressive strength, f'_c (MPa) not less than				
	20	25	32	40	≥ 50
A1	20	20	20	20	20
A2	(50)	30	25	20	20
B1		(60)	40	30	25
B2			(65)	45	35
C1				(70)	50
C2					65

NOTE: Pairs of values with grey background correspond to concession given in AS 3600 Clause 4.3.2

Table 5.2 *Required Cover (mm) for Corrosion Protection, $c_{corrosion}$, where Concrete is Cast on or Against Ground Protected by a "Damp-Proof" Membrane and Standard Compaction Used* [Based on AS 3600 Table 4.10.3.5(a)]

Exposure Classification	Compressive strength, f'c (MPa) not less than				
	20	25	32	40	≥ 50
A1	30	30	30	30	30
A2		40	35	30	30
B1			50	40	35
B2				55	45
C1					60
C2					75

NOTE: No AS 3600 Clause 4.3.2 concession permitted

Table 5.3 *Required Cover (mm) for Corrosion Protection, $c_{corrosion}$, where Concrete is Cast Directly Against Ground Without a "Damp-Proof" Membrane and Standard Compaction Used* [Based on AS 3600 Table 4.10.3.5(b)]

Exposure Classification	Compressive strength, f'c (MPa) not less than				
	20	25	32	40	≥ 50
A1	40	40	40	40	40
A2		50	45	40	40
B1			60	50	45
B2				65	55
C1					70
C2					85

NOTE: No AS 3600 Clause 4.3.2 concession permitted

Table 5.4 *Required Cover (mm) for Corrosion Protection, $c_{corrosion}$, where Concrete is Precast in Rigid Formwork and Intense Compaction Used.* [Based on AS 3600 Table 4.10.3.3]

Exposure Classification	Compressive strength, f'c (MPa) not less than				
	20	25	32	40	≥ 50
A1	20	20	20	20	20
A2	(45)	30	20	20	20
B1		(45)	30	25	20
B2			(50)	35	25
C1				(60)	45
C2					60

NOTE: Pairs of values with grey background correspond to concession given in AS 3600 Clause 4.3.2

5.6 SELECTION OF COVER FOR FIRE RESISTANCE

5.6.1 Guidelines for Fire-Resistance Protection

During the course of a fire, temperatures in excess of about 200°C reduce the strength of both steel and concrete. Fortunately, the insulation properties of concrete are greater than those of steel and the concrete cover is the best and cheapest method of increasing the fire-resistance of structures.

The cover for fire-resistance (c_{fire}) depends on the type of member, how that member carries the loads imposed on it, whether or not it is continuous (flexurally or structurally) with other members, and the type of fire protection it provides.

Concrete strength is not taken into account when selecting cover for fire-resistance. Similarly, the effects of fire need only be considered for members inside the shell of a building which is required, by Building Regulations or through other Authorities, to attain a specified fire-resistance level. In certain structures which have a high exposure-classification, due to proximity with hazardous materials for example, resistance to fire must be considered very seriously.

To use Section 5 of AS 3600, a member must be classified as a beam, a slab, a column or a wall. For example, a staircase would be of slab form, whilst its support may be a wide beam or a slab.

In all cases, a thicker member of concrete with greater cover will have a longer fire-resistance period.

AS 3600 is quite explicit that a wide beam can be treated as a slab and that an exposed column cannot be treated as a wall.

5.6.2 Step-by-step Selection of Cover for Fire Protection

Because there are many interlocking provisions in AS 3600 Section 5, the designer and detailer should refer directly to both the standard and its Commentary. In particular, the required fire-resistance level of each member should be obtained from the Building Code of Australia (BCA). Architectural design should also have allowed for the required member thicknesses – if it has not then there could be some drastic changes to dimensions.

The following procedure may assist:

- Obtain required fire-resistance level from BCA;
- Having already determined the cover for durability for the member concerned, go to the relevant sub-clause of Section 5 of AS 3600:

  - For beams, to 5.4
  - For slabs and ribbed slabs, to 5.5
  - For wide beams, compare 5.4 with 5.5
  - For columns, to 5.6
  - For walls, to 5.7 and possibly 5.6; and
  - For members where the insulating properties need to be increased because of inadequate cover, to 5.8.
- From the relevant Sub-clause of Section 5:
  - If the member is a slab or wall, check that the thickness is adequate for "insulation" and "integrity". The wise designer will have done this before starting the analysis. These two properties are needed to stop the spread of fire and smoke beyond the compartment (room) where the fire occurs.
  - For all types of member, check that the cross sectional dimensions are structurally adequate for fire-resistance. Structural adequacy for fire resistance permits lower load factors than those for normal strength calculations.
  - For fire resistance, the cover to the longitudinal bars of a wide beam (called here band-beam and slab systems or just band-beams) is the same as that for a slab when the web width is at least 700 mm for a simply supported member, or continuous member.
  - If a wall does not have a fire-separating function, it cannot be designed as a wall for fire-resistance. It must be treated as a column.
  - For prestressed members, check cover to tendons exceeds the increased amount.
  - From the appropriate Sub-clause, Figure or Table, read-off the axis distance for fire-resistance. The axis distance is $c_{fire} + 0.5d_b$ where d_b is the diameter of the main reinforcement for slabs. For columns and beams the axis distance is $c_{fire} + 0.5d_b + d_f$ where d_b is the diameter of the main reinforcement and d_f is the diameter of the fitment reinforcement. For walls, an assessment will need to be made as to which is the critical bar, and which layer they are, to arrive at a value for c_{fire}. With different bar diameters in the main reinforcement, an average axis distance can be calculated based on formulae given in AS3600-Clause 5.2.1.

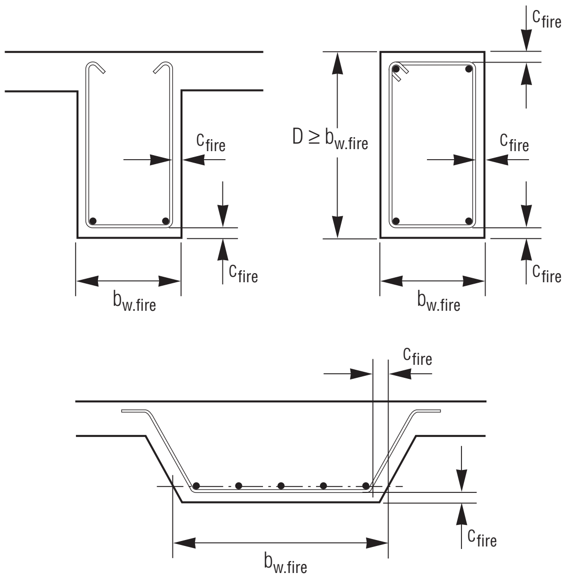
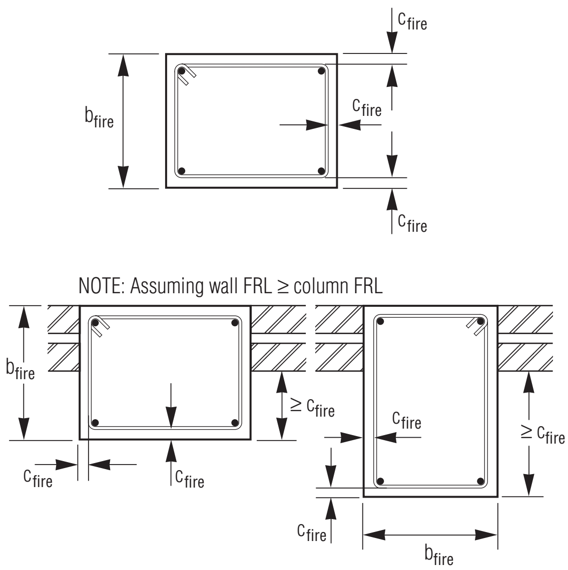


Figure 5.1 *Minimum Beam Widths for Fire*

Figure 5.2 *Minimum Column Widths for Fire*



5.6.3 **Actual Cover for Fire Protection**

For slabs and walls, c_{fire} refers to any load-carrying reinforcement, but obviously the critical steel is that closest to the surface to be protected.

For beams and columns, c_{fire} refers to the load-carrying longitudinal bars or tendons, not to the fitments, see **Figures 5.1** and **5.2**.

5.7 FINAL SECTION OF THE APPROPRIATE DESIGN COVER "c"

The design cover for each component of steel in the member, "c" is the largest value of the covers required for corrosion protection of the steel (**Clause 5.5**), the cover for placement of concrete based on aggregate size, bar size, duct size, etc and concrete compaction (**Clause 5.4.4**) and for fire protection (**Clause 5.6.2**). The Bridge Standard AS 5100 has some differences in cover (refer AS 5100 Part 5 Section 4).

5.8 SELECTION OF MEMBER SIZE

Now that the design cover is determined, design for strength and serviceability may be carried out for each member.

It is essential to check that beam and column widths are adequate for fire resistance and concrete-compaction purposes. Tables given in **Chapter 4** of this Handbook should be consulted.

5.9 BAR SUPPORTS AND SPACERS FOR THE MAINTENANCE OF COVER

- ***Selection of the relevant cover*** includes consideration of:
  - The environment to which each concrete surface is exposed.
  - Whether surface abrasion and/or freeze/thaw is possible.
  - The characteristic compressive strength of the concrete used in the design.
  - The type and quality of the formwork.
  - The quality of compaction of the concrete.
  - The maximum nominal aggregate size.
  - The size of the bar, tendon or duct being covered (ie near the surface).
  - The degree of risk to life and property should a fire occur.
  - How the member is intended to act structurally (ie simply supported or continuous) under normal and fire conditions.
- ***Factors which affect the final position in the concrete*** include:
  - The effects of variations during fabrication of bars, and
  - Variations from the designed (specified) position during construction.

Both of these have a set of tolerances for each situation.

The designer therefore uses calculated values of design cover, the detailer shows the relevant values in the drawings and the steel is fixed within the placing envelope. Onsite inspection must therefore not penalise placement within the allowable range. As noted before, if a designer has concerns with tolerance, it is better to increase the cover.

Not only does the weight of steel have to be supported on bottom formwork, but sideways shifting of cages or mats must also be prevented. Beam and column cages have different requirements, as do slab and wall mats.

It is therefore logical, after taking so much care to calculate the cover, that the methods of chairing and spacing the steel should also be specified in considerable detail.

Clauses 3.1.3 and **3.2** of this Handbook, together with AS 3600 Clause 17.2.5 should be consulted. Some limitations may also be placed on the use of types of bar chairs, eg The Steel Reinforcement Institute of Australia recommends that plastic-tipped wire chairs not be used in exposure Classification B2 or worse.

6

Stress Development and Splicing of Reinforcement

6.1 GENERAL

Earlier sections of this Handbook referred to the fact that whilst structures are generally designed in quite large pieces (such as a complete frame or a continuous beam), they must be constructed in quite small segments, called elements. The art of detailing is to ensure that the materials which connect the individual elements together will provide adequate strength and ductility for the total structure. AS3600 Section 13.1 is concerned with developing stress in reinforcement by bond with in-situ concrete.

AS3600 Section 13.2 describes methods of splicing reinforcement within an element or for jointing elements together. The methods used are laps, welds and mechanical splices.

The purpose of the Tables in this Handbook is to provide consistent values for detailers, schedulers and inspectors. Most values are rounded-up as appropriate.

The clauses related to stress development and splicing of reinforcement in AS3600-2009 are new. The earlier provisions (in AS3600-2001) are out of step with the other major international codes/standards, including ACI318-08 and Eurocode 2 (2004), and they often provide an inadequate factor of safety when compared to the available test data. For bars in beams and columns at close centres, AS3600-2001 may be unduly conservative. For small diameter bars in slabs at clear centres greater than 150 mm, AS3600-2001 specifies unconservative lap lengths – often over 50% shorter than specified in any other international code. The new provisions for development and splicing of deformed bars in tension (Clauses 13.1.2 and 13.2.2) bring the Standard into line with the test data and the other major international codes. It also provides Australian designers and detailers, for the first time, with the flexibility to take into account the beneficial effects of confinement by transverse reinforcement and transverse pressure.

6.2 PRINCIPLES OF STRESS DEVELOPMENT

This Handbook assumes that the reader has a basic knowledge of topics such as bond strength, development length and so on. There are a number of publications available from the Cement Concrete and Aggregates Australia, the Concrete Institute of Australia and by other well-known authors. AS3600 Section 13.1 and its associated commentary give the technical background to stress development as required by the standard.

6.2.1 Basic Development Length of Deformed Bars in Tension $L_{sy.tb}$ (AS 3600 Clause 13.1.2.2)

The development length formula can be expressed as follows:

$$L_{sytb} = \frac{\text{Depth Factor x Cover and Bar Spacing Factor x Yield Strength x Bar Diameter}}{\text{Bar Diameter Factor x }\sqrt{\text{concrete strength}}}$$

A tabulation of the basic development length L_{sytb} is given in **Table 6.1** and **Table 6.2** and which table is used depends on the depth factor.

For concrete strengths greater than 65MPa, use the values obtained for 65MPa concrete grade.

The values of the basic development length L_{sytb} are factored for various conditions as listed below.

(a) Multiplied by 1.5 for epoxy-coated bars
(b) Multiplied by 1.3 for lightweight concrete
(c) Multiplied by 1.3 for slip formed structures
(d) Multiplied by 1.5 for plain bar

The k_3 factor used in the basic development length which relates to cover and clear bar spacing to the next parallel bar uses a c_d value. An explanation of 'c_d' is provided in **Figure 6.2** based on Figure 13.1.2(A) of AS3600.

6.2.2 Refinement of the Basic Development Length.

AS3600 Clause 13.1.2.3 provides for the refinement of the basic development length by multiplying it by up to two factors as applicable.

The effect of transverse reinforcement is accounted for in the k_4 factor, **Table 6.3**. An explanation of 'K' is provided in **Figure 6.3**, based on Figure 13.1.2B of AS3600-2009.

Care should be exercised when using this factor as it may result in two different development lengths depending on the position of the bar; especially in slabs. For example, a bar in a slab laid in the first layer (K=0 in Figure 6.2) could have a longer development length than a bar in the second layer (K=0.5 in Figure 6.2). This is one instance where it would be desirable to specify the development length on the drawings.

The k_5 factor provides for a reduction where there is transverse compressive pressure along the development length perpendicular to the plane of splitting. See **Table 6.4**.

Remember the product k_3, k_4, k_5 must not be taken as less than 0.7. In practice, this means that the maximum reduction of the basic development length is 30%.

In checking the product of k_3, k_4, k_5 so that it is not less than 0.7, the k_3 factor is required. This factor has been included in the basic development length in **Tables 6.1** and **6.2**. Therefore **Table 6.5** is provided so that this check can be easily completed.

6.2.3 What to do if Less than Full Strength is to be Developed

AS 3600 Clause 13.1.2.4 permits a reduced embedment of a bar if the stress to be developed is less than the yield strength f_{sy}.

Use of this Clause by detailers requires considerable caution. If used, the value of the actual design stress must be stated so that checking engineers and inspectors will realise that a short length is acceptable.

6.2.4 What to do if Inadequate Length is Available for Stress Development

Use standard hooks. AS 3600 Clause 13.1.2.6 allows the development length of a deformrd bar with a standard hook to be reduced to 0.5Lsy.t. For plain bars, the development length may also be reduced to 0.5Lsy.t.

There are several reasons why a hook would be used:

- To anchor the ends of fitments so that the yield strength of the steel is developed over a shorter distance.
- To provide end anchorage of a bar where there is insufficient embedment for a straight length to develop its design stress.

Hooks are defined in AS 3600 Clauses 13.1.2.7 and 17.2.3.2. The length of steel needed to physically make each hook (which must be scheduled) is given in **Table 6.6** and shown in the diagrams with the Table. The length of steel in a bar with one hook is the overall length of the straight portion plus the hook length requirement.

Figure 6.1 illustrates the reduced development length using a standard hook.

The bars are both fully developed at the point χ, shown in each figure.

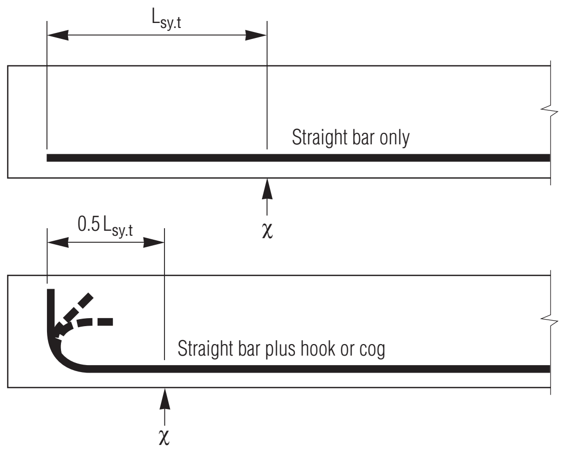
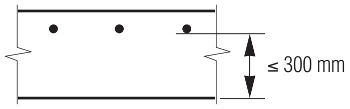


Figure 6.1 *Reduction of Straight Development Length through use of a Hook or Cog*

Table 6.1 *Basic Development Lengths, L_{sytb} (mm) for Grade D500N Bars in tension calculated by AS 3600 Clause 13.1.2.2*

k_1 = 1.0



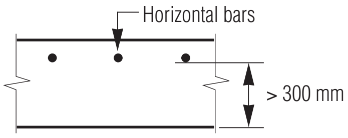
f'c (MPa)	c_d (mm)	Bar size N10	N12	N16	N20	N24	N28	N32	N36
20	20	390	510	750	1000	1250	1510	1790	2100
	25	360	470	710	970	1240	1510	1790	2100
	30	330	440	670	930	1200	1490	1790	2100
	35	330	400	640	890	1160	1450	1770	2100
	40	330	400	600	850	1120	1410	1730	2070
	45	330	400	570	820	1080	1370	1680	2020
	50	330	400	540	780	1050	1330	1640	1980
	55	330	400	540	740	1010	1290	1600	1940
	60	330	400	540	700	970	1250	1560	1890
	65	330	400	540	700	930	1210	1520	1850
	70	330	400	540	700	890	1170	1480	1800
	75	330	400	540	700	870	1130	1430	1760
25	20	350	450	670	900	1120	1350	1600	1880
	25	320	420	640	860	1110	1350	1600	1880
	30	290	390	600	830	1070	1340	1600	1880
	35	290	360	570	800	1040	1300	1580	1880
	40	290	350	540	760	1000	1260	1540	1850
	45	290	350	510	730	970	1230	1510	1810
	50	290	350	490	700	940	1190	1470	1770
	55	290	350	490	660	900	1160	1430	1730
	60	290	350	490	630	870	1120	1390	1690
	65	290	350	490	630	830	1080	1360	1650
	70	290	350	490	630	800	1050	1320	1610
	75	290	350	490	630	780	1010	1280	1580
32	20	310	400	590	790	990	1190	1420	1660
	25	290	380	560	760	980	1190	1420	1660
	30	290	350	530	730	950	1180	1420	1660
	35	290	350	510	710	920	1150	1400	1660
	40	290	350	480	680	890	1120	1370	1630
	45	290	350	470	650	860	1090	1330	1600
	50	290	350	470	620	830	1050	1300	1570
	55	290	350	470	590	800	1020	1270	1530
	60	290	350	470	580	770	990	1230	1500
	65	290	350	470	580	740	960	1200	1460
	70	290	350	470	580	700	930	1170	1430
	75	290	350	470	580	700	900	1130	1390

f'c (MPa)	c_d (mm)	Bar size N10	N12	N16	N20	N24	N28	N32	N36
40	20	290	360	530	710	880	1070	1270	1490
	25	290	350	500	680	880	1070	1270	1490
	30	290	350	480	660	850	1060	1270	1490
	35	290	350	470	630	820	1030	1250	1490
	40	290	350	470	600	800	1000	1220	1460
	45	290	350	470	580	770	970	1190	1430
	50	290	350	470	580	740	940	1160	1400
	55	290	350	470	580	710	920	1130	1370
	60	290	350	470	580	700	890	1100	1340
	65	290	350	470	580	700	860	1070	1310
	70	290	350	470	580	700	830	1040	1280
	75	290	350	470	580	700	820	1010	1250
50	20	290	350	470	640	790	960	1140	1330
	25	290	350	470	610	790	960	1140	1330
	30	290	350	470	590	760	950	1140	1330
	35	290	350	470	580	740	920	1120	1330
	40	290	350	470	580	710	900	1090	1310
	45	290	350	470	580	700	870	1070	1280
	50	290	350	470	580	700	840	1040	1250
	55	290	350	470	580	700	820	1010	1230
	60	290	350	470	580	700	820	990	1200
	65	290	350	470	580	700	820	960	1170
	70	290	350	470	580	700	820	930	1140
	75	290	350	470	580	700	820	930	1120
65	20	290	350	470	580	700	840	1000	1170
	25	290	350	470	580	700	840	1000	1170
	30	290	350	470	580	700	830	1000	1170
	35	290	350	470	580	700	820	980	1170
	40	290	350	470	580	700	820	960	1150
	45	290	350	470	580	700	820	940	1120
	50	290	350	470	580	700	820	930	1100
	55	290	350	470	580	700	820	930	1080
	60	290	350	470	580	700	820	930	1050
	65	290	350	470	580	700	820	930	1050
	70	290	350	470	580	700	820	930	1050
	75	290	350	470	580	700	820	930	1050

NOTES:

(1) Values have been rounded-up to the nearest 10 mm and provide for tolerances.
(2) The tables have been adjusted for the minimum development lenth of 29 d_b as per Clause 13.1.2.2 of AS 3600.
(3) The dimension c_d in this table is determined from the specified cover to the deformed bar being detailed or the specified spacing between bars being anchored. No allowance is made for possible reduction in cover due to placing tolerances, since the strength reduction factor ϕ used in the determination of steel quantities has already made such an allowance. If a designer believes that the situation is critical, the expected minimum cover (specified cover minus tolerance) can be used to determine c_d.
(4) Bar termination points are usually shown on the drawings, rather than specified development lengths.

Table 6.2 *Basic Development Lengths, $L_{sy.tb}$ (mm) for Grade D500N Bars in tension calculated by AS 3600 Clause 13.1.2.2*



k_1 = 1.3

f'c (MPa)	cd (mm)	N10	N12	N16	N20	N24	N28	N32	N36
20	20	510	660	970	1300	1620	1960	2330	2730
	25	470	610	920	1250	1610	1960	2330	2730
	30	420	570	880	1210	1560	1940	2330	2730
	35	420	520	830	1160	1510	1890	2300	2730
	40	420	510	780	1110	1460	1840	2240	2680
	45	420	510	730	1060	1410	1780	2190	2630
	50	420	510	710	1010	1360	1730	2130	2570
	55	420	510	710	960	1310	1680	2080	2510
	60	420	510	710	910	1260	1630	2030	2460
	65	420	510	710	910	1210	1570	1970	2400
	70	420	510	710	910	1160	1520	1920	2340
	75	420	510	710	910	1140	1470	1860	2290
25	20	460	590	870	1170	1450	1750	2080	2440
	25	420	550	830	1120	1440	1750	2080	2440
	30	380	510	780	1080	1400	1740	2080	2440
	35	380	470	740	1040	1350	1690	2060	2440
	40	380	460	700	990	1300	1640	2010	2400
	45	380	460	660	950	1260	1600	1960	2350
	50	380	460	630	900	1210	1550	1910	2300
	55	380	460	630	860	1170	1500	1860	2250
	60	380	460	630	820	1120	1450	1810	2200
	65	380	460	630	820	1080	1410	1760	2150
	70	380	460	630	820	1030	1360	1710	2100
	75	380	460	630	820	1020	1310	1670	2050
32	20	410	520	770	1030	1280	1550	1840	2160
	25	380	490	730	990	1270	1550	1840	2160
	30	380	460	690	950	1230	1540	1840	2160
	35	380	460	660	920	1190	1490	1820	2160
	40	380	460	620	880	1150	1450	1770	2120
	45	380	460	610	840	1110	1410	1730	2080
	50	380	460	610	800	1070	1370	1690	2030
	55	380	460	610	760	1030	1330	1650	1990
	60	380	460	610	760	990	1290	1600	1940
	65	380	460	610	760	950	1250	1560	1900
	70	380	460	610	760	910	1200	1520	1850
	75	380	460	610	760	910	1160	1470	1810
40	20	380	470	690	920	1150	1390	1650	1930
	25	380	460	650	890	1140	1390	1650	1930
	30	380	460	620	850	1100	1370	1650	1930
	35	380	460	610	820	1070	1340	1630	1930
	40	380	460	610	780	1030	1300	1590	1900
	45	380	460	610	760	1000	1260	1550	1860
	50	380	460	610	760	960	1230	1510	1820
	55	380	460	610	760	930	1190	1470	1780
	60	380	460	610	760	910	1150	1430	1740
	65	380	460	610	760	910	1110	1400	1700
	70	380	460	610	760	910	1080	1360	1660
	75	380	460	610	760	910	1060	1320	1620
50	20	380	460	620	830	1030	1240	1480	1730
	25	380	460	610	790	1020	1240	1480	1730
	30	380	460	610	760	990	1230	1480	1730
	35	380	460	610	760	960	1200	1460	1730
	40	380	460	610	760	920	1160	1420	1700
	45	380	460	610	760	910	1130	1390	1660
	50	380	460	610	760	910	1100	1350	1630
	55	380	460	610	760	910	1060	1320	1590
	60	380	460	610	760	910	1060	1280	1560
	65	380	460	610	760	910	1060	1250	1520
	70	380	460	610	760	910	1060	1210	1480
	75	380	460	610	760	910	1060	1210	1450
65	20	380	460	610	760	910	1090	1290	1520
	25	380	460	610	760	910	1090	1290	1520
	30	380	460	610	760	910	1080	1290	1520
	35	380	460	610	760	910	1060	1280	1520
	40	380	460	610	760	910	1060	1250	1490
	45	380	460	610	760	910	1060	1220	1460
	50	380	460	610	760	910	1060	1210	1430
	55	380	460	610	760	910	1060	1210	1400
	60	380	460	610	760	910	1060	1210	1370
	65	380	460	610	760	910	1060	1210	1360
	70	380	460	610	760	910	1060	1210	1360
	75	380	460	610	760	910	1060	1210	1360

NOTES:

(1) Values have been rounded-up to the nearest 10 mm and provide for tolerances.

(2) The tables have been adjusted for the minimum development lenth of 37.7 d_b as per Clause 13.1.2.2 of AS 3600.

(3) The dimension c_d in this table is determined from the specified cover to the deformed bar being detailed or the specified spacing between bars being anchored. No allowance is made for possible reduction in cover due to placing tolerances, since the strength reduction factor ϕ used in the determination of steel quantities has already made such an allowance. If a designer believes that the situation is critical, the expected minimum cover (specified cover minus tolerance) can be used to determine c_d.

(4) Bar termination points are usually shown on the drawings, rather than specified development lengths.

Table 6.3 *Value of k_4 Factor after AS 3600 Clause 13.1.2.3*

	Effect of transverse reinforcement				See **Figure 6.3** for value of K				Note: $0.7 \le k_4 \le 1.0$				
	Value of k_4 Factor for λ										$k_4 = 1.0 - K\lambda$		
K	0.20	0.40	0.60	0.80	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00
0.10	0.98	0.96	0.94	0.92	0.90	0.85	0.80	0.75	0.70	0.70	0.70	0.70	0.70
0.05	0.99	0.98	0.97	0.96	0.95	0.93	0.90	0.88	0.85	0.83	0.80	0.78	0.75
0.0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

NOTE: When using multiple Factors, $k_3 \times k_4 \times k_5 \ge 0.7$

$\lambda = (\Sigma A_{tr} - \Sigma A_{tr.min})/A_s$ where: ΣA_{tr} is cross-sectional area of transverse reinforcement along the development length L_{syt}

$\Sigma A_{tr.min}$ is cross-sectional area of minimum transverse reinforcement (may be taken as $0.25A_s$ for beams or columns and 0 for slabs or walls.

A_s is cross-sectional area of a single anchored bar of diameter d_b

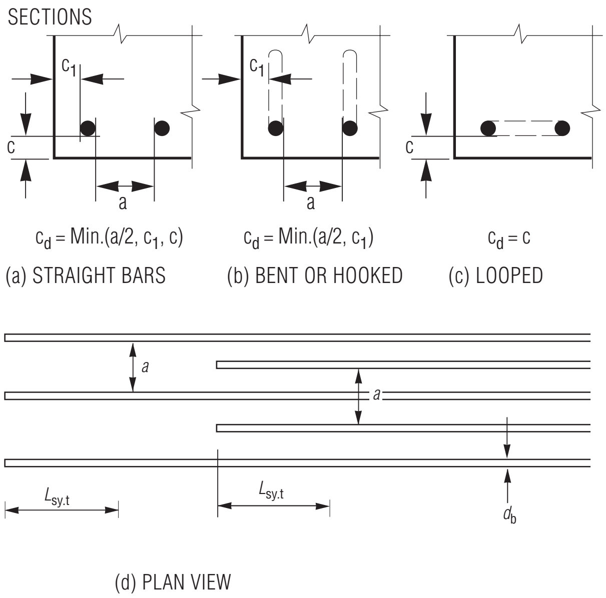


Figure 6.2 *Values of c_d for Beams and Slabs*

Table 6.4 *Value of k_5 Factor after AS 3600 Clause 13.1.2.3*

Accounting for transverse compressive pressure						
Value of k_5 Factor for pressure, p_p (MPa)						
1.0	2.0	3.0	4.0	5.0	6.0	7.0
0.96	0.92	0.88	0.84	0.80	0.76	0.72

NOTE: When using multiple Factors, $k_3 \times k_4 \times k_5 \ge 0.7$

$k_5 = 1.0 - 0.04 p_p$ where: p_p is transverse compressive pressure (MPa) at ultimate limit state along development length perpendicular to plane of splitting ($0.7 \le k_5 \le 1.0$)

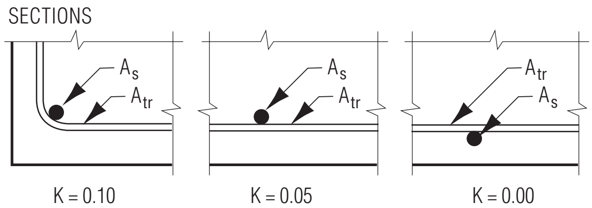


Figure 6.3 *Values of K for beams and slabs*

Table 6.5 *Value of k_3 Factor after AS 3600 Clause 13.1.2.3*

	Effect of cover and bar spacing				See **Figure 6.2** for value of c_d			$k_3 = 1.0 - 0.15(c_d - d_b)/d_b$ (but $0.7 \le k_3 \le 1.0$		
c_d	Value of k_3 Factor for Grade D500N bars of size (mm)									
(mm)	10	12	16	20	24	28	32	36	40	50
20	0.85	0.90	0.96	1.00	–	–	–	–	–	–
25	0.78	0.84	0.92	0.96	0.99	–	–	–	–	–
30	0.70	0.78	0.87	0.93	0.96	0.99	–	–	–	–
35	0.70	0.71	0.82	0.89	0.93	0.96	0.99	–	–	–
40	0.70	0.70	0.78	0.85	0.90	0.94	0.96	0.98	1.00	–
45	0.70	0.70	0.73	0.81	0.87	0.91	0.94	0.96	0.98	–
50	0.70	0.70	0.70	0.78	0.84	0.88	0.92	0.94	0.96	1.00
55	0.70	0.70	0.70	0.74	0.81	0.86	0.89	0.92	0.94	0.99
60	0.70	0.70	0.70	0.70	0.78	0.83	0.87	0.90	0.93	0.97
65	0.70	0.70	0.70	0.70	0.74	0.80	0.85	0.88	0.91	0.96
70	0.70	0.70	0.70	0.70	0.71	0.78	0.82	0.86	0.89	0.94
75	0.70	0.70	0.70	0.70	0.70	0.75	0.80	0.84	0.87	0.93

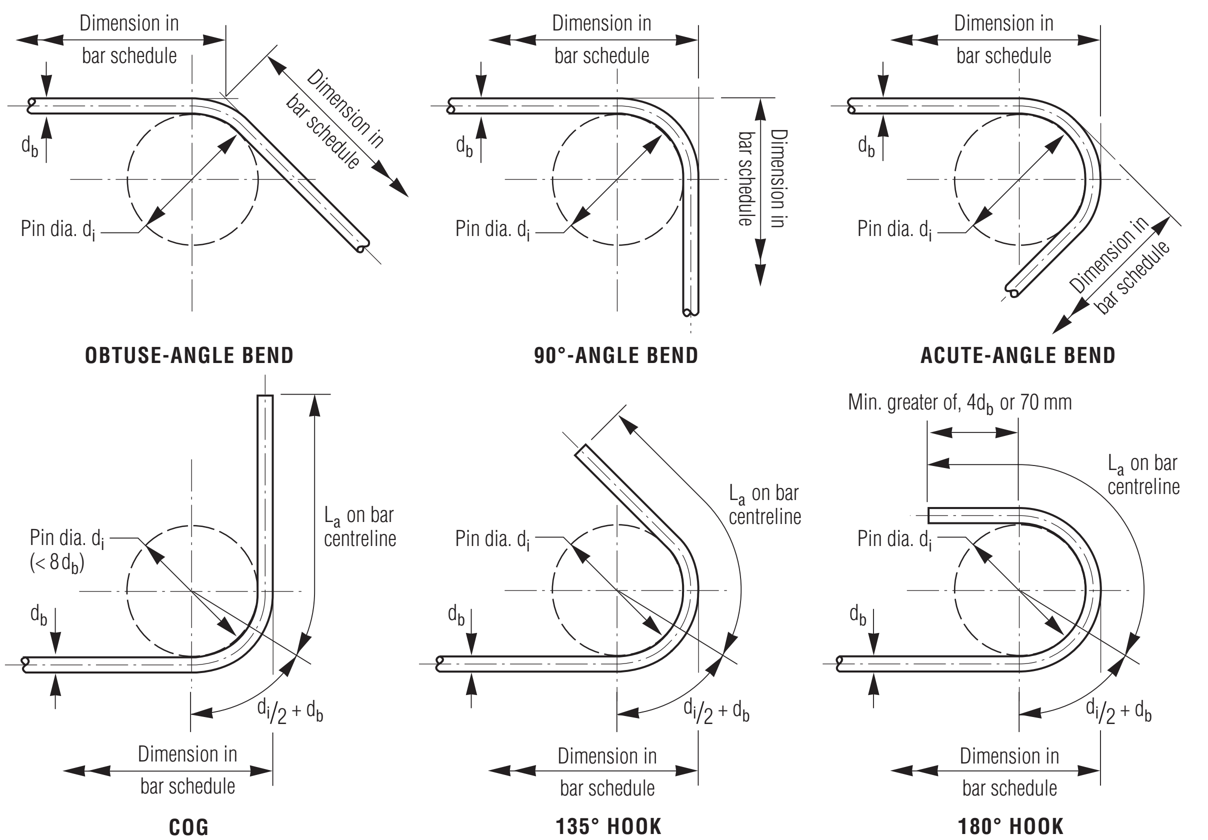
NOTE: When using multiple Factors, $k_3 \times k_4 \times k_5 \ge 0.7$

6.2.5 Cautionary Note on the Use of Hooks

Whether or not a bar should be hooked is a matter for the designer to specify, not for the detailer to decide. Although hooked deformed bars can reduce the development length, hooks cause congestion of steel in critical areas and are a primary source of rusting if allowed to enter the concrete cover. Straight bars are much easier to fix and protect. If there is so little room available that hooks are required, it may be a better solution to use a greater number of smaller-sized bars with a smaller development length. **Table 4.4** helps select bar combinations for area requirements.

Hooks should never be used in sections thinner than about 12 bar diameters or as top bars in slabs.

Table 6.6 *Hook and Cog Length Requirements*



Minimum length of bar, L_a (mm) to form a standard hook or cog

Type of bar	Min. pin dia., d_i	Bar diameter, d_b (mm) 6	10	12	16	20	24	28	32	36
Fitments:										
D500L & R250N bars	$3d_b$	100	110	120	*	*	*	*	*	*
D500N bars	$4d_b$	110	130	140	170	200	230	270	300	340
Reinforcement other than those below	$5d_b$	120	140	160	180	220	260	300	340	380
Bends designed to be straightened or subsequently rebent	$4d_b$	110	130	140	170	*	*	*	*	*
	$5d_b$	*	*	*	*	220	260	*	*	*
	$6d_b$	*	*	*	*	*	*	330	380	430
Bends in reinforcement epoxy-coated or galvanised either before or after bending	$5d_b$	120	140	160	180	*	*	*	*	*
	$8d_b$	*	*	*	*	290	340	390	440	500

* Not to be used

Table 6.7 shows minimum overall dimensions of a hook or cog. The physical size of the hook is defined by its stress-development capacity. Hooks must never be specified as being cut back in size because they are then useless for anchorage. Because of the weight of a hook, it will tend to point downwards to the soffit unless properly tied. A straight bar will not rotate in this way.

6.3 DEVELOPMENT LENGTH OF DEFORMED BARS IN COMPRESSION, $L_{sy.c}$

AS 3600:2009 has a new clause covering development length for bars in compression. Previously all development lengths were $20d_b$ but this new provision is slightly affected by concrete strength. Values for $L_{sy.c}$ are given in **Table 6.8**. The k_6 value of 0.75 may only be used where the transverse reinforcement complies with AS 3600 Clause 13.1.5.3.

Although it is not stated in AS 3600 Clause 13.1.5, the minimum cover and spacing rules still apply. (See **Clause 5.4.4**). Compression causes splitting of the cover in a different way to tensile forces. Bars in compression should not be hooked.

6.4 DEVELOPMENT LENGTH OF BUNDLED BARS (AS 3600 Clauses 8.1.10.8, 10.7.1, 13.1.7, 13.2.5)

Two bars may be tied together to form a bundle, but no increase in development length is specified. Three or four bars can be tied tightly together to form a bundle. Each bar of the "unit" therefore presents a smaller surface area in contact with the surrounding concrete. This requires an increased development length for both compression and tension.

In beams, the bar cut-off point of each bar in a bundle must be staggered by $40d_b$.

6.5 DEVELOPMENT LENGTH OF MESH IN TENSION (AS 3600 Clause 13.1.8)

Welded mesh develops stress in one bar through its normal adhesive bond with concrete, plus bearing of the cross bars welded to it against the concrete.

The shear strength developed by each weld is at least 250 MPa, provided that the relative diameters of the bars do not differ by more than 3 mm. AS 3600:2009 has a more complex formula for calculation of a basic development length for mesh, where reliance is made in full or in part on the weld shear strength. This formula depends on the spacing of the bars S_m, the size of the bars and the concrete strength. For deformed wire meshes when one cross-wire is located within the development length, values may be chosen from **Table 6.9**.

For meshes with no cross bars within the development length the provision of Clause 13.1.2 or 13.1.3 apply and designers can use the Tables in **Clause 6.2**.

6.6 STRENGTH DEVELOPMENT BY A WELDED OR MECHANICAL CONNECTION

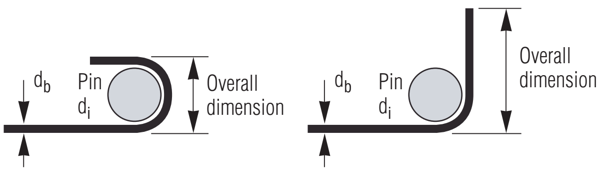
The design and location of these anchorages requires calculations beyond the scope of this Handbook. Section 13.2.6 of AS 3600, and AS 1554, Part 3, should be consulted together with the manufacturer's technical information if applicable.

6.7 GENERAL COMMENTS ON SPLICING REINFORCEMENT

6.7.1 General

Whether or not the project being detailed is a small building or a large civil engineering structure, the

Table 6.7 *Overall Dimensions (mm) of 180° Hooks and 90° Cogs*



Pin dia. d_i	Bar diameter, d_b (mm) 6	10	12	16	20	24	28	32	36
180° Hooks									
$3d_b$	30	50	60	*	*	*	*	*	*
$4d_b$	40	60	70	100	120	140	170	190	220
$5d_b$	40	70	80	110	140	170	200	220	250
$6d_b$	50	80	100	130	160	190	220	260	290
$8d_b$	60	100	120	160	200	240	280	320	360
90° Cogs									
$3d_b$	120	140	160	*	*	*	*	*	*
$4d_b$	130	150	170	200	240	280	330	370	420
$5d_b$	130	160	180	210	260	310	360	400	450
$6d_b$	140	180	200	240	290	340	400	450	510
$8d_b$	160	200	230	280	340	400	470	530	600

* Not to be used (See **Table 6.6** for other limitations)
The bar sizes are nominal

location and design of splices to hold the concrete elements together is a critical factor for the designer and builder, and the necessary detailing will occupy much of this Handbook.

All splices must be designed to carry the full design strength of the steel f_{sy} in tension or compression. No reduction in the splice length is permitted even when the calculated design stress is less than f_{sy}.

Included within the topic of splices will be the connection between:

- A footing and the column or wall that it supports,
- A column below a floor and its continuation above,
- A column and the beams it supports,
- The elements connected by a construction or movement joint,
- Walls at corners,
- Walls and slabs, particularly if the former are being slip-formed.

AS 3600 Section 13.2 and its commentary provide the rules and the background.

6.7.2 Lap-Splices of Bars and Mesh

Welded and mechanical splices need design input and reference to manufacturers' catalogues, and cannot be tabulated.

The dimension of a lap-splice is so important for the strength of the structure that its length, in

Table 6.8 *Compression Development Lengths, $L_{sy.c}$ (mm) for Grade D500N Bars calculated by AS 3600 Clause 13.1.5*

Where non-complying transverse reinforcement is present

k_6 = 1.00

Concrete f'c (MPa)	Compression development length, $L_{sy.c}$ (mm) for Grade D500N bars of size (mm)									
	10	12	16	20	24	28	32	36	40	50
20	250	300	400	500	600	690	790	890	990	1230
25	220	270	360	440	530	620	710	800	880	1100
32	220	270	350	440	530	610	700	790	870	1090
40	220	270	350	440	530	610	700	790	870	1090
50	220	270	350	440	530	610	700	790	870	1090
65	220	270	350	440	530	610	700	790	870	1090
80	220	270	350	440	530	610	700	790	870	1090
100	220	270	350	440	530	610	700	790	870	1090

Where complying transverse reinforcement is present

k_6 = 0.75

Concrete f'c (MPa)	Compression development length, $L_{sy.c}$ (mm) for Grade D500N bars of size (mm)									
	10	12	16	20	24	28	32	36	40	50
20	200	230	300	380	450	520	600	670	750	930
25	200	210	270	330	400	470	540	600	660	830
32	200	210	270	330	400	460	530	600	660	820
40	200	210	270	330	400	460	530	600	660	820
50	200	210	270	330	400	460	530	600	660	820
65	200	210	270	330	400	460	530	600	660	820
80	200	210	270	330	400	460	530	600	660	820
100	200	210	270	330	400	460	530	600	660	820

Notes:
1. Values are rounded-up to the nearest 10 mm.
2. The development length for a plain bar in compression is twice the value for a defomed bar of the same size.

millimetres, must be given in the drawings to ensure consistency and avoid errors during detailing, checking of the design, reinforcement scheduling, construction and supervision.

Lap-lengths need only be based on the diameter of the SMALLER bar to be spliced because the force in that bar is the maximum which can be transferred.

If the size of only one bar is known, then the lap length should be specified for that bar. This situation commonly occurs when adjacent concrete elements are detailed on different drawings, or when protruding bars are to form part of a future construction joint for which details are not yet available.

The reason is that if the second bar is found to be smaller, then the lap length provided will be longer than necessary; if the second bar is larger, then the original lap length for the known bar will be acceptable.

6.8 TENSILE LAP-SPLICES FOR DEFORMED BARS (AS 3600 Clause 13.2.2)

When lapped portions of bars are in contact or spaced less than $3d_b$ apart, the lap splice length of a bar in tension $L_{sy.t}$ lap is the value of the development length, $L_{sy.t}$, multiplied by k_7 =1.25. Use **Tables 6.1** to **6.4** for tensile development lengths.

Bars spliced by non-contact lap splices further apart than $3d_b$, the lap length is the larger of 1.25 $L_{sy.t}$ and $L_{sy.t} + 1.5S_b$ (where S_b is the clear distance between bars of the non contact splice as shown in Figure 6.4).

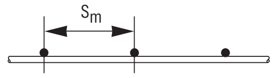
S_b is taken as zero when the distance between the bars of the lap splice is less than $3d_b$.

Lap-splices must always be based on full yield stress transfer. When A_s provided is at least twice A_s required and when no more than half the reinforcement at this section is spliced, then the factor k_7 may be reduced to k_7 =1.0.

- Application of the values are not as complicated as they seem at first sight. For example, on each floor of a building, the same concrete strength is usually specified. The cover also will be the same in most cases (if not, then this fact must be made very clear to the construction workers!). Detailers should therefore select a small set of combinations that will apply most of the time, and these can be tabulated in the drawings.

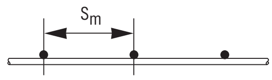
Table 6.9 *Development Length in Tension, $L_{sy.tb}$ (mm) for Grade D500L Mesh calculated by AS 3600 Clause 13.1.8*

s_m = 200



Concrete f'c (MPa)	Development length in tension, $L_{sy.tb}$ (mm) for Grade D500L mesh of bar size (mm)						
	6.0	6.75	7.6	8.6	9.5	10.7	11.9
20	100	100	100	110	130	170	210
25	100	100	100	100	120	150	190
32	100	100	100	100	110	130	160
40	100	100	100	100	100	120	150
50	100	100	100	100	100	110	130
65	100	100	100	100	100	100	120
80	100	100	100	100	100	100	110
100	100	100	100	100	100	100	100

s_m = 100



Concrete f'c (MPa)	Development length in tension, $L_{sy.tb}$ (mm) for Grade D500L mesh of bar size (mm)						
	6.0	6.75	7.6	8.6	9.5	10.7	11.9
20	110	140	170	220	260	330	410
25	100	120	150	190	240	300	370
32	100	110	140	170	210	260	320
40	100	100	120	150	190	240	290
50	100	100	110	140	170	210	260
65	100	100	100	120	150	190	230
80	100	100	100	110	130	170	210
100	100	100	100	100	120	150	190

Care should be taken if the k_4 factor has been used to refine the development length as it will not apply to the outermost layers of reinforcing bars

- On small jobs, it may be advisable to reduce the choice even further, in which case the largest splice-length should be given. As a general rule, provide a table for only one combination of f'_c and cover, and give exceptions on each detail.
- Splice away from maximum stress zone. Although it is a design matter, bars should not be spliced in any element at points of maximum design stress, but the above values must still be used.
- Dimension it. Only the designer has access to the calculations and understands them. Only he will know whether the bar is stressed in tension or compression. Wherever there is a doubt, the

required lap dimensions should be shown.

- Tolerances. The development lengths taken from **Tables 6.1** to **6.4** allow for the bar tolerances given in AS 3600, Section 17. See also **Chapter 3** of this Handbook.
- Overlapped bars not a splice. See **Clause 6.13** for comments on overlapped bars which do not require full strength lap-splices.
- Plain bars. There are no values given for lap-splicing plain bars.

6.9 MESH LAP-SPLICES (AS 3600 Clause 13.2.3)

Mesh laps are generally much easier to specify than bar laps, as they are not dependent on concrete strength or cover, or on the bar strength. The laps are specified only in relation to the spacing of the cross-bars.

In this part of the Handbook, the term 'cross-bar' is used to describe the bar which is welded to the bar being spliced. The 'cross-bar' therefore provides the anchorage necessary for strength development.

Although it is common to describe laps in relation to the sheet edges, that is as 'end-laps' or 'side-laps', this distinction is not really necessary. The following four cases account for all combinations of cross-bar spacings and spliced-bar overhangs.

Figure 6.5 shows the same orientation of bars; that is the sheets are shown as not nested. This orientation is illustrative only. The critical factor is the amount of overlap of the outermost bars. The lapped bars may be in the same plane or be separated by one or two transverse bars.

CASE 'A' Cross-bars have same spacing Spliced-bar overhang small. The two outermost bars of 'Sheet 1' overlap the two outermost bars of 'Sheet 2'.

CASE 'B' Cross-bars have same spacing. Spliced bars have useable overhang. The two outermost bars of 'Sheet 1' overlap the two outermost bars of 'Sheet 2', but the overhangs do not contribute.

CASE 'C' Cross-bars have differing spacing. Spliced-bar overhang not significant. The two outermost bars of 'Sheet 1' overlap the two outermost bars of 'Sheet 2', but the overhangs do not contribute.

CASE 'D' Cross-bars have differing spacing. Spliced-bar overhang not significant. The two

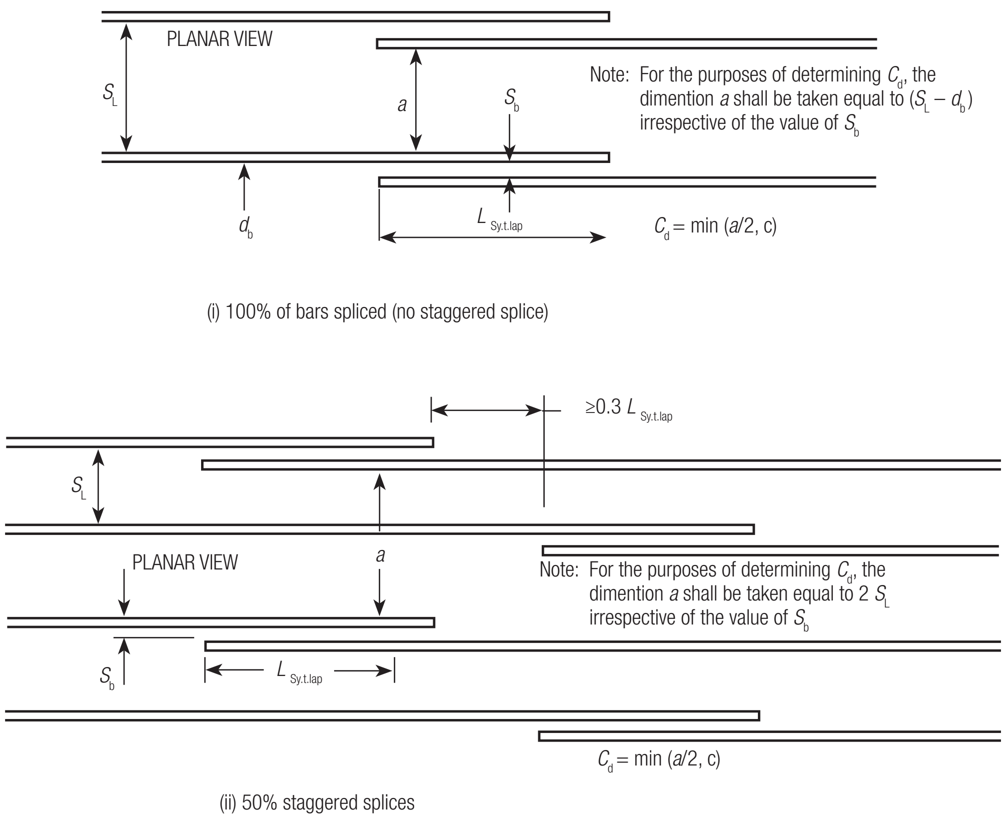


Figure 6.4 *Value of c_d for lapped splices (Figure 13.2.2 of AS 3600-2009)*

Example 6.1 Specification of Lap Splices in a Drawing

Specification: Reinforcement shall not be spliced except where shown in the drawings. The splice length of bars shall be as given in the following Table, except where other dimensions are stated on the actual detail. Spliced bars shall be in contact or spaced less than $3d_b$ apart. The factors k_1, k_4 and k_5 have all been taken as 1.0.

Type of member	f'_c (MPa)	Cover (mm)	Tensile lap length (mm) for grade D500N bars of size (mm)							
			10	12	16	20	24	28	32	36
Slab or wall	25	20	440	570	830	1130	-	-	-	-
		25	400	530	800	1080	1390	-	-	-
Other main bars	25	40	360	440	680	960	1260	1590	1920	2310
		50	360	440	610	880	1180	1490	1840	2210

NOTE:
All lap lengths rounded up to the nearest 10mm

outermost bars of 'Sheet 1' have not overlapped the two outermost bars of 'Sheet 2', the overhangs do not contribute, and the splice is NOT CORRECT.

Suggested specification: Mesh sheets shall be lap-spliced so that the two outermost transverse bars of one sheet overlap at least the two outermost bars of the other sheet. (Sketches similar to **Figure 6.5** may be added if desired).

6.10 COMPRESSION LAP-SPLICES FOR DEFORMED BARS (AS 3600 Clause 13.2.4)

For D500N bars in a compression zone of the concrete, the lap length is $40d_b$. This is approximately two times the compressive stress development length. Under AS 3600 Clause 13.2.4, there are two other conditions that reduce the lap-splice to 0.8 of the value given above.

Compression bars should not be hooked.

Values are not restricted to use in columns and walls. Where the concrete at the bottom of a beam over a column carries an excessively large compression load, extra bars lapped for compressive stress transfer will be required there. (See **Chapter 13** on beam cages).

6.11 COMPRESSION LAP-SPLICES FOR BUNDLED DEFORMED BARS (AS 3600 Clause 13.2.5)

Lap splicing of bundled bars is messy, complicated, uses excessive steel, and causes overcrowding of the column area. Such splices should be avoided where possible.

See AS 3600 Clause 13.2.5 for the design requirements for splicing main bundled bars.

Wherever possible, bundled bars should be spliced by end bearing (no laps) or by a mechanical splice because these give a simpler solution.

Two bars may be tied together as a bundle but no increase in development length is specified.

6.12 TENSION SPLICE OR COMPRESSION SPLICE, WHICH SHOULD BE USED?

The simple answer is that if a bar can be in tension under one loading condition, and change to compression under another (or vice versa), then the splice must carry the "worst-case" load. As examples, the above situation can occur when the wind blows alternately from opposite directions, or when trucks move across a bridge.

6.13 LAP SPLICES AND OVERLAPPED BARS

There are obviously many situations where there is no need to transfer stress from one bar to the next, except that the ends of bars should be overlapped and tied together for fixing purposes.

In the latter case, the overlap may only need to be 100-150 mm for a small bar and up to 300 mm for a large bar.

In each case, the overlap should be specified in the drawings, otherwise a full splice may be provided, or even worse, a short overlap provided where a full lap is essential.

These overlaps can be tabulated in many cases to avoid repetitive notes.

At the end of some bars a 90° bend can be mistaken for a 90° hook.

Without knowing the purpose of the bend, a clear distinction often cannot be made. As a general rule, most 90° bends are taken to be cogs (90° hooks) having the steel allowance given in **Table 6.6**. Remember that these lengths are the smallest lengths which can be bent around the given pin sizes.

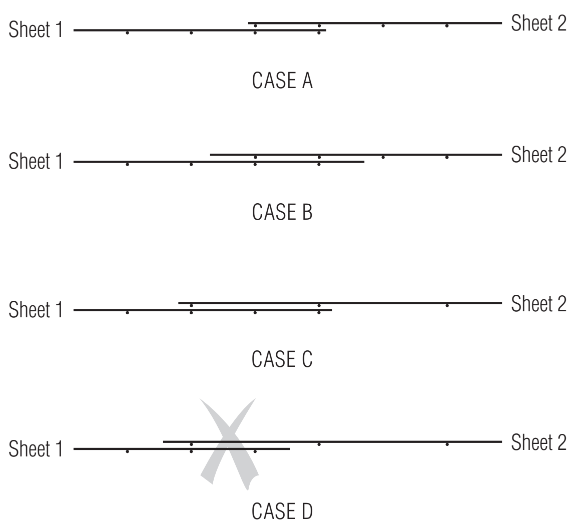


Figure 6.5 *Correct and Incorrect Mesh Lap-Splices*

Where the bar dimension appears to fit into the concrete, allowing for covers, a 90° bend would be assumed. Where it will not fit, then the detail should be revised to avoid the bar-end from sticking out of the concrete.

6.14 STRESS DEVELOPMENT AND COUPLING OF PRESTRESSING TENDONS

This is best left to the designer and prestressing supplier because of the very high forces involved.

Proprietary anchorages, couplers, anti-burst reinforcement and other details are beyond the scope of this Handbook, other than in general statements from time to time in later chapters.

6.15 CRACK CONTROL REINFORCEMENT

This topic is dealt with in the relevant sections for each type of member. The quantity of reinforcement is a design matter, and detailing is similar to that for other reinforcement requirements.

6.16 WELDED AND MECHANICAL ANCHORAGES

These must be detailed in accordance with the manufacturers' instructions and with AS 1554 if applicable.

7

Drawing Standards

7.1 AUSTRALIAN STANDARDS

7.1.1 AS 1100.101:1992 *Technical Drawing, – General Principles*

It contains all the relevant information on drawing sheets, lines, letters and numerals, scales and sectioning. It cross-references other AS 1100 standards such as Parts 201 to 501. This "Reinforcement Detailing Handbook" assumes the detailer/reader is familiar with this standard.

Much of Part 501 was based upon the CIA's "Reinforced Concrete Detailing Manual", 1975 edition.

7.1.2 AS 1100.501:2002 *Technical Drawing – Structural Drawing*

It contains recommendations for the classification of drawings, dimensioning lines, symbols, identification of structural elements, and other matters.

Many of the items related to detailing of reinforced and prestressed concrete will be covered in greater detail in this Handbook.

Clause 1.2 Application reads in part:

"*The standard is intended as a basis for common practice and consistency of application upon which technical organisations can base their own detailed rules or manuals for the preparation and presentation of drafting work*".

This Handbook is prepared under that authority. Where it is considered necessary, some sections of Part 501 will be repeated in this Handbook, although the source may not always be quoted.

7.2 DRAWING STANDARDS FOR REINFORCED CONCRETE

7.2.1 Sizes of Drawings (AS 1100.101)

Recommended sheet sizes are given in Clause 2.4 and layout of drawing sheets in Clause 2.5.

Prints of both architectural and engineering drawings for a particular job should always be on the same size cut sheet.

7.2.2 Drawing Types (AS 1100.501)

Of those listed in AS 1100.501, Clause 1.5, the following are most applicable to structural concrete, with reinforcement and prestressing steel as applicable:

(d) *general information* drawing often containing the "General Notes", and including the requirements of Clause 1.4 of AS 3600 covering such matters as covers, lap lengths, etc.
(a) *design layout* drawing.
(b) *design detail* drawing.

Also listed are:

(c) *shop detail* drawing, which is applicable more to precast concrete and would include items such as formwork, fixings, etc, and have been prepared by the precast concrete manufacturer.
(e) *as-built* drawings, which are not common in smaller projects.

Additional drawings sometimes prepared are:

(f) *design intent* drawings, which show the concrete shapes, and reinforcement areas and arrangements, for further detailing by draftsmen.
(g) *reinforcement marking* plans are usually prepared by the reinforcement scheduler to correlate the reinforcement schedules with their bar marks to the most applicable of the other structural drawings.

Not covered, but of considerable importance for building works are the ***architectural*** drawings (AS 1100.301).

In building work, it is common practice to combine the reinforcement and the concrete outlines on the same drawing, but this should only be done where the reinforcement is simple in plan.

In both civil engineering and structural work, it is also common to prepare a dimensioned concrete outline and a separate reinforcement drawing with the concrete outline drawing not dimensioned. In many cases where there are two layers of reinforcement, each layer would be shown on a separate plan-view. Hard and fast rules cannot be made; clarity and good communications are the ideal.

7.2.3 Title Blocks (AS 1100.101)

Typical layouts are given in AS 1100.101, Figure 2.9, with the type of information to be shown. The initial date of issue must be shown. It is also extremely important that the amendment number and a brief description of changes are shown when they occur as they have significance in the building contract. It is common when making revisions to provide a thin wavy line (cloud) around the section of the drawing that has changed to highlight the changes.

Adequate use of revision letters (A, B, C etc for first, second, third, etc) must be made on all drawings, particularly when A4-size sheets are used to amend details given on larger size sheets. Revision dates are extremely important.

The system for specifying drawing numbers is left to each individual office practice.

7.2.4 Key Drawing and North-Point

Where a portion of the work has to be divided over several drawings, a small diagrammatic key plan on each drawing should be used to define the portion covered.

Always show the North-point on all plan views for rapid orientation. A “Project North-point” is often used so that the terms “North, South, East and West” can be established more easily.

7.2.5 Lines (AS 1100.101 and AS 1100.501)

The object of the line thicknesses recommended in this Handbook is to show how differentiation between line thicknesses can improve clarity of details rather than insisting upon a rigid set of rules. This will permit detailers to maintain a drafting style consistent with the procedures used in their own drawing office.

With CADrafting it is a simply matter to draw complex rebar layouts to any desired scale and even to use double lines to get the diameter into scale; in these cases “thin” lines are appropriate. CADrafting also has the ability to change the intensities of lines at any time from thick to thin, and vice versa.

NOTE: The choice of thick or thin lines for concrete outlines or reinforcing bars as adopted in practice is left to individual office practice. In many situations both systems can be used, even on the same drawing sheet, for differing types of details. Because of the problem of line separation and ensuring clarity of detail, this Handbook has a preference for “thin” concrete outlines to define the limits of the bar shape and a “medium” line for the reinforcement itself.

7.2.5.1 Types of Lines (AS 1100.501)

Line types for use in reinforced concrete detailing are given in AS 1100.501, Table 2.1. Each line type is defined by a designating letter, an example of its appearance and the applications for which each are recommended.

The designating letters are “A” to “K”, plus “M”, “N” and “P”. The types of line are “continuous”, “dashed” and “chain”. “Full”, “broken” and “chain” are terms also used.

7.2.5.2 Line Thickness (AS 1100.101)

In addition to the above, there is a range of line thicknesses given in AS 1100.101, Figure 3.1, Line Groups. Each line group consists of three thicknesses which bear a consistent relationship to each other, the “thin-line” being 0.5 times the “thick-line” and the “medium-line” being 0.7 times the thickest of the group.

The thickness range is suitable for both pen and pencil; when pencil is used, a heavier line is strongly advised to obtain the necessary density and contrast on subsequent prints.

A line thickness of 0.25 mm is common for all dimension, grid and “call-up” lines but AS 1100.101 only permits three thicknesses per group.

A four-pen plotter should be adequate for all concrete work.

Table 7.1 *Range of Thicknesses in Each Line Group (AS 1100.101)*

	Line thickness (mm) for:		
Line Group	Thick	Medium	Thin
1.0 mm group	1.0	0.7	0.5
0.7 mm group	0.7	0.5	0.35

All lettering should comply with Section 4 of AS 1100.101. Line thicknesses for lettering of general notes, material lists, dimensions, reinforcement notation, etc, should not be less than 0.35 mm.

7.2.5.3 Line Separation

Parallel lines drawn too close together will tend to merge into one when printed, photocopied or photo-reduced. This is a real problem when reinforcement, actually occurring in the same plane, is drawn using two parallel lines or with reinforcement drawn close to a concrete surface.

A physical gap of 1.5 to 2 mm on the final print, should be allowed. When CADrafting is used, such a spacing must be allowed for during detailing; this may create inaccurate scaling with incorrect automatic dimensioning as a result. Bent bars and fitments will be the most likely to suffer.

7.2.5.4 *Selection of the Line Type and Thickness Groups*

Line Group 0.7 mm should be the smallest group used for reinforced concrete detailing, regardless of the size of drawing sheet and therefore degree of photo-reduction. This assumes that sheets A0 and A1 may be reduced to A2; sizes A2, A3 and A4 would not be reduced.

Because site conditions are considerably dirtier than a drawing office, thin lines and printing are more likely to be unreadable than thicker lines.

Drawings which will be microfilmed for storage purposes should have line thicknesses and line separation as large as practicable.

Table 7.2 reproduces Table 2.1 of AS 1100.501 because of its importance to the topic. Line thicknesses from the 0.7 mm Group are shown to assist pen selection.

In the same way as CADrafting systems permit the selection as desired of drawing scales and the appropriate sheet size for the final drawing, so line thicknesses also can be selected to match each individual detail without incurring a penalty for photo-reduction. For example, if a CAD detail requires a “thick” line (0.7 mm) when drawn on an A0-size sheet, then the same 0.7 mm line would be used on a similar CAD detail on an A2 or A4 sheet. If the original A0 drawing was detailed manually, the line should probably be 1.0 mm “thick” for similar reductions.

In this Handbook, the designing letter has combined the type with the thickness based on the 0.7 mm Group as this will be most suitable for CAD work. This is not part of AS 1100.501.

Lines representing parallel reinforcement will be drawn closer more often than concrete surfaces; thus concrete outlines should be selected as “continuous medium” lines (M.5 mm) and reinforcement as “continuous thick” (A.7 mm). In large scale details, where a reinforcing bar is drawn with two lines to define its real size, “continuous thin” lines (B.35 or .25 mm) would be suitable.

7.2.6 Drawing Outlines of Structural Elements

Outlines of structural elements are shown in plan-views, elevations and cross-sections. These topics are covered in detail in the chapters which relate to the particular elements. The following Clauses cover the general requirements.

7.2.7 Shading, Stippling and Cross-Hatching

“*Shading*” means colouring-in (painting) the enclosed area which is being discussed. This treatment indicates that the member below (column or wall usually) supports the member above (column, wall, slab or beam).

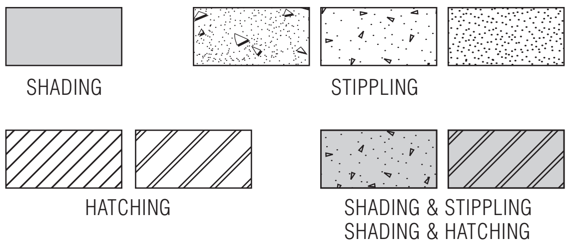
“*Stippling*” means dotting the enclosed area, or at least around the edges (stippling indicates aggregate-exposed by the plane of the cross-section).

“*Hatching*” means drawing, within the outline of the element, a series of lines or symbols to highlight it.

“*Fill*” is a term used with CADrafting whereby an enclosed area can be highlighted from a set of patterns.

In this Handbook, computer aided “fill” patterns are used rather than hand methods, see **Figure 7.1**.

Figure 7.1 *Shading, Stippling and Hatching*



Examples as Used in this Handbook

7.3 PLAN-VIEWS

Plan-views are used to show the location of elements such as footings, columns, beams, slabs and walls and also to show their grid or number reference as applicable. They should be drawn as a horizontal view of all structural elements taken immediately above the level of the structural element under consideration.

Figure 7.2 illustrates detailing the outlines of beam and columns in plan view. For plan-views, the cross-section is usually taken just above the slab. Reinforcement is generally omitted.

Figure 7.3 illustrates walls of various materials and situations. Clarity of wall views is critical to ensure support is properly provided.

Columns and walls are the most critical load-supporting members in a structure.

In a plan-view, the cross-section of each column and wall which supports part of the structure above it must be shaded to indicate that it is a support.

7.4 ELEVATIONS AND SECTIONS

7.4.1 Elevations

In reinforced concrete construction, an elevation is drawn as a section defined by a vertical cutting plane located immediately in front of the element under consideration.

The outline of members shown in elevation should be continuous thick lines (A.7).

The outline of members in front of (and connected to) the member being viewed in elevation is also shown by a continuous medium line (M.5).

The outline of members behind the member being detailed in elevation should only be shown if it is essential that special features are being highlighted; they are drawn in dashed medium lines (N.5).

The shape of a connecting member cut by the cutting plane may be highlighted by stippling.

Beam elevations are normally drawn as viewed from the bottom or right-hand side of the sheet.

Wherever possible, elevations should be drawn as the view seen by the form-workers and steel fixers – that is from the position where the member will be viewed when standing on the formwork or scaffolding. This applies particularly to the outermost members of a building such as walls, except for beams as stated above.

7.4.2 Cross-sections

In this Handbook, the terms “section” and “cross-section” mean the same thing. A section is a view from a cutting plane located through a structural element previously drawn as a plan-view or an elevation.

Only material intersected by the cutting plane should be shown; details beyond that section should be omitted but outlines may be indicated only if they do not confuse but clarify the section.

A section should be drawn close to the plan or elevation to which it relates and both should be cross-referenced by a suitable system.

See AS 1100.501 for conventions for cross-referencing sections to the relevant plan-view or elevation. This method will be used throughout this Handbook. Changes in direction of the cutting-plane should be shown by a chain line as in **Table 7.2**.

Outlines of sections should be continuous lines; the enclosed area may be stippled.

Figure 7.4 illustrates detailing the outlines of beams and other elements taken in side elevation and in cross-section, but with reinforcement omitted.

Figure 7.5 illustrates selected examples of reinforcement located within concrete outlines.

7.5 HOLES, RECESSES, PLINTHS, AND SET-DOWNS

Figure 7.6 illustrates detailing the outlines of holes, recesses, plinths or set-downs. More than one view may be necessary to define the complete shape of the outline. The sizes and depths of these must be specified on the plan or elevation, and in additional sections.

7.6 DIMENSIONING

7.6.1 Value Expression

All building dimensions, including those used in the specification of section, must be expressed in millimetres (mm) as a whole number. Values should be expressed as a multiple of 10 mm if possible, but certainly not less than a multiple of 5 mm. The letters “mm” generally may be omitted, for example 3330.

Site layout and external measurements should be in metres (m), expressed to three decimal places. The unit “m” can sometimes be omitted, for example 3.330, provided each set of drawings is consistent.

7.6.2 On the Drawings

Arrangement drawings should show all setting-out dimensions and sizes of members. Reinforcement drawings should contain only those dimensions which are necessary for the correct scheduling and location of the reinforcement including concrete member sizes if applicable.

It should not be necessary to reduce or scale any dimensions although in many cases the location of ends or of bends in reinforcement will be obvious without the need for exact dimensions.

Architectural dimensions normally take precedence and engineering drawings should avoid duplication to reduce possible conflict, but dimensions critical to the design should be stated in the engineering drawings.

The thickness, length, etc of a structural element should be given once only. Figured dimensions should be placed in such a way that they may be read when viewed from the bottom of the drawing or, if essential, from the right-hand side.

As previously mentioned, dimensions calculated automatically during CADrafting may be too accurate for practical construction. Default values should be structured to produce values rounded off to 10 mm or 5 mm as above.

Although there are some valid reasons why architectural dimensions should not be repeated on structural drawings, "fast-track" construction makes it essential that the most recent dimensions are available to reinforcement schedulers, formworkers and others on site.

7.6.3 Levels

All levels should be expressed in metres to three decimal places to either Australian Height Datum (AHD) or a site datum.

7.6.3.1 Datum

As a minus sign may be misread, 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. Particularly on large jobs, it is necessary to relate the job datum to the local survey datum or AHD.

7.6.3.2 Levels on Plan Views

It is important to indicate on site plans the difference between existing levels during construction; for example, a level may be shown to structural floor level (SFL) or to finished floor level (FFL).

7.6.3.3 Levels on Sections and Elevations

The same methods should be used as for levels on plan views. The level may be shown on a line projected beyond the drawing with an arrowhead indicating the appropriate line; minor dimensions may be shown from this projection.

7.7 SCALES

Scales should comply with AS 1100.101, and be in the form of a ratio, eg 1:100. The scale should be as small as will clearly show the desired amount of detail, yet large enough to avoid possible reading errors.

The following scales are suggested but larger scales may be used if desired:

- "*Small scales*"

Site layout and simple general arrangement	1:200 or 1:500
General arrangement	1:100 or 1:50
Simple wall and slab details	1:50

- "*Large scales*"

Beam and column elevations	1:20
Beam and column sections	1:20 or 1:10
Large size details	1:5 or 1:2 or 1:1

When laying out a drawing by hand on tracing paper, an underlay of graph paper in millimetre squares will save considerable time. Such a grid will not readily match 1:25 or 1:250 scales.

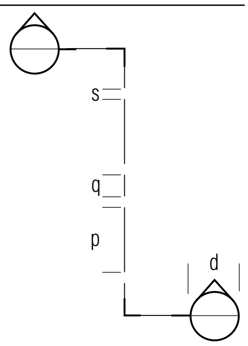
When more than one scale is used on a drawing, the scale should be shown under each detail, and the notation "*SCALES AS SHOWN*" entered in the title block. Where a dimension on a scale drawing is "*not to scale*", the dimensioned figure should be followed by the abbreviation "*NTS*".

Drawings which may be enlarged or reduced should show a graphic scale as well as a descriptive scale. Where microfilm is used, special methods may be necessary. Final prints should have a prominent note such as "*DRAWING REDUCED TO HALF-SIZE*".

Distortion of scales should be avoided. Techniques for CADrafting provide the facility to manipulate scales to either enlarge or reduce details for any desired result.

The drawing size notation (A0, A1, A2, A3, A4, B1, etc) must be shown on the original sheet in case reduction occurs later.

Table 7.2 *Lines and Their Application*

Designation (thickness in mm)	Type of line	Example	Application
A.7	Continuous thick		Visible lines and change-in-level lines. Reinforcement where 'M.5' or 'B.35' concrete outlines used (preferred method).
M.5	Continuous medium		Concrete outlines where 'A.7' reinforcement used (preferred method). Reinforcement where 'P1' concrete outlines used. Elevations of intersecting beams and slabs.
P1	Continuous extra thick		Concrete outlines where 'M.5' reinforcement used.
B.35	Continuous thin		Visible masonry walls in elevation and plan. Hatching of masonry walls over. Diagonals across holes or recesses (under or over). Welding symbols.
B.25	Continuous extra thin		Reinforcement extent lines across slabs (plan view), walls (elevations), beams and columns for fitments. Dimension lines, leaders and associated lines.
C.35	Continuous thin (drawn freehand)		Break lines around large areas such as slabs and special details to large scale or as a cloud to a revision.
D.35	Continuous thin (ruled with zig-zag)		Break lines in individual elements such as at sections and elevations.
F.35	Dashed thin	s q s = 1 mm min. q = 2s to 4s	Hidden masonry, particularly walls under, including hatching. Column-strip and middle-strip outlines on plans for flat slabs.
N.5	Dashed medium	s q s = 1 mm min. q = 2s to 4s	Hidden outlines of structural or supporting elements. Reinforcement indicated in view shown, but fully detailed elsewhere.
G.35/G.25	Chain thin/extra thin	p s q s = 1 mm min. q = 2s to 4s p = 3q to 10q (6s to 40s)	Gridlines. Centre-lines.
H.7 + H.35	Chain, thick at ends and change of direction; thin elsewhere	 s = 1 mm min. q = 2s to 4s p = 3q to 10q (6s to 40s) d = 12 mm	Cutting plane for a section indicating direction of view. If the G.35 chain line conflicts with other lines, it may be omitted leaving only the cross-reference and change-of-direction lines.
J.7	Chain thick	p s q s = 1 mm min. q = 2s to 4s p = 3q to 10q (6s to 40s)	Indication of a surface to meet a special requirement (eg granolithic or terrazzo finish) or to receive special treatment. Match lines between drawings.
K.35	Chain thin (double dashed)	s q p s = 1 mm min. q = 2s to 4s p = 3q to 10q (6s to 40s)	Outline of adjacent or existing parts.

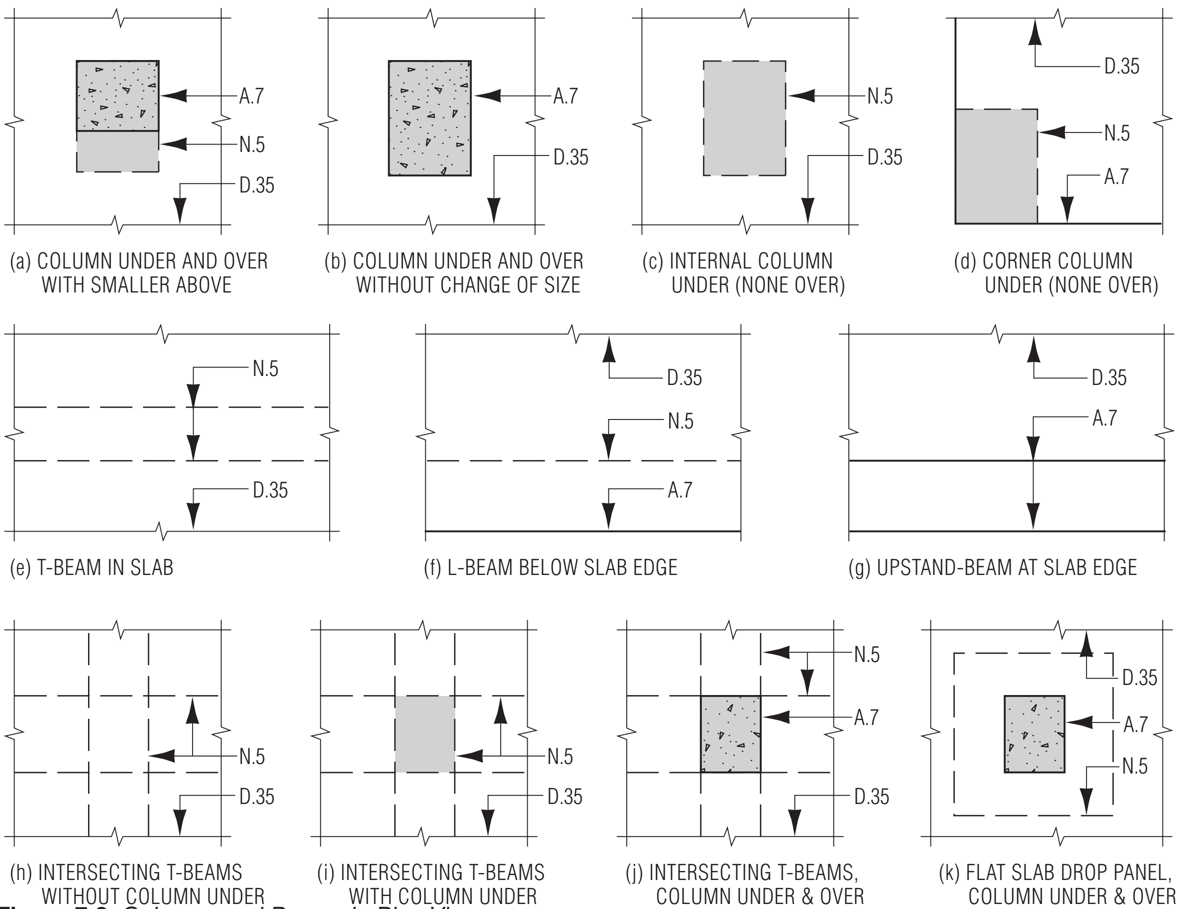


Figure 7.2 *Columns and Beams in Plan View*

(a) Column under and over, with offset face (smaller size) above. Any "visible" face of the column-under is enclosed by dashed medium lines. The whole column section-under must be shaded to define its supporting action.

The column-over area is enclosed by continuous thick lines and must be both shaded and stippled.

(b) Column under and over without change in size. The outline is a continuous thick line. The enclosed area must be both shaded and stippled.

This example illustrates an internal column through a slab and is very common.

(c) Column under with no column over (internal column). The area is enclosed by dashed medium lines and must be shaded. The example is of an internal column at, say, roof level.

(d) Column under with no column over (external column). A corner column at roof level is illustrated. It shows a combination of continuous thick lines for the slab and column edges, and dashed medium lines for the column faces below. The enclosed area should be shaded.

(e) T-beam, implying a beam with a slab at the top surface. The outline of the web is given by two dashed medium lines because it is always under the slab. No stippling or shading is required for beams.

(f) L-beam at the edge of a slab (often called a spandrel). The exposed outer edge is shown in a continuous thick line and the hidden edge by a dashed medium line. No stippling or shading is required.

(g) Upstand beam. The example shown is a spandrel, so both edges are visible and therefore are in continuous thick lines.

(h) T-beams intersecting under a slab without column under. Both outlines are in dashed medium lines. This situation often requires extra details to define which is the supporting beam.

(i) T-beams intersecting over a supporting column under. All outlines are in dashed medium lines.

For structural safety, the column area must be shown shaded to distinguish it from case (h) above, where there is no support below the beam intersection.

(j) T-beams intersecting over a supporting column under and over. The beam outlines are in dashed medium lines. The column is shown by continuous thick lines.

For structural safety, the column area must be shown shaded to distinguish it from case (h) above where there is no support below the beam intersection.

(k) Drop panel for flat slab and column heads for flat plates (with column under and over). The column outline is a continuous thick line and the enclosed area is stippled.

The drop panel outline is in dashed medium lines and is neither stippled nor shaded. The plan view dimensions, including the panel depth, should be given on the plan-view in note form, for example 2400 x 2400 x 350 deep.

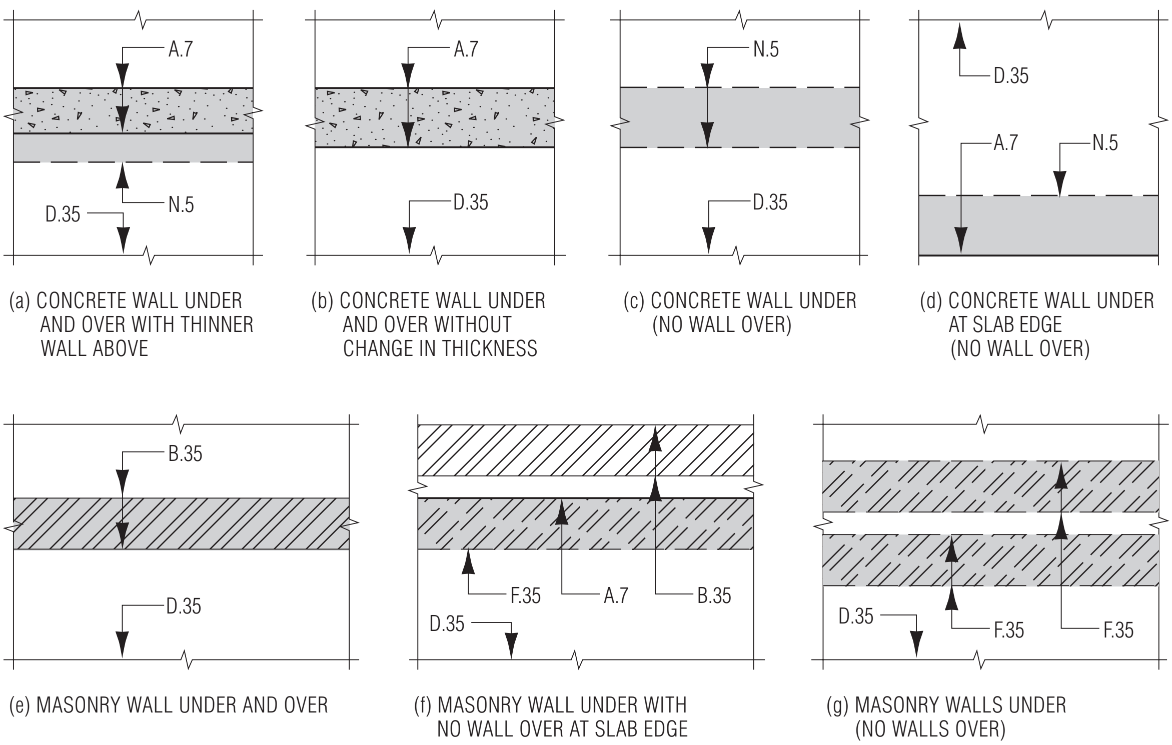


Figure 7.3 *Walls in Plan Views*

(a) Concrete wall under and over, with offset face (thinner wall) above. Any "visible" face of the wall-under is enclosed by dashed medium lines. The whole wall section under must be shaded to define its supporting action.

The wall-over area is enclosed by continuous thick lines and must be both shaded and stippled.

(b) Concrete wall under and over without change in thickness. Each outline is a continuous thick line. The supporting area must be stippled and shaded

This example illustrates an internal wall viewed through a slab and is very common.

(c) Concrete wall under with no wall over (Example #1). The supporting area is enclosed by two dashed medium lines and must be shaded. The example is of an internal wall at say, roof level.

(d) Concrete wall under with no wall over (Example #2). An external wall at roof level is illustrated and shows a combination of continuous thick and dashed medium lines.

The supporting area must be shaded.

(e) Masonry wall under and over. A single-skin wall is shown supporting a slab. Both faces are in continuous thin lines. The wall area is shown cross-hatched in continuous thin lines and must be shaded if it is a loadbearing wall.

(f) Masonry wall under, with no wall over (Example #1). The example illustrates a double-skin wall supporting a slab on the inner skin.

For the inner skin, the internal face is shown by a dashed thin line and the outer face by a continuous think line indicating the edge of the slab in this case. This skin must be shaded to indicate that it supports the slab.

The outer skin is defined by full thin lines.

Both enclosed areas are hatched with continuous thin hatching.

(g) Masonry wall under, with no wall over (Example #2). A double-skin wall is illustrated, both faces being drawn in dashed thin lines and hatched with continuous thin lines. Both supporting areas must be shaded if loadbearing. AS 1100.301 recommends double hatching to be used for brickwork and single hatching for concrete blockwork.

If the wall-under is to be non-loadbearing, this must be stated in a note (eg *NON-LOADBEARING WALL UNDER*) and the method of separating the wall from the slab above must be detailed to show the separating material.

Note: Continuous-line hatching is quicker than using dashed-lines.

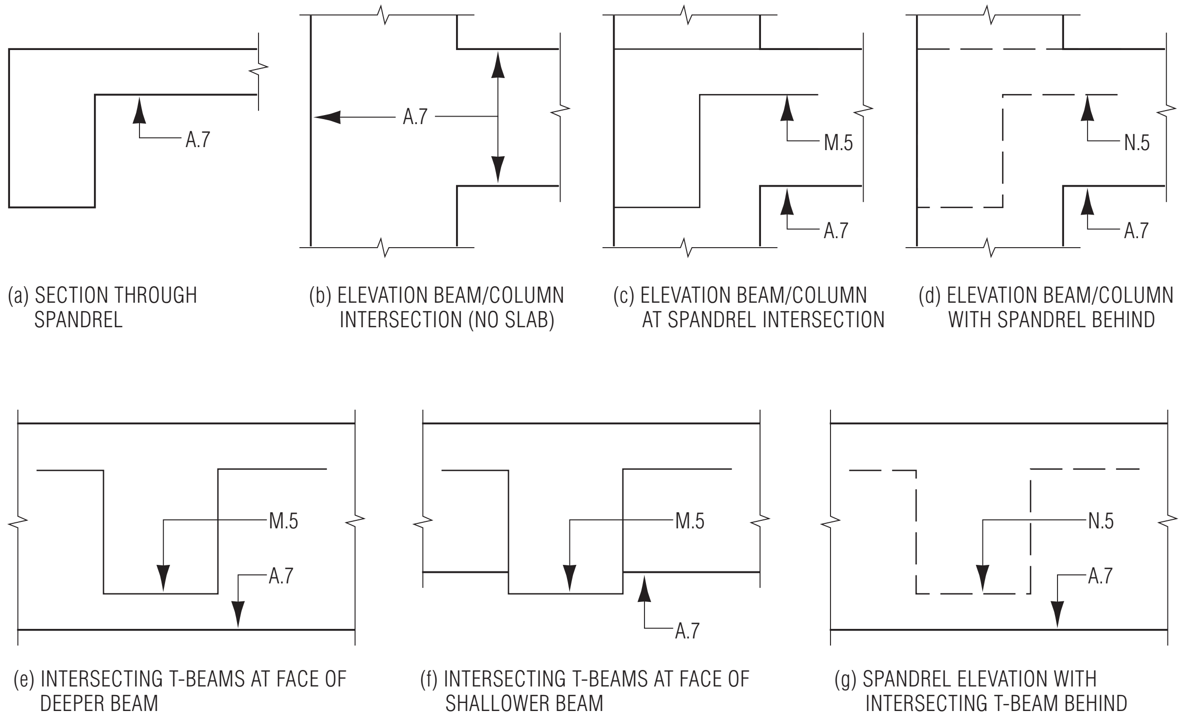


Figure 7.4 *Beam Elevations and Sections*

Note: Detailing of outlines shown, reinforcement omitted for clarity.

(a) Section through a spandrel or L-beam with slab. Continuous thick lines are used.

(b) Beam/column joint in elevation (Example #1). Example illustrates an external column supporting a rectangular beam without a slab. The outlines are thick, continuous.

(c) Beam/column joint in elevation (Example #2). Example is of an external column with the view taken just in front of the column.

The spandrel and slab (together forming an L-beam) are shown as a cross-section in medium full lines. The exterior T-beam and the column are shown as a side-elevation in continuous thick lines.

The slab is common to both beams.

(d) Beam/column joint in elevation (Example #3). Example is of an external column at a corner with intersecting L-beams.

Here the L-beam is behind and hidden by the column, so both spandrel and slab are shown as a cross-section in dashed medium lines.

The L-beam extending right and the column are shown in side-elevation in continuous thick lines.

The slab is common to both spandrels.

(e) Intersection of two T-beams (Example #1). The view is taken at the near surface of the deeper beam which is defined by full thick lines.

The shallower beam and the common slab are shown in cross-section by full medium lines.

(f) Intersection of two T-beams (Example #2). The view is taken at the near surface of the shallower beam which is defined by full thick lines.

The deeper beam and the common slab are shown in cross-section by full medium lines.

NOTE: Without more information, it is impossible to tell which is the supporting beam. In cases such as these, both views Example #1 and Example #2 should be detailed to ensure that the correct reinforcement is continuous through the joint.

(g) Elevation of external L-beam intersecting a T-beam. The spandrel is defined by full thick lines and the T-beam and the common slab by broken medium lines.

In this case, again determination of the supporting beam requires further details; the T-beam could be a cantilever supporting the spandrel.

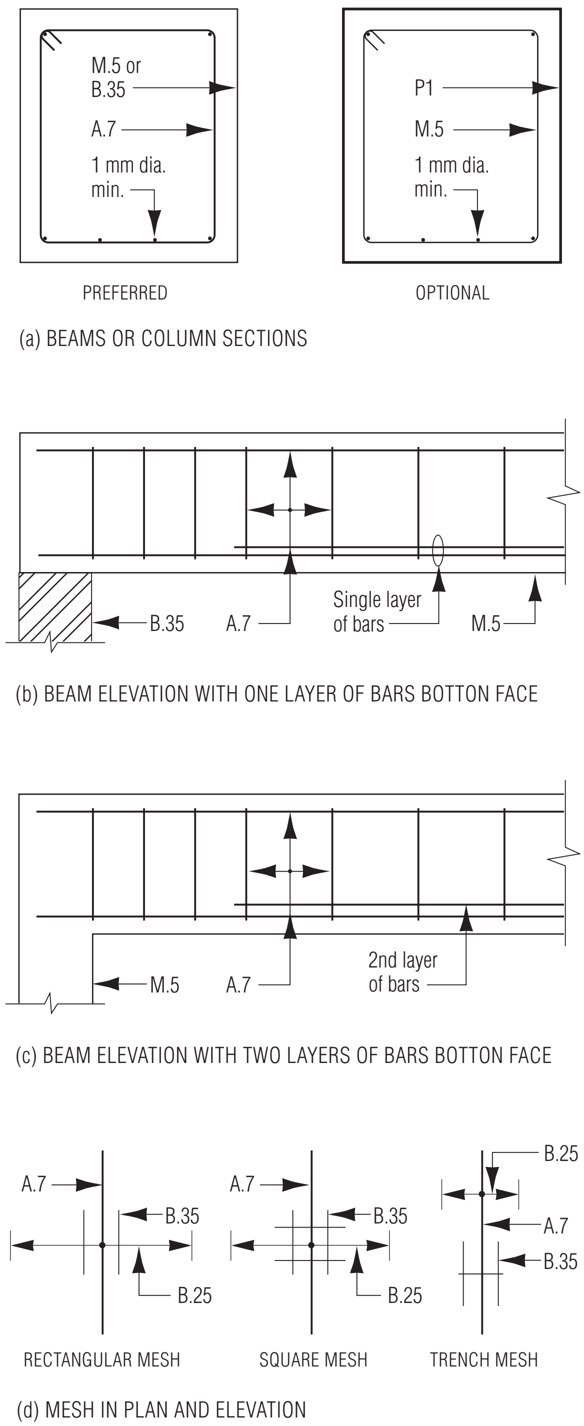


Figure 7.5 *Reinforcement Within Outlines*

Only selected examples are given, since this topic is the major purpose of the Handbook. Line separation is illustrated, based on the use of the “M.5” (medium) line type and thickness for concrete outlines and the “A.7” (thick) lines for reinforcement. Bars in cross-section are shown in “P1” dot form.

(a) Column or beam in cross-section. The concrete outline defines the dimensions and shape of the fitment drawn inside it.

The spacing between the main bars must be adequate for placing and vibrating the concrete to AS 3600 requirements, but is generally diagrammatically represented in this type of detail. A bar is relatively thicker than a dot from a pen.

(b) Beam with one layer of bars. Only the line types and separations are illustrated, not the structural requirements. This detail shows top and bottom bars with fitments (stirrups) separating and supporting them.

Indicate longitudinal bars of different lengths in same layer with a circle.

(c) Elevation showing two layers of bar in the same face of a member. The lower and upper layers of bottom reinforcement are shown and the space between both layers is detailed with a minimum distance.

(d) Mesh in plan and elevation. Mesh is already a two-dimensional material and may require more than one view for complete definition.

The bars being viewed are shown as continuous thick lines. Transverse bars shown in plan-view or elevation are in continuous thin lines.

The detailer should take special care when showing mesh to distinguish between rectangular and square meshes. The direction of the main (longitudinal) bars is shown in thicker lines and the thinner lines indicate the total width made up by the sheets (cross-bars).

See also later Chapters for applications.

Note:

1. Bars in cross-section are shown as “P1” dots.
2. In some cases, it is important for design purposes to define which bars are closest to the concrete surface. This can be done by careful location of the “dots” in each view, for example in a cantilever retaining wall. Where it is not important structurally, excessive description is not required.
3. The same comment applies to bar arrangements, except that the order in which bars are fixed will need to be considered. (See later Chapters).

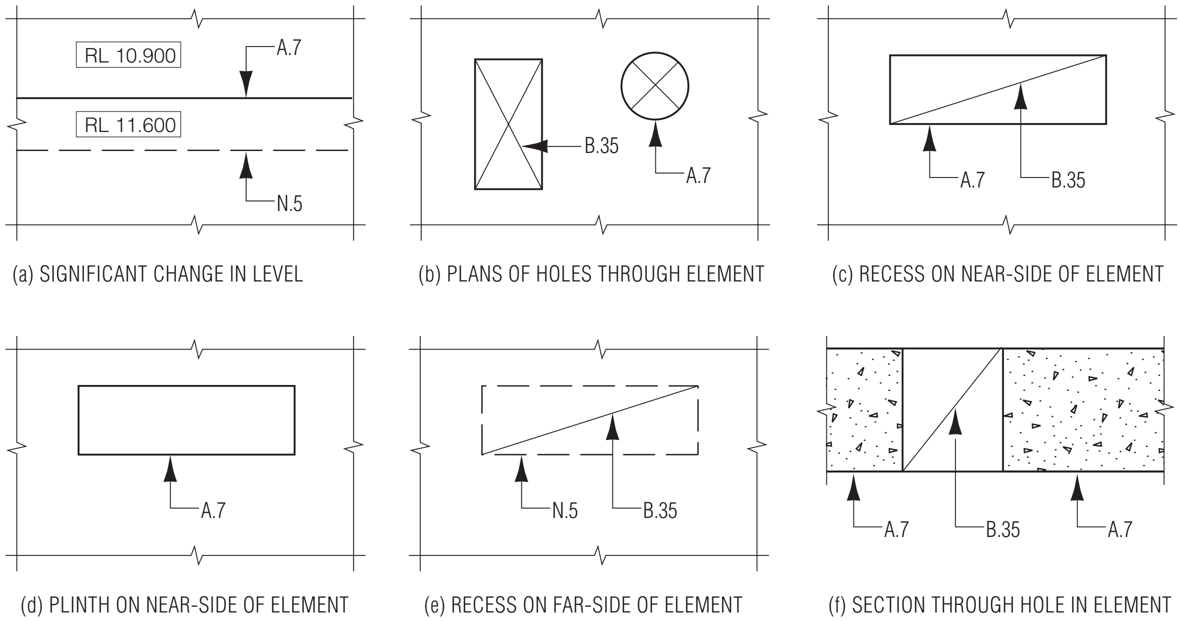


Figure 7.6 *Holes, Recesses and Set-Downs*

(a) Significant change in concrete level (in plan-view). The example illustrates a plan-view of a step-down in a slab, or possibly over a concrete beam.

The visible edge is shown by a continuous thick lines, and the hidden face by a broken medium line.

The supporting beam neither hatched nor shaded.

Note that the levels are given in metres to three decimal places (see **Clause 7.6.3**).

(b) Holes through the element (in plan-view or elevation). The concrete edge is shown in thick full lines. Two diagonal continuous thin lines define the opening.

This detail could apply to holes through a slab or to a door opening in a concrete wall.

(c) Recess into, or small set-down, on near side of member (in plan-view). The concrete edge is shown in thick full lines. One diagonal continuous thin line defines the extent of the recess.

(d) Plinth or a thickening on near side of member. The concrete outline is shown in thick full lines, but the area is not defined by a diagonal line. Levels may be advisable, with or without a cross-section.

Examples are a machine base or a corbel in end elevation.

(e) Recess under or on far side of member. The concrete outline is shown by broken medium lines, and the extent is defined by one continuous thin line. This case is unusual and may require extra descriptive notes.

(f) Section taken through a hole. The surfaces of the member and the sides of the opening are defined by full thick lines.

One diagonal thin continuous line defines the extent of the opening as if it was a recess.

Stippling of the remaining concrete may assist the visual impact, but reference to the section cutting plane is essential.

8

Identification and Dimensioning of Concrete Elements

8.1 PRELIMINARIES

Clause 2.2 described the construction of a reinforced concrete structure using the concept of placing zones. It was suggested that structural members were built by alternating horizontal zones with vertical zones, for example footings followed by columns, floor, columns and walls, floor, columns and roof.

This concept is too vague for real design and construction. At many stages, it is necessary to define both large portions of the structure (such as the "1st floor" or the "roof") and the individual structural "members", called "elements", which when combined make up the floor or roof.

In a building, the most common method of describing vertical position is to use the term "level" or "floor level" for the horizontal floor zone and the column/wall system immediately above that level, and the term "element" to describe the individual member, say "beam, slab, wall, column or footing" which makes up that "level".

Having defined the level at which each element is located, its position horizontally is defined in two ways – by either structural element number or by grid-line references.

Within each of the elements will be found reinforcing steel (mesh or bar), prestressing materials (ducts, tendons and anchorages) and perhaps some extra fixings, etc. For convenience, here we will refer to these as the "components" which combine to make up the "element", and which in turn combine into the structural "level". All of these will eventually require identification.

If architectural drawings use a particular method of referring to levels and elements, the identical system must be adopted for the engineering drawings. To do otherwise, would cause confusion.

8.2 STRUCTURAL ELEMENT CONSECUTIVE NUMBER SYSTEM (AS 1100.501)

With this method, the elements at each level are numbered consecutively using a combination of letters and numbers. The levels are determined from the "prefix" defined below. The full reference should comprise the following:

- *Prefix* – the location or floor level of the structural element. Floor levels may be designated either by sequential levels or by the traditional storeys.
- *Stem* – the type of structural element such as beam, slab, etc.
- *Suffix* – the individual number of the structural element, which is explained further in the following sections.

Table 8.1 shows the numbering system described in AS 1100.501.

Further examples will be given throughout this Handbook. See also **Clause 8.5.1** on plan-views.

Table 8.1 *Consecutive Numbering System for Elements*

PREFIX		STEM	
Location or floor level	Code	Structural element	Code
Sequential levels		Selected members	
Lowest level, then in ascending order to top-most level (eg tenth level)	1 10	Column	C
		Slab	S
		Beam	B
		Joist	J
		Lintel	L
Traditional storeys		Footings:	
		Footing beam	FB
Roof	R	Pad footing	FP
Third floor, etc	3, etc	Strip footing	SF
Second floor	2	Raft footing	RF
First floor	1	Cantilever footing	CF
Mezzanine	M	Pier (or pedestal)	P
Ground floor	G	Pile cap	PC
Basement	B	Portal Frame	PF
Footing level	F	Stairs:	
		Stair flight	F
		Stair landing	L
		Truss	T
		Retaining wall	W
		Construction joint	CJ

Example 8.1	
Fourth floor, beam 21	*4B21*
Example 8.2	
Level 10, slab number 4	*10S4*

8.3 GRID-LINE SYSTEM (AS 1100.501 AND AS 1100.301)

A grid-line system is used generally to define the horizontal location of elements at any level. Vertical location is defined by the "level" or "storey".

A grid reference system consists of one set of grid-lines in one direction with a second set of grid-lines in, generally, a perpendicular direction. (See **Clause 11.16 Drawing Sheet No 11.1**). Grid systems are most often used with regularly shaped floor plans, but grid-lines do not necessarily have to be straight or at right angles to each other. Additional secondary grid-lines can always be incorporated on the original grid to cater for amendments during construction.

Where architectural or project drawings use grid-lines as reference, the engineering drawings must refer both to the identical grid dimensions and the numbering method.

It is recommended that, for structural grids, the grid-lines running down the sheet should be marked alphabetically (A, B, C, etc) and the grid-lines running horizontally should be marked numerically (1, 2, 3, etc).

Grid directions should be chosen to allow for any future expansion, nevertheless a project grid may be adopted with a completely arbitrary orientation, bearing no relation to any recognised map grid or to "true north". Grid system notation is not abbreviated.

8.4 SUGGESTED ABBREVIATIONS FOR LOCATIONS, MATERIALS AND REINFORCEMENT PLACING.

In the same way as element labels are given in an abbreviated form, so can many other names of construction items be shortened. It is essential that the abbreviation is common throughout the construction industry and is clearly understood. Various examples are given in AS 1100.101, AS 1100.301 and AS 1100.501; traditional abbreviations for reinforced concrete construction are given in **Table 8.2**. Other abbreviations should not be used unless clearly defined on every sheet on which they appear.

Abbreviations mean the same in the plural as in the singular. Only capital letters are to be used. Full-stops and apostrophes should be omitted.

Wherever possible, the direction from which the member is viewed should be from a location which is at least attainable; that is, if a view of a lift well wall is required, do not draw the view from inside the well if there is no scaffolding there or, if a retaining wall is to be cast against the earth, do not detail the view from the earth side. However, it is common practice to give elevations of external beams as viewed from either the bottom or the right-hand side of the sheet, not as viewed from inside the structure.

If in doubt, spell it out in full.

Table 8.2 *Abbreviations for Locations, Materials and Reinforcement Placing*

Words	Abbreviation
Locations	
Structural floor level	SFL
Finished floor level	FFL
Existing level	EXL
Reduced level	RL
Horizontal	HORIZ
Vertical	VERT
Materials	
Reinforced concrete	RC
Precast concrete	PC
Prestressed concrete	PSC
Brickwork	BWK
Concrete	CONC
Reinforcement	REINF
Reinforcement placing information	
Each way	EW
Each face	EF
Near face*	NF
Far face*	FF
Horizontally	HORIZ
Vertically	VERT
Maximum	MAX
Minimum	MIN
Top or Top-face	T or TOP
Centrally placed	CENTRAL
Bottom or Bottom-face	B or BOT
Internal face	INTF
External face	EXTF
At centres (spacing)	CTS
Continuous	CONT
Typical	TYP

Note: * In these cases, the direction of viewing must be carefully defined.

8.5 STRUCTURAL ELEMENT NUMBERING

Structural element numbers for footings, columns, walls and slabs are written consecutively from left to right in each horizontal row starting from the top left corner, working downwards and read from the bottom of the sheet.

Beam numbers should be consecutive from left to right "horizontally" in each row reading from the bottom of the sheet, and consecutive from bottom to top of the page for each "vertical" row reading from the right-hand side of the sheet.

Grid references for columns and footings are described in **Clause 8.7**; lettering should be read from the bottom of the sheet. See **Clause 8.3**.

For the method of dimensioning elements in plan-views, see **Clause 8.7**. Any necessary dimension lines on plan-views should be kept clear of structural details.

8.6 DIMENSIONING OUTLINES OF STRUCTURAL ELEMENTS

8.6.1 General

Sufficient dimensions to describe the structure must be given on the contract or construction drawings whether they are architectural, concrete-outline or reinforcement-placing drawings.

In Australian practice for detailing buildings, the designer often combines concrete outlines and reinforcement details on the same drawing. Dimensions are obtained from the architectural drawings.

Many civil engineering structures however show concrete outlines with dimensions on one drawing, and reinforcement details on another because architectural drawings are rare for these structures. This method is used when it is necessary to provide more dimensions and details of holes, pockets, inserts, etc, than is required when architectural drawings are supplied. Reinforcement details are then given on separate construction drawings or even on separate sheets.

On projects where the structural engineer details concrete outline dimensions, member sizes and associated locations of reinforcement and tendon, the job can be formed and scheduled from common information, and consequently built with greater accuracy.

Further, misfits between elements are discovered during design or early scheduling, and not at the last minute before a concrete pour. As a general rule, faster real-time construction can be achieved also. The following sections apply particularly to the reinforcement drawings.

8.6.2 Compatibility of Dimensions

Where dimensioning of concrete outlines is required for satisfactory construction, the method adopted must be compatible through the various drawings. For example, if architectural drawings use centreline dimensions for beam and column locations, the engineering drawings should use the same method.

Fast-track methods of construction throw an extra burden on all members of the design and construction team. Where drawings are amendments to the original set, there will always be the likelihood that dimensional changes are not transmitted to the site. It is strongly recommended that dimensions essential to strength and stability of the structure should be highlighted on these amendment sheets.

It will be obvious that extreme care must be taken to ensure that a dimension shown twice or more must be identical in each case.

With CADrafting, where dimensions can be generated automatically, the addition of critical dimensions are not time consuming and they should be included as a matter of course.

8.7 DIMENSIONING CONCRETE OUTLINE SHAPES

Engineering drawings are used for erection of formwork as well as for reinforcement details. Whilst the architectural drawings will show the basic dimensions of the building as a whole, the size and shape of each structural element must be shown on the engineering drawings. This is done by numbering each element (see **Clauses 8.2** and **8.3**) and by indicating the overall structural dimensions (mm) as shown below.

A combination of the element-number/ dimensions is most effective in providing the maximum amount of information with the minimum amount of effort.

All the following should be regarded as minimum requirements for satisfactory communications.

8.7.1 **Beams**

Dimensions of beams should be given once only, and that must be on the plan-view. AVOID repetition of dimensions on a section because it requires considerably more effort to check that future amendments have been transferred to all details. It does not matter if the section is slightly out of scale.

See **Figure 8.1** for the following examples.

(a) Rectangular beam (ie one without an integral slab)

Specify on the plan-view, the overall depth first, following by the width. The floor level and beam number is also given.

eg 4B21 – 650 x 300

(b) A ”T” or “L-beam” with integral slab

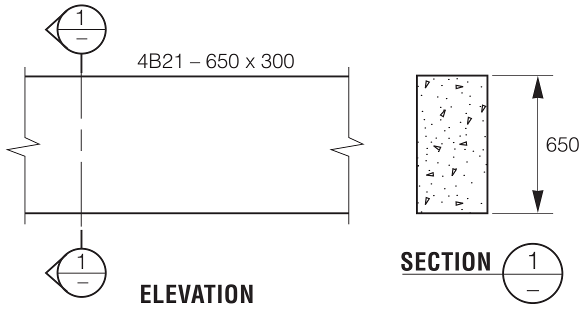
Specify on the plan-view the overall depth first, including the slab thickness, followed by the web width. Also give the floor level and beam number.

eg MB6 – 500 x 275

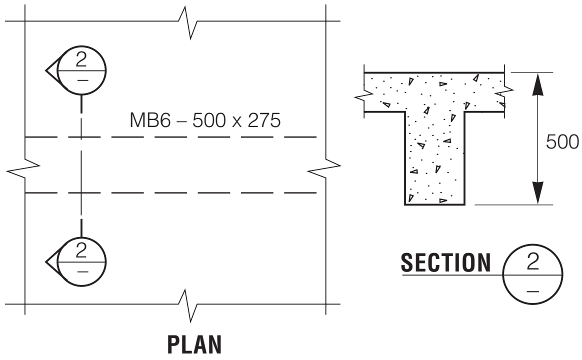
In major projects, beam dimensions may be set out in a separate schedule, but plan-views must still indicate these values to assist construction trades. For example, air conditioning and electrical trades use plan-views, not cross-sections, for information.

(c) Beams with non-rectangular shapes

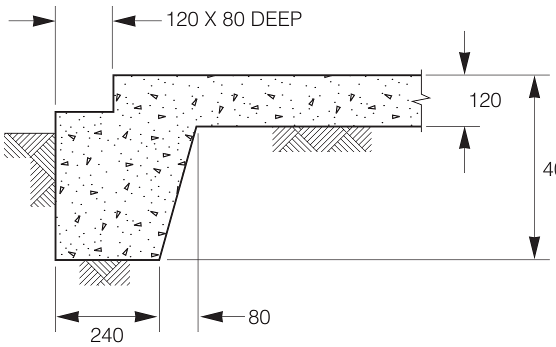
The general dimensions of depth and width should be given on the plan-view. The cross-section must also be fully dimensioned so that formwork can be made. The examples given above also apply.



(a) RECTANGULAR BEAM WITHOUT SLAB



(b) T-BEAM WITH SLAB



(c) EDGE BEAM TO SLAB-ON-GROUND

Figure 8.1 *Beams*

8.7.2 **Columns**

See **Figure 8.2** for the following examples.

(a) Rectangular columns – minor projects

Specify on the plan-view the orientation of the column faces and the dimensions. The column number is given but the floor level is not required.

eg **C15 – 450 x 350** (on the plan-view)

(b) Rectangular column – major projects

Specify on the plan-view the column reference number or use the grid-line reference. The floor level is not required.

eg **C15** (on the plan-view)

If a separate column schedule is provided, specify the orientation of each column face (say by drawing a North Point) and the dimensions. Such a schedule should have full details of the reinforcement as well.

(c) Circular column

Specify as in (a) and (b) as applicable.

eg **C9 – 700** DIA (on the plan-view)

If the orientation of the main bars in the column are critical, additional dimensions should be given.

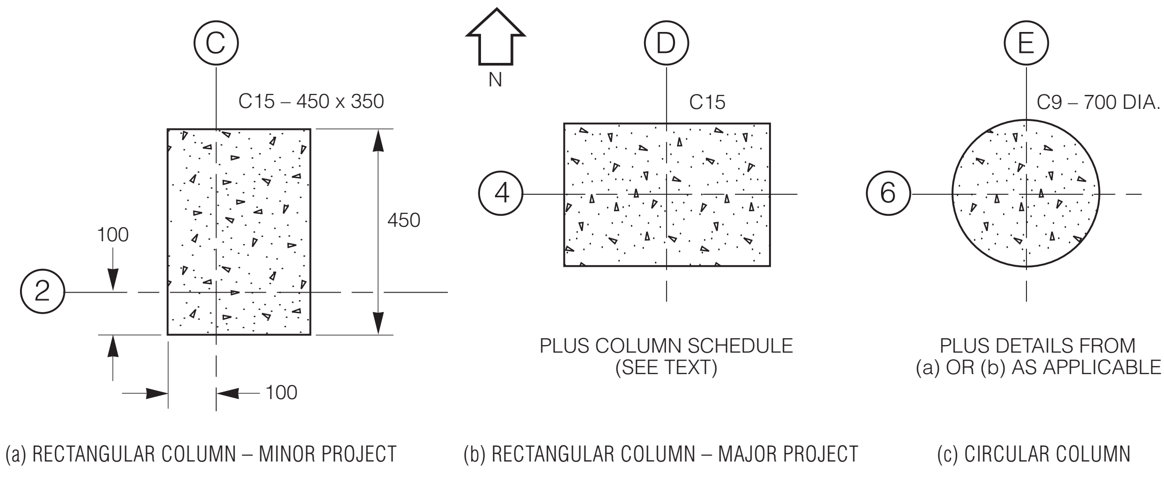


Figure 8.2 *Columns*

8.7.3 Slabs, Walls and Stairs

See **Figure 8.3** for the following examples.

(a) Slabs

Specify on the plan-view the predominant thickness, together with major variations. The slab number should be given; it is often shown in a circle for clarity.

On cross-sections, dimension all relevant thickness, recesses, step-downs, etc. Where a slab outline is indicated on an elevation, its thickness may be dimensioned if this will save an additional detail without loss of understanding.

(b) Walls

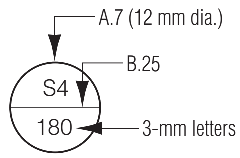
Draw and dimension the outline on the plan-view. Do not repeat the thickness dimension on sections.

The location and size of penetrations such as doors and windows should be indicated on an elevation; the dimensions are obtained from architectural drawings.

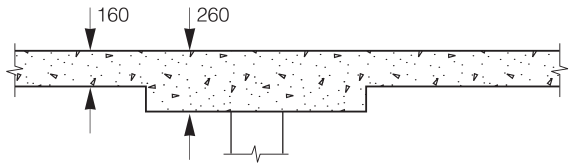
(c) Stairs

Draw the outline as an elevation for flight and landings.

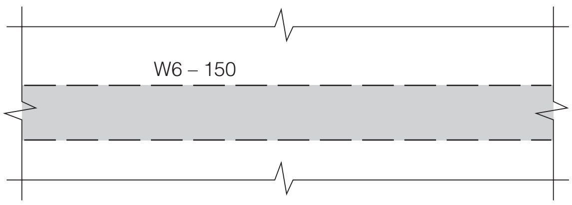
Dimension the landing and flight throat thicknesses. Tread and riser dimensions are generally fixed by architectural requirements such as floor-to-floor heights and the requirements of the Building Code of Australia (BCA) for tread and riser dimensions.



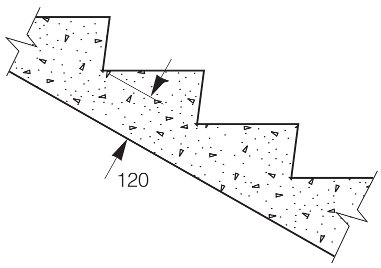
(a)(i) SLAB THICKNESS NOTATION ON PLAN VIEWS



(a)(ii) SLAB THICKNESS DIMENSIONS ON CROSS-SECTIONS



(b) WALL DIMENSIONING ON PLAN VIEWS



(c) THROAT THICKNESS FOR STAIR SECTIONS

Figure 8.3 *Slabs, Walls and Stairs*

8.7.4 **Footings**

See **Figure 8.4** for the following examples.

(a) Pad footings, pile caps, etc.

A footing drawing must show its own orientation in relation to the structure and also that of any associated columns. In particular, the details of the column's starter bars must be given in the footing drawing.

Pile-cap drawings must show the location of the piles as well.

Draw a plan-view and dimension length and width.

Below a separate cross-section of elevation, specify the "length x width x depth", and dimension the depth.

eg F5 – 2500 x 2000 x 500 DEEP

It is strongly recommended that footing details be given on the same sheet as the column which it supports where possible. This recommendation applies particularly when a column schedule is provided.

(b) Strip footings (generally supporting a wall)

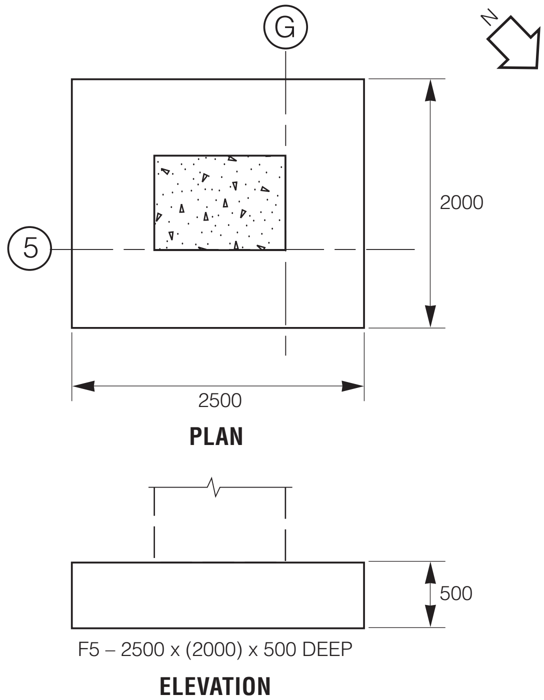
Draw the outline in plan-view and dimension each width. If cross-sections are not given, specify on drawings or in the Specification the dimensions as: *DEPTH x WIDTH*.

If cross-sections are drawn, dimension the width and specify underneath as for beams the element number and dimensions as:

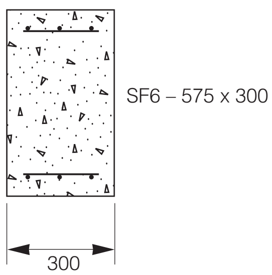
DEPTH x WIDTH.

eg SF6 – 750 x 300

THIS DESCRIPTION MAY CONFLICT WITH PAST PRACTICE IN SOME DESIGN OFFICES, BUT IT IS STRONGLY RECOMMENDED BECAUSE DIMENSIONING OF GROUND BEAMS AND STRIP FOOTINGS MUST BE CONSISTENT WITH AS 2870.



(a) PAD FOOTING



(b) STRIP FOOTING

Figure 8.4 *Footings*

8.7.5 Length and Height of Various Members, Areas of Slabs and Walls, etc.

For elements having an irregular shape or variable dimensions, the outline must be drawn separately in plan-view, elevation and section with all dimensions shown.

Examples are:

- Haunched beams.
- Columns with irregular shape for architectural purposes, particularly precast concrete units.
- Floor joists with webs tapered in plan-view.
- Corbels

8.8 DIMENSIONING FORMWORK

Chapters 3 and **5** have considerable information about allowing for tolerances in construction and the effect of insufficient cover on the durability of the structure. Rebates and drip grooves will reduce cover and therefore are a potential source of corrosion of reinforcement if they are not properly detailed.

Architectural drawings tend to show finished-surface drawings; these may not be suitable for formwork dimensions!

Properly-dimensioned reinforcement drawings are more suited for formwork manufacture as formwork size and reinforcement scheduling can be better coordinated. Failing this, separate dimensioned concrete outlines are required.

Element sizes should be related to formwork surfaces with any additional finishes to the concrete shown by extra dimensioning.

Fillets are drawn only in large-scale details when their omission would affect cover, etc. Special details on fillets may be given in the Specification.

Consideration should be given at the design stage to the use of standard formwork panels or sheet sizes. Table-forms, “left-in-place forms” and similar methods for maintaining the planned cycle times must always be considered. Multiple re-use and ease of erection and stripping of forms are an essential part of economical construction.

9

Identification and Dimensioning of Reinforcement Components

9.1 PRELIMINARIES

Within each "element" of structural concrete, there will be "components" such as reinforcing mesh and bar, tendons, fixings, and similar items. Each component must be capable of definition to show:

- What it looks like (shape, product number). See **Clause 9.2**.
- Its location within the element (cover, dimensional position). See **Clause 9.3**
- Its performance specification (steel strength, reference code). See **Clause 9.4**.
- How many of them (number of bars and tendons, wires/sheets of mesh, basic design notation). See **Clause 9.5**.
- Where it goes (placing information). See **Clause 9.6**.
- How to identify it from schedules, etc (element labels, bar marks). See **Clause 9.7**.
- Special features (laps and anchorage, proprietary splices, welding, bending-pin size, galvanising or epoxy-coating). See **Clause 9.8**.

Designers are required by the AS 3600 to provide certain information on the drawings and this is quoted in **Clause 1.2.3** of this Handbook. In many cases, preprinted *General Notes* can have spaces for details to be inserted. See **Appendix B**.

9.2 REINFORCEMENT SHAPES

Steel reinforcement is incorporated in concrete to resist tensile, compressive, shear and torsional forces. It is therefore located in the concrete section where it best serves its purpose and this, with the concrete outline, dictates the actual shape.

Although more than sixty percent of bars used are straight and more than this percentage of mesh is in flat sheets, both materials are also required to be shaped (bent) to reflect the shape of the concrete surface and often for structural reasons.

9.2.1 "Standard shapes" for reinforcement

The Standard Shapes in AS 1100.501 are used in reinforcing steel schedules for manufacturing purposes.

The most common basic shapes are shown in **Figure 9.1**. Throughout the rest of the Handbook, these shapes will often be referred to by the codes given there. Some shapes require additional explanation. The first five groups constitute about 95% of all bars fabricated, sizes notwithstanding.

Comments on some of the shapes in **Figure 9.1** are as follows:

SHAPE	COMMENT
S	A straight bar referred to in this context, really means a "straight bar". It could be a stock length bar (see **Clause 2.1**), or it could be a bar cut from a stock bar without any bending being done.
L, LL	These bars include cases where a 90° hook (cog) is added at one or each end as dimensions 'A' and 'C'. If you are in any doubt as to the use and specification of hooks and cogs, please re-read **Chapter 6**.
CC	This shape allows for a small offset (dimension D ≥ $2d_b$) so that column bars can be lapped, dimension 'A' represents the lap-splice. The crank dimension 'C' should be no less than $6d_b$, but for smaller bars 300 mm is used. (See **Clause 12.2.10**). It can also be used for beam bars.
T, HT, DT	These are "closed ties"; used principally with rectangular members.
SH, SC, RT	These are "open ties"; give easy access for fixing beam cages (See **Chapter 13**).
J, JJ	These shapes should be used where a small crank is required at bar ends to avoid interference with intersecting steel. The shapes used to be known as "bent-up" bars for shear stress design in beams and slabs. They are now obsolete. (Dimension 'D' approximated the depth of the member, and the angle was 45º).
V, VL, VV	If known, the angle of bend can be given. The other dimensions are often obtainable from the concrete shape.
A, AL, AV	The latter two are logical extensions of shape A, similar to shape V above.
U	This should be specified in lieu of shape LL if the overall dimension 'B' is less than about 200 mm; LL cannot be bent to that size.
H, HH	Both of these bars are defined as having 180° hooks at one end or each end respectively as dimensions 'A' and 'C'. For bars other than these and some fitments, hooks can be added as shown later.

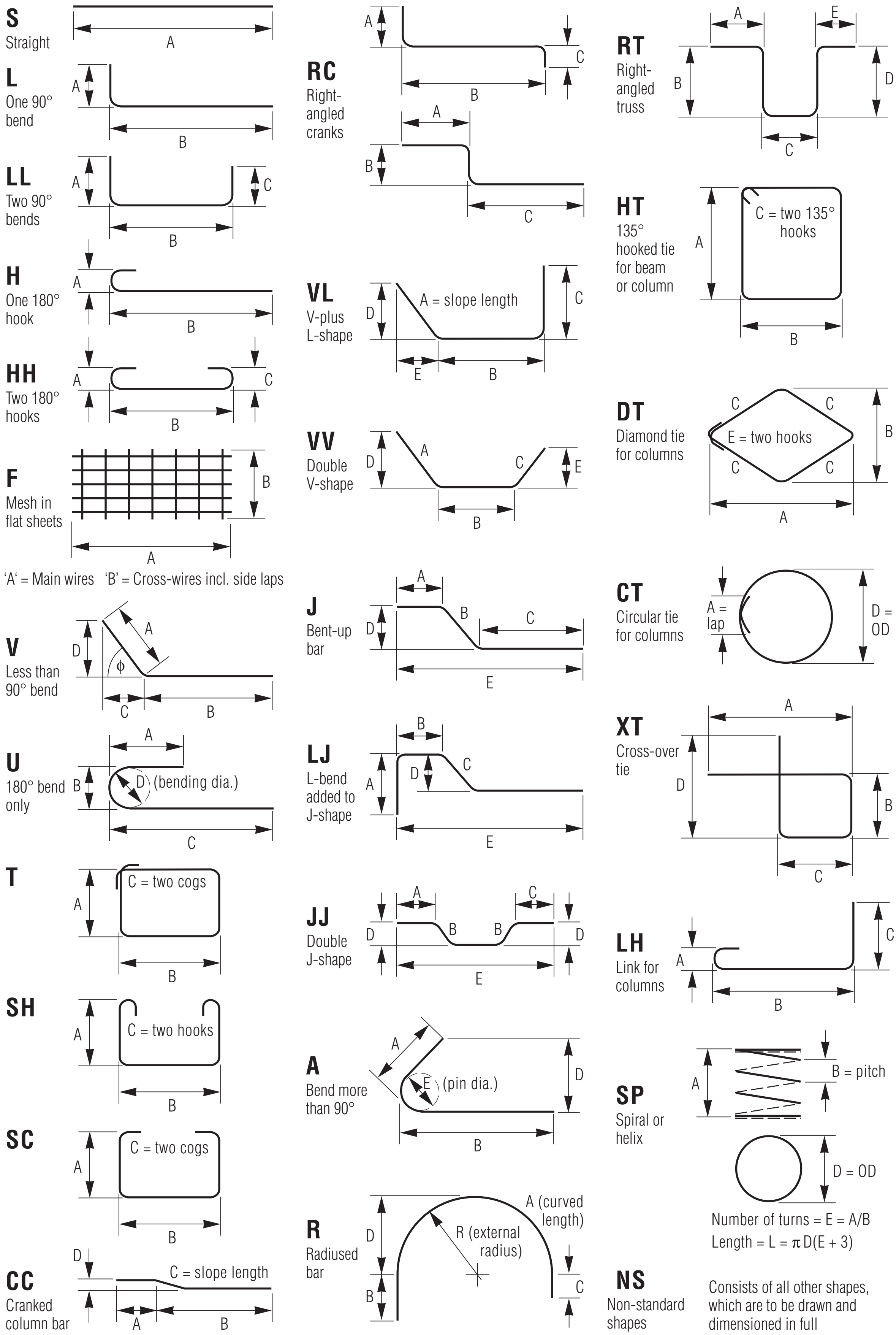


Figure 9.1 *Standardised Bending Shapes for Reinforcement*

9.2.2 **Addition of Hooks to Standard Shapes**

As a general rule for good design and detailing, hooks and cogs should never be used unless structural requirements for end anchorage cannot be achieved without them.

Hook length allowances are given in **Table 6.6**.

Anchorage with hooks or cogs is incorporated with fitment shapes T, HT, DT, LH, SH and SC, and with RT having dimensions 'A' and 'E' as out-turned cogs. 135º hooks are included with shapes HT and DT.

No provision need be made for 90º cogs under this system. In most cases where they would be needed, shapes L, LL, VL, LJ and RT are adequate and are easily recognised. **Clause 6.2.5** advises precautions on use of cogs in thin members because they can protrude into concrete cover if care is not taken.

Except for the fitment shapes and H and HH, all standard shapes can have a 180º or 135º hook added to either or both ends. To enable the steel to be bent, the type of hook and its orientation in relation to the next bend must be defined. An indication that a hook is required is given by the letters "H" (one hook) and "D" (two hooks) with the normal shape code.

The range of hook combinations is illustrated in **Figure 9.2**.

Example 9.1

An "L" shape with a hook at one end is defined by "LH", whilst one with two hooks is called "LD".

In addition to this combination are the letters "I" (means the hook is bent "into" the next bend) and "O" (means it is bent "outward" from the next bend). See **Figure 9.2**.

9.2.3 **Tendon Shape and Reinforcement**

In prestressed concrete, the tendon is the primary longitudinal strengthening component. The position of the tendon and duct must be located and dimensioned first, then the reinforcement must be detailed to fit around the tendons. In some cases, the reinforcement will need unusual bending shapes which can only be classed as NS.

9.3 REINFORCEMENT LOCATION

Tolerances are allowances for inaccuracies of manufacture or for placement from specified dimensions or position. Tolerances are dealt with fully in **Clause 3.2**

9.3.1 **Effect of Cover**

A longitudinal bar will have its shape defined by that of the surface to which it is parallel so that this surface cover has almost no influence on the bending dimensions. A fitment is defined by the cross-sectional shape of the concrete and the cover is critical to the bending dimensions.

Chapter 5 describes how to select durable concrete and the appropriate cover for corrosion resistance and general durability.

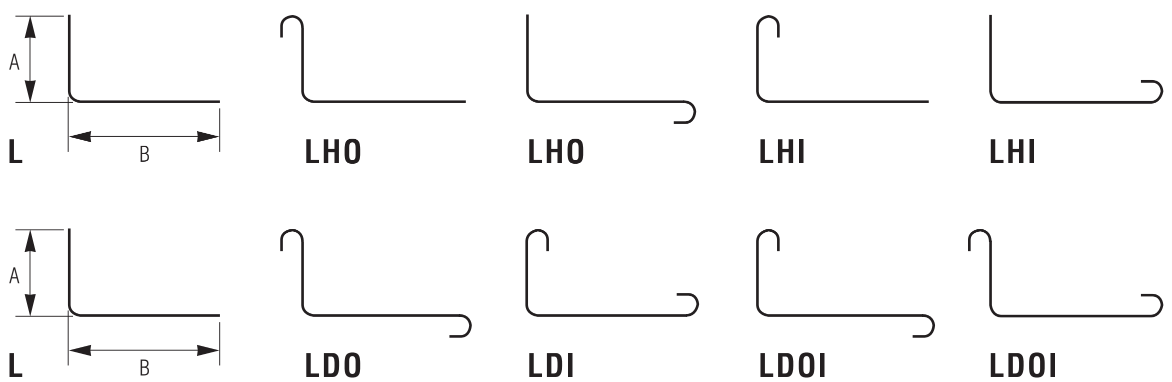


Figure 9.2 *Shape Code Example of L-Shaped Bar with 180° Hook Orientation Definitions*

9.3.2 Effect of Position

Main bars enclosed by the fitment require additional information such as the span length for their dimensions to be determined.

The calculation of dimensions takes into account the type of member (beam, slab, column) and the particular type of end condition (for top-bars, the extension into the span; for bottom-bars, the extension into a support, for columns the floor-to-floor height; lapping requirements; and so on).

Cover to the ends of bars is often not a dominant factor. Span length and floor height are critical.

As an example, if the soffit of a beam is flat, then the main bottom bar will probably be straight, but the length of the bar cannot be calculated without knowing the design factors which affect the end anchorage. This is a design matter and must be specified in some way.

9.3.3 Dimensioning of Reinforcement with "Typical" and "Standard" Details

Reinforcement bending dimensions are usually obtained by subtracting cover from the concrete sizes. In other cases, a dimension is required on the detail to enable the scheduler to calculate the bar length and for the steel fixer to locate the bar in the formwork. As a general rule, always establish the location of the bar by reference to a setting-out line or to formwork, and not by reference to a grid-line which cannot be readily identified on the site.

Although "typical details" for minor sections are not recommended, such details may be of value if they are located close to the plan-view or cross-sections to which they apply (on the same sheet obviously), if one detail truly represents every case to which it meant to apply, and if the shape and dimensions are clearly stated.

Another useful drawing is a "standard detail" which applies for the whole project, and would therefore be shown in the introductory drawings. Standard details should define such matters as bar arrangements in columns, or bar and fitment cut-off points in beams or slabs.

The location of the steel must be definable on site. For example, as will be seen in **Chapter 14**, with slabs and slab systems, the "clear span" for the placing strips is measured from a line drawn between the faces of columns some distance away, so that a dimension on the "standard detail" such as "*0.3 TIMES CLEAR SPAN*" may not always be appropriate. Steel-fixers and inspectors rarely have a calculator so that a figured dimension is always preferable.

"Standard details" can be supplemented by tables which contain numbers of bars in each placing zone, the label and even the spacing. When extra bars are needed, say at a hole, these are shown on supplementary views or cross-sections on the appropriate drawing sheet.

Often it will be essential to state a figured dimension, for example at lap splices, or where the anchorage length is critical, or where bars are not symmetrically placed.

It is designer's responsibility to locate the reinforcement correctly and to state this in the drawings. (See **Clause 1.2.3**).

9.4 SPECIFICATION OF STEEL STRENGTH

9.4.1 New Projects

There is one primary strength grade for reinforcement –

500 MPa for hot-rolled deformed bars and mesh.

There is also a 250 MPa grade for plain round bars, but these are generally allowable only for dowel bars and fitments. A 250-MPa deformed bar is also available only in a 12-mm diameter and is used for free-form swimming pool reinforcement.

There are also eight Standard Grades of concrete (20, 25, 32, 40, 50, 65, 80 and 100 MPa), each of which can be ordered as either *Normal Class* concrete or *Special Class* concrete.

The applicable Australian Standards are quoted in **Chapter 4** with other pertinent information such as bar sizes.

To ensure that the correct strength of materials is specified, there are a number of recognised conventions that must be followed.

The Australian Standard AS/NZS 4671 has three levels of ductility that are designated by the letters L, N or E representing *Low*, *Normal* or *Seismic* (Earthquake) ductility respectively. The shape is also designated by the letters R, D or I, representing plain (Round), Deformed-ribbed or deformed-Indented, surfaces respectively. The strength grade is a numeral value of the lower characteristic yield stress expressed in megapascals. The bar is designated with the shape factor first, the strength factor second and the ductility last. A typical reinforcing bar grade is D500N, ie a deformed bar of normal ductility and a yield strength of 500 MPa. The indented shape is not used in the general construction industry and is mainly used in the manufacture of reinforced concrete pipes. The seismic "E" ductility for bar is required for New Zealand only. To simplify the notation on drawings, a simple code is provided in the **Table 9.1** which is used by the general industry.

Table 9.1 *Notation for Commonly-Available Reinforcement*

Material type	Yield strength, f_{sy} (MPa)	Bar notation	Simplified notation
Welded Mesh (Square)	500	D500L	SL
Welded Mesh (Rectangular)	500	D500L	RL
Deformed Bar	500	D500N	N
Deformed Bar	500	D500L	L
Deformed Bar	250	D250N	S
Plain Round	250	R250N	R
Plain Round	500	R500L	L

NOTE:
For mesh notation, 'S' and 'R' are Square or Rectangular meshes respectively. The normal spacing of bars in mesh is 200 mm with some meshes with 100 mm spacing of bars. This spacing if not given in the mesh notation will be standard at 200 mm centres for bars. Other spacings of bars can be manufactured such as 300 mm but this would be classified as non-standard. These meshes can be manufactured on a project by project basis to the engineer's design.

9.4.2 Renovation of Older Structures

Sometimes in the course of renovations, the strength of materials has to be determined. If a sample of steel can be obtained, it should be tensile tested. If a test cannot be made, the surface appearance is often a good guide. Reinforcement used prior to 1914 was most likely imported.

All mesh since 1914 can be assumed to be of grade 450 MPa until year 1998.

If the bar surface is "plain" then a yield strength of 230 MPa should be the maximum assumed. Since wire is indistinguishable from plain bars, use 230 MPa also.

If the surface is "deformed", only 230S grade should be assumed for a non-twisted deformed bar if construction occurred up to 1986 and it cannot be positively identified. Construction after 1986 would probably use grade 410Y or 400Y deformed bars as main reinforcement. From 2003, this allows 3 years for all old stock to be used up, the grade can be assumed to be 500N.

Construction from 1957 to 1963 often used a twisted, square bar; its yield strength was 410 MPa. The surface should be easily identifiable.

Between 1963 and 1983, twisted deformed bars may be assumed to be of grade 410C. If it is intended to join old and new bars by welding or mechanical splices, any untwisted portion at an end must be cut off first.

Table 9.2 provides a chronological list of bar and mesh yield strengths.

Table 9.2 *Historical Values of Yield Strengths (as at September, 2010)*

Surface appearance of steel	Year of construction	Probable yield strength, f_{sy}	
		MPa	psi
Mesh	Before 1914 to 1995	450	65 000
Deformed Mesh	1995 to now	500	-
Plain round or any other unidentifiable steel	Before 1914 to 1988	230	33 600
Twisted square[Note 4]	1957 to 1963	410	60 000
Deformed Intermediate Grade[Note 1]	1960 to 1962	275	40 000
Deformed Hard Grade[Note 2]	1960 to 1964	345	50 000
Twisted deformed[Note 4] (CW60)	1962 to 1983	410	-
Deformed hot-rolled	1983 to 2000	410[Note 3]	-
Deformed hot-rolled	2000 to now	500	-

NOTES:

1. Intermediate Grade was rare and probably only in Victoria. Weldability very doubtful.
2. Hard Grade was common in NSW, but unusual elsewhere. Unweldable.
3. After 1988, AS 3600 specified only a design yield strength of 400 MPa for deformed bars.
4. Remove untwisted ends (about 150 – 200 mm) before splicing by end-butt welding or mechanical splicing.

Table 9.3 *Examples of Basic Design Notation*

Member Type	Position of Steel		Typical basic information: Notation	Actual area provided
Beam	Bottom bars		4N36	4080 mm^2 total
Column	All bars in section		8N24	3600 mm^2 total
Slab	Bottom mesh		RL918	636 mm^2/m width
Flat Slab	Bottom Bars	(a) (b)	20-N16-160 N16-160	4000 mm^2 total, or 1250 mm^2/m width

9.5 REINFORCEMENT QUANTITY FOR STRENGTH CAPACITY – "Basic Design Notation"

The strengthening effect of reinforcement depends on the total area of steel of the required yield strength being provided at each appropriate cross-section. This is done by specifying the number of bars of the selected size, each having a known strength. In this Handbook, we use the "*Basic Design Notation*" to provide this information.

The Basic Design Notation should only be shown once for each bar in an element and this should be on that portion of an element which is cast first. For example, a starter bar is drawn with the footing, not the column. The reason should be obvious!

The actual shape of the bar must be defined in this view of the element, even when it is indicated again on a separate detail. To assist in identification, draw a small sketch of the shape, or enter the "shape code" described earlier, after the notation.

9.5.1 Examples of Basic Design Notation

See **Table 9.3** and **Figure 9.3**. From the information given in column 3 "*Notation*" of **Table 9.3**, it would be possible to check the strength of the section by calculation at any time in the future – the yield strength is defined by the simplified notation N and RL, and the steel area is obtained from a combination of bar size and number off, or bar size and spacing, or directly from the mesh reference number. Area values would be obtained from Tables in **Chapter 4**.

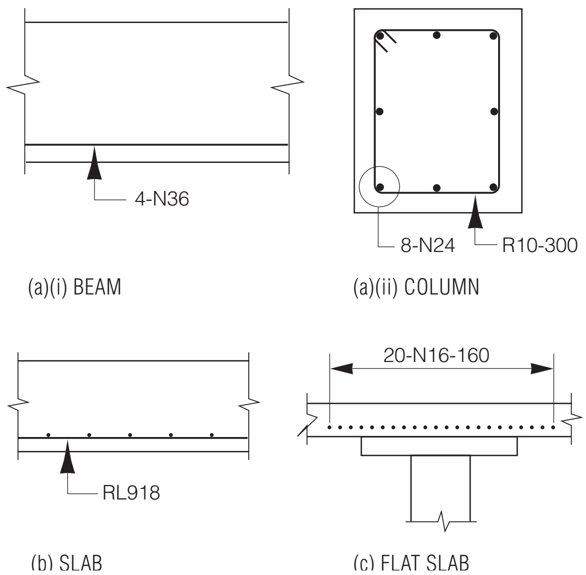


Figure 9.3 *Examples of Basic Design Notation*

9.5.2 Reasons for the Recommended Basic Design Notation

Several variations of notations are suggested because each correspond with the way different members are designed, see **Figure 9.3**.

(a) The number of bars in narrow members such as beams or columns is calculated from the total cross-sectional area of steel (mm^2), hence a notation like 4-N36 for bars in one face, or 8-N24 for the total.

(b) For wide members such as floors and walls, the area of steel is calculated as area per unit width (mm^2/m), hence notations like 20-N16-160 or N16-160 or RL918.

(c) For certain structural elements such as flat slab floors, it is strongly recommended that the designer specifies the number of bars as well as the spacing, or that the width of the column and middle strips are dimensioned on the structural details and the number of bars in each strip are specified with the assumption that uniform spacing is implied. By this means, the correct total cross-sectional area of steel is specified and the spacing has secondary importance. (The steel fixer still wastes time working out the spacing however!). Preferred methods are 20-N16-160 and RL918.

9.5.3 "Number-off" Calculations for Wide Sections

The methods differ for bars and mesh.

Bars. The preferred method of calculating the number of bars is to obtain the overall width (mm) and divide by the bar spacing. If the answer is not a whole number, take the next higher number of bars.

As an example, if the N16-160 bars were located in a slab 3100 mm wide from edge to edge, 3100/160 = 19.4 bars would be required; because part of a bar cannot be provided. 20-N16 are specified.

Note that the calculation is based on the "*total width of the slab*" not "*total width minus side cover*" because the bars must reinforce the edge cover. The answer gives the number of bars, not the number of spaces between the outermost bars. This means that the extreme bars on each side of the section are located from that side not more than one-half the specified spacing.

Provided that cover is maintained, the location of the outermost bar is often not critical. Because this fact is often not appreciated by site inspectors, the designer should state the number of bars. Some designers also require a trimmer bar around the edge. In this case it too should be specified so that it will be included.

Mesh. Standard mesh sheets are made 2400 mm wide. When a slab width is less than this, mesh can be cut from a standard sheet, or a narrower sheet can be manufactured to the specified width for large projects where the mesh manufacturer is prepared to make special sheets.

When a member width exceeds 2.4 m, two or more sheets are required. However, on a drawing it is not necessary to specify the number of sheets required for coverage. Provided that the side overlap is specified (if not the AS 3600 lap will be assumed – see **Clause 6.9**) the total width of mesh can be determined. It is then up to the mesh supplier to decide whether to provide several sheets 2400 mm wide with a "make-up" sheet less than 2400 mm, or to manufacture all sheets the same width but which will total the slab width plus side laps. This latter method will also permit the sheet length to be cut to size from the machine without creating scrap.

Standard mesh sheets are made 6000 mm long, but this is just traditional. Longer or shorter sheets, with almost any width; can be manufactured to suit the project so that the specified steel area is provided in each direction. Transport lengths and mass for handling are the two major constraints; the latter can often be solved by using a number of narrower strips; for example, twice as long, half as wide.

9.6 PLACING INFORMATION

For design purposes it was necessary to identify every structural element. (See **Clause 8.2** for element-numbering system). Each component within the element must also be identified and located, and this is done with bar marks and other notes. (See **Table 8.2** for placing abbreviations).

9.6.1 Abbreviations for Placing Steel

The reason for using an abbreviation is to separate the different sets of bars into their correct layers and directions. Abbreviations have greater value when cross-sections are not drawn and the designer uses a plan-view or an elevation to detail the reinforcement.

- Sufficient information is needed for the bar to be placed in its correct location, preferably without the need for an excessive number of cross-sections, etc. Too many cross-sections of obvious details will confuse rather than instruct.
- Extra details of complex arrangements may well save many man-hours later when interpretations are requested.
- Where different layers of reinforcement are superimposed on one detail (eg bottom and top in a plan-view, or near-face and far-face in an elevation of a wall) the detailer will improve communications by indicating the layer, and sometimes the direction, in which the steel is to be placed.
- The simplest method of providing placing information is by making use of the preferred abbreviations given in **Table 8.2**.

No other abbreviations should be used unless clearly defined on every drawing on which they appear. All abbreviations mean the same in the plural as in the singular. Only capital letters are to be used and full stops are not required after them.

The placing information is located after the Basic Design Notation, or as a special Note to that detail.

9.6.2 The "EACH WAY" Abbreviation

The loose term "both ways" must not be used. "Each way" means that the same component of reinforcement is required twice – once in one direction and again at right angles.

When the "EW" instruction is given, do not use the complete basic design notation stating both "number off" and "spacing" unless it is absolutely certain that the identical number of bars is required in each direction. As an example, if say N16 bars are to be placed in two directions in the same element, then use EITHER;

(i) 20-N16-160 EW where the spacing is known;
or
(ii) 20-N16 EW when spacing is not critical.

9.6.3 Comments on Placing Abbreviations

Abbreviations EF, NF, and FF refer to the layer(s) of reinforcement adjacent to a surface of a wall drawn in elevation. Whether or not the face is "near" or "far" depends on the direction from which the elevation is viewed, so this direction must be made clear. It is also essential that a workman can position himself so that he can in fact see the element from that view.

Abbreviations INTF and EXTF may be better for exterior walls.

Abbreviations B and T refer to the position of reinforcement near the surfaces of a thin element such as a slab or a staircase.

Abbreviations HORIZ and VERT apply to the direction of the axis of a bar at the time concrete is cast. VERT cannot be used with slab reinforcement.

Two or more abbreviations may be used together, particularly for bars which form a grid. Examples are:

(i) *N12-200-EW-EF* – there are four layers of bars, but take great care about specifying number of bars in this case.

(ii) *SL102-EF* – there are two sheets of mesh, one in each face.

(iii) *N16-100-FF-VERT* & *N12-200-FF-HORIZ* – there is one grid of bars in the far face.

(iv) *RL818-FF-MAIN BARS VERT* – there is one sheet of mesh, but because of the difference between main- and cross-bar areas, the orientation must be specified.

Detailers will easily distinguish the circumstances where these extra instructions will clarify a difficult detail, or will remove the need for additional cross-sections.

9.7 BAR MARKS

The *Basic Design Notation* together with the *Placing Information* will enable a group of components to be identified as belonging to a particular concrete element. In some cases, it is necessary also to distinguish between the individual bars within that element.

The traditional method is to use a system of bar marks. The term "bar mark" refers to mesh as well.

The bar mark is a number or letter-number combination which identifies one bar or a group of bars with (usually) one placing location. The bar mark must always be shown on the reinforcement schedule and also on a metal or plastic tag attached to each bundle of steel. See both **Clauses 9.7.1** and **9.7.2**.

9.7.1 Bar Marking by Structural Element Number (Placing Zones)

Each footing, column, beam, slab or wall element is identified by a structural element number or useable grid number. This number also becomes the placing zone. See **Clauses 8.2** and **8.3**.

The system is common to columns, to bottom steel in beams and slabs, and to most fitment arrangements. Slabs are usually numbered as well-defined placing zones bounded by column centre lines or slab placing strips; typical placing-zone labels for bottom steel are S1, S2, etc. Top steel in slabs is often not identified by the designer, and the scheduler may need to invent a system.

For both methods the placing zones must be identified on a marking plan to assist the steel fixer.

Individual bars or sheets are not marked on the drawings. Each item on the schedule is labelled with the structural element number into which that item is to be placed provided that the scheduler can identify it.

This method reduces the amount of work of all concerned, but it does require the detailer to provide adequate element numbers. Some simple rules should be followed by the scheduler:

- If there are several items or bundles for one structural element, the same element mark can appear more than once on the same schedule; for example, bars and fitments in the same beam.
- There should always be as many tags with labels as there are bundles, even though they bear the same placing zone reference.
- It is often the case that several members (especially columns) have bars which are identical (shape, diameter, length, etc). All of these bars can be bundled together with one over-riding label. The grouping would be identified on the schedule.
- If bars are extracted from a bundle containing steel for several elements, the bundle should be retied and the tag replaced.

9.7.2 Bar Marking of Individual Bars

This method is common for many civil engineering structures, particularly where individual elements are large and contain a number of different bar shapes and lengths.

The individual elements are still numbered but, in addition, the bars themselves are marked by an additional number or letter-number combination.

This bar mark is shown in the reinforcement drawings by the detailer so that there is no need for the contractor or scheduler to prepare an additional marking plan.

Although the detailer would do more work, the detailer may also prepare the reinforcement schedules. These may be separate documents or drawn on the original tracings.

9.7.2.1 Identical Bars

Throughout this Handbook, the term "identical bars" will often be used.

For bar fabrication purposes, two bars would be regarded as being "identical" only if they were exactly the same for grade of steel, bar-size, bent shape, cut-length and individual bending dimensions.

For placing purposes, a group of bars in the same placing zone may have the same bar mark if they have the same grade, bar-size and bent shape, although they may have different individual bending dimensions and different cut-lengths.

> **Example 9.2:**
> A typical situation would be a sloping retaining wall. Adjacent bars will have a different length and significant sorting of bars will be necessary, but the placing zone can be identified with one mark. The situation is similar to that of **Clause 9.7.1**.

9.7.2.2 ***Basic Rules for an Individual Bar Marking System***

Rules (f) and (g) illustrate advantages of individual bar marking.

(a) Identical bars for fabrication, as defined, may have the same mark even if they are not in the same placing zone.

(b) Where a clearly defined placing zone requires numerous bars which differ marginally in length, the bars may have the same mark.

(c) The mark should be placed near the Basic Design Notation. Sample drawings may show them in different ways.

(d) The only restriction on the form of the marking system is that it should be consistent throughout any one project and must be consistent on any one structure – particularly if the same contractors are involved.

(e) Letters and numerals may be used in any combination, but it is recommended that the maximum number be limited to six. Only capital letters should be used. Letters “O” and “I” can be confused with numbers “0” and “1” – do not use them.

(f) To ensure that reinforcement which may be embedded in two different concrete placements is not omitted, the Basic Design Notation for any one bar must only be given once, and this should be on the detail of that part of the structure where the bar is first encased in concrete; for example, column starter bars are defined with the footing.

(g) Where a bar appears elsewhere on drawings, the bar is identified by its bar mark only. Identification on the site is simplified and the detailer is unlikely to duplicate (or leave out) reinforcement.

(h) In any marking system with numbers, it is suggested that numbering should commence with the first bar to be placed, that is, at the footings, bottom layer in a slab, etc.

Examples of bar marks are given throughout this Handbook.

9.7.3 **Other Aids to Reinforcement Identification**

(a) Check the tags to select the correct bars on site. Coloured tags can often be provided to a pre-arranged system.

(b) On a civil engineering site, the different colours can be used to differentiate between various areas within the project.

(c) In buildings, the layer into which slab bars are placed can be defined by coloured tags (**Figure 9.4**) which would be defined on the schedule, as for example:

TOP UPPER LAYER – BLUE
TOP LOWER LAYER – YELLOW
BOTTOM UPPER LAYER – RED
BOTTOM LOWER LAYER – WHITE

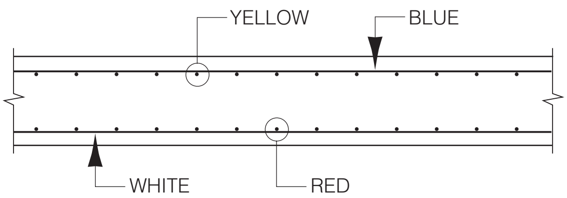


Figure 9.4 *Application of Coloured Tags*

9.8 SPECIAL DETAILS

9.8.1 Splices

All details must be shown in the drawings. Further information is given in **Chapter 6** and many examples will be given throughout the Handbook. In many cases, an intelligent use of Notes will help.

Column lap splices are the most common splices. They generally occur just above a floor level so that the length of the lower level bar protruding above the floor forms the lap. This length must be adequate – once the floor is poured, the protruding length cannot be increased.

End-bearing splices require height above the floor level and the stagger between splices to be specified. In this case, a typical detail may be used.

Bundled bars require extra details to show the order in which bars are to be spliced.

Tension lap-splices must be located on the drawing and the length of lap shown by figured dimensions or in a table on the drawing. All dimensions are to be in millimetres not in bar diameters.

Mesh lap-splices have been described in **Clause 6.9**.

9.8.2 Proprietary Splices

Many types are on the market and details should be obtained from manufacturers' technical literature. In particular, the location should be specified in the drawing. Requirements for testing these devices should be given in the Contract Specification and reference to this should be in the drawings.

9.8.3 Welding

All welding details require special attention. Welding should comply with AS 1554.3 *Structural steel welding - Welding of reinforcing steel*.

9.8.4 Bending-Pin Sizes

Pin sizes are given in considerable detail in AS 3600 Clause 17.2.3.2. Because of the effect of bending on steel strength, these rules must be followed, (See also **Clauses 6.2.4** and **6.2.5** in this Handbook).

9.8.5 Galvanising and Epoxy-Coating

Coatings such as these are not specifically within the Concrete Structures Standard. Details must therefore be provided individually for each project.

10

General Comments on Presentation of Details

10.1 IMPORTANT MESSAGE

The details shown in this Handbook are illustrative only.

UNDER NO CIRCUMSTANCES SHOULD THESE EXAMPLES BE COPIED INTO CONTRACT DRAWINGS UNLESS THE NECESSARY CALCULATIONS PROVING THEIR ADEQUACY HAVE BEEN PREPARED BY A PROFESSIONAL ENGINEER.

10.2 DETAILS ACCOMPANYING THE TEXT

10.2.1 Drawing Types

The drawings include:

- Two-dimensional plan-views, elevations and sections which illustrate the text.
- Some illustrations showing in three-dimensional form how the reinforcement must be fitted together on the site; a detailer would rarely need to prepare such a drawing, although it would be a most useful technique with complex or congested bar arrangements where physical size is a problem; and
- "Standard Details" which are examples of a technique used in many design offices to standardise internal procedures. No attempt is made for these to be taken as the only solutions. They are called "standard details" in the sense of being "office standards", and not "CIA standards" or "AS standards".

10.2.2 Omission of Design Information

The purpose of the following Chapters is to show how to draw the reinforcement within the concrete outline. In this context, the design requirements and dimensions are not always essential. For the purpose of referring to parts of the drawings in the text, some reinforcement is marked using an appropriate system.

When concrete, reinforcement and other details and dimensions are given to illustrate the applicable text, non-essential reinforcement information and concrete outline dimensions are often omitted because the text describes other matters. In no way should the element be considered fully detailed.

Most details are not shown to any particular scale.

10.3 SELECTION OF EXAMPLES

10.3.1 Types of Structural Element

The most common elements are footings, columns, beams, slabs-on-ground, suspended slabs, cantilevers, walls and staircases. Each is discussed in various detail and suggested arrangements of reinforcement are shown. Other layers are equally satisfactory, but these are left to the individual detailer's previous experience.

However, this Handbook does have many recommendations to make about good practice and a detailer should be prepared to accept and try them at least once before rejecting them.

10.3.2 New Ideas

Advice given in the Handbook related to one situation need not be restricted only to one element. Solutions for one problem may be equally applicable in situations not discussed here at all, for example:

- Intersecting reinforcement problems are not limited to beam-column connections.
- The suggested methods of allowing for tolerances in stair reinforcement can be related to many members where accuracy of formwork is not critical.
- "Opening" and "closing" corners of walls are similar to slab/balustrade connections.
- Each Drawing Office should assemble a stock of details which are accepted as giving a good solution in several situations. For uniformity, they should be used by the whole office and not regarded as personal property. In this way, future amendments can be made with the minimum of difficulty.

10.3.3 Construction Tolerances

The location of planned construction and movement joints, connections and splices must be shown in the drawings.

Also, it is good practice to define how a construction joint is to be made *JUST IN CASE* it will be needed; that is, to plan for an unplanned joint. If reinforcement is to be spliced at the joint, the splice length should be dimensioned and the location of the splice from a concrete surface or set out line must be defined.

Where splices are required at construction breaks, any reinforcement protruding from hardened concrete will become reduced in length if that concrete is placed oversize. Detailers can allow for this by specifying the extension to be greater than the lap-length values given in AS 3600. (See **Chapter 6** of this Handbook). The amount of increase will depend on the circumstances.

Example 10.1:

(i) Lap-splice bars in columns require a minimum 300 mm lap. This column bar extends from the floor below the working floor and the splice length will be above the working floor. Once the column and floor are cast, the splice length is fixed. An additional allowance may need to be added to the 300 mm to account for any error in either floor level. (Refer to AS 3600 Clause 13.2.4 for the calculated splice length).

(ii) Allow for variations in concrete sizes. To permit a bar to be fixed between two previously-poured surfaces, such bar should be, say 200 mm shorter than the planned gap and the protruding bars on each side of the gap dimensioned one-half of this amount longer, that is add 100 mm to each splice length.

10.4 TECHNICAL TERMINOLOGY

Many technical terms familiar to draftsmen, schedulers, architects and engineers are used throughout the Handbook without further definition.

The trainee detailer must apply terms such as bending moment, strength and stress, tension and compression, positive and negative reinforcement, shear, footing, column, beam, etc. For this purpose, a suitable textbook on structural mechanics and design should be studied. Consult the Concrete Institute of Australia and the Cement, Concrete Aggregate Australia for information.

10.5 DETAILING OF ELEMENTS FOR SEISMIC RESISTANCE

10.5.1 General Comments

Detailing of the structure is an integral and important part of the seismic design process. For reinforced concrete, structural detailing centres around arrangement of the reinforcing bars. There must be sufficient transverse steel to suppress brittle shear or crushing failures and to prevent buckling of the main compression steel, once the cover concrete has been lost. The main steel bars must not lose their anchorage into the surrounding concrete during the repeated reversing loading cycles to which they would be subjected during a major earthquake.

Appendix C of AS 3600 sets out design and detailing criteria for structures subject to Earthquake actions, AS 1170.4 Structural Design Actions for Earthquake in Australia classifies all structures based on Importance Level (Refer AS 1170.0 Structural Design Actions General Principles) and site subsoil class A to E. All buildings in Importance Level 1 and domestic structures (housing) satisfying Appendix A of AS 1170.4 are not required to be designed to satisfy Appendix C of AS 3600. All other structures, including parts and components are required to be designed for earthquake actions as determined in AS 1170.4 and designed and detailed as per Appendix C of AS 3600. The relevant level of ductility is to be met by following the detailing requirements for the particular structural system concerned.

It should perhaps be restated here that design and detailing are inseparable. Proper detailing is required to ensure that the structure will respond under seismic loading in the manner for which it has been designed.

With a limited additional quantity of properly-detailed extra ligatures and continuity reinforcement, plastic hinges can be induced to form at a given load. However, yielding will be ductile (gradual) even if the design earthquake load is exceeded (ie the hinge will act as a 'fuse' preventing transfer of the larger forces).

The choice for the designer/detailer is clear. A fully-elastic response by the structure, whilst allowed by the Code, cannot be guaranteed. Therefore, to prevent catastrophic collapse and probable loss of life under a greater than designed-for event, a ductile failure must be ensured. This minimum required level of ductility may be readily achieved by judicious detailing in selected areas.

10.5.2 Moment-Resisting-Frame Systems

There are three types of moment-resisting frames:

(a) ***Ordinary Moment-Resisting Frames***. These require no specific detailing for seismic resistance. Standard detailing as set out in the body of AS 3600 is considered to provide structural adequacy to reinforced concrete structures when coupled with the higher earthquake design forces consequent from the use of lower 'μ/S_p' values (ie reduce the 'ductility demand', or likely joint rotation, on the frame and assume they are essentially elastic). The value μ/S_p is the structural ductility factor divided by the structural performance factor.

The designer should note that for OMRFs, normal detailing to AS 3600 will result in only limited frame ductility, primarily as a result of poor joint performance. Joint failure will result in collapse (Kobe, Northridge, Mexico City). In order to achieve the required structural ductility factor μ of 2, the designer needs to ensure that an excess value of this magnitude (or higher) is available (see as a Reference: Goldsworthy H.M. *Earthquake Resistant Design of Concrete Structures: Design and Detailing Requirements in AS 3600:1994 – Appendix A for Moment Resisting Frames*, University of Melbourne, 1994), or that detailing is provided such that plastic hinges may form. (See *Intermediate Moment-Resisting Frames* below).

It is important to ensure, however, that the non-seismically-designed frames are sufficiently ductile to cater for forces they will attract if the earthquake is bigger than that assumed in the model. The designer must detail with care to ensure that plastic hinges, if any, form at the locations specified in **Figure 10.1**. It is important to remember that AS 3600, Appendix C, does not specifically direct the designer to provide a strong-column/weak-beam mechanism, so any of the three indicated modes could occur during a seismic event of sufficient magnitude to cause yielding of reinforcement.

(b) ***Special Moment-Resisting Frames***. These will rarely be required in Australia. As such, AS 3600 does not include any design and detailing requirements for this category. If it is required and for the structural ductility factor (μ) greater than 3, the structure should be designed and detailed in accordance with NZS 1170.5 and NZS 3101.

(c) ***Intermediate Moment-Resisting Frames***. In the following Chapters, attention will be concentrated on the detailing requirements for these systems as they will more commonly be seen, especially in dual systems where for instance shear walls are provided only in one direction. Further, some of the provisions must be considered as good detailing practice in OMRF systems as well.

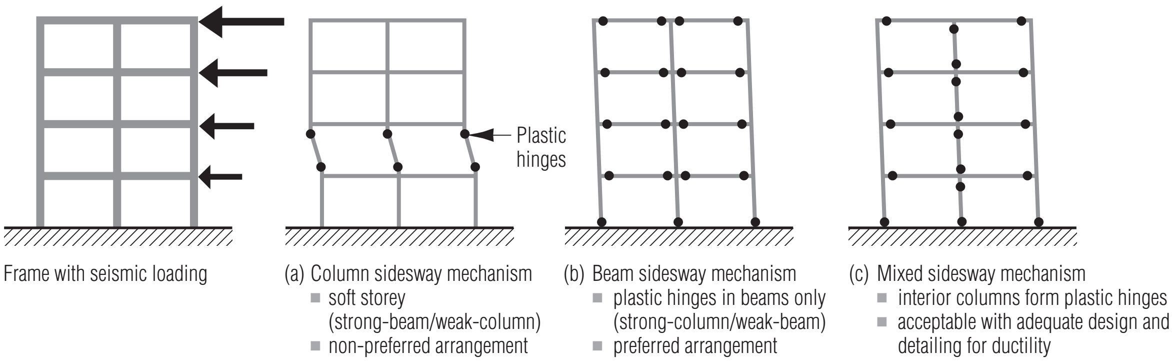


Figure 10.1 *Three Possible Mechanisms of Post-Elastic Deformation of Moment-Resisting Frames During Severe Seismic Loading* **[After Goldsworthy]**

10.5.3 **Reinforced Braced Systems**

Bracing members of braced frames are to be designed as struts or ties, as they will be subject to alternating compression and tension, and connections between members are to have greater strength than each connected member.

In terms of detailing, it is important to provide adequate lateral restraint along the whole length of the longitudinal reinforcement when it is subject to compression in the form of:

Helices. The volume of steel divided by the volume of concrete, per unit length of member must be greater than $0.12(f'_c/f_{sy.f})$; or

Closed ties.

$A_{sv} \geq 0.30\ s\ y_1(A_g/A_c - 1)\ (f'_c/f_{sy.f})$

(unless $\phi N_{uo} > N^*$)

or

$A_{sv} \geq 0.09\ s\ y_1(f'_c/f_{sy.f})$

whichever is the greater

where:

s = centre to centre spacing of the ties

y_1 = the larger core dimension

A_g = the gross cross-sectional area of column

A_c = the cross-sectional area of the core measured over the outside of the ties

f'_c = the characteristic compressive cylinder strength of concrete at 28 days

$f_{sy.f}$ = the yield strength of the ties

ϕ = a strength reduction factor

N_{uo} = the ultimate strength in compression of an axially loaded cross-section without eccentricity

N^* = the axial compressive or tensile force on a cross-section.

11

Footings

11.1 GENERAL

11.1.1 Foundation

The ground on which a structure rests, or is supported by, is called the foundation.

11.1.2 Footing

A footing is that part of the structure which is in contact with the foundation. It is essential that the footing and foundation are in complete contact and, for this reason, concrete is the only satisfactory material; when placed and compacted properly, concrete will fill any hollows in the foundation and, after it hardens, will transfer the load from the structure to the foundation.

11.1.3 Preparation of the Foundation

In certain circumstances, it may be necessary to increase the strength of the surface layers of the foundation by using special techniques. Some of the common methods include compacted back-fill, crushed rock, lean concrete, etc, and full details must be given in the drawings or Specification.

The minimum depth at which footings are to be founded must be indicated so that an estimate of the excavation cost can be made, together with provision for altering as applicable the length of the supported column.

11.2 AS 3600 REQUIREMENTS

The Concrete Structures Standard does not have a section specifically allocated to footings. For design purposes, a footing is considered to act as if it was a beam or a slab, depending on its shape and loading condition.

11.3 FOOTING PLAN-VIEWS

11.3.1 Types

Two types of drawings are usually required to describe the footing arrangements:

- a complete footing plan for the whole structure, and
- an individual plan-view, depending on the types of footings used in the structure.

11.3.2 Complete Footing Plan for the Whole Structure

See **Drawing Sheet No 11.1** – **Clause 11.16**.

- Define the location of every footing. If architectural drawings use a grid-line system, the identical system must be adopted. As distinct from many other elements, location dimensions for footings are as much the responsibility of the engineer as that of the architect because the footing layout affects the strength of the whole structure. Footing centre lines are often used as locating dimensions.
- Indicate the general shape looking down at each footing. This view will also show the orientation of each footing. Detailed dimensions of each footing are normally given on its own drawing or, where the footings are rectangular, in a footing schedule.
- Give a reference number for each footing and for the column or wall which is supported by it. Normally, the footing reference number will be the same as the reference number of the supported column; this is mandatory when a column schedule is used, **Drawing Sheet No 11.7**.

11.3.3 Individual Footing Plan-Views

Where the shape and dimensions of a footing are not obvious:

- Draw the exact shape of the footing with all necessary dimensions for excavating the hole in the foundation.
- Specify the minimum depth to which the excavation must be made and, in at least a General Note in the drawing, an indication of the type of ground expected or allowed for together with its predicted bearing capacity. If the engineer requires soil tests, this can be stated in the drawings although it is often given in the Specification in more detail.
- Give the location, orientation, shape and dimensions of the column or wall supported by the footing. Within this shape will be shown the location of all reinforcement cast with the footing but extending into the column or wall.
- Reinforcement of the footing is usually not shown in a plan-view except in the case of simple pad footings. As a general rule, footing details tend to follow beam rather than slab detailing methods in that the number of bars should be stated, not just the spacing.

11.4 FOOTING ELEVATIONS

These are usually given as longitudinal-sections; that is, as a view taken along the length of the footing giving the same information as a beam elevation. They will need to be supplemented by cross-sections. See **Drawing Sheet No 11.4**.

11.5 FOOTING CROSS-SECTIONS

These differ with the type of footing being detailed.

- Where the footing shape is rectangular, similar to a strip footing, cross-sections like those of beams are suitable. These would show the fitment shape and the main reinforcement layout. See **Drawing Sheet No 11.4**.
- Where pad-footings or complex footings are detailed, the shape of the main steel can be defined by the shape of the section.

11.6 GENERAL COMMENTS ON FOOTING DETAILS

11.6.1 Selection of Cover for Footings

Refer to **Chapter 5** of this Handbook and AS 3600 Section 4.10. Selection of cover must be done by the designer; once settled, values can be tabulated in the General Notes section of the drawings. Note that the increase in cover for footings is to accommodate the uneven nature of excavation.

11.6.2 Starter Bars

- Footing reinforcement is generally required quickly at the start of a job, and must therefore be scheduled as shown on the original drawings.
- Once the excavation is completed, the footing steel and starter bars are fixed, and approval is given to pour a footing, this is done with utmost speed to prevent rain or ground water from affecting the foundation.
- All starter bars for columns or walls must be detailed with the footings by which they are supported; generally starter bars are an L-shape with the bottom end resting on and supported by the footing reinforcement. The length of this part should be at least twice the spacing between the footing bars.
- Because the bottom RL of a footing can change from that shown on the original drawings, provision must be made for adjusting the length of main bars in the columns rather than altering the column starter bars at the last minute.
  An extension to the vertical part of the L-shape starter bars will ensure an adequate lap at the top of the footing. By "cranking" or "offsetting" the column bars, and locating that portion at the *BOTTOM* of the column, additional changes can be minimised at a higher level of the building.
  The starter bars should not be cranked.
- Fixing of starter bars must be accurate as they affect the position of the whole structure. Inspection for location is just as important as checking that the steel layout is correct. If starter bars are connecting with precast, tie bars may need to be set out using a template or checked by survey prior to and after concreting to ensure they are in the correct locations.

11.7 STRIP FOOTINGS

Strip footings are traditionally used to support walls of concrete or masonry.

11.7.1 Strip Footings for Masonry Walls

Drawing Sheet No 11.2 shows a strip footing under a masonry wall. See also **Drawing Sheet No 11.1**.

- Strip footings for residential work must comply with AS 2870, *Residential slabs and footings*, for both strength and detailing purposes.
- The width of a strip footing is controlled firstly by the width of the wall it supports; accuracy of excavation is generally not great and it is important that the wall above (particularly if it is of masonry) is seated in its design location (usually central).

  The second requirement for the width is to limit the bearing pressure of the footing on the foundation. In some cases, the footing width is greater than the depth to spread the load and therefore reduce the pressure; in other types of soil, the width is kept as narrow as possible, depending on the wall width, and the depth is increased to add flexural strength to the footing.

  Dimensioning of strip footings is described in **Clause 8.7.4**. There it is recommended that the depth of a strip footing be given first to be consistent with a ground beam, regardless of which is the greater – depth or width. However, a dimensioned drawing is far more descriptive.
- Traditionally a layer of reinforcement is located in each of the top and bottom of a strip footing because the force from the ground below and that from the wall above may not always balance, as can occur at doorways in the wall or soft-spots in the foundation.

  Ties are used both to separate and position the layers; the spacing between ties is often nominal, and could range from 300 mm to 800 mm. Such ties in residential work are rarely designed as reinforcement for strength, unless the footing is very wide.
- At corners, the intersecting main steel should extend across the full width of the intersecting strip. Laps within the strip can be specified by notes or a drawing. In residential work, the actual lap should be given rather than a reference to a Standard; onsite copies of these are rare.
- In residential and commercial work, "trenchmesh" such as L8TM, L11TM and L12TM is the most common form of strip footing reinforcement. Descriptions are given in **Clause 4.6**. The layers are held apart by nominal-size ties, generally at about 600 mm centres.

  In heavier construction, strip footings would be designed individually with trenchmesh or bars as main steel. Designed ties are used to maintain the footing reinforcement relative to the ground surface. For masonry, steps should match the course height. The concrete overlap must also be dimensioned.

11.7.2 Strip Footings for Concrete Walls

Drawing Sheet No 11.3 illustrates a strip footing under a concrete wall. See also **Drawing Sheet No 11.1**.

- Where the concrete wall acts structurally in a similar manner to masonry walls, the strip footing will be shown in the same way. Wall starter bars must also be detailed and scheduled with the footing.

  Longitudinal footing reinforcement is more important in this case than transverse reinforcement.
- Where the concrete wall is used to support horizontal loads, as with a retaining wall, concrete and reinforcement detailing is critical because of the heavy loads involved.

  Concrete walls are described in **Chapter 15**, with particular attention being paid to detailing of corners.
- Cantilever retaining walls depend on the footing for support against overturning forces and footing reinforcement placed perpendicular to the wall is more important for strength than that parallel to the wall.

11.8 PAD FOOTINGS, ISOLATED FOOTINGS AND SPREAD FOOTINGS

These terms mean the same thing. See **Drawing Sheet Nos 11.1**, **11.5** and **11.7**.

- A pad footing spreads the load from a single column over a large area of the foundation. Reinforcement must be placed in the bottom of the pad because the reaction of the ground acts upwards on all sides of the column. Note particularly that the reinforcement is placed in TWO directions because of this reaction. Not only is the pad footing designed for flexure but it must be checked for punching shear. Avoid the use of shear reinforcement by using a deeper pad footing or higher concrete strength or both.
- The pad bars are often shown as LL-shaped, but in many cases, this is not necessary unless there is a length deficiency for stress development. The cover over the outermost bars in one direction is increased by hooks on the bars at right angles; thus the number of bars should be stated, not only the spacing.
- Where the pad is less than 2500 mm wide, one or two sheets of mesh may be used, nested together. The cross-wires form part of the transverse steel as well.
- Concrete columns must be reinforced and the bars must extend into the footing pad. As previously discussed, the starter bars are supplied and fixed with the footing reinforcement and adequate lap lengths must be allowed above the pad.
- The orientation and location of the starter bars in relation to the column shape is extremely important for strength and architectural purposes; a fully dimensioned cross-section will be required for odd-shaped columns.
- Embedment of the starters in the pad is a design matter, and the anchorage requirements may need to be dimensioned in critical cases. Generally, the starter bars will be scheduled as L-shaped to be stood-up on the pad steel. For fixing purposes, at least three fitments should be detailed and supplied with the starters – two go within the pad depth and the other is tied around the exposed lap length. Provided the starters do not have to be cranked (see **Clause 11.6.2** earlier), the size of these fitments would normally be the same as those for the column above.

11.9 COMBINED FOOTINGS AND CANTILEVER FOOTINGS

- These footings are similar to pad footings except that, in most cases, they support more than one column. In the case of a cantilever footing, the second column tends to counter-balance the other at the end of the footing. In **Drawing Sheet Nos 11.1** and **11.4**, element CF3 is a cantilever footing. Column 10 is at the boundary and is counterbalanced by column 7 inside the building. Footings CF4 and CF8 are similar.
- The upward reaction of the foundation is complex and outside the scope of this Handbook. The main design factor is that the concentrated downward loads from the columns create the upward forces on the bottom of the footing, so that in this case, the TOP surface of the footing must be the more-heavily reinforced. This is the reverse loading for a normal pad footing, and indeed for a suspended beam. The elevations and sections in **Drawing Sheet No 11.4** show that the top has much more longitudinal steel than the bottom.
- Shear reinforcement in the form of mesh or bar stirrups is a critical design factor because the loads are much more severe than for strip footings.

11.10 RAFT FOOTINGS

- A raft footing is used when the soil foundation is poor or it is often regarded as a flat slab upside down with thickenings under the column. It enables the mass of the building to be supported by the lowest-floor (basement) slab. Similar to the cantilever footing described above, the foundation reaction requires that the top reinforcement between the columns may be heavier than the bottom. However there will be considerable reinforcement in the bottom face under the columns, probably in two directions.
- In domestic construction, raft footings are often used for reactive clay sites and they consist of beams in two directions intersecting at 4 to 6 metre centres both ways with a slab joining the beams.
- It is not uncommon for two layers of steel to be required in each direction top and bottom – that is eight layers altogether. Spacing for pouring and vibrating must be allowed, bundling pairs of bars where possible.
- Where a raft is used for a large multi-storey building, the distance between the top and bottom layers may be one metre or more. A considerable amount of extra material will be needed just to support the two grids of reinforcement. The Bill of Quantities if used should indicate the quantities involved, and how to price this work if extras are to be avoided.

11.11 RESIDENTIAL AND COMMERCIAL BUILDINGS – SLAB-ON-GROUND

- This element follows the same principles as for a raft but the magnitude of construction is much less. In this case, the wall loads are taken directly to the ground by the edge footings or by internal beams or thickened strips, all poured at the same time as the slab.
- Reinforcement in the footings resembles that in strip footings, with trenchmesh predominating. Mesh is the preferred steel for the slabs and is located near the top surface.
- A vapour barrier must be specified together with reinforcement spacers on a suitable base which will prevent puncturing the membrane for all habitable areas.
- Residential work is controlled by AS 2870; commercial buildings may need an engineering design because walls will be higher than permitted by that standard, but the detailing principles will be similar.

11.12 PIER AND BEAM FOOTINGS

- Where there is a poor soil overlaying a good material, bored piers are often used to transfer the vertical loads to the latter. The piers would be detailed as for columns. Wall loads are transferred to the piers by beams which are detailed normally. The piers may be of uniform cross-section or be belled out at the bottom.
- In certain soils, the beam underside must be separated from the earth below – upward expansion can be catastrophic if the gap is inadequate. The method to be used is a design matter, and the solution must be detailed.

11.13 PILES AND PILE CAPS

- A group of piles is used to perform the same function as a pier when the load exceeds the capacity of a single pile. The pile cap distributes the column load to the piles. The load transfer system can be very complex and there can therefore be several layers of bars in both top and bottom faces. The bars are often not on a rectangular grid so careful detailing is required if the required arrangement is to be obtained. Large scale details may be advisable.
- In large buildings and civil engineering structures, a piling contract is often let well in advance of the building contract. If this is done, the actual location of the piles as driven must be given in the drawings for the building contract. It may be necessary to alter the pile cap design because the actual locations differ more than expected from the original design.
  The designer should allow for reasonable variation on the location of piles after driving, say ± 75mm. The tolerance permitted must be shown in the drawings, with the required cut-off points detailed.
  Reference should be made to AS 2159:2009 *Piling - Design and installation*.
- As with many footing designs, the top reinforcement will restrict access to the inside of the cage so that the method by which the cage is assembled should be a design and detailing matter. Access is required for placing concrete and vibrating it, as much as for fixing reinforcement and other embedments.

11.14 EXAMPLES OF FOOTING DETAILS

The following notes are based on the Detailing Examples shown in **Drawing Sheet Nos 11.1** to **11.7** at the end of this Chapter in **Clause 11.16**.

11.14.1 Example of Strip Footings

Drawing Sheet Nos 11.1, **11.2** and **11.3** illustrates a footing plan for a small building and details of strip footings. See also the notes in **Clause 11.7** for both strip footings supporting a masonry wall and supporting a concrete wall.

11.14.2 Example of a Cantilever Footing

Drawing Sheet No 11.4 shows the details of cantilever footings CF3, CF4 and CF8. The following comments discuss factors which must be considered by designers and detailers to ensure the member can be constructed "as designed". They apply to members other than footings as well.

- *The concrete outlines*. The elevation CF4 defines the concrete length and the cross-section CF4 clarifies the beam depth and width. Architectural drawings should be used to provide the column centreline dimensions.
- *Reinforcement layout for strength*. Take the cantilever footing CF4 as an example. It has been designed as an "upside-down" beam, that is there is more steel in the top than in the bottom. (See **Clause 11.9**).
  This situation requires strong tie bars to support the top steel, each bar of which weighs about 60 kg. These tie bars are shown on cross-section CF4 as three sets of N16-HT at each stirrup.
  The top main steel is the group labelled 20-N36-LL-T. In both cases, LL is the shape, T means TOP and the combination is quite adequate to define the bars and location.
  The bottom main bars are 8-N28-LL-B, and are drawn inside the fitments.
  Because of the heavy downward column loads and the footing width being 2000 mm, the ends of the cantilever footing are reinforced transversely with 6-N24-100-LL-B at one end, and 4-N24-100-LL-B at the other.
  In practice, these 10-N24's are identical because the footing width is constant. There is no need to show them on the cross-section because they have been fully defined on the elevation by the complete notation, thus eliminating at least one extra detail.

- *Reinforcement layout for assembly*. Footing CF4 is heavily reinforced. The total steel mass is about 1800 kg (1.8 tonnes), of which the main top bars comprise 1.2 tonnes. These bars must be supported upon the foundation (see also **Clause 11.1.3**) by means of the vertical legs of the N16 fitments.

  Just to assemble the cage as it is drawn, and tie it together with wire, will not be adequate.

  To maintain the whole cage properly will require additional longitudinal bars to be placed under the fitments resting on strong concrete or purpose-made steel chairs.

  As an alternative, 2 or 3 of the 8-N28-LL-B bars can be placed first on the supports to form the initial platform free of the earth. The remainder of the steel can then be built upon them.

  Examination of cross-section CF4 shows that there are actually three "beam" segments, each of which can be assembled separately and craned into position upon the pre-set supporting bars.
- *Problem areas*. The N24-100-LL-B bars across the bottom of the footing under the columns will need to be assembled early, so that the column starter bars (not shown here) can be tied to them.

  A width of 2000 mm for 20-N36 bars is inadequate if concrete is to be placed properly (see **Chapter 4**). To allow concrete to be cast and compacted, and the column starter bars to be placed through them, the top bars should be grouped into a series of 2-bar bundles or placed in two layers with a spacer bar. This requires designer's approval, so it is simpler to detail it that way in the first place.

  The individual stirrups of bars can perhaps be replaced by mesh bent to the fitment shape. This will reduce the time to tie the bars and will provide a rigid cage which does not require bracing.

Drawing Sheet No 11.4 gives two examples of cantilever footings.

11.14.3 Pad Footings - Standard Detail

Drawing Sheet No 11.5 illustrates a Standard Detail for an isolated pad footing under a reinforced concrete column.

- The number, orientation and layout of the footing bars and associated ties are not provided with the Standard Detail because these vary for each footing; neither are column cross-sections given here. All of these are shown in the column schedule.
- **Clause 12.9** and **Drawing Sheet No 11.7** show footing and column details in schedule format. This combines the application of a Standard Detail for a footing and one for a column (see also **Cause 12.8** and **Drawing Sheet No 11.6**).
- To assist in construction, note that two of the upper-layer pad bars are used as supports for the remainder.
- Splice lengths for column bars and embedment lengths for starter bars would also need to be scheduled, such as shown in **Table 11.1**.

Table 11.1 *Embedment Lengths for Starter Bars and Splice Lengths for Column Bars for 25-65 MPa Concrete Strength (as an example)*

Bar Size	Straight embedment in footing of 22 DIA. (mm)	Splice length of 40 DIA. (mm)	Number of fitments at column bar crank
N20	440	800	2-R10 or 1-L10
N24	530	960	2-R10 or 1-L12
N28	620	1120	1-N12 or 1-L12
N32	700	1280	2-N12 or 2-L12
N36	790	1440	2-N12 or 2-L12

11.15 DETAILING OF FOOTING SYSTEMS FOR SEISMIC ACTIONS

11.15.1 General

Adequate footing design is critical for ensuring that a building structure will be able to resist both the gravity loads and seismic forces calculated.

Where there is no possibility for inelastic deformations to develop under earthquake conditions, it is considered that standard detailing of reinforcement as for gravity loads and wind forces will be adequate. This will be the situation in the majority of buildings constructed in Australia.

However, where design indicates the occurrence, or possible occurrence, of reinforcement yielding during seismic action, the foundation structure, like the superstructure, must be detailed accordingly. As already mentioned, as a result of code loading requirements or design decision, the seismic response of the structure may be elastic.

Paulay and Priestley suggest footing systems that may support elastic superstructures. (See as a Reference: Paulay, T. and Priestley, M.J.N. *Seismic Design of Reinforced Concrete and Masonry Buildings*, John Wiley and Sons Inc, 1992). Two of these will be relevant to Australian designers:

- *Elastic Footing Systems*. In regions of low seismicity (as is generally the case in Australia) or for low buildings with structural walls, it will be possible to design and detail the entire structure to respond within elastic limits.
- *Ductile Footing Systems*. In certain cases, the potential strength of the superstructure with respect to the specified seismic forces may be excessive (eg large shear wall structures). The designer might therefore consider that it will be preferable for the footing system rather than the superstructure to be the principal source of energy dissipation during inelastic response. A potential drawback for this system is that damage may occur during moderately strong earthquakes. Large cracks may form if yielding of reinforcement has occurred. Further, repairs to footings may be difficult and costly if required below the water table or under a floor slab.

Footing Structures for Frames as discussed in *Design Methodology*, AS 3600 provides some limited guidance regarding footing design and detailing. Although the Standard AS 1170.4 Clause 5.2.2 stipulates that for footings located in soils with a maximum bearing capacity of less than 250 kPa, restraint must be provided in the horizontal direction to limit differential movement during an earthquake. It should be noted that reports from Kobe indicate that although liquefaction is a problem in poor soils, the water in the saturated reclaimed area acted as a dampener, restricting damage to significantly less than that experienced in the adjoining 'dry soil' areas.

The Code considers that there is no possibility for inelastic deformations to develop under earthquake loading, and that standard detailing of footings for gravity and wind induced loads only will be sufficient. However, the author considers that certain additional precautions can be warranted.

11.15.2 Isolated Footings

These can prevent a problem with rocking or tipping if a plastic hinge forms in the base of the column. Unless precautions are taken, permanent deformation of the footing can occur due to plastic deformation of the soil despite both the column and footing remaining elastic. The detailing of the column/ footing joint must be carefully considered.

11.15.3 Combined Footings

It may prove more feasible to absorb large moments transmitted by plastic hinges at column bases by using stiff tie beams between footings, whereby a high degree of elastic restraint against column rotations can be provided. In fact, this detail is such that reinforcement yielding is unlikely to occur and it is considered that no special detailing requirements for ductility need be provided. It would, however, be necessary for the tie beams to have sufficient reserve strength over that of the hinging columns.

If it is required to reduce the bearing pressure under the footing pads, they may be joined to provide one continuous footing.

Stub columns do require special consideration if inelastic deformations and shear failure are to be avoided. Paulay and Priestley (see Reference in **Clause 11.15.1**) consider that plastic hinges should therefore be restricted to the column section immediately above the beam.

11.15.4 **Piled Footings**

Piled systems supporting structural walls may be subject to large concentrated forces due to vertical load causing overturning moments and shear forces. Careful design is therefore required.

Detailing of reinforced concrete piles should follow the recommendations set out for columns in **Chapter 12**. The end region of a pile under the footing structure should be detailed to ensure full confinement of the longitudinal reinforcement using closed or helical ties. The locations of peak moments in the pile may necessitate the length confinement being considerably extended. Further, even if calculations indicate no tension loads, it is recommended that minimum longitudinal reinforcement be provided. The arrangement of longitudinal reinforcement should be as for columns, and the reinforcement should be fully anchored within the pile cap. In non-critical regions, nominal transverse ties or spiral hoops should be provided. Paulay and Priestley (see Reference in **Clause 11.15.1**) recommend that vertical spacing not exceed 16 times the diameter of longitudinal bars. See **Figure 11.1**.

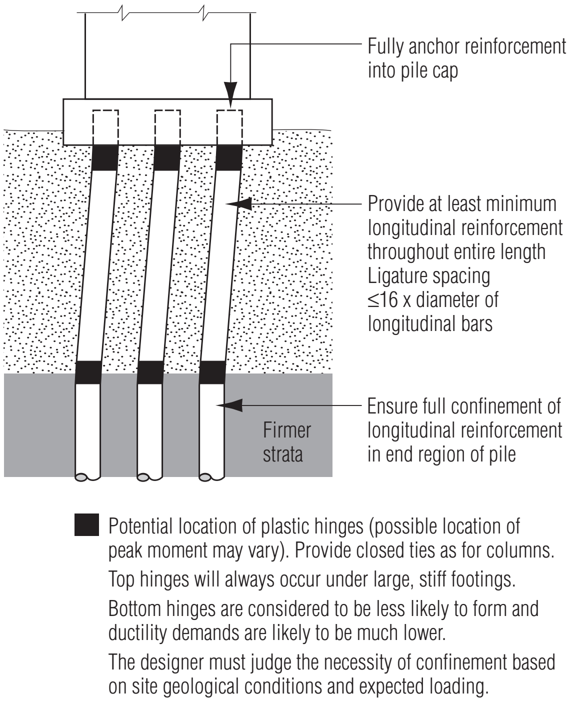
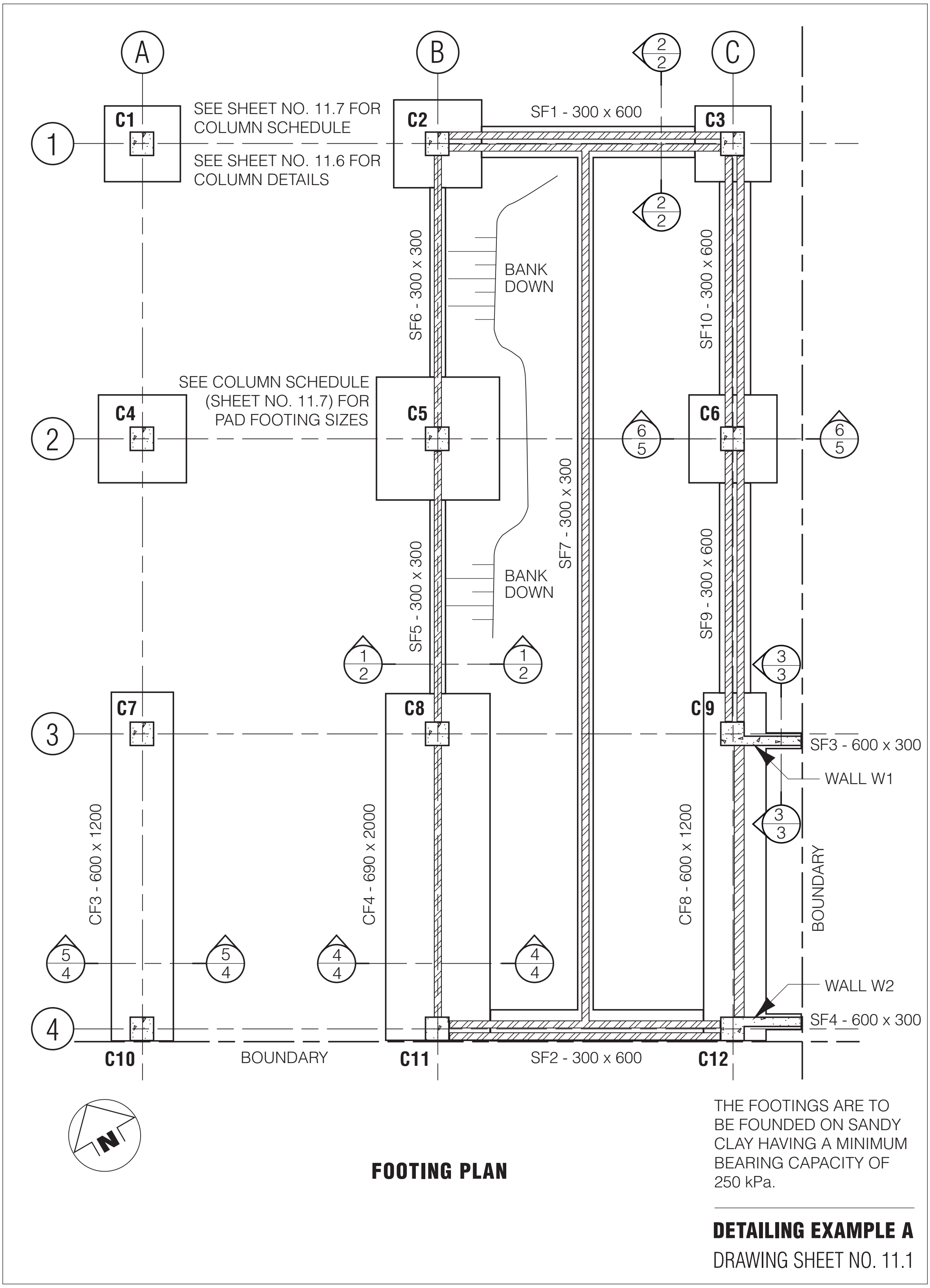


Figure 11.1 *Piled Footings*

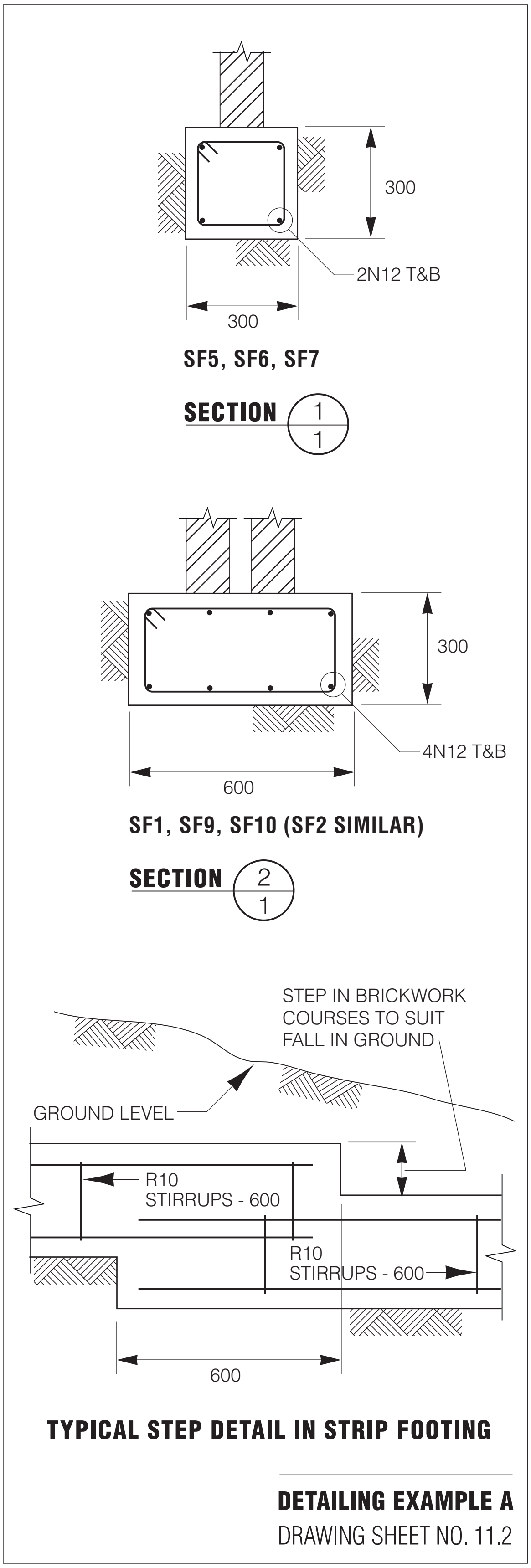
11.16 DETAILING EXAMPLES – DRAWING SHEETS NUMBERED 11.1 TO 11.7

The following Drawing Sheets represent selected detailing examples for a small building covering mainly footings and columns. They have been referenced throughout Chapter 11 and are also referenced in Chapter 12.

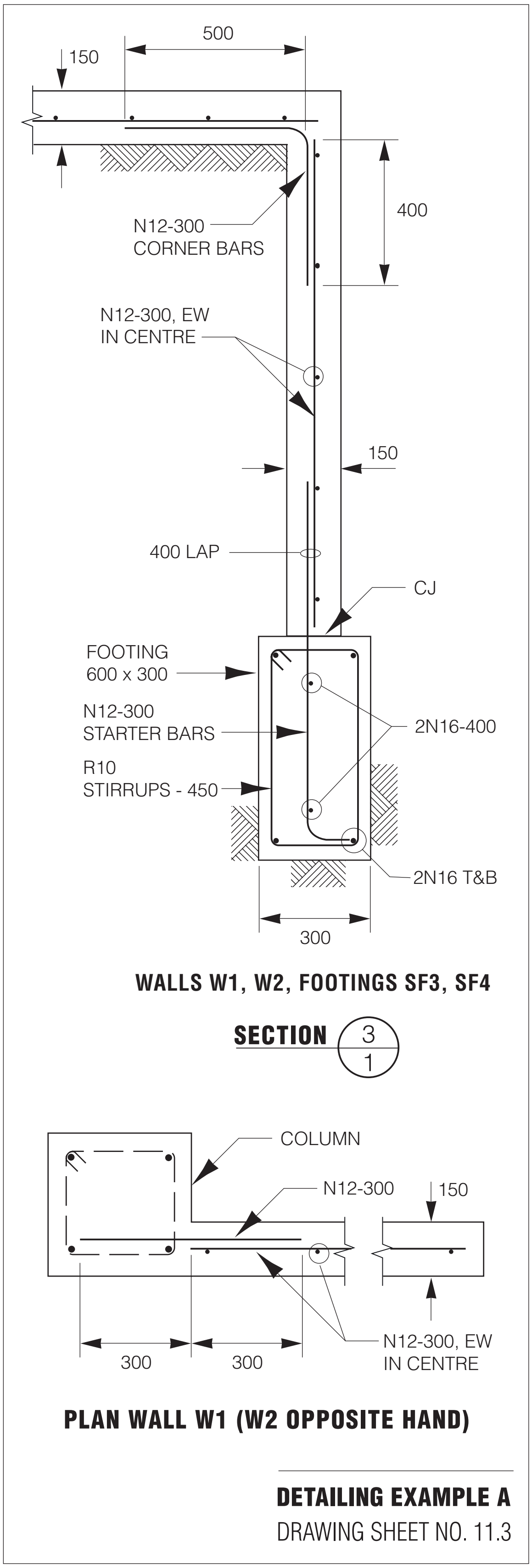
11.16.1 **Drawing Sheet Number 11.1**



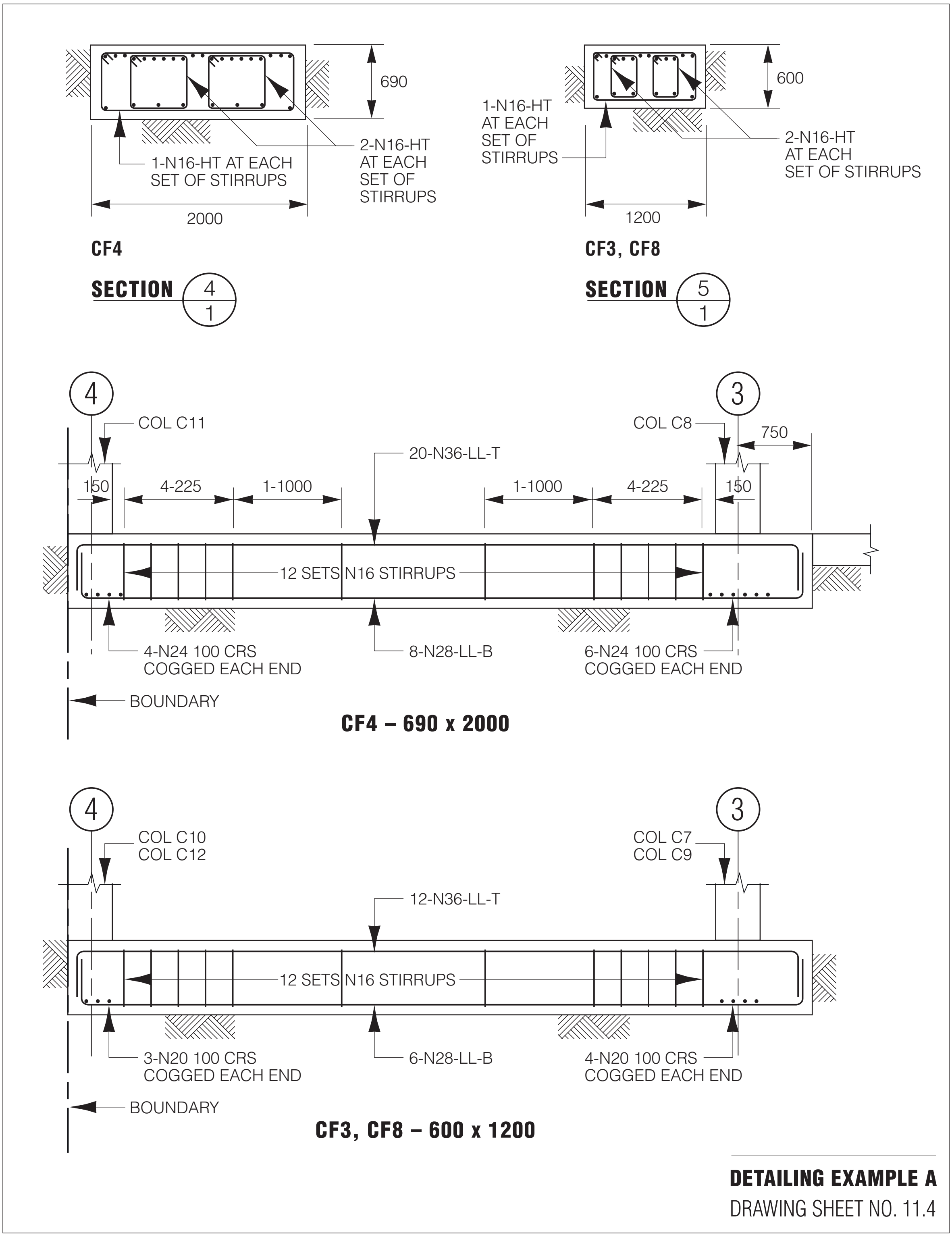
11.16.2 **Drawing Sheet Number 11.2**



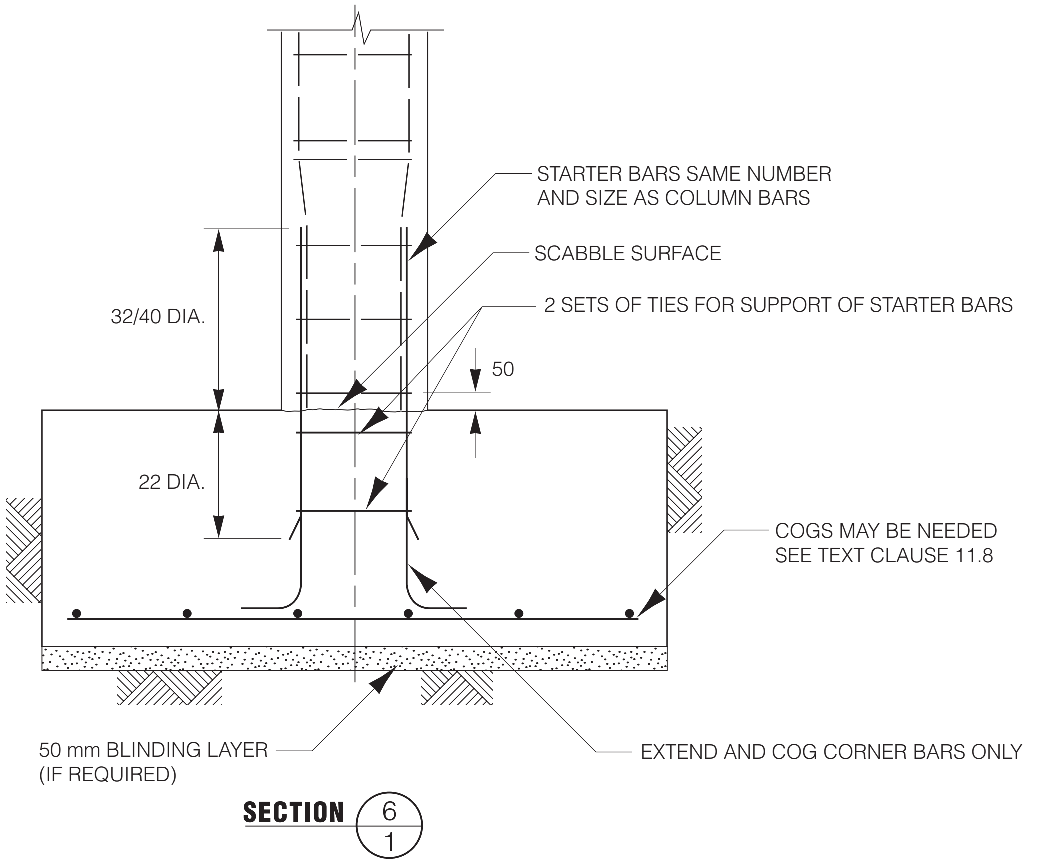
11.16.3 **Drawing Sheet Number 11.3**



11.16.4 **Drawing Sheet Number 11.4**



11.16.5 **Drawing Sheet Number 11.5**



NOTES

1 FOR LEVEL TO UNDERSIDE OF FOOTINGS, DIMENSIONS AND REINFORCEMENT SEE SHEET NUMBER 11.7.

2 OVERBREAK BELOW FOOTINGS TO BE FILLED TO UNDERSIDE OF FOOTING WITH GRADE N15 CONCRETE.

3 OVERBREAKS AROUND FOOTINGS TO BE FILLED WITH CONCRETE OF SAME GRADE AS FOOTING.

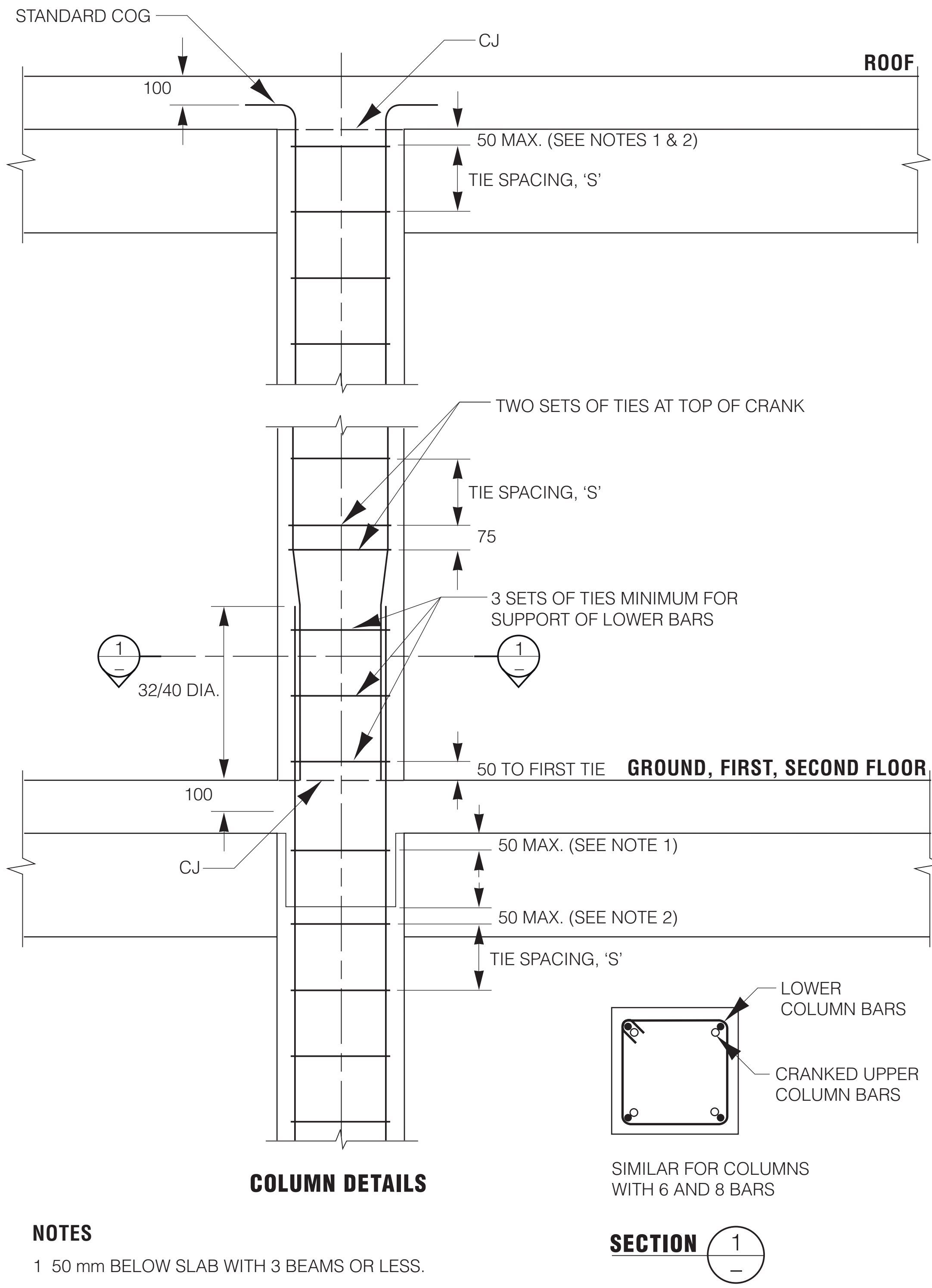
4 DETAILS ABOVE APPLY UNLESS SHOWN OTHERWISE ON DRAWINGS.

5 REFER ALSO TO STANDARD NOTES ON SHEET NUMBER ...

DETAILING EXAMPLE A

DRAWING SHEET NO. 11.5

11.16.6 **Drawing Sheet Number 11.6**



NOTES

1 50 mm BELOW SLAB WITH 3 BEAMS OR LESS.

2 50 mm BELOW SHALLOWEST BEAM WITH 4 BEAMS.

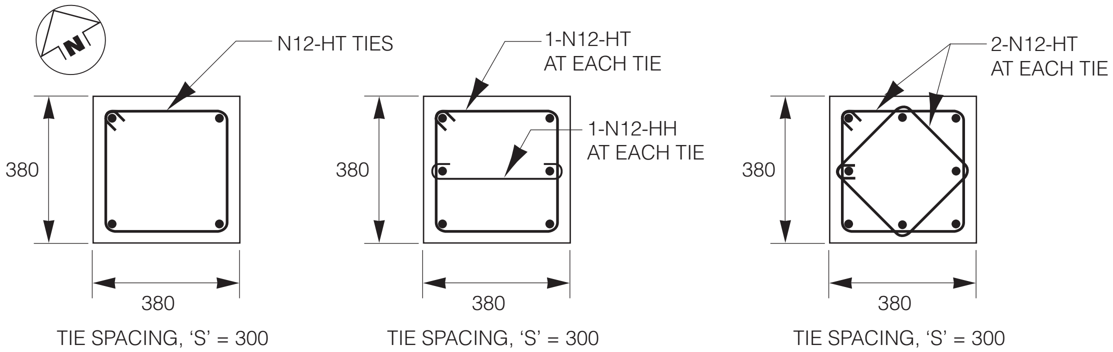
3 FOR SIZE AND REINFORCEMENT DETAILS, SEE COLUMN SCHEDULE ON SHEET NUMBER 11.7

4 REFER ALSO TO STANDARD NOTES ON SHEET NUMBER ...

DETAILING EXAMPLE A

DRAWING SHEET NO. 11.6

11.16.7 **Drawing Sheet Number 11.7**



TYPE 1 **TYPE 2** **TYPE 3**

TYPICAL COLUMN TYPES

COLUMN SCHEDULE

	COLUMN MARK	**1, 3**	**2, 4, 6**	**5**	**8**	**7, 9**	**11**	**10, 12**
ROOF		–	–	–	–	–	–	–
SECOND FLOOR	COLUMN SIZE MAIN BARS CONCRETE GRADE COLUMN TYPE	380 x 380 4-N20 N25 1	380 x 380 4-N20 N25 1	380 x 380 8-N20 N25 3	380 x 380 6-N20 N25 2	380 x 380 4-N20 N25 1	380 x 380 4-N20 N25 1	380 x 380 4-N20 N25 1
FIRST FLOOR	COLUMN SIZE MAIN BARS CONCRETE GRADE COLUMN TYPE	380 x 380 4-N20 N25 1	380 x 380 4-N24 N25 1	380 x 380 8-N24 N25 3	380 x 380 6-N20 N25 2	380 x 380 4-N24 N25 1	380 x 380 4-N24 N25 1	380 x 380 4-N20 N25 1
GROUND FLOOR	COLUMN SIZE MAIN BARS CONCRETE GRADE COLUMN TYPE	380 x 380 4-N24 N25 1	380 x 380 4-N28 N25 1	380 x 380 8-N32 N25 3	380 x 380 6-N28 N25 2	380 x 380 4-N28 N25 1	380 x 380 4-N32 N25 1	380 x 380 4-N24 N25 1
TOP OF FOOTING	COLUMN SIZE MAIN BARS CONCRETE GRADE COLUMN TYPE	380 x 380 4-N24 N25 1	380 x 380 4-N28 N25 1	380 x 380 8-N32 N25 3	380 x 380 6-N28 N25 2	380 x 380 4-N28 N25 1	380 x 380 4-N32 N25 1	380 x 380 4-N24 N25 1
FOOTING	STARTER BARS REINFORCEMENT FOOTING SIZE FOOTING DEPTH	4-N24 6-N16 EW 1400 SQ. 360	4-N28 7-N16 EW 1750 SQ. 400	8-N32 8-N20 EW 2450 SQ. 540	6-N28 SEE SHEET NO. 11.4	4-N28 SEE SHEET NO. 11.4	4-N32 SEE SHEET NO. 11.4	4-N24 SEE SHEET NO. 11.4
COLUMN MARK		**1, 3**	**2, 4, 6**	**5**	**8**	**7, 9**	**11**	**10, 12**

FOOTING LEVELS

COLUMN MARK	**1**	**2**	**3**	**4**	**5**	**6**	**7, 10**	**8, 11**	**9, 12**
UNDERSIDE OF FOOTING LEVEL	100.040	100.000	100.540	100.100	99.900	101.710	101.300	101.400	101.500

DETAILING EXAMPLE A

DRAWING SHEET NO. 11.7

12

Columns

12.1 GENERAL AND PURPOSE

Columns are vertical members of relatively small size which progressively pick up the vertical loads on each floor and, together with any lateral forces due to wind or earthquake resulting in shear forces if the columns are part of a moment frame, finally transfer all forces down to the footing.

The vertical load in the column is smallest at the roof and greatest at footing level. The load is carried by both the concrete and the embedded reinforcing bars. To carry this increasing load downwards from roof to footing, four alternatives may be considered.

(1) The concrete size is increased floor by floor, but this makes formwork costs excessive.
(2) The concrete size is kept constant and the number of longitudinal bars is increased, but this leads to steel congestion after its area exceeds about 4% of the cross-section.
(3) The concrete size is kept constant and its compressive strength (f'_c) is increased.
(4) A combination of alternatives is used.

This last solution is common with high-rise buildings. Solution (2) is suitable for low-rise buildings to ensure internal dimensions remain constant floor by floor.

12.2 AS 3600 REQUIREMENTS (Section 10.7)

The Concrete Structures Standard has a Section complete in itself on the design of columns and detailing of reinforcement. The major headings are listed here.

12.2.1 Limitations on the Longitudinal Steel Area

The minimum area of steel is 1% of the cross-sectional area unless the column is lightly loaded (Refer Clause 10.7.1 of AS3600). See also **Table 12.1** and **Figure 12.1**. The maximum steel area is 4%.

Table 12.1
Maximum Square Column Size for 1% Steel Area

Number of bars	Maximum square column size (mm) for bar size						
	N12	N16	N20	N24	N28	N32	N36
4	210	280	350	420	500	570	640
6	260	350	430	520	610	690	780
8	300	400	500	600	700	800	900
10	330	450	560	670	790	890	1010
12	360	490	610	730	860	980	1110
14	390	530	660	790	930	1060	1190
16	420	570	700	850	1000	1130	1280
18	440	600	750	900	1060	1200	1350
20	470	630	790	950	1110	1260	1430

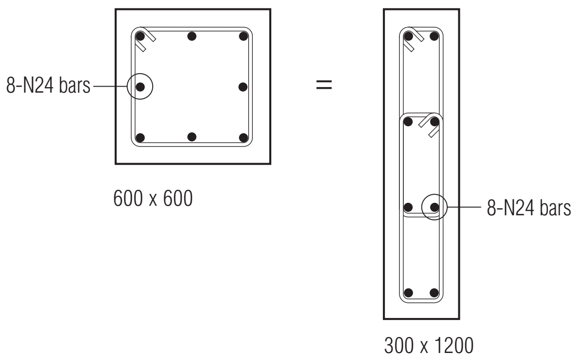


Figure 12.1 *Maximum Column Sizes for Minimum Steel Areas*

> **Example 12.1**
> A 600 mm square column must contain at least 4-N36 bars or 6-N28 bars or 8-N24 bars to be above the lower limit of 1% steel.
> See also **Clause 4.3.3** for minimum column widths based on concrete placement and **Clause 4.3.1** for fire resistance.

12.2.2 **Bundled Bars**

The minimum and maximum quantities are the same as for single bars. Spacing of bundles is based on their equivalent diameter; this is the diameter of a circle having the same area as the total of all the individual bars, **Figure 12.2**.

Table 12.2 gives rounded-off equivalent diameters of bars using the factors as shown. See also AS 3600 Clause 8.1.10.8 for bundled bars in beams.

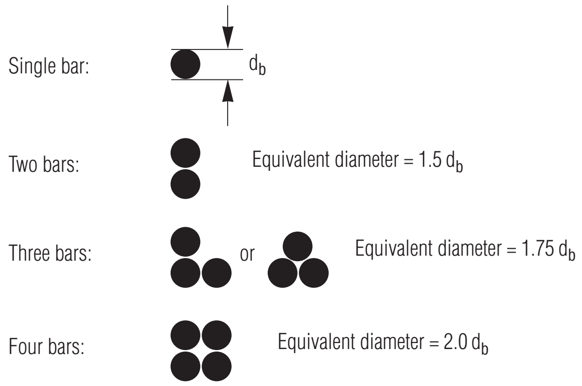


Figure 12.2 *Equivalent Diameter Factors of Bundled Bars*

Table 12.2 *Equivalent Diameter of Bundled Bars*

Number of bars in each bundle	Factor	Equivalent diameter (mm) for bundles, of bar size N12	N16	N20	N24	N28	N32	N36
2	1.50	18	24	30	36	42	48	54
3	1.75	21	28	35	42	49	56	63
4	2.00	24	32	40	48	56	64	72

12.2.3 **Lateral Restraint of Longitudinal Reinforcement**

All the main bars must be enclosed by ties. Whenever the centre-to-centre spacing of adjacent single bars is 150 mm or more (**Figure 12.3**) extra ties must be used. (See **Clause 11.16.7 Drawing Sheet No 11.7**). Each bundle must be restrained to the other bundles by ties.

Ties may also act as shear reinforcement for columns which resist lateral loads as part of a moment frame system.

For columns where $f'_c \leq 50$ MPa, confinement to the core reinforcement with fitments shall be as detailed in **Clauses 12.2.4, 12.2.5, 12.2.6** and **12.2.7** of this Handbook.

For columns where $f'_c > 50$ MPa confinement to the core reinforcement with fitments shall be calculated.

The fitments shall be designed to provide a minimum effective confining pressure to the core of $0.01f'_c$ calculated using AS 3600 Clauses 10.7.3.2, 10.7.3.3 and 10.7.3.4. The spacing of the fitments in this case shall not exceed the lesser of 0.8 of the smallest dimension of the column or 300 mm. Under certain conditions of axial force and moment on the column as detailed in AS 3600 Clause 10.7.3.1, the confining pressure may be relaxed by decreasing the spacing of the fitments to the maximum of the lesser of 0.6 of the smallest dimension of the column, 300 mm or that of Clause 10.7.4.

12.2.4 **Shape of the Ties**

The shape of the ties is defined in AS 3600 and can be described by reference to **Figure 9.1**. Shape HT would be used for the surrounding (outermost) tie, shapes HT and DT would provide a fitment with a bend of included angle of 135º or less, and an LH or HH shape could be the single tie across the column for internal-bar restraint or a pair of ties of shape HT can be used as shown in **Figure 12.3**.

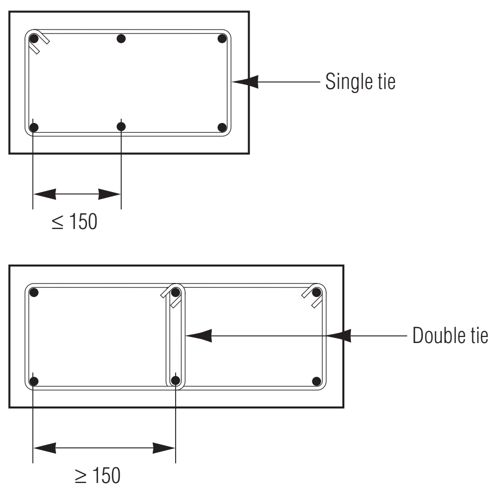


Figure 12.3 *Requirements for Lateral Restraint of Longitudinal Reinforcement*

12.2.5 **Circular Ties and Helices**

These are generally made by a machine which curves the wire into a continuous circular helix (or spiral). A circular tie can be made from a helix by cutting it to the length needed for one turn plus a lap plus two 135° fitment hooks. To ensure a fixed diameter, a welded circular tie without hooks may be specified.

12.2.6 **Design of Ties and Helices**

This is done by selecting a suitable bar or wire size $d_{b.fit}$ and then checking that the maximum tie spacing (based on $15d_{b.m}$ for single main-bars, and $7.5d_{b.m}$ for bundled main-bars) does not exceed the column smaller-dimension for single main-bars and half of the column smaller dimension for bundled main-bars, **Figure 12.4**. Maximum spacings are given in **Table 12.3** .

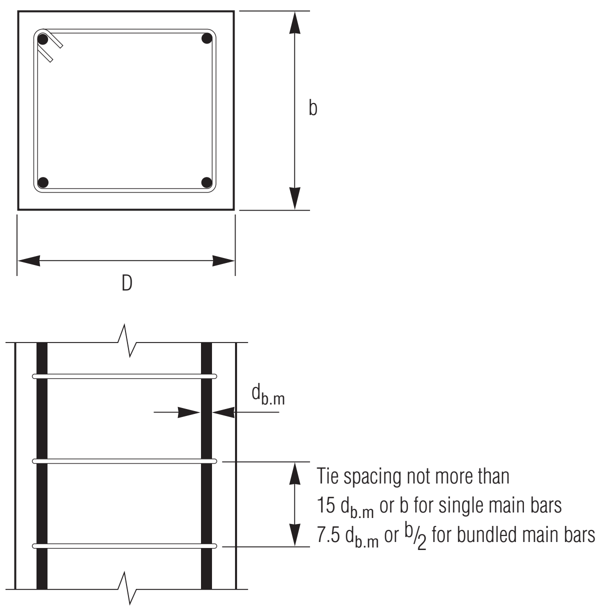


Figure 12.4 *Tie Spacings*

12.2.7 **Welded-Wire Mesh of Equivalent Strength to Bars**

Table 12.4 gives one solution based on maximum allowable tie spacing. A strength-conversion factor of 250/500 is used because grade 250 bars are indicated by AS 3600.

12.2.8 **Lateral Shear Forces at Beam-Column or Slab-Column Joints. (AS 3600 Clause 10.7.4.5 and others)**

A calculation is required to obtain the quantity of reinforcement within the joint. A formula is provided to give the quantity of bar or mesh.

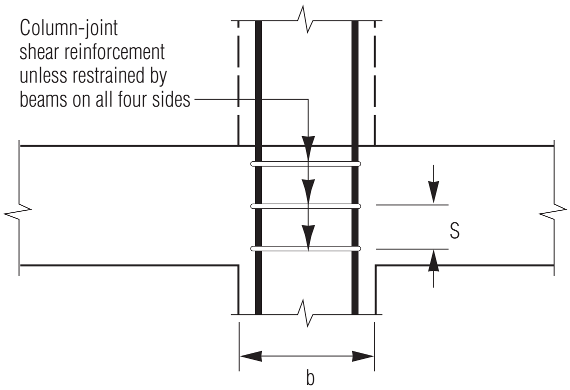


Figure 12.5 *Column-Joint Shear Reinforcement*

Example 12.2

A column has dimensions 450 x 300 mm with N28 single main bars. Ties can be R10 or L10 or greater. Based on 15 x N28, the maximum spacing could be 420 mm, but the smaller column dimension of 300 mm reduces the spacing to 300 mm.

If bundles of N28 bars were used, the ties must be R12, N12 or L12 and the spacing is based on smaller of the 7.5 x N28 = 210 mm or 300/2 = 150 mm and hence spacing is 150 mm.

Table 12.3 *Maximum Tie Spacing – Based on Relationship between Main-Bar Size and Column Smaller-Dimension* (AS 3600 Table 10.7.4.3)

Main bar arrangement	Tie size & spacing	Maximum tie spacing (mm) for main bar size							
		N12	N16	N20	N24	N28	N32	N36	N40
Single	R6 @ $15d_{b.m}$	180	240	300	N/A	N/A	N/A	N/A	N/A
Single	R10 @ $15d_{b.m}$	180	240	300	360	420	N/A	N/A	N/A
Single	R12 @ $15d_{b.m}$	180	240	300	360	420	480	540	-
Single	R16 @ $15d_{b.m}$	180	240	300	360	420	480	540	600
Bundled	R12 @ $7.5d_{b.m}$	90	120	150	180	210	240	270	-

N/A = Not Allowed

Table 12.4 *Mesh Substitution for Ties (After AS 3600 Clause 10.7.4.3 Note)*

Main bar and tie arrangement	Smallest main-bar size $d_{b.main}$ in the column						
	N12	N16	N20	N24	N28	N32	N36
Single R6 @ 15 $d_{b.m}$	180	240	300	–	–	–	–
Equivalent Mesh:	SL52	SL52	SL52	–	–	–	–
Single R10 @ 15 $d_{b.m}$	180	240	300	360	420	480	540
Equivalent Mesh:	SL82	SL72	SL62	SL62	SL52	SL52	SL52
Bundles R12 @ 7.5 $d_{b.m}$	90	120	150	180	210	240	270
Equivalent Mesh:	RL918	RL818	RL718	SL92	SL92	SL82	SL82

Table 12.5 *Fitment Bar Size Required to Restrain a Cranked Column Bar of Length 10 $d_{b.main}$*

Calculations based on force in main bar	Bar size, $d_{b.main}$						
	N12	N16	N20	N24	N28	N32	N36
Offset (mm) 1.12 $d_{b.m}$ + 10	23	28	32	37	41	46	50
Slope (mm)	120	160	200	240	280	320	360
Fitment bar sizes, $d_{b.fit}$ based on a 90° bend located at a crank							
Mesh and wire	L5	L7	L8	L9	L10	L11	L12
Grade D500N[1]	N12	N12	N12	N12	N12	N12	N12
Grade R250N[2]	R10	R10	R10	2-R10[3]	2-R10[3]	2-R12[3]	2-R12[3]

Notes:

1. N10 is the smallest size of Grade D500N bar.
2. R10 is the most common. Use wire instead if necessary.
3. Use two fitments of common size rather than one larger-size bar.

Author's Note:

The values in the Tables 12.3 and 12.4 appear illogical because a smaller effective area of mesh will provide "strength equivalent to bar fitments" as the latter spacing increases. The reverse would appear more logical.

Example 12.3

Referring to the **Example 12.2**, the mesh substitute is SL92 for the bundled bars because the fitment spacing is 150 mm. Where the smaller column size controls the tie spacing, mesh SL52 is used as an equivalent for spacing of R10 at 300 mm.

12.2.9 **Splicing Column Steel**

This Handbook is based on the premise that concrete elements are detailed on an element-by-element basis, and that the art of detailing is in showing how the pieces can be joined together structurally. Splicing of column reinforcement is critical. Suitable methods include lap-splices, welding, mechanical splicing, and end-bearing for columns only if always in compression.

The length of compressive and tensile lap-splices is given in **Chapter 6** for both single and bundled bars.

12.2.10 **Restraint of Column Bars at Crank Points**

The most popular and economical method of splicing column bars is by lapping bars which are offset-bent (cranked). The slope of the inclined part must be less than 1 in 6 to attempt to prevent the bars from buckling at the crank due to the horizontal component of the downward force on the bars. Additionally, extra ties should be required at the offset. **Table 12.5** gives some values for the type and size of reinforcement needed to provide this restraint for a slope of 1 in 10. A length of 300 mm along the crank is commonly used by schedulers.

The bar size of the ties depends on the horizontal component of the vertical force in the cranked portion. These forces are derived from factored loads.

The Table assumes that corner main bars are restrained by a 90° corner of a tie, carrying 1.5 times the horizontal component; hence both legs share the load. The 1.5 factor is not stated in AS 3600, but comes from AS 1480:1982 which was not a limit state standard.

For an internal bar, a separate link or pair of links with one leg, of the same size shown in the Table, provide restraint for a force of 1.0 times the horizontal component.

12.2.11 **Transmission of Axial Force through Floor Systems**

If the concrete strength specified for the floor system is greater than or equal to 0.75 times that specified for the column and the longitudinal reinforcement is continuous through the joint, transmission of forces through the joint is deemed to be provided.

If the concrete strength specified for the floor system is less than 0.75 times that specified for the column and the longitudinal reinforcement is continuous through the joint, then the effective compressive strength of the concrete in the joint can be calculated by formulae given in AS 3600 Clause 10.8. The formulae is different depending on whether there are four beams or two beams on opposing sides at the joint.

12.3 COLUMN PLAN-VIEWS

The location and orientation of all columns is shown on footing and floor plans-views. The scale is far too small to show reinforcement.

The column shape is indicated but full details are given separately on cross-sections or by reference to the column schedule. Columns which are rectangular or circular are easy to define but other shapes will require full dimensioning.

12.4 COLUMN ELEVATIONS

12.4.1 **Column Main-Bars**

Unless extra cross-Sections and other details are provided, it is advisable to use only one bar size in each storey of a column. If this approach is used, only one bar shape need be drawn in full on the elevation (see **Clause 11.16 Drawing Sheet No 11.6**). Where a column schedule is not used, the basic design notation consisting of number off and bar type-size is given on a leader to this bar and other bars can be arrowed by an extension of this leader.

Where circular and rectangular columns are shown on the same sheet, more than one column elevation may be useful because the arrangement of ties will probably differ.

Where column sizes change throughout the height of the structure, adequate elevations and sections must be used to define offsets to concrete and bars.

12.4.2 **Location of Main-Bar Splices**

The main bars are spliced by lapping, end-bearing, welding or by mechanical splices; the form of splice can be defined by notes, but the location of the splice must be dimensioned in relation to the floor level below the splice.

A “kicker”, or a small (50 mm) plinth, can be cast above the floor to help define the column area and to provide a strong seating for the next set of column formwork. Kickers should be detailed. Current construction practice does not normally use kickers.

12.4.3 **Lap Splices**

Lapping is usually done at floor level so that the lower end of the new (upper) bar is supported on hardened concrete. The lap length must be specified in the drawings.

The main bars may extend more than one floor if there are no changes in column dimensions. Within **Chapter 13** on beam detailing, there is considerable comment made on avoiding steel congestion at column-to-floor intersections.

12.4.4 **Location of End-Bearing and Welded Splices**

These splices can best be done when located at a convenient working height above a floor, say 600 to 1200 mm. The splices should be staggered within the column storey to ensure adequate tensile strength is obtained throughout, **Figure 12.6**. See AS 3600 Clause 10.7.5 and **Clause 12.4.6** of this Handbook.

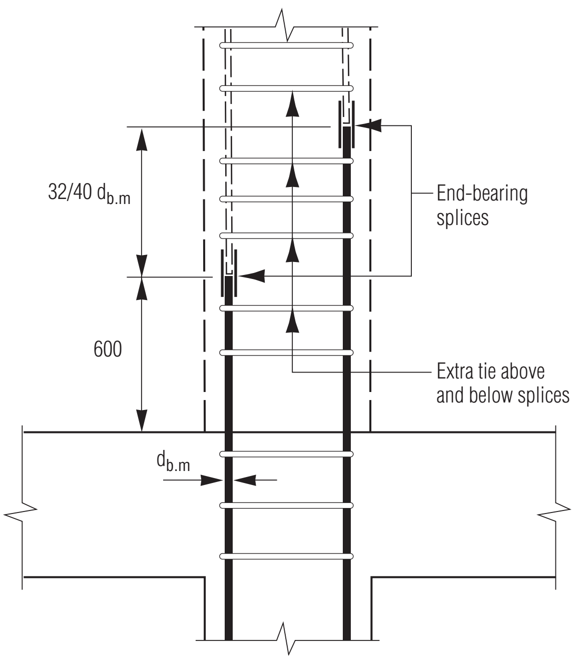


Figure 12.6 *Location of End-Bearing Splices*

12.4.5 **Main-Bar Arrangement at Lap-Splice Level**

Lapped longitudinal bars are achieved by using cranked bars (shape CC).

If a column face is offset by 75 mm or more, the main bars are not continued through the construction joint. Separate short straight bars are to be used to splice the lower and upper main-bars. The splice length above and below the joint will depend on the stress, **Figure 12.7**. See also **Clause 6.12** and others.

With CC bars, the slope in the crank must not exceed 1:6 and is commonly specified as 300 mm for all sizes. The normal offset of the centre-line is one bar size. This allows the overlapped portions to be tied together.

There are three common methods of arranging the offset portion of the main bars at a lap splice.

(1) The offset is located just above the lap at the "working floor level". Orientation problems of the crank are eliminated, the bar continues straight through the floor above and fitment dimensions can be made identical on each floor and through the joint itself if shear steel is needed, **Figure 12.8**. See also **Clause 12.2** above. Column bars can be continuous through two floors or more depending on lifting capacity and a continuous mesh cage can provide full-height rigidity. Beam details can be standardised to provide repetition of prefabrication.
This method is illustrated on the column elevation in **Clause 11.16 Drawing Sheet No 11.6**, where one floor lift is detailed. Note particularly how variations in the levels of the footings can be accommodated without any need to replace bars previously supplied. It is strongly recommended that this method be used wherever possible.

(2) The column bars are straight and are not concentric throughout adjacent columns. This method has many of the virtues of the first method above, although the changes in location from lift to lift may be of concern. However in wall construction, and with wide blade columns, it has much to commend it for the internal bars, if not for the corner bars.

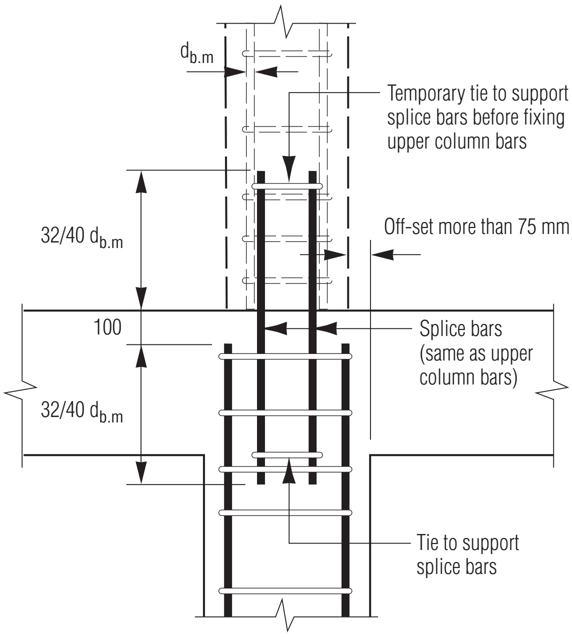


Figure 12.7 *Splice Treatment at Offset Column Faces*

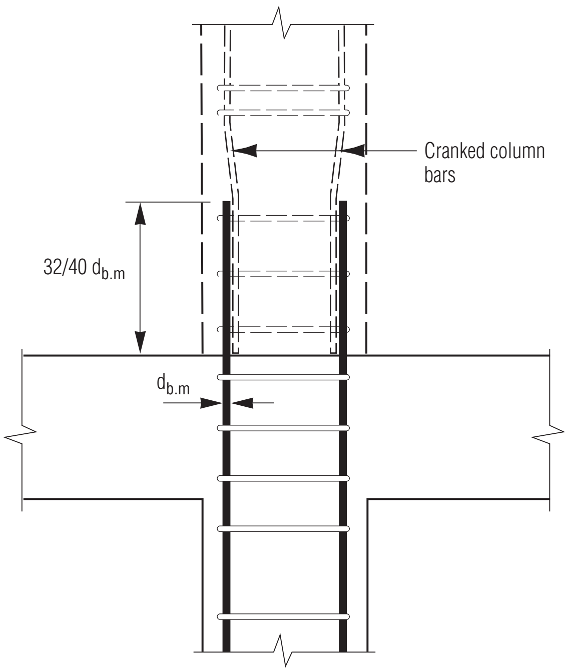


Figure 12.8 *Cranked Column Bars above Working Floor Level*

(3) The offset occurs through the beam or floor level. Unless the beam steel can be moved sideways, the cranked portion creates scheduling and fixing problems in deciding how to get beam steel through the cranked portion. Beam-column intersection problems will always be severe with narrow beams. Band beams provide a good solution, **Figure 12.9**. Orientation of the lap at the top and through the beam is critical and must be ensured by robust tying of the main bar to prevent rotation during the column pour. Remember that the crank is waving around in the air one floor or more up. Only one floor lift can be made at one time unless beam details are to be altered on alternate floors to accommodate the crank.

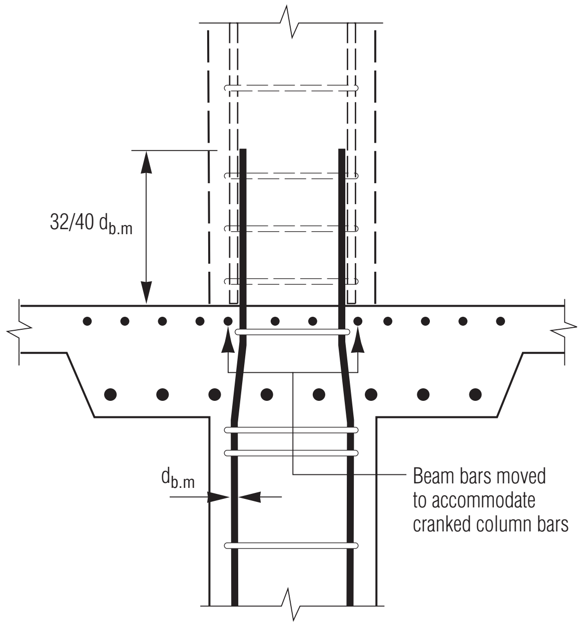


Figure 12.9 *Cranked Column Bars within Band Beams*

12.4.6 **Main Bars with End-Bearing and Mechanical Splices**

An elevation is essential for defining the location above floor level of the end-bearing splices. In particular, cross-sections are required for bundled bars. Bundled bars in columns require careful attention to layout to ensure bars in each column lift can be kept concentric with the columns above and below, **Figure 12.10**. A sleeve of some form, or a mechanical connection, must be fixed around each splice to ensure that the sawn ends are concentric.

Bar lengths should be multiples of the floor height for any method.

All bars used with end-bearing splices must be straight and have ends sawn or machined square. The ends must be aligned concentrically by a clamp.

Bars spliced by mechanical means such as crimped sleeves may not require special end preparation unless specified otherwise by the manufacturer.

Threaded connections require special treatment with reliable protection for both female and male threads.

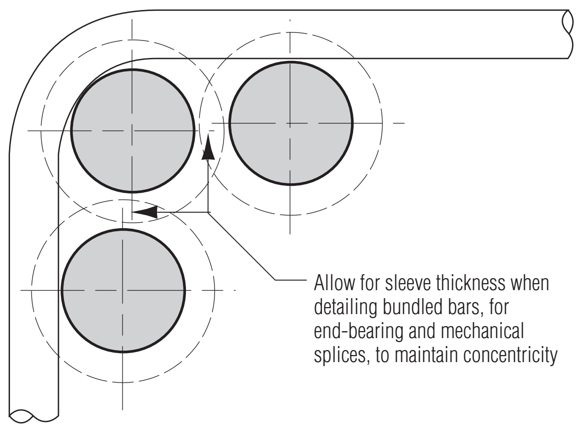


Figure 12.10 *Bundled Bars Must be Kept Concentric*

12.4.7 **Location of Column Ties within the Column Height**

- Spacing is generally uniform but it is necessary to indicate the location of the highest and lowest ties, usually 50 mm above the floor or kicker below and 50 mm below the highest soffit above, **Figure 12.11**. See the AS 3600 because the rule is quite complex.
- For scheduling purposes, the number of ties is taken as the height from floor to soffit-above, divided by the spacing, the result being rounded off to the next higher number.
- The number of turns of a circular helix is given in **Figure 9.1** for shape SP, as is the length of wire used to make the helix.
- One or more ties should be shown at the point where the main bar is cranked to resist any horizontal force there. This is a design matter. See **Clause 12.2.10**.

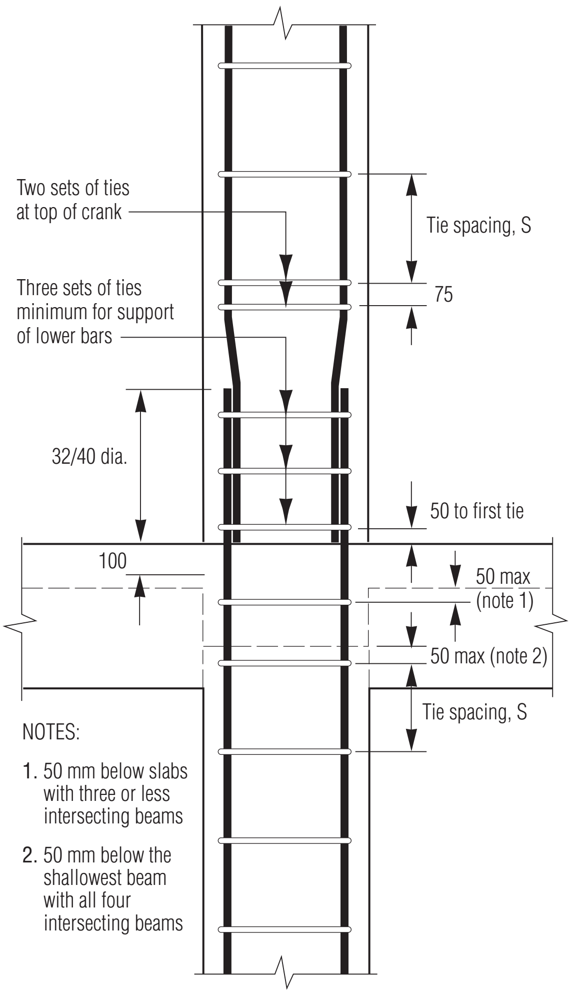


Figure 12.11 *Location of Column Ties within Column Height*

- Column ties may be required within the depth of a beam or slab under special circumstances. See earlier for appropriate guidance on quantities.
- Column ties should be located above and below end-bearing type splices to resist forces, particularly during construction.

12.5 COLUMN CROSS-SECTIONS

To be of use, these sections must be drawn to a larger scale than used with a plan-view. Essential information includes:

- The concrete strength f'_c for each lift, particularly if the column-concrete strength and the floor-concrete strength in the vicinity of the column, varies from the remainder of the floor-concrete f'_c.
- The orientation, shape and dimensions of the concrete outline for formwork construction. The use of a North Point or relationship to gridlines is essential.
- The shape and dimensions of the ties (usually determined from the concrete shape) with the basic design notation clearly stated. This should consist of the number-off, the steel type and the nominal spacing, **Figure 12.12**. If there is more than one tie at each spacing, the same information must be restated.
- The layout of all main bars within the section, often by a “typical drawing” if the section is rectangular or circular. This must include changes to the column size and the appropriate bar re-arrangement.
- Any special bar arrangements at lap-splices; that is, whether the upper bar is lapped inside or alongside the lower bar.
- How the bar arrangement is to be modified progressively throughout the height of the building from the footings. A grid system and templates for setting out the centre lines of the starter bars should be detailed on the contract drawings rather than requiring repeated calculations based on nominal concrete dimensions and concrete cover by several other people such as schedulers, formworkers and steelfixers.

- Details of ties which act as shear reinforcement within the beams or slab depth.
- Allowances for adequate tolerances for fixing main bars into corners of ties or at lap splices, etc. Generally values are obtained from the AS 3600 and are not stated in the drawings – perhaps they should be.

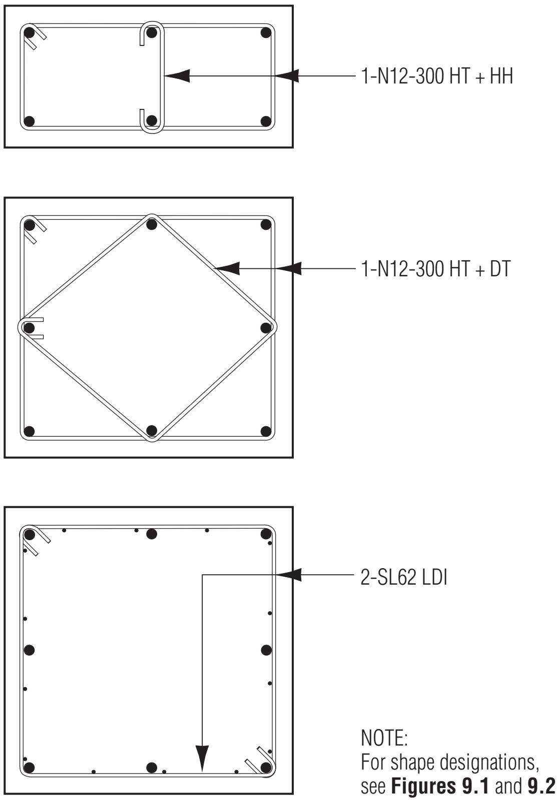


Figure 12.12 *Examples of Tie-Bar Notations*

12.6 DETAILING COLUMNS FOR CONSTRUCTION

The following comments are offered to assist column construction and to reduce cycle times.

- Use the fewest number of bars possible at any section. This reduces the quantity of bars to be handled on site and could reduce the number of ties making concrete placement simpler.
- Manual hoisting of column bars into place is heavy and time-consuming work. Contrary to the above comment, a greater number of smaller size bars may be an advantage in many cases, provided the extra ties do not increase fixing time.
- Finding the correct bundle of steel for each column, sorting the steel and then moving it near to its correct position is one of the most time-consuming tasks on site. It is advantageous if all column bars have the same size and dimensions, and this should normally be possible.

  When method (1) of **Clause 12.4.5** for designing main bars is used, small variations in floor-to-floor heights can be taken up within the splice length above the floor.

  Method (3) of **Clause 12.4.5** requires every column bar to be detailed for a particular column; this leads to longer sorting times, more chance of the wrong bars being used, reordering of replacement bars because the leftovers will not fit, additional delays, etc.
- Never use more than one bar size in any one column, even if the loads are eccentric. Murphy's law of material interchange will strike again.
- Maintain the same column section from footing to roof, particularly if bundled bars are used. If this is not acceptable, restrict changes to one face only.
- If the same column size cannot be maintained, the column bar arrangement above and below the change point must be detailed. The beam reinforcement layout may also require re-detailing.
- Where column faces are offset 75 mm or more, the main bars are not to be cranked but additional splice bars are to be used, **Figure 12.7**.
- Keep the tie layout as simple as possible. The number of ties is controlled by the centre-to-centre spacing of the bars in each face.

12.7 **IDEAS FOR PREFABRICATION**

Column cages can often be fabricated away from the forms and lifted into place by a crane or other mechanical method. For this to happen, a reasonably rigid cage is required. It is not essential that all the bars be tied or welded before erection.

Often the corner bars can be fixed firmly to the outer cage of bars or mesh, and the remainder secured inside during the lift. Once the cage and corner bars are placed over the starter bars at each floor level, the others are released and moved into position. Some flexibility should be permitted in the cage until it is positioned, then additional tying will be needed.

To prevent movement during concreting, the number and spacing of spacers should be specified in the drawings.

By placing the lap-splice crank at the bottom of the column, a mesh cage for the fitments can be used full height and even through the floor above. This method is compatible with the concept of beam caging described in this Handbook. As well as simplifying column-bar placement, this concept enables the main beam bars to be pre-assembled outside the form, and for shorter splicing bars to be passed through the column cage in such a way that there is no interference between column and beam bars. There are no AS 3600 requirements for the bottom bars required at mid span of a beam to be “continuous” into or through a support; “continuity” by splicing is perfectly legitimate.

12.8 **EXAMPLES OF STANDARD DETAILS FOR A REINFORCED CONCRETE COLUMN**

Clause 11.16 Drawing Sheet No 11.6 illustrates the lapping arrangement for one column of the same size above a floor as below. Another column where the face above is offset from that below is shown in **Figure 12.7**.

12.9 **EXAMPLE OF A COLUMN SCHEDULE**

Clause 11.16 Drawing Sheet No 11.7 provides a column schedule for a pad footing and the column above. The example is from the footing plan given in **Clause 11.16 Drawing Sheet No 11.1** and *Examples of Footing Details* **Clause 11.14.2**.

Column cross-sections accompany the column schedule. Each section is defined by a “type number” which is common for all columns having the same general shape (rectangular or square, say), the same number of bars and same tie layout. A well-designed schedule can save detailing time if the number of possible combinations is reduced to a practical minimum. Future amendments can be done merely by changing the type number.

Column orientation is important; a north-point may be necessary especially for rectangular columns.

The cantilever footings are detailed in **Clause 11.14.2** and **Clause 11.16 Drawing Sheet No 11.4**.

The pad footings are detailed in **Clause 11.14.3** and **Clause 11.16 Drawing Sheet No 11.5**.

Table 12.6 is an example of the type of details which can be given in the General Notes for the project, or on the same sheet as the column schedule.

Table 12.6 *Embedment Lengths for Starter Bars and Splice Lengths for Column Bars for 25-65 MPa Concrete Strength (as an example)*

Bar Size	Straight embedment in footing of 22 DIA. (mm)	Splice length of 40 DIA. (mm)	Number of fitments at column bar crank
N20	440	800	2-R10 or 1-L10
N24	530	960	2-R10 or 1-L12
N28	620	1120	1-N12 or 1-L12
N32	700	1280	2-N12 or 2-L12
N36	790	1440	2-N12 or 2-L12

12.10 DETAILING FOR SEISMIC (INTERMEDIATE MOMENT-RESISTING FRAMES)

12.10.1 General

As discussed in **Clause 10.5.2**, *Moment-Resisting Frame Systems*, it is desirable to ensure that any plastic hinges that may form should do so in the beam elements rather than the columns by ensuring that the flexural capacity of the column is higher than that of the beam by a significant margin to allow for any 'overstrength' due to design or materials. This is known as the 'weak beam/strong column' philosophy. Although it may not always be possible to achieve this, especially with such forms of construction as band beams (see below), care should be taken that catastrophic collapse, especially due to brittle shear failure in the column will not occur.

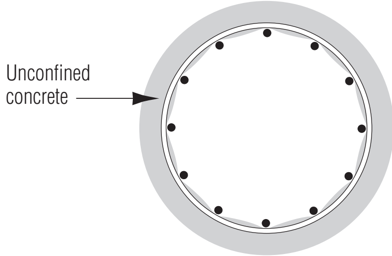
In many cases, the ultimate compression strain of unconfined concrete is inadequate to allow the structure to achieve the design level of ductility without excessive spalling of cover concrete. Adequate transverse reinforcement must therefore be provided to confine the compressed concrete within the core region to maintain its axial-load-carrying capacity and to prevent buckling of the longitudinal compression reinforcement and subsequent failure. Plastic hinge regions are particularly susceptible where substantial axial forces are present, eg in columns where inelastic deformations must occur to develop a full-hinge mechanism.

(Note: This may occur even where the design is based upon weak beam/strong column philosophy, such as at the base of all columns, see **Figure 10.1**).

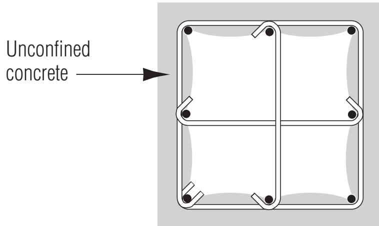
12.10.2 Confinement

Close-spaced transverse reinforcement acting in conjunction with longitudinal reinforcement restrains the lateral expansion of the concrete. This enables the concrete to withstand higher levels of compression.

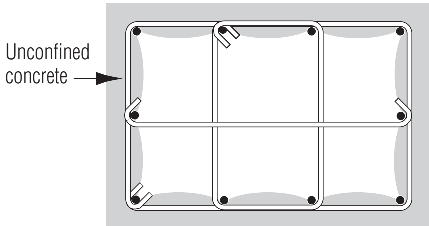
Circular or helical ties, due to their shape, are placed in hoop tension by the expanding concrete and provide confinement to the enclosed concrete **Figure 12.13(a)**. Rectangular ties apply full confinement only near their corners as the pressure of the concrete bends the legs outwards. This tendency should be counteracted by the use of cross-ties or interconnected closed ties. This has the additional benefit of increasing the number of legs crossing the section. The profiles of the unconfined zones of concrete between longitudinal bars are shallower, and consequently a greater area of concrete is confined. The presence of a number of longitudinal bars, enclosed by closely spaced ties will also significantly aid confinement. **Figure 12.13(b)**, **(c)**, **(d)** and **(e)**.



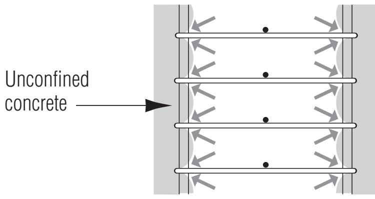
(a) CIRCULAR COLUMNS



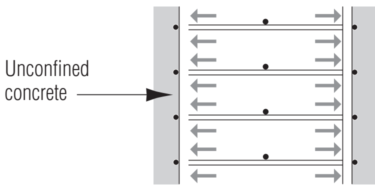
(b) SQUARE COLUMNS



(c) RECTANGULAR COLUMNS



(d) SECTION BETWEEN MAIN BARS



(e) SECTION AT MAIN BARS

Figure 12.13 *Confinement of Column Sections by Transverse and Longitudinal Reinforcement*

The confinement of concrete is addressed in Appendix C of AS 3600 by the provision of closed ties, within a distance from each end of the clear height of a column within a storey for a distance greater than the larger of:

- The maximum dimension of the column cross-section; or
- One-sixth of the least clear distance between consecutive flexural members framing into it. Further, the spacing of the closed ties is not to be greater than required by AS 3600 Clauses 10.7.3 and 10.7.4 with the first tie located at half this spacing. The overall cross-sectional area of the ties must obviously be sufficient to satisfy the shear requirements of the column **Figure 12.14**.

12.10.3 Lapped Splices

It is inevitable that splices will occur in the column reinforcement of multi-storey buildings. It is important therefore to ensure that these are detailed and located such that failure will not occur under earthquake action. Splicing is usually achieved by the use of overlapping parallel bars. In this method, force transmission occurs due to the bond between the bars and the surrounding concrete, as well as due to the response of concrete between adjacent bars.

Under severe cyclical loading, column splices tend to progressively 'unzip'. Further, where large steel forces are to be transmitted by bond, splitting of the concrete can occur. To prevent these occurrences, ties are required to provide a 'clamping force' to the

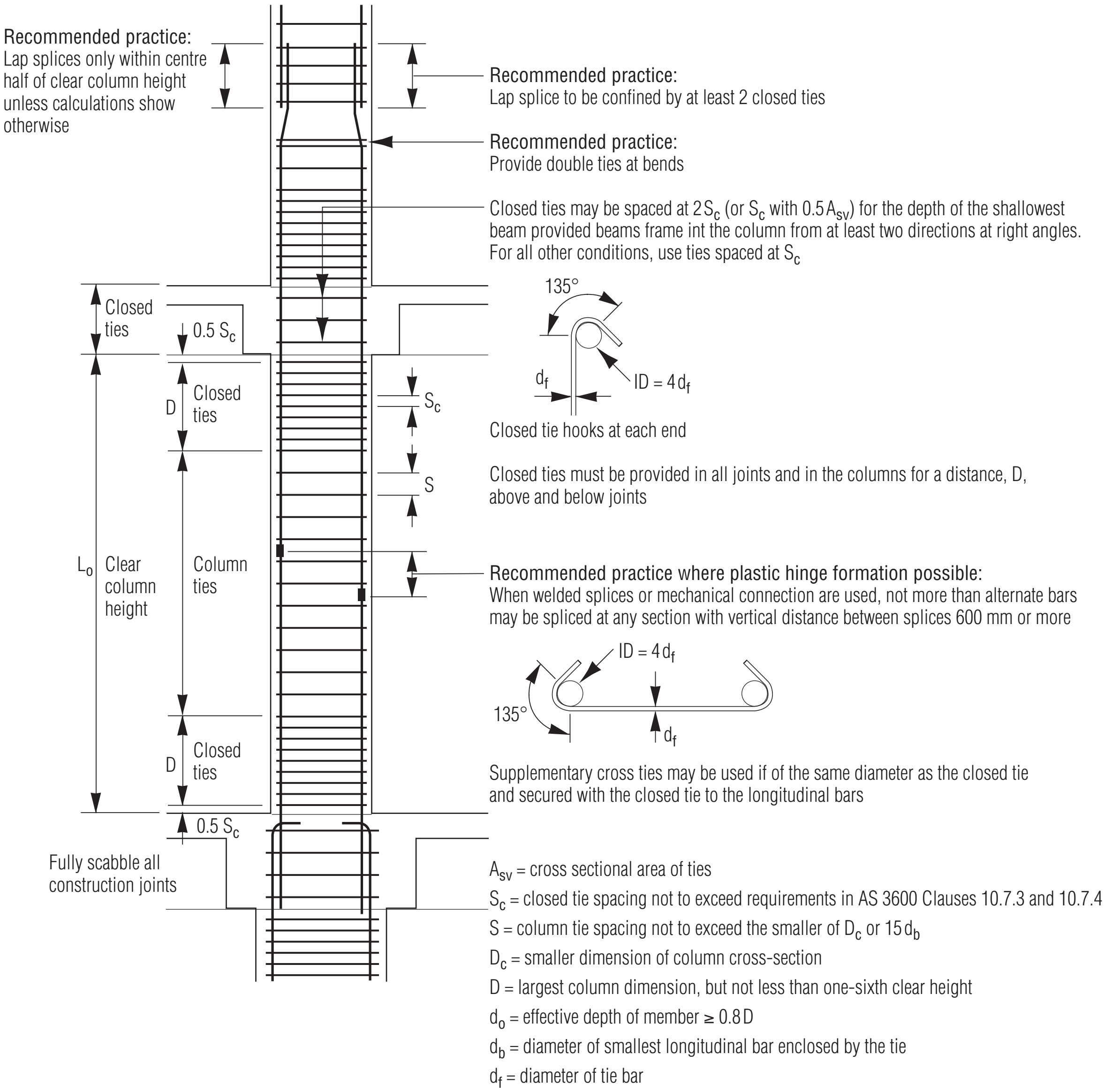


Figure 12.14 *Typical Column Details for Intermediate Moment-Resisting Frame Structures*

longitudinal reinforcement against the core concrete. In circular columns, the clamping force is provided by helical or circular ties. This form of reinforcement has been shown to be very efficient at resisting the radial cracks that can develop. Further, these ties can restrain an unlimited number of splices.

Unless the capacity has been checked by design, it is recommended that splices should not be placed in potential plastic hinge regions. Whilst transverse ties may ensure strength development of the splice under cyclical loading at up to but still below yield stress of the reinforcement, they will not ensure a satisfactory ductile response. This is especially true where large-diameter bars are lapped in the plastic hinge zone. The splice will fail after a few cycles of loading large enough to induce inelastic behaviour in the longitudinal reinforcement, with a consequent gradual deterioration of bond transfer between the bars (see Reference: Paulay, T. and Priestley, M.J.N. *Seismic Design of Reinforced Concrete and Masonry Buildings*, John Wiley and Sons Inc, 1992). For example, a plastic hinge would normally be expected to occur at the base of first-storey columns. (Note: This is true for all frame types). Consideration should therefore be given to carrying the column bars above first floor level before splicing. A less preferred alternative would be to locate the splice at mid-height of the column.

New Zealand practice allows that columns that have greater than 1.25 to 1.4 times the flexural strength of the adjoining beams are unlikely to yield and form plastic hinges – providing the column shear strength is similarly higher, ie matching the column flexural capacity. If the formation of plastic hinges is precluded, then splicing of longitudinal bars by lapping may be undertaken immediately above the floor level.

Splicing by welding or the use of mechanical couplers (eg Alpha or Lenton) is often done where bar congestion may prove problematic. It is recommended that under no circumstances should these be situated in a potential plastic hinge region, in order to help ensure a strong column/weak beam failure.

Site welding of bar splices requires special consideration and care during execution. It is recommended that lap welding should be avoided. Butt welding is acceptable, provided it is carried out using a proper procedure but, again, it is recommended that welded splices are never used in a potential plastic hinge region. (**Figure 12.14**).

12.10.4 Beam/Column Joints

Under seismic loading, reversing moments induced above and below the column joint and simultaneously occurring reversals of beam moment across the joint, cause the region to be subject to both horizontal and vertical shears of much greater magnitude than those experienced by the adjoining beams and columns themselves. However low the calculated shear force in a joint resisting earthquake-induced forces, transverse reinforcement must be provided through the joint to prevent the occurrence of brittle joint shear failure, rather than obtaining the desired flexural beam hinges. (See Reference details at end of this Clause). This transverse reinforcement is provided by continuing the closed ties required for columns adjacent to the joint.

The area required A_{sy} is to be the greater of:

$0.30 s y_1 (A_g/A_c - 1)(f'_c/f_{sy.f})$ [unless $\phi N_{uo} > N^*$]

or

$0.09 s y_1 (f'_c/f_{sy.f})$

where:

s = centre to centre spacing of the ties

y_1 = the larger core dimension

A_g = the gross cross-sectional area of the column

A_c = the cross-sectional area of the core measured over the outside of the ties

f'_c = the characteristic compressive cylinder strength of concrete at 28 days

$f_{sy.f}$ = the yield strength of the ties

ϕ = a strength reduction factor

N_{uo} = the ultimate strength in compression of an axially loaded cross-section without eccentricity

N^* = the axial compressive or tensile force on a cross-section.

The area of reinforcement required may, however, be reduced by half where equal resistance to joint rotation provided in at least two directions at right angles, but only over the depth of the shallowest of the framing members. (See **Figure 12.14**).

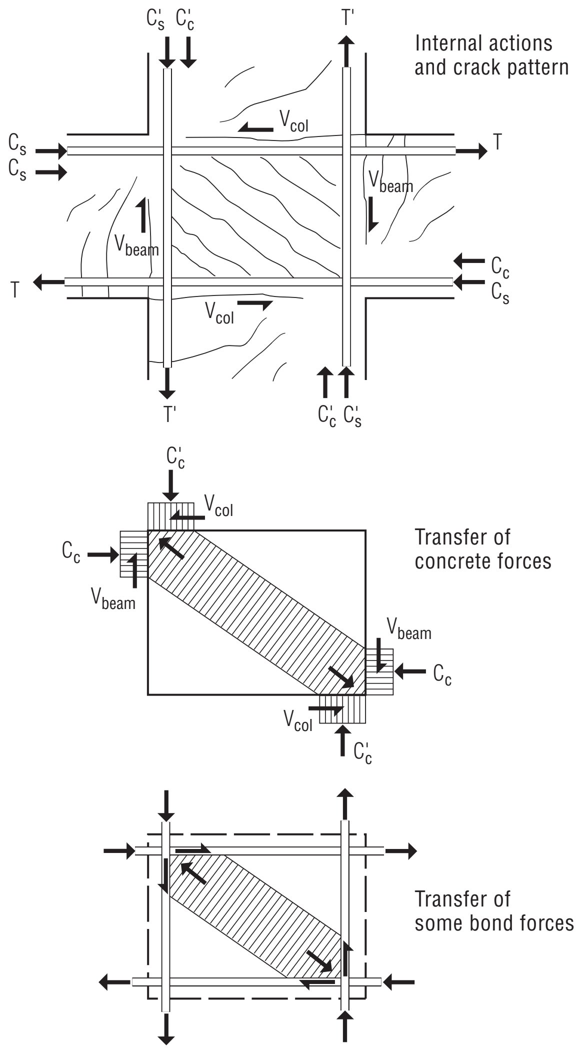
Figure 12.15(a) shows the effects of shear transfer of concrete compression forces and some bond forces which, especially at external beam/column connections, require special consideration with regard to reinforcement anchorage. A considerable length of the top bars is ignored when calculating the development length because of expected bond deterioration under cyclic load reversal. It should also be noted that the bottom beam bars are bent upwards at the end, **Figure 12.15(b)**. If they are not, this will result in poor behaviour of the joint in the direction of loading, In addition, proper anchorage of the bottom beam bar is necessary in order to transfer shear through the joint via a strut mechanism. However, tests have shown that U-bars are not as effective as top and bottom bars anchored separately. (Reference NZS 3101:2006).

See the following references for more information:

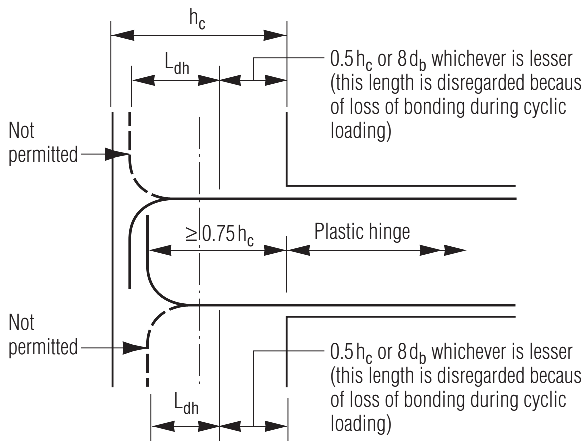
(i) Paulay, T. and Priestley, M.J.N. *Seismic Design of Reinforced Concrete and Masonry Buildings*, John Wiley and Sons Inc, 1992

(ii) American Concrete Institute, ACI 318-89 (revised 1992) *Building Code Requirements for Reinforced Concrete* and ACI 318-89R (revised 1992) commentary Chapter 21 *Special Provisions for Seismic Design*.

(iii) Irvine, H. Max and Hutchinson, G.I. (eds) *Australian Earthquake Engineering Manual* 3rd Edition, Techbooks, 1993.



(a) Shear transfer of concrete compression forces and some bond forces from longitudinal bars by diagonal compression strut mechanism



(b) Anchorage of beam bars when the critical section of the plastic hinge forms at the column face

Figure 12.15 *Shear Transfer at Beam/Column Connections and Suggested Beam Reinforcement Anchorage at External Columns*

13

Beams

13.1 GENERAL

13.1.1 Purpose

For most practical purposes, a beam is a horizontal member of relatively small size which carries a vertical load and transfers that load to its supports. These supports can be either another beam, a column or a wall.

For structural design purposes as interpreted by AS 3600, some of the methods used to design beams may also be used for slabs and walls. The physical shape of the member, that is its cross-section, has considerable effect on the method to be used.

For simplicity of description, beams are usually called “rectangular”, “T-beams” or “L-beams” because of the way they look and because this shape also illustrates the manner by which the vertical loads are applied to the top face of the beam – directly on to the rectangular beam, or on to the attached slab for the T-beam and L-beam. In the case of the latter two types, the attached slab is called the “flange” and this is a very important part of the total beam cross-section. Beams can also be upstand or downstand. For an upstand beam, the slab should remain propped until the top section of the beam is cast and cured.

Figure 13.1 illustrates various beam shapes.

The rectangular part of a T- or L-beam below the slab is called the “web”, in the bottom of which is the main “bottom tensile” reinforcement. The deeper the beam, the greater will be its load-carrying capacity. The flange at the top carries the compressive forces in the concrete to balance the tensile forces in the bottom reinforcement. To a lesser degree, the wider the flange the greater the load carrying capacity as well.

Wide shallow beams (known as “band beams”) are a compromise between shallow beams and deep slabs, whilst narrow closely-spaced beams (called “ribs”) are another form with particular uses.

“Prestressed” and “precast” concrete beams including beam shells are not included in this Handbook. Refer to the *Precast Concrete Handbook*, jointly published by National Precast Concrete Association Australia and Concrete Institute of Australia, for details of these.

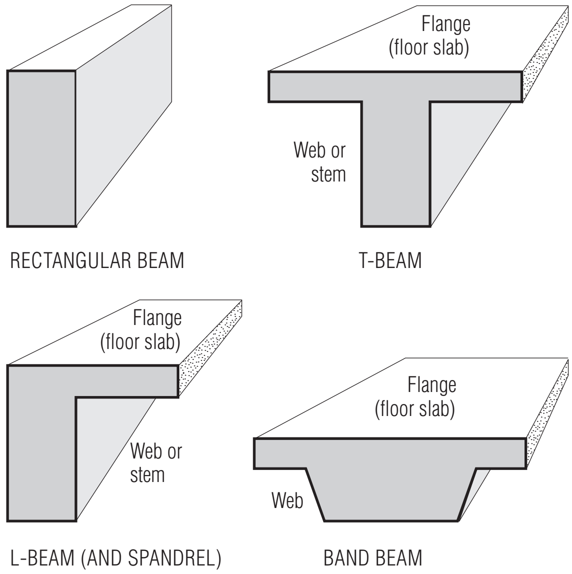


Figure 13.1 *Beam Shapes*

All of these apparently different types of beams have their own particular methods of design although many are common.

The span of a beam is a term often used here and includes “single span”, “continuous span”, “simply supported span”, etc.

Example 13.1

1. In **Clause 11.14.2**, the cantilever footing detail CF4 would have been designed as a beam – it is called a footing because of its location – although the load along it comes from the earth below due to the vertical downwards column loads.
2. In **Chapter 12** on columns, the fact that some columns must be designed as beams did not need to be known for detailing purposes, but it is important for the designer. Columns do not always have the main bars arranged uniformly around the edges.

13.1.2 Description of Methods of Load-Carrying by Beams

Concrete beams are reinforced to carry applied bending moments, shear forces and torsional forces. To find out more about these terms the reader should consult other texts on the design of reinforced concrete.

*13.1.2.1 **Bending***

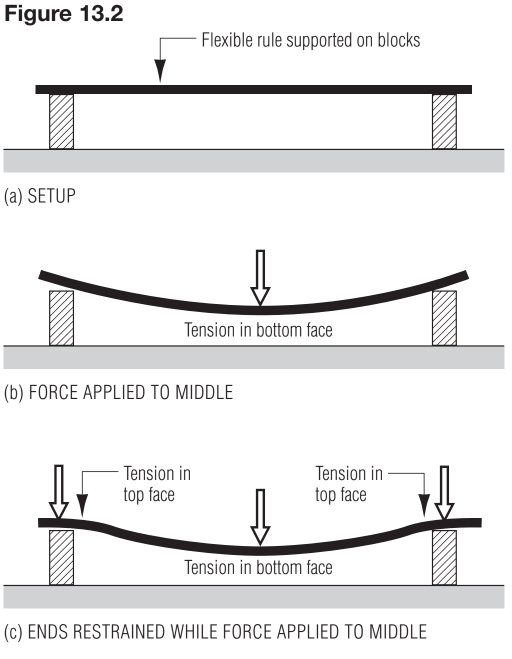
The terms “positive” and “negative” require some explanation.

Example 13.2 (See **Figure 13.2**)

To demonstrate a positive bending action, place a scale rule on two supports and push down on the middle. The rule becomes curved downwards; this is called “positive bending”, the bottom of the rule is in “tension”. To “reinforce” or strengthen the bottom face of a concrete beam, steel bars are placed there – this is the “positive reinforcement” for the “positive” bending.

Now ask a friend to restrain the ends of the ruler while you load it again. There is still positive bending near mid-span but “negative bending” is also created at the ends. The top of the rule is in tension for some distance into the span and requires “negative reinforcement”, whilst the mid-span region still requires positive reinforcement.

Figure 13.2



*13.1.2.2 **Shear***

Shear forces try to cause simultaneous horizontal and vertical sliding within the beam.

Shear action in concrete is not quite so simple because concrete does not crack in nice straight lines. The positive and negative longitudinal reinforcement already provided is just not enough on its own to strengthen the beam against shear failure, so vertical reinforcement is used in addition to, and in combination with, the longitudinal bars.

*13.1.2.3 **Torsion***

Torsion means twisting. If one of the blocks just picked up was longer than the others, it would try to twist out of your grip. Torsion reinforcement is similar to shear reinforcement, but there are two particular requirements.

Reinforcement used to strengthen a beam against torsional forces must consist of both “closed ties” and additional longitudinal (main) bars.

13.1.3 Summary of Beam Reinforcement Terminology

The AS 3600 standard refers often to “flexural reinforcement”. This term means “reinforcement to resist forces caused by bending” (flexure means bending). It includes both positive and negative moment reinforcement.

Common terms for flexural reinforcement are “main” or “longitudinal” bars. Additional descriptions are “bottom main bars” and “top main bars” depending on their location, and so on.

Common terms for shear and torsional reinforcement are “fitments” which in turn include “stirrups”, “ties”, “ligatures”, etc. Fitments may be “open” or “closed” – see **Figure 9.1** shapes SH, SC and RT for the former, and HT, T and DT for the latter. Torsional reinforcement also includes main reinforcement, as well as closed ties.

Figure 13.3 illustrates some of the terms used with beam detailing.

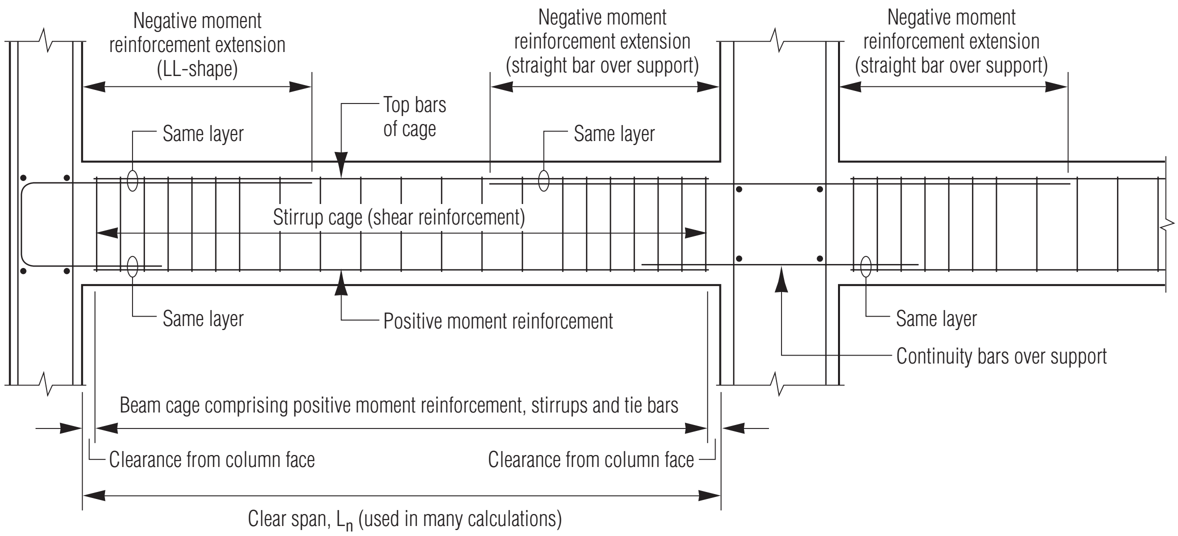


Figure 13.3 *Beam Reinforcement Terminology*

13.2 AS 3600 REQUIREMENTS

There are a number of Clauses devoted to detailing of reinforcement in beams for flexure (bending), shear, torsion, and crack control.

In the Standard, reference is often made to a quantity of steel such as “one-quarter of the (positive- or negative-moment) reinforcement” being terminated or continued. This refers to the total area of steel specified, not to the number of bars. However, because a fraction of a bar is not possible, an appropriate number of bars will be terminated or continued.

Example 13.3

Assume the “tensile reinforcement at mid span” is five bars. One bar = 20%, 2 bars = 40%, 3 bars = 60%. The following combinations are possible:

1. Not less than one-half shall extend:
   3 bars must continue, 2 may cut-off.
2. Not less than one-third shall extend:
   2 bars must continue, 3 may cut-off.
3. Not less than one-quarter shall extend:
   2 bars must continue, 3 may cut-off.
4. Not more than one-half shall terminate:
   2 may cut-off, 3 bars must continue.
5. Not more than one-third shall terminate:
   1 may cut-off, 4 bars must continue.
6. Not more than one-quarter shall terminate:
   1 may cut-off, 4 bars must continue.

13.2.1 Distribution of Tensile Reinforcement (AS 3600 Clause 8.1.10.2)

Bars should be spread throughout the tensile zone concrete, but effective depth must be maintained. In particular, avoid bunching beam top-bars together over columns; the top-flange may be used.

13.2.2 Cut-Off Points for Flexural Reinforcement

Using the appropriate theory for determining the theoretical cut-off point (AS 3600 Clause 8.1.10.1).

AS 3600 permits any valid method of determining where reinforcement may be terminated (cut-off). Because the reinforcement is used to resist forces in the concrete, it may in theory be cut-off when the calculated stress in the bar is zero. The location of the zero-stress point requires a design calculation.

However, AS 3600 Clause 8.1.10.1 says that the main bars must be extended past the calculated stress termination point by at least the overall depth “D” of the member, and then be extended for a further development length, $L_{sy.t}$.

This is because the real stress condition may not agree with the calculations, or perhaps the bar could be fixed out of position.

The term “point-of-contraflexure” in AS 3600 Clause 8.1.10.3 applies to continuous members and members built-in to the support. It is a particular cross-section where there is no tensile or compressive stress anywhere across that section. AS 3600 requires the determination of the point of contraflexure for the negative moment reinforcement.

13.2.3 **Theoretical Requirements for Anchorage of Flexural Reinforcement (AS 3600 Clause 8.1.10.4)**

See also **Chapter 6** for stress development information.

Positive moment anchorage requirements in beams under AS 3600 Clause 8.1.10.4 requires a design calculation. To illustrate the complexity of a full calculation, the following analysis is provided.

(a) At all simple supports, a primary calculation is required in accordance with AS 3600 Clause 8.1.10.4(a), see **Figure 13.4**.

The anchor point for positive moment reinforcement shall be taken *either* halfway along the length of the bearing (support), or determined by calculating the width of the compressive strut in accordance with AS 3600 Clause 7.2 using the strut and tie model. Sufficient tensile reinforcement must be anchored for a distance L_{st} past this anchor point to develop a tensile force which is the summation of the tensile forces arising from shear, torsion and any other longitudinal tensile force in the member.

The tensile force arising from shear is $T^*/\phi = V^* \cot\theta_v/\phi$ **(see Figure 13.4)**, where θ_v is the truss angle and V* is the design shear force at a distance $d\cot\theta_v$ from the anchor point.

The design longitudinal tensile force arising from torsion is calculated in accordance with AS 3600 Clause 8.3.6(a).

(b) In addition, at all simple supports, a secondary calculation is needed using **Table 13.1** from AS 3600 Clause 8.1.10.4(a)(ii).

Of the number of bottom bars at mid-span, assuming they are the same size, the following proportion must extend past the face by the length shown:

(1) up to 100% by $6d_b$, *or alternatively*,

(2) at least 50% by $12d_b$, *or alternatively*,

(3) at least 33% by $(8d_b + D/2)$.

(c) At supports where the beam is continuous or flexurally restrained, AS 3600 Clause 8.1.10.4(b).

Of the number of bottom bars at mid-span, at least 25% must continue past the near face of the support. The distance is not specified in AS 3600, but a common value is 20 to 50 mm.

If the beam-caging methods recommended in this Chapter are adopted, greater penetration can be obtained with extra continuity bars, and without interference with column steel. In any case, if the beam is part of a framed structure that is an IMRF or SMRF, then continuity must be provided at the column in the bottom in accordance with Appendix C of AS 3600.

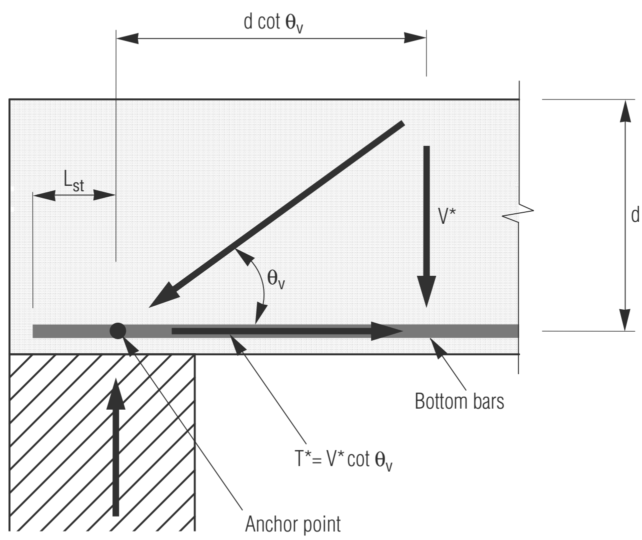


Figure 13.4 *Shear Force at a Simple Support*

Table 13.1 *Common Minimum-Anchorage Factors*

Support option [Clause 13.2.3(b)]	Factor kd_b	Minimum anchorage length (mm) for bar size						
		N12	N16	N20	N24	N28	N32	N36
Option (2)	$12d_b$	144	192	240	288	336	384	432
Option (3)	$8d_b$	96	128	160	192	224	256	288
Option (1)	$6d_b$	72	96	120	144	168	192	216

NOTES:

1. Rounded-off values should be used in the drawings.

13.2.4 Theoretical Requirements for Shear Strength if Flexural Reinforcement is Terminated in a Tensile Zone (AS 3600 Clause 8.1.10.5)

If no main bars are terminated in a tensile zone, then no action is required. Extend all bottom bars into the support, and all top bars past the point of contraflexure by the development length.

Of the three conditions, only one need be met for compliance. Two of the conditions require calculations before a decision is reached.

If termination of main bars is specified by the designer, at any section do not terminate more than one quarter of the bottom and/or top bars with bar ends closer than '2D'.

13.2.5 Simplified Method for Detailing Flexural Reinforcement in Continuous Reinforced Beams (AS 3600 Clause 8.1.10.6)

This section does not apply to prestressed members.

(a) For single-span, simply-supported beams, AS 3600 clauses 8.1.10.3 to 8.1.10.5 must be used. There is no simplified method given as such.

(b) For continuous beams, a series of visual checks and minor calculations are satisfactory. All the following restrictions must be met:

- The beam is continuous over its supports, or is flexurally restrained at a support, and
- For adjacent spans, the ratio of the longer to the shorter length must not exceed 1.2, and
- The loads are uniformly distributed, and
- The distributed live load must not exceed twice the distributed dead load.

Check list for main bar termination in continuous reinforced beams assuming there are "N" bars of the same size.

If there are "N" top bars provided at the support, the number which must extend away from the support and into the beam is:

(i) over whole span,	N/4 or more	Do this first
(ii) at least to 0.3 x clear span,	N/2 or more	Then do this
(iii) at least to 0.2 x clear span,	the balance	Avoid this.

If there are "N" bottom bars provided at mid-span, the minimum number which must continue towards the support is:

(i) into a simple support by $12d_b$ extension, N/2, or
into a simple support by $6d_b$ extension, all bottom bars

(ii) into a restraining support, extension unstated, N/4

(iii) to within 0.1 x clear span from support, the balance.

For shear strength reasons, do not terminate more than one-quarter of the bars (ie N/4) in the top or bottom within a distance of two times the beam's overall depth (that is, within 2D).

Bundled bars (AS 3600 Clause 8.1.10.8). Four longitudinal beam bars can be bundled together, leaving more space for concrete placement. Ends terminated within the span must be staggered by at least $40d_b$ for each bar.

Note:

It is strongly recommended that detailers avoid multiple cut-off points. The extra cost of detailing and scheduling, cutting and bundling, searching on site for lengths which vary marginally, and then checking that they are placed correctly, often provides no economic gain.

13.2.6 Restraint of Compression Reinforcement (AS 3600 Clause 8.1.10.7)

Clause 12.2.3 of this Handbook provides suitable information for beams and columns.

13.2.7 Bundled Bars (AS 3600 Clause 8.1.10.8)

See **Clauses 13.2.6** and **12.2.2**.

13.2.8 **Shear Reinforcement (AS 3600 Clause 8.2.12)**

Detailing shear reinforcement requires calculations and AS 3600 should be consulted. The following points should be read with **Figure 13.5**.

- Both mesh and separate bars may be used as fitments for shear strength. Each would be bent to the desired shape. See **Figure 9.1** for standard shapes.
- Fitments as separate bars may be angled to the axis of the beam, but this requires more than normal design calculation.
- The maximum spacing of shear steel is restricted. Taking "D" as the overall depth of the beam, in each case the spacings are limited to:
  - A maximum longitudinal spacing less than either 0.5 D or 300 mm,
  - Or when the shear force is small, less than either 0.75 D or 500 mm, and
  - A maximum spacing across the width of the beam of less than D or 600 mm. Refer to the detail of CF4 in **Drawing Sheet No 11.4**.
- Shear steel spacing is continued for an additional distance "D" beyond the theoretical cut-off point in the same way that longitudinal bars are extended a distance "D". The quantities are a design decision.
- Fitments should be as close to the beam surfaces as possible consistent with cover requirements and the location of other bars.
- The ends of fitments must be properly anchored, and this is done either by hooks for bars and mesh or embedded cross-wires for mesh.
- Fitment hooks with bars will generally be 135º or 180º in rectangular beams; 90º cogs may be used in T-beams where open fitments are desirable for fixing and not within 50 mm of a surface of the beam. See AS 3600 Clauses 8.2.12.4, 8.2.12.5, 13.1.2.5 and 17.2.3.2.

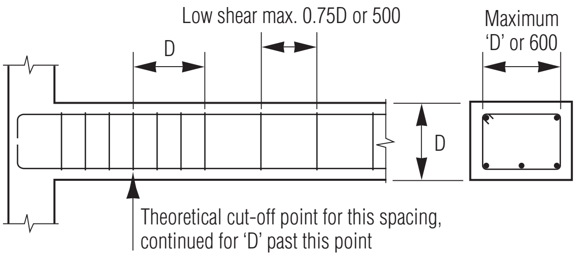


Figure 13.5 *Shear Reinforcement*

13.2.9 **Torsion reinforcement (AS 3600 Section 8.3)**

Both longitudinal bars and closed fitments must be used in combination for torsion. The standard should be consulted because calculations are always required. In most buildings, shear reinforcement will generally provide enough steel for torsional strength. Because of this, torsional reinforcement cannot be checked visually.

13.2.10 **Longitudinal Shear**

Fitments or other steel bars must also transfer longitudinal shear forces across shear planes through the web or flanges of beams. See AS 3600 Section 8.4 for design procedures, and AS 3600 Clause 8.4.4 for reinforcement. Any shear and torsion reinforcement already provided may be included as part or all of the shear-plane reinforcement.

13.2.11 **Reinforcement for Crack Control (AS 3600 Section 8.6)**

The various clauses generally give "deemed-to-comply" rules which must be checked individually. Crack control of beams is based on limiting the spacing of longitudinal bars, and on placing reinforcement in the side faces and around openings. In the side-faces of deep members, N12-200 or N16-300 may be used as longitudinal reinforcement known as side-face reinforcement. See **Figure 13.6**.

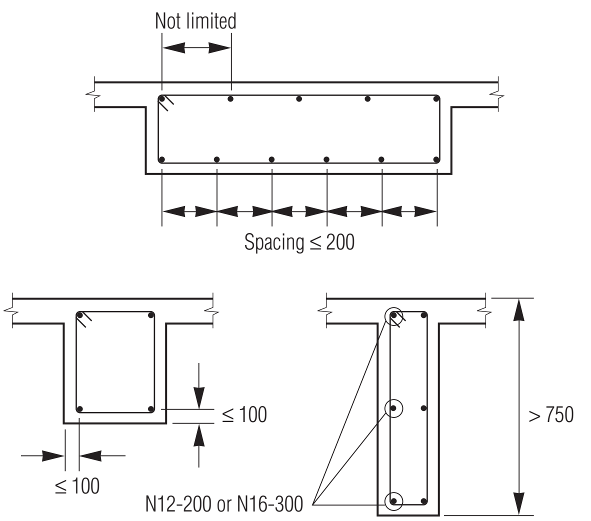


Figure 13.6 *Crack Control of Beams*

13.3 BEAMS IN PLAN-VIEW

- Plan-views of beams are drawn as a concrete outline as shown in **Figure 7.2**. The beams are shown incorporated with the layout of any floor slabs and with the supporting columns, beams or walls.
- Beams are numbered as given in **Clauses 8.3** and **8.5**.
- The overall dimensions of a beam are given on the plan-view with the depth, including any slab thickness, given first. (See **Clause 8.7.1**).
- Reinforcement within the width considered as part of the beam is not shown on plan-views. For an exception, see the later comments on T-beams with heavy top steel.

13.4 BEAM ELEVATIONS

13.4.1 Concrete Outlines

The outlines of the beam and of all supporting or intersecting beams, columns or walls are required. The outline of slabs supported by the beams is generally omitted other than as shown in **Figure 7.4**.

13.4.2 Beam Main Bars – Basic Design Specification

- The basic design notation (see **Clause 9.5**) must be given for every bar. The number of bars, their size and grade of steel is vital to the strength of the structure.
- Every differing longitudinal bar is drawn separately in such a way that its shape and bending dimensions are fully defined by the concrete surfaces inside which it is fixed.
- The shape can often be easily defined using the shape codes of **Figure 9.1**, but a drawn shape would take precedence because it will be assumed that the detailer has taken more time to draw it.
- A bar marking system on the engineering drawings will also assist all construction workers to identify each component of reinforcement.
- Extra dimensions may be required to define the shape or to specify the fixing location. See **Clause 9.3.3**.

13.4.3 Dimensioning Main Beam Bars Generally

- Defining the location of the ends of main bars is more difficult than for column bars where the floor-to-floor height generally controls.
- The bar ends are controlled by end anchorage as discussed in **Clause 13.2**.
- The most important factor in selecting a method of dimensioning is to use a common system throughout each structure. In this way, schedulers and fixers can self-check dimensions much more accurately. Consistency will also reduce requests for interpretations by the designer.
- The choice of using either formwork or column set-out lines as the origin of dimensions can depend on personal preference. The location of the set-out line should be marked clearly on the formwork to assist in fixing the steel. If the setting-out line happens to be the column centreline in every case, so much the better, but this is not essential and not possible in some cases. Where column set-out lines do not coincide with column centre lines, then this must be clearly shown in the drawings. Using formwork for setting-out implies that it will always be in the correct location, and may reduce accuracy of checking.
- In building work, the set-out dimensions of footings and columns are usually obtained from separate architectural drawings. These dimensions should be repeated on the engineering drawings to highlight changes made in the architectural drawings, but not altered in the engineering drawings.
- The **Standard Details 14.1** (**Clause 14.13**) of beams illustrate dimensioning of main bars.

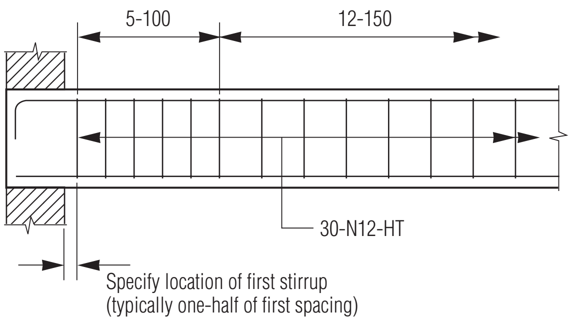
13.4.4 **Specifying Fitments in Beams**

- The essential basic design information for bar fitments includes the grade and size of steel, the number required, the spacing and location.
- The essential information for mesh fitments includes a description of the mesh characteristics (often by a separate schedule), the applicable wire diameters and spacing in each direction, the shape of the cage and its length along the beam.
- Of the above, all details can be given on the elevation except for the shape which is best shown in a cross-section, although a shape code is permissible for regular shapes. The number of cross-sections can be reduced if they are used solely to describe the fitment shape, using the elevation to show all other details.
- Basic design notation should only be given once.
- In all beams, draw the two outermost fitments on the elevation and dimension their location. The dimension may be from existing formwork surfaces, set-out lines, etc as preferred, but use a consistent method. Often a figure of 50 mm from the face of a column or intersecting beam is used.
- When the fitments are uniformly spaced, the number-off and spacing may be given on the cross-section, with the first fitment location dimensioned on the elevation.
- When the fitments are not uniformly spaced, the spread and location of the spacing change points should be defined on the elevation. The total number of fitments should be stated to avoid continual calculation later. The first fitment location from each support is also required. See **Figure 13.7**.
- When mesh is used, the length of each cage is given in the elevation and the shape in a section. The mesh configuration is given in a separate schedule. Identification of the cage is by a marking system.
- Provided the number of fitments is specified by the designer, the spacing at the centre of a beam has some flexibility.
- Do not omit a spacing except in the mid-span region where a "free" dimension is permitted.
- As a general rule, shear stress in a uniformly-loaded beam is greater at the ends than at mid-span. The fitments will therefore be spaced closer near the supports. However when the beam supports a concentrated load, the shear forces are more uniform along the beam and the fitment spacing will be uniform also. This sort of information requires correctly-detailed drawings.
- A beam subjected to torsion will possibly have the fitments at a uniform spacing throughout also, and there must always be a longitudinal bar in each corner of the outer fitment.
- Wide beams such as used in band-beam and slab systems, enable specification of one mesh-fitment cage full length (eg SL82) with a short segment (eg SL92) providing supplementary shear strength from the support to the point of contraflexure.

13.4.5 **Spacer Bars**

An example is given in **Standard Details 14.1** (**Clause 14.13**). Spacers are usually made from a very short length of N-grade bar not less than the diameter of the bars being separated. Their purpose is to allow two layers of bars to be fitted into the concrete section. This spacing may control the development length. See **Chapter 6**.

Figure 13.7 *Spacing of Fitments*



13.5 BEAM CROSS-SECTIONS

13.5.1 Concrete Outline and Dimensions

Draw the outline of the beam and any slab with which it is associated, together with any additional concrete dimensions required to specify the concrete shape.

Where beams and columns intersect and have the same width and cover, then the column bars will clash with the beam bars. This can be a significant problem when dimensions are small. Having columns that are larger than beam width may assist in alleviating the congestion of reinforcement.

Depth and width dimensions must be shown on the cross-section, together with any rebates and minor shape changes. These details are used by formworkers.

13.5.2 Fitments and their Shape

The main purpose of a cross-section is to show the shape and dimensions of the concrete beam and of the associated fitments (shear reinforcement).

13.5.3 Dimensions

Provide sufficient dimensions for the fitments to be scheduled. In general, the fitment dimensions are obtained from the beam dimensions by subtracting the cover all round.

If there is more than one fitment at a cross-section, each must be defined. In **Drawing Sheet No 11.4** (**Clause 11.16**) cross-section CF4 shows that there are three fitments making up each set. In this case, the bending dimensions are not critical and can be derived from the general layout; in other cases, more precise dimensioning will be required.

13.5.4 Spacing for Placing

Ensure that there is sufficient space between main bars to permit placing and compacting of the concrete. Bars rarely fit snugly into the corners of fitments and clearances which may appear adequate on paper may be greatly reduced in the field.

See **Clause 4.3** for minimum beam widths.

13.6 INTERSECTION OF REINFORCEMENT AT ENDS OF BEAMS

The location of any main bars of beams which intrude into or pass through an elevation is shown as in a cross-section (see **Figure 7.5**). The reason for this requirement is that intersecting bars can be identified and due allowance made for the size of fitments and any special bending of the main bars to avoid interference.

Particular care will be needed to ensure consistency in these connections.

Column bars and slab steel are generally not shown on beam elevations because they do not contribute to an understanding of the construction methods.

Where there is no column supporting a beam-to-beam intersection, make sure that plan-views, elevations and sections are totally compatible.

13.7 INTERSECTION OF REINFORCEMENT IN BEAMS AND COLUMNS

It is a simple matter to detail the elevations of two beams, or of two beams and a column, to show how the bars in each member are meant to pass over each other.

It is far more difficult to ensure that this can be done on the site.

The following sections describe how beam and column reinforcement, which is detailed separately in drawings, can be brought together in the formwork.

The recommendations made here may not be applicable to every project, but the principles described will help overcome everyday problems of steel congestion.

We are trying to show how the arrangement of reinforcement in one element will affect the arrangement in other elements. Some three dimensional views are given to explain the procedure – it is not suggested that details be presented in this fashion, although in very complex situations, similar illustrations will be of great assistance to designer, detailer, scheduler, steel fixer and inspector.

Applications for this type of detail with CADrafting should be developed as a normal office procedure.

13.8 INTERSECTION OF A RECTANGULAR BEAM AND A COLUMN

13.8.1 Assembly Principles

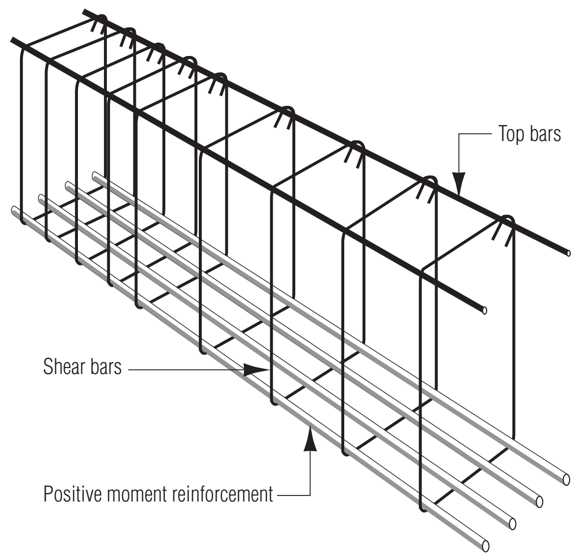
The column reinforcement will generally be placed and encased in concrete up to the underside of the beam before the beam reinforcement is fixed. The location of the main column bars is assumed to be unchangeable.

The beam bottom reinforcement must be capable of being assembled into cages, and placed in the forms without interfering with, or being interfered by, the column steel. Beam top steel must be capable of being added later.

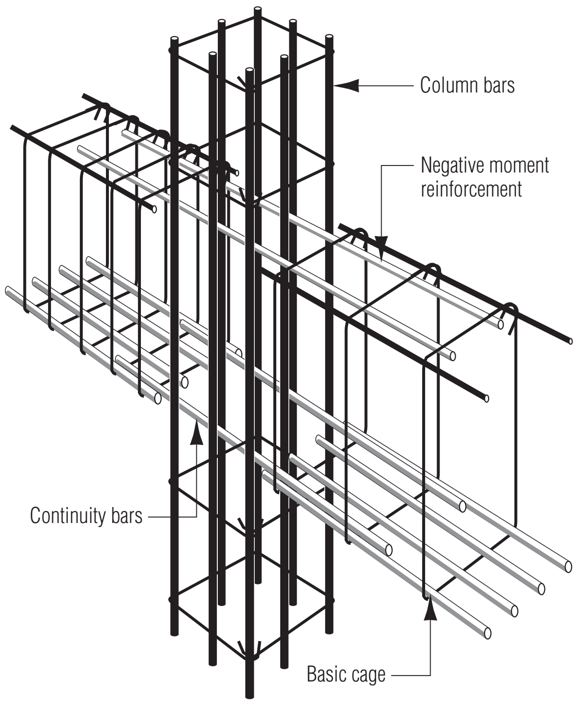
13.8.2 Method

The ideal solution requires several principles to be accepted. See **Figures 13.8** and **13.9**.

- The beam cage should include the main bottom bars for the beam, the fitments can be in the form of mesh or bars and, if the latter, nominal size bars will be placed in the top to hold the fitments apart while being hoisted into the forms.
- The cage should have as small a mass as possible to permit manual handling. Additional material can be added later.
- The length of the cage should enable it to be located between the column bars (assumed already encased). It could be from 100 mm less than the clear span, to perhaps 400 mm less.
- Within the depth of the intersection zone, the column bars will be straight; that is the gooseneck for a lap splice does not occur in that zone to ensure maximum room for fixing bars. See **Chapter 12**.
- Closed ties should be used where torsion is a design condition. Cogs are not allowed on fitments where the ends of the bar are near the concrete surface. *Therefore hooks are required on all fitments*. As the beam cage has been formed with the HT-shaped fitment, all reinforcement both negative or positive over the support points of the beam must be threaded into the beam cages and tied to the stirrups.
- Under the provisions of AS 3600, the covers to beams and columns are the same unless fire ratings require different values. Any cover differences are marginal, and will not prevent beam and column bars from clashing without additional treatment.
- Positive moment anchorage is required in the bottom (see **Figure 13.9**) and consists of short bars dropped through the beam cage and the column bars. Their length will depend on the stress level and type – tension or compression.
- No top tensile reinforcement is placed with the initial cage; it is all located after the bottom anchorage bars have been placed. The top bars are tied to the HT-shape fitments.



BASIC CAGE ARRANGEMENT



AFTER ASSEMBLY AT INTERSECTING COLUMN

Figure 13.8 *Isometric Details of Beam Cages*

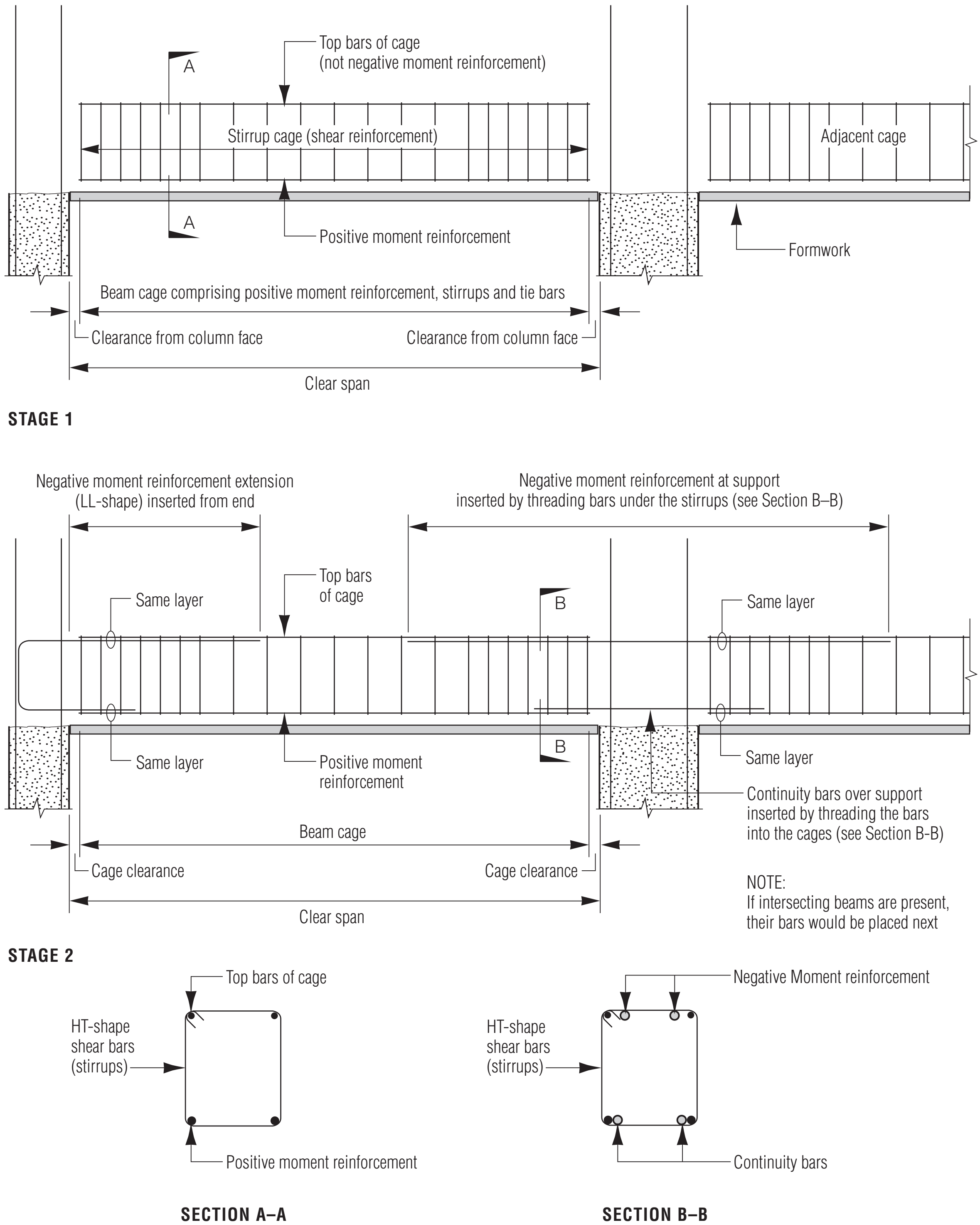


Figure 13.9 *Basic Assembly of Beam Cages*

13.9 INTERSECTION OF FOUR BEAMS OVER A COLUMN

In this situation, all four column cages are made up and dropped into position. The tops are left open.

The bottoms and sides of the beam cages possibly have the same cover but the designer will need to specify the top cover as will be explained later.

It is possible to add additional main bottom bars at this stage; the original cage should be kept as light as possible.

The detailer will need to decide in which order the bottom anchorage bars are placed; one set will be in the same plane as its own main bottom steel, the other set will sit on top at right angles.

Once the bottom bars are fixed, the top (negative moment) bars for both are fixed. They will have been slotted down through the column bars, threaded into the cage, and then lifted and fixed to the HT-shaped fitments at the top of the beam. Again, the designer must decide which beam is to have which layer of top steel.

Note that because there is not much interference from the column bars (straight not cranked) through the beam-column intersection zone, the layout of the additional loose bars is greatly simplified.

If the beams are of different widths or depths, the solution is even easier to obtain because the bottom anchorage and top negative moment bars can be spread out.

13.10 INTERSECTION OF FOUR T-BEAMS OVER A COLUMN

The situation is the same as above with the addition of arranging the slab steel over the column into two layers. It is good practice to spread the top beam steel into the slab (the flange) rather than concentrate it over the column.

13.11 INTERSECTION OF T-BEAMS WITHOUT A COLUMN

Because there is no column here for support, that complication is not added. However, if one of the beams supports the other then the designer must ensure that the supporting beam is not split into two "cages" or there will be a collapse due to loss of tensile strength in the bottom.

This does not mean that the cage method cannot be used – in fact, the beam intersection will be easier to assemble when the supporting beam is placed first.

13.12 OPPORTUNITIES FOR PREFABRICATION

If clear spans are of similar length and the loading is essentially uniformly distributed, repetitive prefabrication of many cages should be adopted. The cage length would suit the shortest span and the anchorage bar lengths adjusted accordingly. Extra fitments may be added between the cage and the column on site.

The size and weight of each cage will depend on the materials handling capacity on site. If craneage is available, then the cage can contain all positive reinforcement, perhaps being assembled on the ground rather than on the forms, and the top bars can also be loosely tied inside. If craneage is not available, the cages will contain only those bottom bars necessary to get it into place, with the remainder lifted in and tied just enough to prevent them moving during concreting.

With a mesh cage, the amount of tying is greatly reduced and the cage can be made quite rigid. Together with pre-assembled column cages, the total system has considerable scope for improving cycle time.

13.13 EXAMPLES OF STANDARD DETAILS FOR NARROW BEAMS

(See **Standard Details 14.1** in **Clause 14.13**)

The cage consists of the bottom bars (in one or two layers, although the latter is not common), the fitments and two top bars which separate the fitments if they are bars; fitments of mesh will use the continuous negative moment steel. See **Clause 13.2.5**, *Check list, top bars, item (i)*. With similar beam and column widths, the beam cage is deliberately made shorter than the clear span. Wherever possible, all cages for a floor should be basically identical to permit interchange.

13.14 DETAILING FOR SEISMIC (INTERMEDIATE MOMENT-RESISTING FRAMES)

13.14.1 General

Under the effects of earthquake action, flexural members are subjected to a number of reversals of bending moment. To ensure adequate ductility potential in IMRFs, beams are always doubly, and continuously, reinforced. See **Figure 13.10**.

If yield occurs, the Young's Modulus of the reinforcement will not remain within the elastic part of the stress-strain curve, and that Bauschinger softening will occur under cyclic loading. (The "Bauschinger effect' is the change in the stress-strain relationship that occurs when a reinforcing bar is yielded in tension or compression and the direction of the stress is reversed. The distinct yield point is lost and the stress-strain relationship takes on a curvilinear form). The stable hysteretic response of the potential plastic hinge region can be diminished through the 'pinching' of the hysteretic loop due to the influences of shear degradation of the region. This could be as a result of inadequate transverse reinforcement or poor construction joints, for instance.

The effect of reversing moments is generally concentrated at the junctions between beam and column. Appendix C of AS 3600 therefore, stipulates that in a span:

- The positive moment strength at a support face is to be not less than one-third of the negative moment strength provided at the face of the support; and
- Neither the negative nor the positive moment strength at any section along the member length is to be less than one-fifth of the maximum moment strength provided at the face of the support.

All longitudinal reinforcement must be anchored beyond the support face, so that at the face the full yield strength of the bars can be developed. This requires that:

- Longitudinal reinforcement is continuous through intermediate supports; and
- Longitudinal reinforcement extends to the far face of the confined region and is fully anchored.

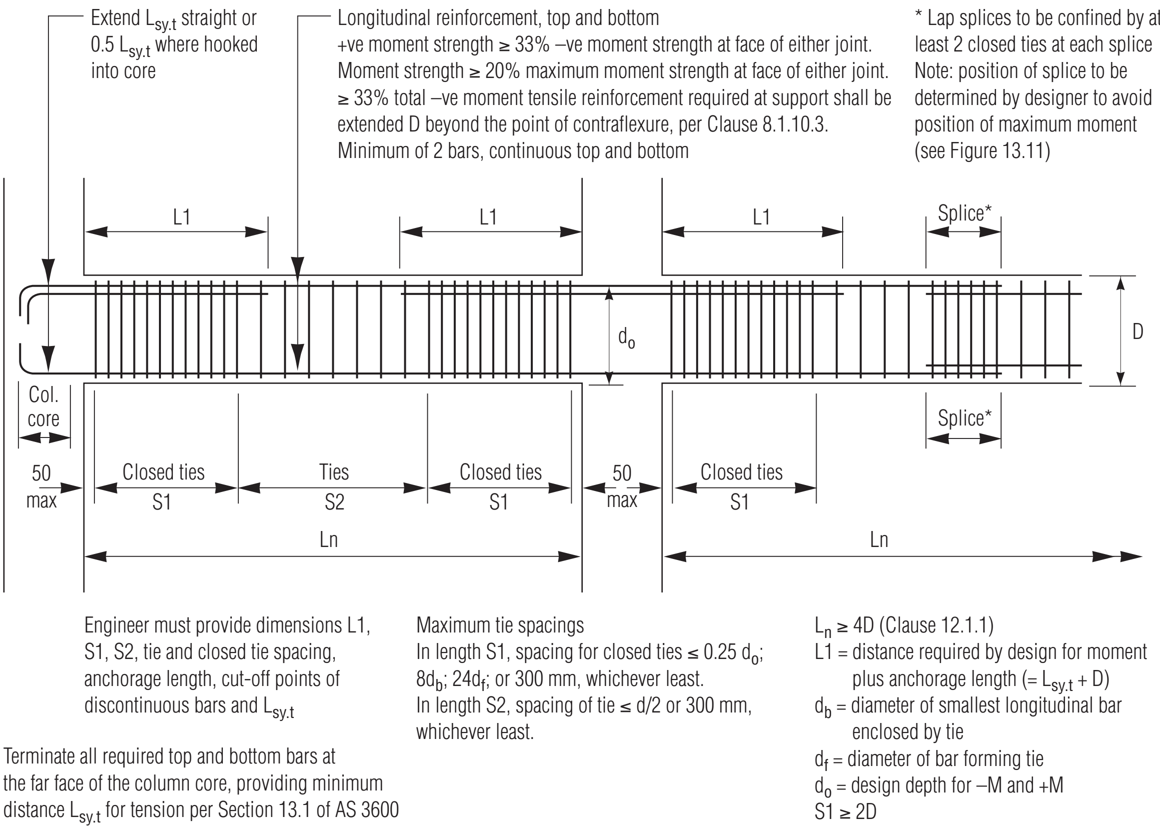


Figure 13.10 *Typical Beam Restraint Details for IMRF Structures*

13.14.2 **Lapped Splices**

Lapped splices in longitudinal reinforcement, located in a region of tension or reversing stress, are to be confined by a minimum of two closed ties at each splice to inhibit the possibility of non-ductile failure at this point. The position of maximum moment under seismic load will be dependent upon the magnitude of the earthquake. (**Figure 13.11**).

The position of the splice should therefore be located at a position of known moment, perhaps in the middle third of the span, unless the designer is confident that the splice is sufficiently confined to safely locate it elsewhere in the span.

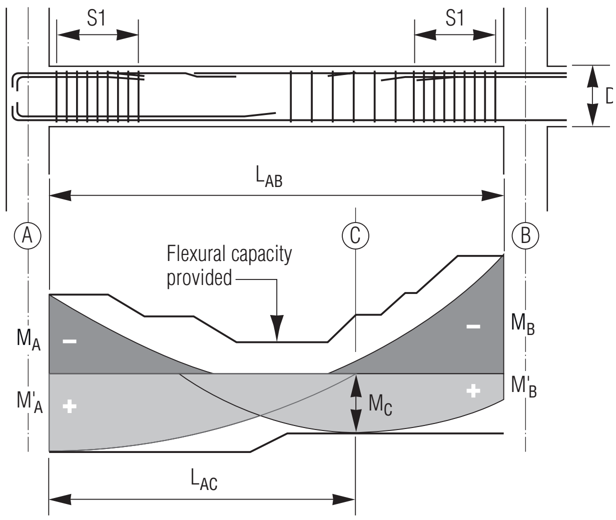


Figure 13.11 *Localities of Plastic Hinges when Stirrups are Required. Note: Plastic Hinges will Form when the Flexural Capacity Envelope and the Actual Moment Coincide*

13.14.3 **Detailing for Shear**

Shear type failures tend to be brittle. Also, as mentioned above, maintaining a stable hysteretic response of plastic hinge regions requires that the compression bars be prevented from buckling. It must therefore be assumed that major spalling of concrete cover will occur and that compression bars must rely solely upon transverse support provided by the ties. Limitations on maximum tie spacing are required to ensure that the effective buckling length the compression bars is not excessive and that concrete within the stirrup ties has reasonable confinement. Furthermore, due to the possible occurrence of the *Bauschinger effect* and the reduced tangent modulus of elasticity of the steel, a smaller effective length must be considered for bars subject to flexural compression, rather than compression alone. Appendix C of AS 3600 specifies a minimum area of shear reinforcement:

$A_{sy} \geq 0.5 b_w s / f_{sy.f}$

(ie 50% greater than stipulated in the body of the Code) with closed ties provided over a minimum distance of 2D from the face of the support. The first placed 50 mm from the support face, and the remainder spaced at $0.25 d_o$, $8d_b$, $24d_f$ or 300 mm, whichever is least.

Where:

b_w = width of web.

s = centre to centre spacing of ties.

$f_{sy.f}$ = yield strength of ties.

D = overall depth of cross-section in the plane of bending.

d_o = the distance from the extreme compression fibre of the concrete to the centroid of the outermost layer of tensile reinforcement, but not less than 0.8D.

d_b = the diameter of the smallest longitudinal bar enclosed by the tie; and

d_f = the diameter of the bar forming the tie.

Since tension in vertical tie legs acts simultaneously to restrict longitudinal bar-buckling and to transfer shear force across diagonal cracks, it is considered that the tie areas are sufficient to satisfy both the requirements for bar buckling and those for shear resistance. See Figure **13.10**.

(Note: These requirements do not preclude efficient fabrication techniques such as loose bar detailing described elsewhere in this manual).

14

Suspended Slabs and Slab Systems

14.1 GENERAL

14.1.1 Purpose

The term 'slab' is generally thought of as a floor, although it is equally applicable to a roof or other member whose structural behaviour is the same as a slab.

The width and length of a slab are much greater than the depth.

Figure 14.1 shows various slab types. The slabs transfer the floor loads to the supporting beams, walls and columns and ultimately by footings to the foundations. The lowest level floor slab may transfer its load directly to the ground.

Some of the terms used with slab design are:

- *Single span* or *multiple span slabs* – determined by the number of supports.
- *One-way* or *two-way slabs* (see AS 3600 Clause 1.6.3) – depends whether the slab is supported on two opposite sides or on all four sides.
- *Combinations* of the above.
- *Beam-and-slab* systems – where the slab is supported by the beams and becomes the flange of the T-beam, L-beam or band-beam.
- *Solid slab* – supported by columns without the need for beams. Variations are *flat plates* in which the slab is of uniform thickness throughout, and *flat slabs* where drop panels thicken the slab for some distance around the column.
- *Ribbed slabs* which consist of narrow beams or ribs at close centres and a very thin slab above. Ribbed slabs can be one-way or two-way (*waffle slabs*) in **Figure 14.1**.
- *Hollow core slabs* are floor units, precast and prestressed.
- *Concrete soffit-slabs* – where the positive moment reinforcement is included in the precast permanent-formwork soffit-slab.
- *Precast Tee-beams* and extruded pretensioned beams.

14.1.2 Description of Method of Load Carrying by Slabs

- *Bending*. Slabs carry the applied loads either as one-way or two-way bending. Once the magnitude of the bending moments is calculated (the analysis), the design of the cross-section is similar to that for beams. Therefore, as for beams, slabs must be capable of resisting both positive and negative bending moments.
- *Shear*. Shear forces cause complex shear stress effects on slabs. Spandrel beams and torsion strips may be needed.

  For flat slabs and flat plates, punching shear around the column support requires careful attention by the designer.
- *Torsion*. Torsional forces on slabs are treated with the shear stress analysis. The most critical torsion effects occur at spandrels (edge beams) which can require closed-ties to be used as the fitment.

  Torsion steel may also be required in the corners of slabs on walls. This is to resist stresses caused by the slab trying to lift itself off its supports. Without torsion steel here, slabs can crack diagonally across the corner.

14.1.3 Slab Reinforcement – the Meaning of "Grids"

Suspended slab reinforcement is placed in one or two grids of steel – one always near the bottom surface and one, if needed, near the top surface.

Each grid consists of two layers, usually at right angles. Thus there are four layers of steel.

In AS 3600, for strength purposes the term positive moment reinforcement refers to the bottom steel, and negative moment reinforcement means the top steel.

Slabs may also be post-tensioned in one or two directions, but this is outside the scope of this Handbook.

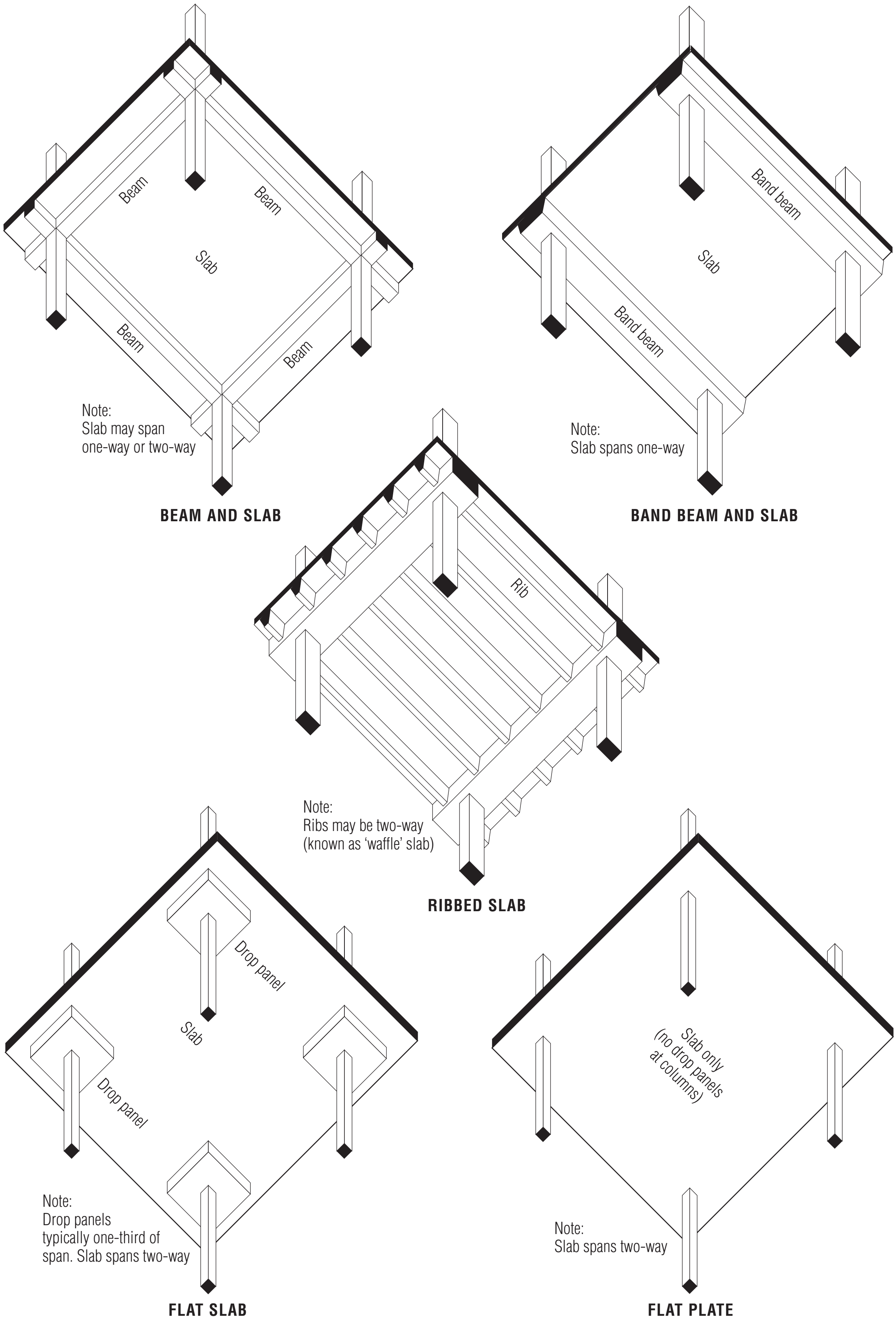


Figure 14.1 *Slabs and Slab Systems used in Buildings*

14.2 AS 3600 REQUIREMENTS (Clauses 9.1, 9.2 and 9.4)

Most of AS 3600 Clause 9 refers to reinforcement. Slab reinforcement detailing is generally controlled by "deemed-to-comply" rules. The amount of flexural steel is calculated similarly to beams, and is then evenly distributed across the width of the slab. Slab steel areas are therefore stated as area per unit width (mm^2/m). See **Chapter 4** for values of steel areas. See **Clause 9.5.3** for calculation of numbers of bars in slabs.

14.2.1 Minimum Steel for Bending Strength (AS 3600 Clause 9.1.1)

Table 14.1 gives the minimum steel ratio A_{st}/bd for mesh and bar to be evenly-distributed in each direction as the bottom grid of reinforcement.

AS 3600 Clause 9.4.1 gives the maximum spacing of reinforcement for crack control due to flexure as the lesser of 2.0D or 300 mm.

Table 14.1 *Minimum tensile reinforcement for strength f_{sy} = 500 MPa*

Slab support condition	Bar or mesh area, A_{st} (mm^2/m)
Supported by columns	$0.24(D/d)^2 f'_{ctf}/f_{sy}$
Supported by beams or walls	$0.19(D/d)^2 f'_{ctf}/f_{sy}$

Example 14.1

A 150 mm thick two-way slab is supported by walls with a concrete characteristic strength of 32 MPa. Allowing for cover of 20 mm plus 5 mm for bar thickness, the effective 'd' would be 125 mm. Thus, the minimum mesh area would be 235 mm^2/m (L8 @ 200 or SL82) and for steel 235 mm^2/m (N12 @ 400).

14.2.2 Special Requirements for Two-Way Flat Slabs and Flat Plates (AS 3600 Clause 9.1.2)

At least 25% of the design total negative moment MUST be resisted by reinforcement and/or tendons within a width of ($b_{col} + 2t_{slab}$) for flat plates and the drop panel width plus the width of the column centred over the supporting columns. (AS 3600 Clause 9.1.2).

Detailers must check that adequate room is left for concrete placement. Tendons can be concentrated within this strip whilst reinforcement remains uniformly distributed.

Normal beams, band-beams and their associated slabs are not required to comply with this rule.

Also, with draped post tensioned cables which are not directly over a column, these can induce local bending and shear in slabs at columns which the designer must consider.

14.2.3 Detailing of Tensile Reinforcement in Slabs (AS 3600 Clause 9.1.3)

Of all parts of a building, slab detailing is the most time-consuming. This is caused more by the complexity of the shape and layout of slabs than by the detailing requirements of the Standard.

AS 3600 divides detailing of slab systems into two major procedures.

(a) *Where the bending moment envelope is calculated*. It is compiled from the "worst case" situations of bending, and is not just the bending moment diagram for just one worst-case loading arrangement. In fact, the envelope can contain segments which come from normally quite incompatible loading arrangements. Only calculations can define it.

(b) *Where the bending moment envelope has not been calculated*. Appropriate "deemed-to-comply" methods can be used. These are based on slab type, support conditions, span lengths, loading conditions, etc.

It is requirement that in some cases where the envelope is calculated, the "deemed-to-comply" rules must also be followed. However, the procedures in (a) never override procedure (b).

14.2.4 Termination when the Hypothetical Bending Moment Diagram has been Calculated. (AS 3600 Clause 9.1.3.1(a))

The hypothetical BMD gives the theoretical cut-off point of all bars, but the additional checks are still required.

- Negative moment steel. **Figure 14.2** illustrates a hypothetical bending moment diagram.
  One-third of the negative steel area can be provided simply by using one length of steel and staggering alternate pieces so that the ends are beyond the hypothetical point of contraflexure by a distance greater than either D or $12d_b$.
  This actually provides one-half $A_{st}+$, but reduces detailing times and sorting on site.
- Positive moment reinforcement at supports. A proportion of the positive moment steel is carried to or past the face of the support to provide some shear strength there.

In **Figure 14.3(a)**, 50% of $A_{st}+$ can extend past the face of a simple support by the greater of $12d_b$ or D, or 100% of $A_{st}+$ and can extend a distance of $6d_b$ or D/2.

In **Figure 14.3(b)** and **(c)**, bottom steel extension into a restrained support is nominal and is left to the designer. Fixing of slab steel at beams takes longer and is harder work if the ends must be poked through fitments. Theoretically, there is no need for bottom steel to extend into a restrained support unless there are reversals of moment – in those cases, a calculated hypothetical bending moment diagram will show this.

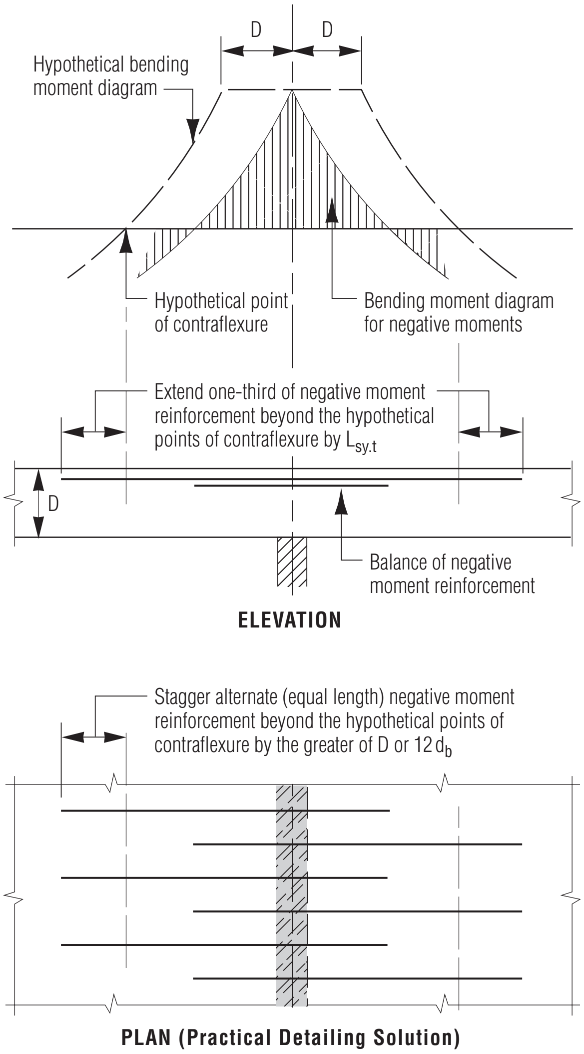


Figure 14.2 *Termination of Negative Moment Slab Reinforcement*

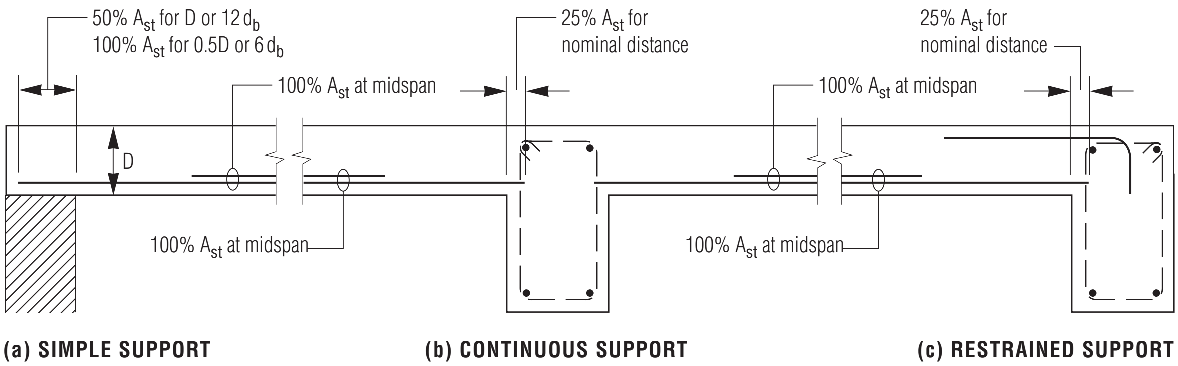


Figure 14.3 *Termination of Positive Moment Slab Reinforcement*

14.2.5 **Arrangement when the Bending-Moment Envelope is Not Calculated (AS 3600 Clause 9.1.3.1(b))**

Typical examples are when the simplified methods of analysis are used. These include AS 3600 Clauses 6.10.2, 6.10.3 and 6.10.4, together with the use of other moment-coefficient tables published elsewhere.

Table 14.2 gives a guide to the relationship between the analysis Clauses of AS 3600 Section 6 and the detailing Clauses of Clause 9.1.3.

Table 14.2 *Selection of Deemed-To-Comply Arrangements for Slab Reinforcement*

Condition to be satisfied	Detailing Rule to be used (based on Analysis Clauses)		
Analysis Clause	6.10.2	6.10.3	6.10.4
Flexural Action	One-way continuous spans	Two-way, single or continuous spans	Two-way slab system
Method of Support	Beams or walls on two opposite sides	Beams or walls on four sides	Multispan systems of beam-and-slab, solid slabs, flat slabs, waffles, and slab bands
Number of Spans	Two or more in one direction	One or more in two directions	Two or more and continuous, in two directions
Limitations on Structure			
Ratio of adjacent spans L_x/L_x	≤ 1.2	Not specified	≤ 1.33
Ratio L_y/L_x within one panel	Not applicable	2.0 is hinted at	2.0 maximum stated
Ratio of distributed loads	$q \leq 2g$	Not limited	$q \leq 2g$
Are additional bending moments permitted at supports?	No. Go to Clauses 6.9 and 9.1.3.1	No. Go to Clauses 6.9, 6.10.4, and 9.1.3.1	See Clause 6.10.4.5 for flat slabs
Limits on Forces and Moments			
Lateral forces may be carried?	No	No	Taken by walls and/or frame
Moments may be redistributed?	No	No	Yes, 10% maximum See 6.10.4.3
Reinforcement Arrangement Clause			
For the supporting beams	8.1.10.6	8.1.10.6	8.1.10.6
For the slabs	9.1.3.2	9.1.3.3	9.1.3.3 or 9.1.3.4

14.2.6 One-Way Slabs – "Deemed-to-Comply" Rules

See **Figure 14.4** for the following discussion.

- Bottom steel at restrained support – the standard does not specify the extension into the support so the designer must specify the appropriate solution for each case.
- Top steel – only one termination point at 0.3 times clear span past the support's face is recommended for economical detailing and construction.
- Bottom steel at a simple support – must go to the support centre line, but must NOT protrude into the concrete edge cover.
- Outermost bar location – the outer bar parallel to an edge should be located at a cover of one-half the specified spacing. See **Clause 9.5.3** for calculation of bar numbers across a slab.
- Tie bars perpendicular to the span are not shown for clarity. See **Clause 14.3.9**.

See also **Clause 14.13 Standard Details 14.2**.

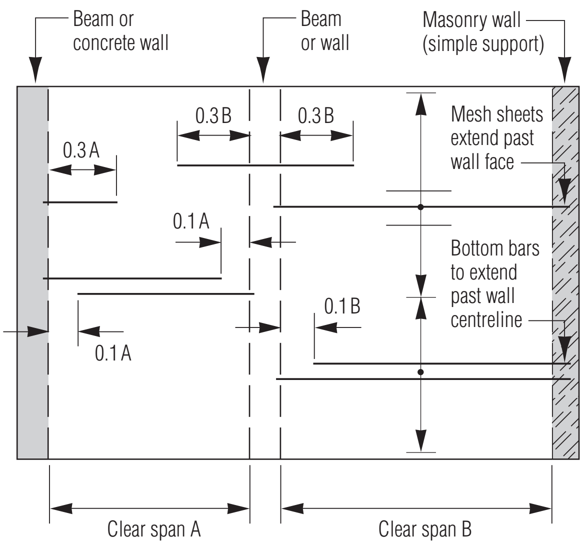


Figure 14.4 *Deemed-to-Comply Rules*

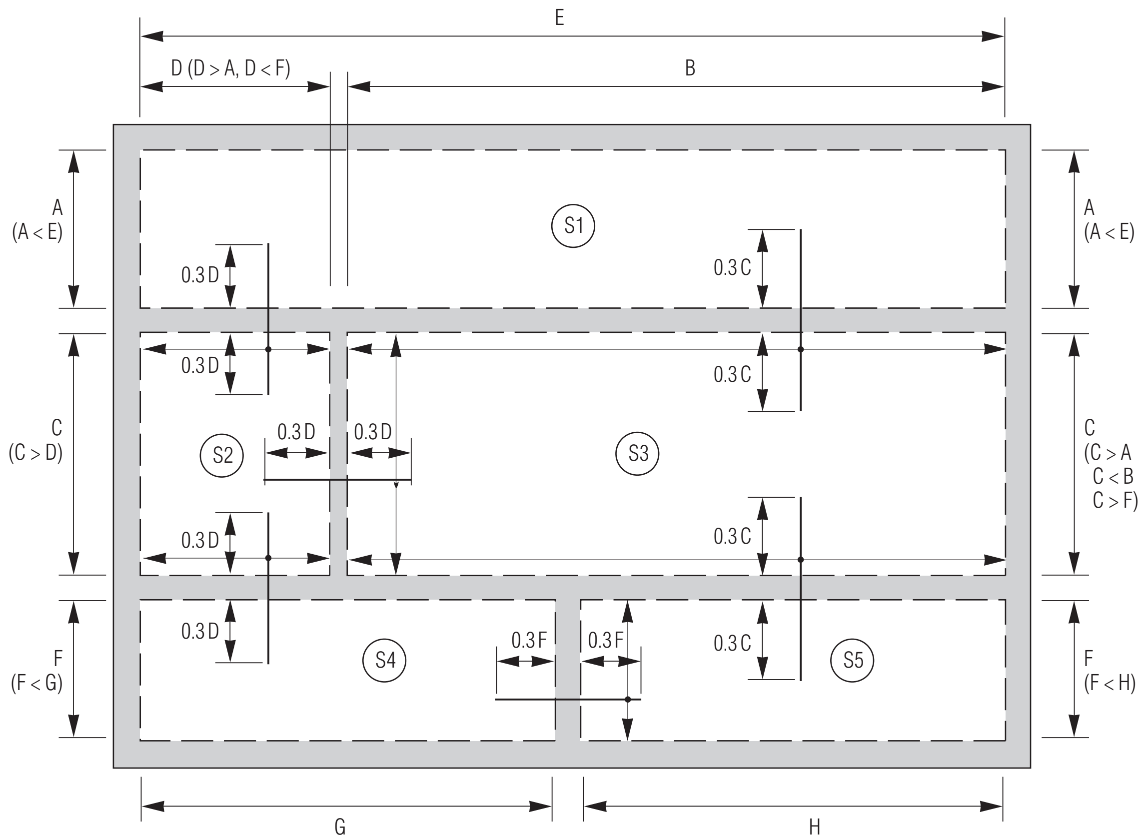
14.2.7 Two-Way Slabs Supported by Beams or Walls – "Deemed-to-Comply" Rules

See AS 3600 Clauses 6.10.3, 6.10.4 and 9.1.3.3. For this type of two-way system, the shortest span of a panel is the important dimension.

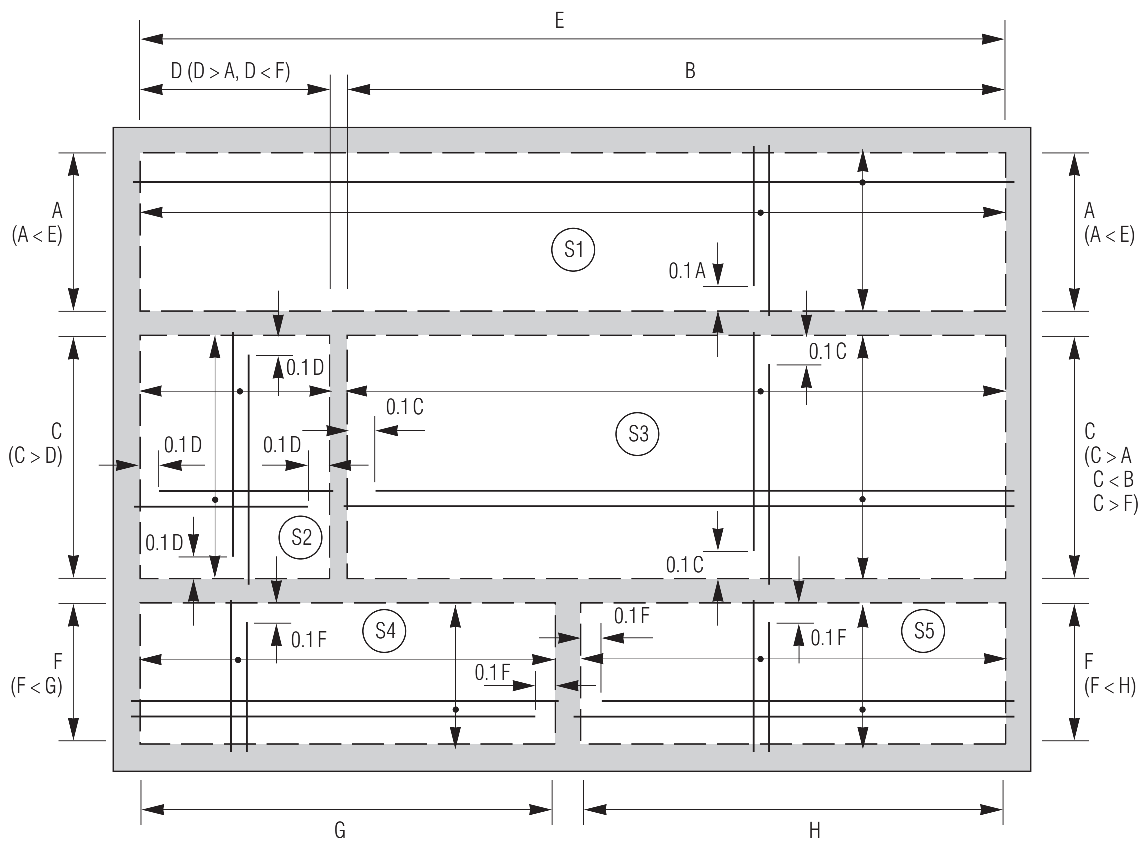
Figures 14.5 and **14.6** illustrate the effect which the shorter span of a rectangular slab has upon the bottom steel of that slab only, and the top steel over its four supports.

In this example, the longer spans E, B, G and H have no effect because they are longer than the corresponding spans A, C and F (twice).

- Top steel. Spans C and D of slab (S2) affect the top steel of each adjacent span. Whichever is smaller is used to calculate 0.3C or 0.3D. If span A was shown larger than span C, then the top steel to the slab group (S1 – S2 –S3) would extend 0.3A, but the other top steel of slab (S2) would still depend on spans C or D.
  Where both spans of a panel are nearly equal, considerable detailing and fixing time can be saved by using one extension length throughout, particularly when the support widths are similar also (internal walls). In these Figures, all extensions could be 0.3C or 0.3D except for 0.3F between slabs (S4) and (S5).
- Bottom steel. Again, the shorter span of each individual panel controls the maximum distance from a support. External spans are not considered.
  In this example, staggered bottom bars are shown in some slabs. This arrangement can double the number of steel items to be drawn, scheduled, fabricated and found on-site, so one length per layer is recommended.
- Outermost bar location. The outer bar parallel to a support should be located no closer than one-half the specified spacing. Bending stresses in this zone are negligible.
- Calculation of number of bars. See **Clause 9.5.3** for calculation of numbers of bars in slabs and **Clause 14.3.9** on the use of tie bars for the top steel only in this case.
  See also **Clause 14.13 Standard Details 14.2**.

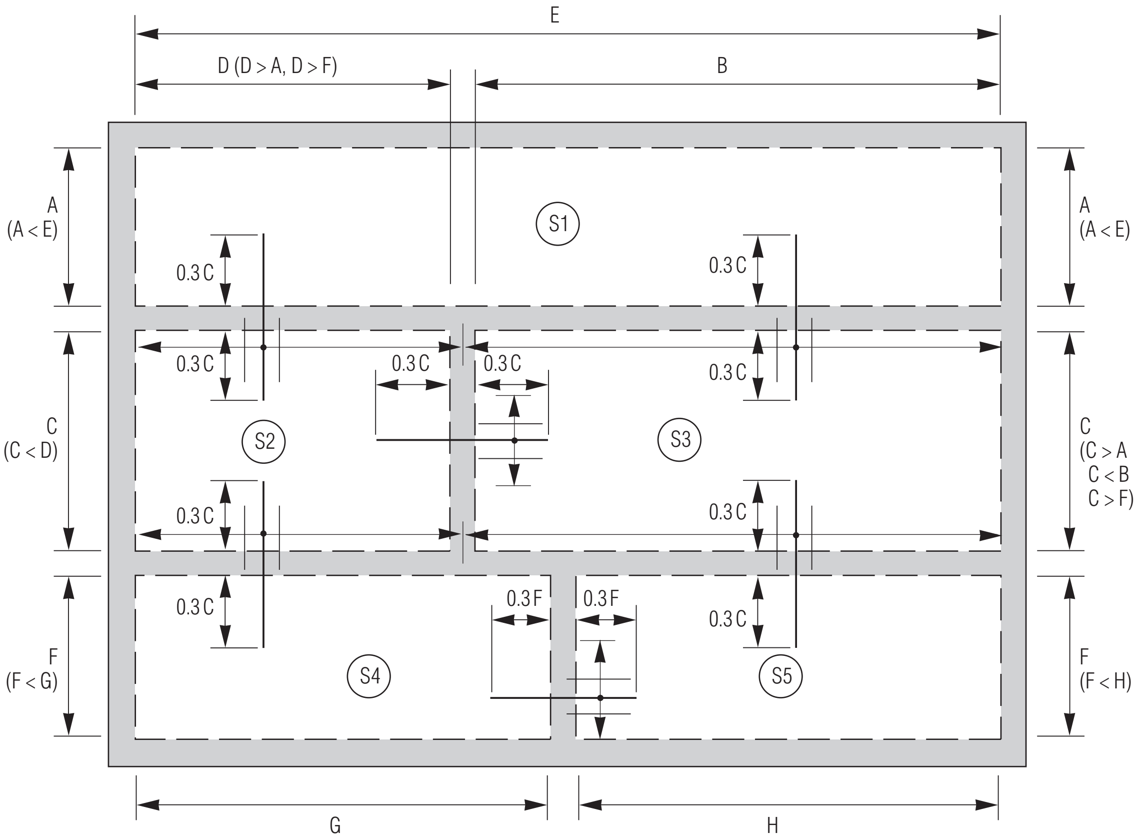


(a) TOP BARS AT SUPPORTS

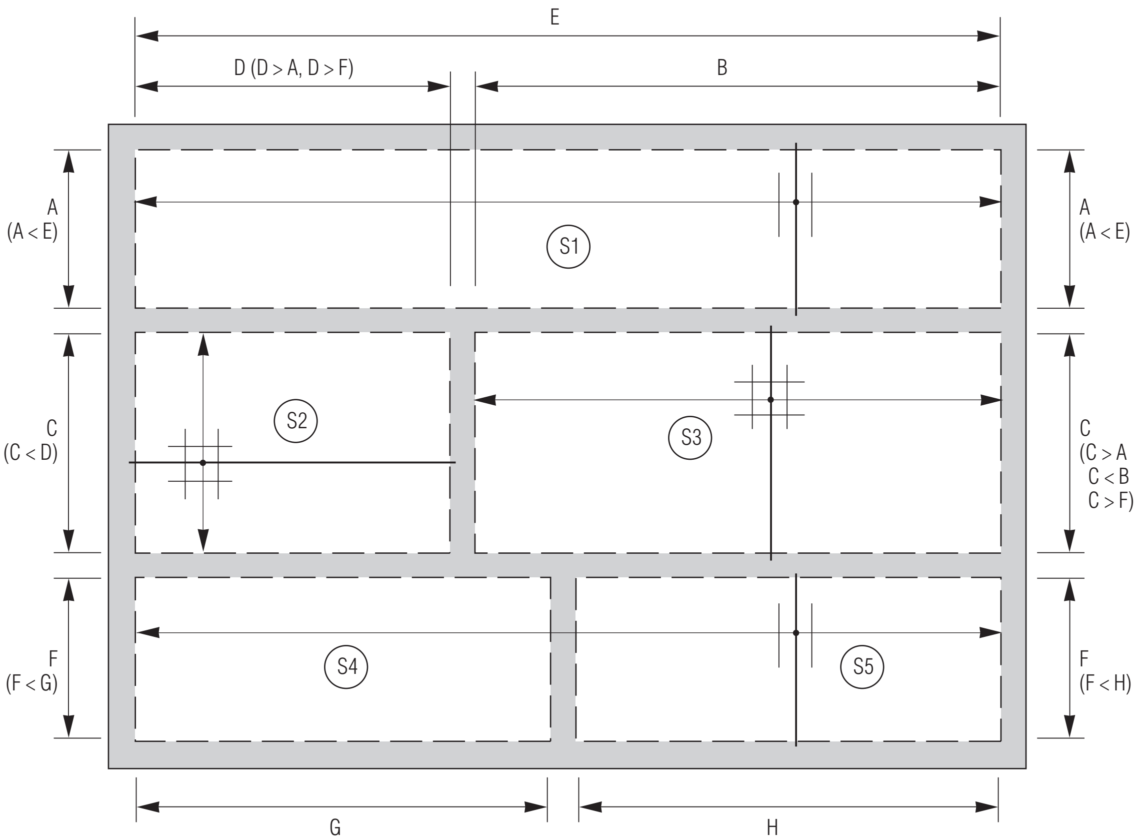


(b) BOTTOM BARS AT MIDSPAN AND SUPPORTS

Figure 14.5 *Bar Reinforcement Detailing for Two-Way Slabs Supported by Beams or Walls. On Small Projects, the Number of Different Lengths should be Reduced for Faster Detailing and to Speed Steel Fixing*



(a) TOP MESH AT SUPPORTS



(b) BOTTOM MESH AT MIDSPAN AND SUPPORTS

Figure 14.6 *Mesh Reinforcement Detailing for Two-Way Slabs Supported by Beams or Walls. On Small Projects, the Number of Different Lengths should be Reduced for Faster Detailing and to Speed Steel Fixing*

14.2.8 Multi-Span, Two-Way, Solid-Slab Systems

To understand the method of detailing a solid-slab system requires a short explanation of the design process for slab-systems generally. The whole floor system is divided into a series of strips which for design purposes are called design strips, column strips and middle strips in AS 3600 Clause 6.1.4, and for steel fixing purposes in this Handbook are called placing strips.

A solid-slab floor is a special type of slab system. Solid slabs are supported by columns and/or walls. There are no beams.

Placing drawings for solid slabs must distinguish between the different grids of steel – solid slabs in particular are hard enough to detail without confusing the design requirements. Two methods may be used.

- Grid separation. This explains the two-way bending action by putting the bottom grids of reinforcement on one plan-view, and the top grids on another.
- Layer separation. In this method, the reinforcement in the layers running one way is drawn on one plan-view, and that in the other on a separate plan. This explains how the design strips are acting.

14.2.8.1 "Design Strip" for Strength Calculations

This is a concept introduced in AS 3600; it also applies to slab systems using beams and to band-beam and slab systems. The width of the design strip is half the sum of the distances to each adjacent parallel support.

For analysis purposes, and the calculation of bending moments, the floor plan of a flat slab is divided into two series of parallel strips. One series is in one direction, say north-south, and the other at right angles or east-west. Each series of strips is centred approximately over the columns. Therefore, each column will support two design strips which are at right angles to each other.

Each design strip carries the full design load applied to its width; there is therefore some "double counting" because any part of the slab is always common to two perpendicular design strips. Bending moments and shear forces are calculated in turn for each strip in each direction.

Figure 14.7 describes slab system design strips; NS for north-south and EW for east-west. A flat-plate is illustrated; there are no drop panels in this form of construction.

- Dimensions are given only to provide a sense of scale.
- Columns are 800 mm square.
- Note that column C12, offset 600 mm within the design strip, and span C10 to C13 will control detailed dimensions over much of the floor; nevertheless design strip NS2 is shown here with a constant width.
- For example, strip NS2 has a width of 8000 mm whether measured at C6, C9 or C12.
- As another example, the width of design strip EW3 is (8400 + 9400)/2, or 8900 mm.

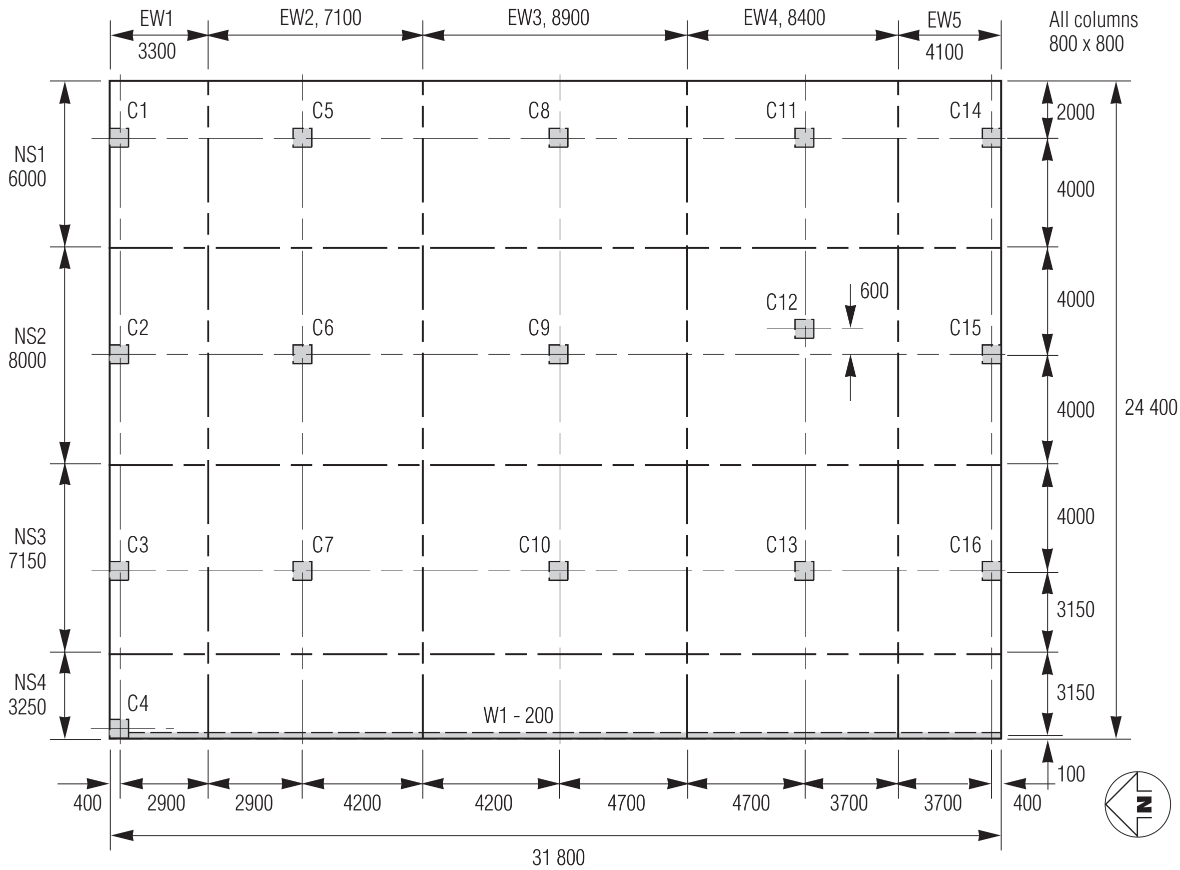


Figure 14.7 *Slab System Illustrating Design Strips of a Flat Plate*

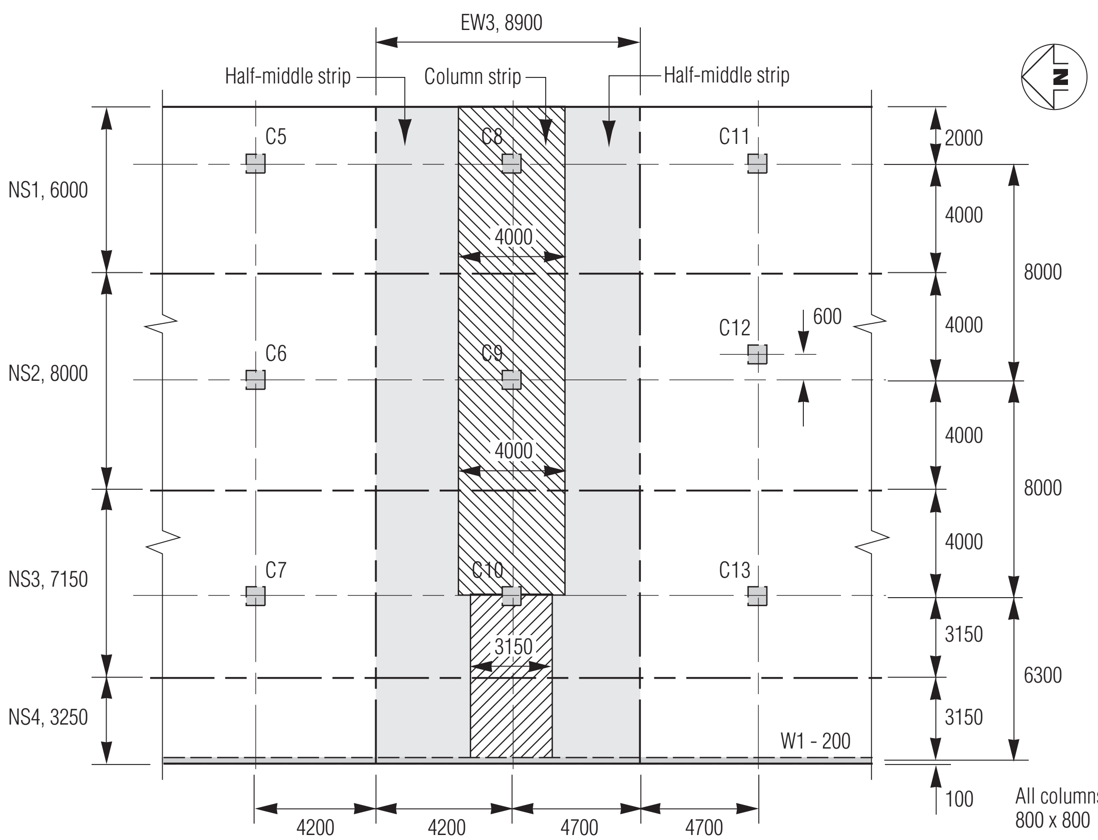


Figure 14.8 *Subdivision of Design Strip into Column and Middle Strips. The Maximum Column-Strip Width is One-Half its Span*

14.2.8.2 “Column Strips” and “Middle Strips” – for Reinforcement Placing

The term “placing strip” is used in this Handbook to refer to the reinforcement placing zones in flat slab floors. “Middle” and “column” strips are used for detailing and fixing purposes with all floor systems, not just flat slabs.

Figure 14.8 illustrates one east-west design strip taken from **Figure 14.7**. Having calculated the loads and subsequent bending moments, this design strip (for the purposes of calculating the quantities and placing the reinforcement) is itself subdivided into a central “column strip” along the column line, and two adjacent “half middle-strips”, one on each side.

Design strips, column strips and middle strips are defined in AS 3600 Figure 6.1.4(A). The maximum width of the column strip must not exceed one-half of the centre-to-centre span of the design strip itself. Any width not accounted for is added to the middle strips.

For T- and L-beams, AS 3600 Clause 8.8.2 defines the “effective width” of the beam which is used for strength and deflection calculations. Although this width will be used in the design of spandrels with flat-slabs, the “effective width” should not be confused with the various “design strips” above. See also **Clause 14.2.9**.

The total design strip bending moment is distributed to these three strips and the reinforcement size and spacing can be calculated using AS 3600 Clause and Table 6.9.5.3. This method applies to other slab systems also. This procedure is repeated for each strip in both directions.

Figure 14.8 shows the subdivision of the design strip EW3 into column and middle strips.

- The width of design strip EW3 is (8400 + 9400)/2 = 8900.
- The apparent column strip width is (8400 + 9400)/4 = 4450
- The column strip width for reinforcement placement reduces to one-half of the span in each case, ie 4000 mm from C8 to C10, and 3200 (rounded) between C10 and the west wall.
- The middle placing-strips form the balance of the design strips.
- In the North-South direction, the column placing-strip width will be one-half the North-South design strip because the centre-line spans are longer than the design-strip width.

14.2.8.3 Reinforcement Distribution to the Placing Strips of a Solid Slab

AS 3600 Clause 6.9.5.3 allows the designer to allocate the relative distribution of bending moments to the column and middle strips, and from these the reinforcement size and spacing is calculated.

Because of a greater proportion of the design strip bending moment is allocated to the column strip than to its two adjoining half middle-strips, it probably has a greater proportion of the total design strip reinforcement.

The column placing strip can be regarded as resembling the beam of a beam-and-slab system although it is much thinner and wider.

It should be noted that the amount of reinforcement in a middle placing strip consists of the total amount allocated to the two adjoining half middle strips from which it is created.

To assist fixing and inspection on site, it is recommended that different bar sizes be used for the column and middle strips in each layer, eg N16 for the middle strip and N20 or N24 for the column strips. Also, the minimum bar spacing of Clause 9.1.5 of AS 3600 should be met.

Example 14.2

Using span C9-C10 of design strip EW3 of **Figure 14.8** as an example, assume the total reinforcement area is 12,300,mm2 distributed over 8900. One method is to provide 62-N16 in this area. If 60% of the moment resistance is allocated to the column-strip, then 38 bars must be placed over 4000 mm, giving the design notation 40-N16-100. The balance of 22 bars are distributed as 10-N16 and 12-N16, proportional to their widths, at 220 mm spacing. It is the number of bars which is important, not the spacing.

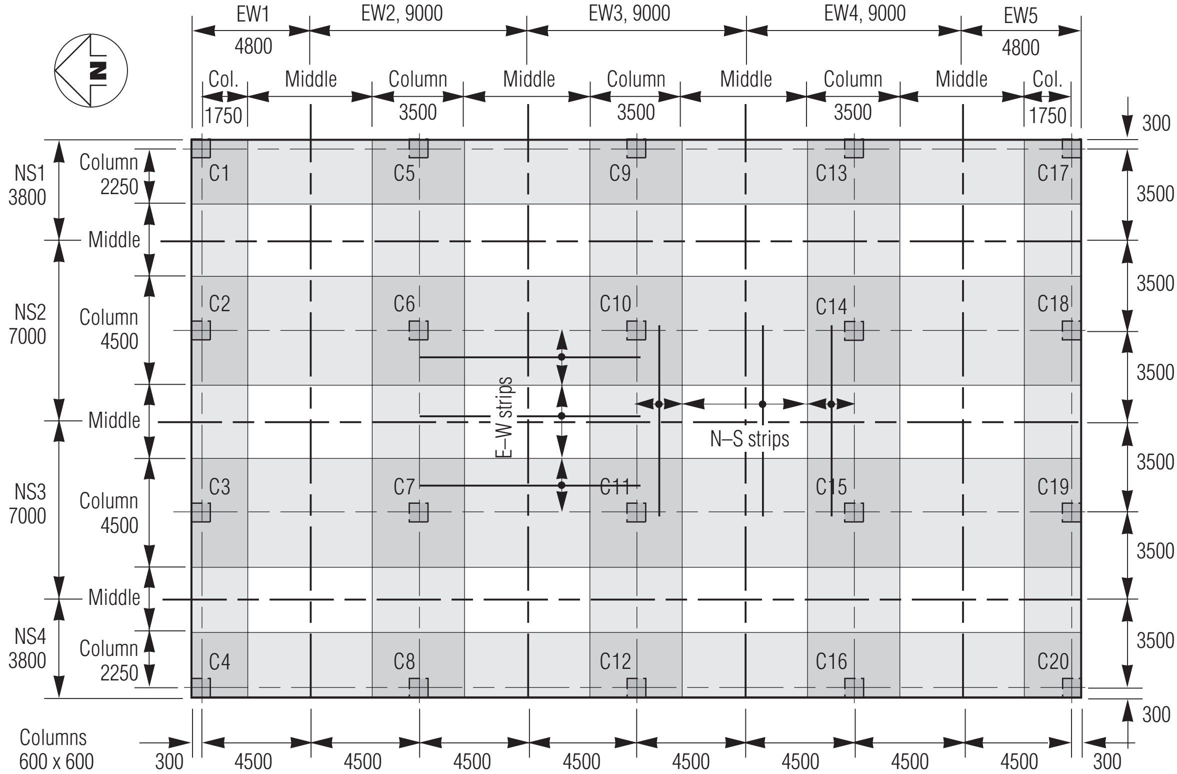


Figure 14.9 *Bottom Steel Layout for a Flat Plate. Shown is a Typical E-W Strip and N-S Strip. Note how the Bottom Steel is Distributed across One Middle Strip and Two Half-Column Strips*

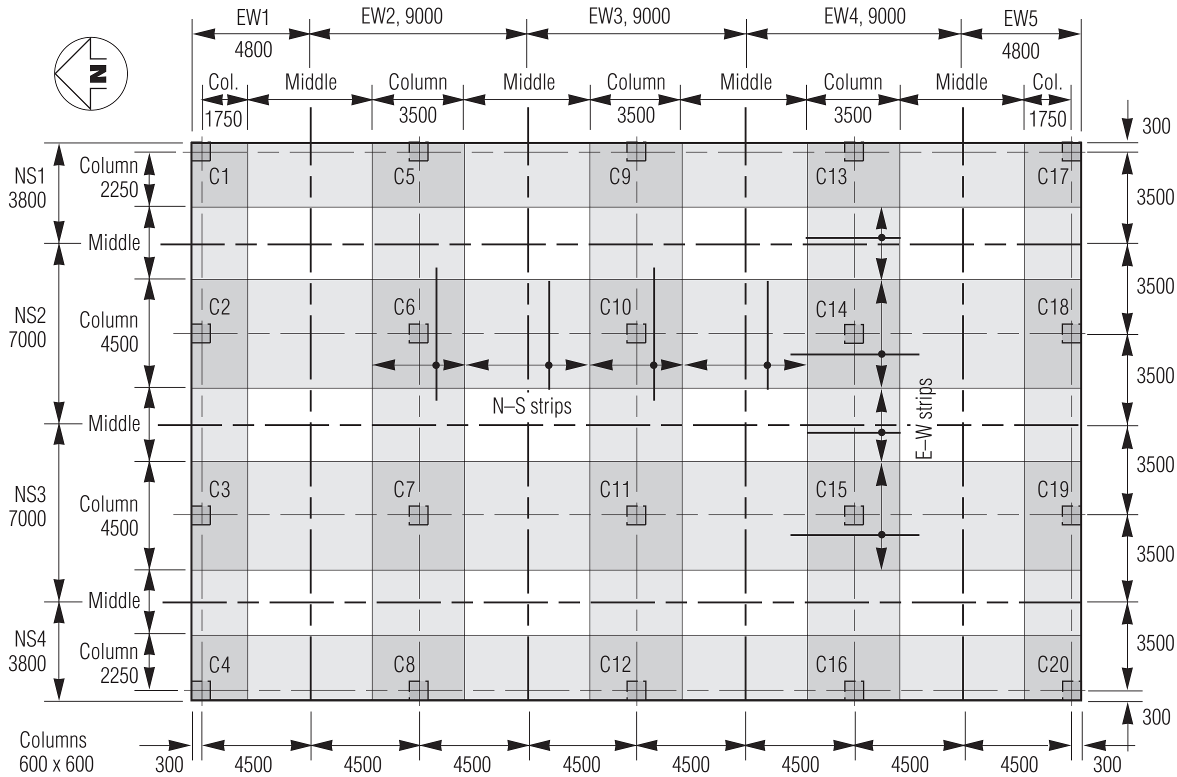


Figure 14.10 *Top Steel Layout for a Flat Plate. Note the Double Layer of Top Steel within the Intersecting Column Strips and a Single Layer in the Intersecting Middle Strips*

14.2.8.4 *Reinforcement Detailing for Solid Slabs*

Extension of reinforcement in column or middle placing strips is measured in relation to the line which joins the face of the columns in the transverse direction. The "clear span" (L_n) is the distance from one column-face line to the other in the direction of the span of the design strip being detailed.

Top steel must be fully anchored on each side of this column face line using straight bars, L-bars or mesh with cross-wire anchorage. The larger value of L_n each side of a common support determines the extension on both sides.

Bottom steel cut-off points from the column face line depend on whether the detail is for an internal or external support, whether it is in a column or middle placing strip, or whether there are drop panels or not.

- *Order of placement*. At the commencement of the slab design, a decision must be made by the engineer as to which design strip direction (N-S or E-W) will be laid first for both top and bottom, as ties will affect the effective depth used for the design. See **Figure 14.9**.
- *Avoiding confusion*. From the **Figures 14.9** and **14.10** it is obvious that EW and NS layers would become totally confused if the direction of laying varied from strip to strip. Solid slabs are analysed for bending moments on the design strips which have their centrelines along the columns and their edges approximately midway between columns. First one direction is analysed, then the other. It would be common for the bottom steel in the longer-span design strip to be laid first.
- *Bottom steel layout*. In theory for strength design, the bottom steel in the direction of the span of a design strip is spread out across (distributed across) its column strip and its two adjacent half-middle strips. See **Figure 14.8**.
  In practice, the bottom steel must be laid out as a rectangular panel with corners at the columns. The steel length equals approximately the span on column centrelines. See **Figure 14.9**. If the spacing varies between the column and middle placing strips, this must be defined, as would the length of bar in each strip.
- *Top steel layout*. Ensure **Clause 14.2.2** is complied with. Top steel for flexural strength is required within and parallel to the column placing strip (approximately one-half as wide as the design strip). The column placing strips intersect over the columns so a two layer grid of steel is used. This is illustrated in **Figure 14.10**.
  One layer of top steel for strength is also required parallel to and within each middle placing strip. It is supported by a layer of tie bars which can be an extension of the top column-strip strength bars. Tie bars are omitted for clarity from **Figure 14.10**.
- *Cut-off points*. These are shown in **Clause 14.13 Standard Details 14.2**.

14.2.8.5 *Flat Plates and Flat Slabs*

A *flat plate* refers to a column-and-slab system where the slab is of uniform thickness all over and therefore the slab soffit (underside) is flat. Sometimes the top of the supporting column is widened to form a "column capital".

A *flat slab* is generally of uniform thickness except where it is thickened by a drop-panel.

A drop-panel is a thickened area centred over a column below, but forming part of, the slab. It is usually square in plan but neither the shape nor the thickness is specified by AS 3600. Traditionally, it has been taken as about 1/6 span in each direction and rationalised to the nearest 100 mm. In area, it should not be greater than that bounded by two intersecting column placing strips. Dimensions and thickness can be changed to suit the design requirements.

14.2.9 Other Multi-Span Systems

14.2.9.1 Band-Beam and Slab Systems

A band-beam and slab consists of several parallel wide beams supported by columns and a continuous one-way slab perpendicular to and supported by the bands.

Because the beams are usually wide and shallow, AS 3600 requires them to be checked as both beams or slabs for their mode of failure. The principal distinguishing factors are cover for fire resistance and shear resistance.

Cover for fire resistance applies to the longitudinal steel. Fitments and tie-bars can be located within the fire resistance cover, provided exposure cover is maintained.

As a first estimate, the cover for fire resistance of a beam and a slab become equal when the width of the web is 700 mm for a simply-supported beam, or continuous beam

In AS 3600, both beams and slabs are designed for flexural strength by the same rules (AS 3600 Clause 9.1 refers back to Clause 8.1). For shear strength, a slab must be checked for the method of failure, and designed for both failure across the slab (Clause 8.2) or locally around the support (Clause 9.2.2). Thus a band beam can be designed as either a beam or slab, and detailed accordingly.

Shear reinforcement design requirements for beams are given in AS 3600 Clause 8.2.5, and detailing in Clause 8.2.12. In particular, even the minimum amount of shear steel need not be provided for shallow wide beams if the shear force is less than a certain level, and the band-beam depth, D, is less than the greater of 250 mm and $0.5b_{web}$. Therefore, for a beam web width greater than 500 mm, and depth greater than 250 mm, shear steel may not be required for strength purposes. If shear reinforcement is required by AS 3600 Clause 8.2.5, the longitudinal and transverse spacing is controlled by AS 3600 Clause 8.2.12.2. See **Clause 13.2.8**.

The wide beam permits the main bars to be moved sideways as necessary to avoid column bars, so a beam cage system is optional. However a wide LL- or VV-shaped mesh sheet, used as a shear cage, reduces tying to a minimum. Nested cages of mesh will provide additional vertical steel over the length of the span where this is needed.

Because the band beams and the slabs are both one-way systems, a schedule is a convenient method of showing the actual steel sizes and distribution based on a Standard Detail.

Four co-ordinated Standard Details are given in **Clause 14.10.3**. These combine details for the band beam and the slab.

AS 3600 Clause 9.1.2, requiring 25% of the total design negative moment of a flat slab to be resisted by reinforcement and tendons over the support, does not apply to band beam systems.

14.2.9.2 Other Two-Way Slab Systems

Slab systems other than flat slabs are also designed by AS 3600 Clause 6.10.4.

However when a beam is part of the design strip, it should be detailed as in **Chapter 13** of this Handbook, and the slab will be detailed as in this Chapter appropriate to the slab type. See **Clauses 14.2.6** and **14.2.7**.

14.2.10 Spacing of Reinforcement and Tendons

There are no minimum values stated in AS 3600 Clause 9.1.5, however Clause 9.4.1 has maximum spacing for crack control of $2D_s$ or 300 mm. The only requirement is that concrete can be "*properly placed and compacted in accordance with Clause 17.1.3*". This statement puts the onus on the detailer to ensure that bars are not too close.

As already mentioned in **Chapter 6**, tensile strength development length is controlled by spacing between, and cover to, the bar. The spacing factor for slab bars in the formula, k_2, is 1.7 when "*the clear distance between adjacent parallel bars developing (their) stress is not less than 150 mm*". The value of k_2 is 2.4 in all other cases, an increase of 50%! This does not mean that slab bars must not be spaced closer than 150 mm, but extra checks on development requirements must be made in those cases. See **Clause 6.2.2** for development length tables. Staggered bar-ends will obviously reduce the development requirements.

14.2.11 Shear and Torsion Reinforcement in Slabs (AS 3600 Clause 9.2.6)

This situation is not common but, if torsion is critical, then it is generally controlled by fitments in spandrel beams. “Closed-ties” of shape HT (**Figure 9.1**) are shown in AS 3600 Figure 9.2.6.

Closed-tie spacing must not exceed any of 300 mm or D_b (beam depth) or D_s (slab thickness).

One longitudinal bar must be placed in each corner of these ties. This is very important for adequate torsional strength.

14.2.12 Crack Control for Flexure, Shrinkage and Temperature Effects (AS 3600 Clause 9.4)

The maximum spacing of reinforcement for control of cracking due to flexure does not apply to slabs on the ground. (See AS 3600 Clause 9.4.1 and **Clause 14.2.1** earlier).

AS 3600 Clause 9.4.3 applies to slabs on the ground as well as to suspended slabs. The designer should decide the degree to which the slab will be restrained, and then calculate the amount of reinforcement required.

Where a slab is more than 500 mm thick, the steel in each face is calculated by substituting a value of 250 mm for the symbol “D” in the formulae, and not the actual overall depth as “D” and providing the required steel area in both the top and bottom layers. A heavy raft footing could be included in this category.

AS 3600 Clauses 9.4.4 and 9.4.5 may require additional reinforcement in the areas which connect the slab to a rigid restraint and where openings, discontinuities and re-entrant corners occur. Previous experience rather than calculations may be used.

14.3 SLAB PLAN VIEWS

Plan views are by far the most common method of detailing slabs. Dimensions are given as necessary to ensure correct scheduling; tabulated values of cut-off points can often be adopted. This Clause also applies to detailing walls in elevation, with the necessary adjustments.

14.3.1 Slab Outlines

The outline is drawn to show how the slab edges are related to the floor plan and to the slab supports. For structural safety, it is essential that the supports are clearly defined. See **Clause 7.3**.

14.3.2 Slab Thickness and Plan-View Dimensions

The most common slab thickness and the variations are shown as in **Clause 8.7.3**. Similarly, other dimensions should be provided as required.

14.3.3 Holes

Holes through the slab, recesses over or under, setdowns, plinths, etc, must be outlined and dimensioned as from **Clause 7.5**. This action is particularly important where there are no architectural drawings.

14.3.4 Structural Element Numbers

The location and reference numbers of all supporting beams, columns and walls should be as shown in **Clauses 8.2** and **8.5**. Slab reference numbers should define clearly the area to which each applies.

14.3.5 Slab Reinforcement – Basic Design Specification

- Specify the basic design notation (that is, the number off, type and size, spacing and placing information) for all slab reinforcement including some means of defining its shape and bending dimensions. See **Clauses 9.2** and **9.5**.
- If reinforcement is bent, the shape may be drawn on the plan view even if this is not the true shape when viewed in plan. If there is any doubt as to the shape, draw it on a separate elevation or cross section.

14.3.6 **Reinforcement Location**

- The most common placing zones for slab reinforcement are "bottom" and "top". There would normally be two layers of bars in each zone, or one layer of mesh in each. See **Clause 9.7** for marking.
- The area of slab which represents the appropriate placing zone is defined by the "direction line" and the "extent line" as shown in **Figure14.11**.
- The placing zone is generally assumed to have the same shape as the concrete outline into which the reinforcement fits. This outline must be defined however.

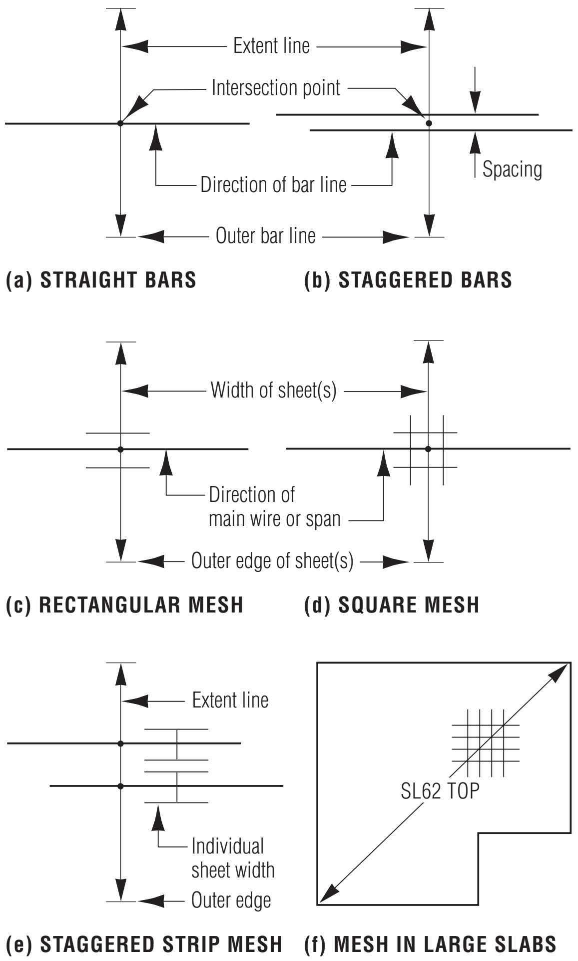


Figure 14.11 *Drawing Slab Reinforcement in Plan View*

14.3.7 **Drawing Slab Reinforcement in Plan View**

- *Bars generally*. Draw one bar in the direction in which it is laid in the placing zone indicating its shape if suitable.
  Define the width of the zone by an extent line perpendicular to the bar axis, **Figure 14.11(a)**.
  Indicate the intersection of bar and extent line with a dot or circle.
  Specify the basic design notation (the number of bars, the bar size and grade, spacing if required, placing instructions, etc) on the extent line.
  Spacing is always measured perpendicular to the direction of the bar.
- *Multiple bars*. One extent line can be used with more than one bar. A common situation is when bars of one length are to be placed with ends staggered. See **Figure 14.11(b)**.
- *Standard rectangular mesh*. The main wires are drawn with a short line on each side to indicate the close spacing of 100 mm. The main wires represent the sheet length. See **Figure 14.11(c)**.
  The extent line defines the concrete width to be covered by the mesh; the concrete area is defined by the outline of the concrete slab.
  The extent line represents the cross-wire of rectangular meshes.
  The mesh reference number and placing instructions are given on the extent line.
- *Standard square mesh*. The method is similar to rectangular meshes except that four extra wires define the square mesh. See **Figure 14.11(d)**.
  The extent line represents the cross-wire direction; reference number and placing instructions are given there also.
- *Strip meshes*. Strip meshes, and others which differ in mesh specification and sheet size from the standard meshes, are drawn similarly to the above. Although a reference number can be placed against each mesh in a placing zone, it is better to provide sheet details on a separate schedule with the sheet mark on the extent line. See **Figure 14.11(e)**.
  To specify these mesh types tabulate, for both the longitudinal wires and cross-wires, the wire size, spacing, and number to ensure the correct mesh is manufactured. The overhangs at ends and sides is sometimes critical to the design.
  Strip meshes are detailed similar to multiple bars.

- *Mesh used for shrinkage and temperature control only*. Where mesh is used to cover large areas of slab, the method of **Figure 14.11(f)** may be suitable if confusion with other reinforcement will not occur.
  Contraction and construction joints can still be located on this view; details of joints should be drawn separately, possibly as a typical detail.

14.3.8 **Placing Notation**

The slab plan-view must describe the placing zone in area and the layer in which the mesh is placed usually "bottom" or "top", and for bars, which layer is placed first. One method was described in **Clause 14.2.8.4** for solid slabs, and it can be applied to other systems as well. See **Clause 9.7.3** also.

Where the number-off per placing zone is given in the drawing or in a table, this value takes precedence over a calculation based on spacing requirements.

14.3.9 **Purpose of Tie Bars (Cross-Rods, Distribution Bars, etc)**

Several Clauses of the AS 3600 require reinforcement to provide for shrinkage and temperature control, and also to spread loads across the slab (distribution steel). However, there is no direct reference to the need to provide additional steel to support and space the reinforcement required for strength or serviceability.

This generally means that slabs are reinforced in two directions whether or not bending moments are calculated each way.

Tie bars provide a method of keeping the main slab bars apart and, with bar chairs, supporting other steel. With mesh, the "cross-wires" perform this task; with bars, extra "tie-bars" are placed perpendicular to the main bars. The quantity of shrinkage and temperature reinforcement in slabs is calculated by AS 3600 Clause 9.4.3.

The location of tie bars is a design decision so they must be specified by:

- Drawing the tie bar and the extent of the placing zone, with bar notation, as described already. This method tends to clutter-up a small scale drawing.
- Using one or more General Notes –
  eg "TIE BARS TO BE N12-250-BOT-UNO".
  "TIE BARS OVER WALLS TO BE 4N16 PER ZONE"
- Where more control is required on tie bars, the number and spacing can be indicated by short lines perpendicular to the main bar line, drawn to spacing scale. This is explicit but time consuming. It may be necessary to draw the bar layers in a cross section to define the order of placing.

14.4 SLAB ELEVATIONS

Slab longitudinal-sections are usually used for this purpose. See the Standard Details in **Clause 14.10**.

14.5 SLAB CROSS-SECTIONS

14.5.1 **Concrete Outlines**

Draw the outline with dimensions of all surfaces of the slab, particularly any changes in level or thickness, as for example at drop panels in flat slabs.

14.5.2 **Slab Support System**

Show the members which support the slab. Show, in particular, the method of support by a brick wall (which leaf for example) or, for T- or L-beam supports, draw the true cross-sectional shape of the beam. See **Clause 13.5**.

14.5.3 **Reinforcement Shape**

Generally, dimensions given on the plan-view need not be repeated on a section and vice-versa. Architectural dimensions need not be repeated unless additional information is being supplied, such a defining reinforcement shape or location.

Nevertheless, ensure there is sufficient information to define the length, bending dimensions and location of all reinforcement parallel and adjacent to the plane of the section, and the number of bars cut by the section. If the shape of these latter bars is not defined on the plan, another section at right angles to the first is necessary.

14.5.4 **Reinforcement Identification**

Bars fully detailed on the plan-view must be correlated with those on the cross-section. Repeating the bar mark is the best method. The basic design information should be given only once, and that should be on the plan-view.

14.5.5 Sequence of Construction

At least illustrate the order in which reinforcement is to be placed; that is, starting from the formwork, the lower and upper layer comprising the reinforcing mesh in each of the bottom and top face. A cross-section will show this automatically, but ensure that cross-sections are consistent with each other. See **Clause 9.7.3**.

14.6 INTERFERENCE OF SLAB TOP REINFORCEMENT WITH COLUMNS AND BEAMS

The problems associated with intersecting beam and column bars have been covered in **Chapter 13**.

The situation is worse with two T- or L-beams. When two layers of top slab reinforcement are also required at the same intersection, it becomes necessary to specify adequate depth (actual cover) to beam top steel so that slab steel will also have adequate cover. This can lead to a decreased strength for the beam if it is not treated as a design requirement and allowed for in calculations. (For a designer, to increase cover means the “effective depth” for that beam is less than for the other).

Cover for exposure in AS 3600 can be the same for slab steel as for the fitments. Cover for fire applies generally to the soffits of beams and slabs. Therefore, if top cover for the fitments and main bars of a T- or L-beam is not increased, the latter can have inadequate cover because the slab steel rests on the beam top bars.

A suitable method for either a T- or L-beam is shown in **Figure 14.12**.

This solution may be used regardless of which beam is the “primary” beam.

Where top slab steel can develop its strength at an edge or over a spandrel without using a hook, do not use a hook. If a hook is essential (with a narrow beam, say) locate it within the beam cage, not in the outer cover. See **Figure 14.13**.

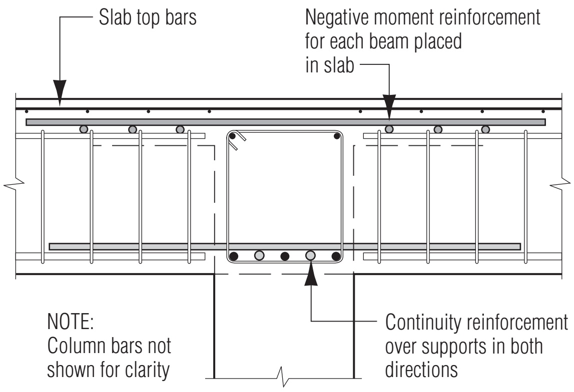
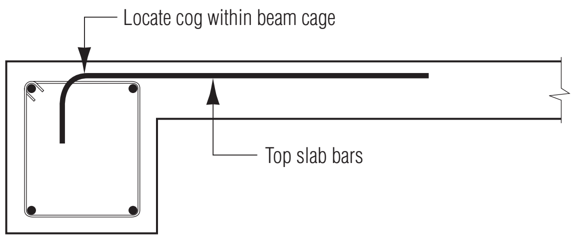


Figure 14.12 *Steel Layers at Beam-Column-Slab Intersections*

Figure 14.13 *Anchorage of Slab Steel at Edge-Beams*



14.7 T-BEAMS WITH HEAVY TOP REINFORCEMENT

Beam top-steel is actually negative moment reinforcement for the design strip. Therefore, it should be distributed over the column placing strip at the support. This steel will also reinforce the slab in the top, so extra slab material may not be required.

14.8 SIMPLIFICATION OF SLAB REINFORCEMENT

Wherever possible, different length bar groups should be kept to the smallest number consistent with adequate strength. Every extra bar drawn increases detailing, scheduling and fixing costs.

14.9 HOLES AND OPENINGS

Holes of dimension more than 150 mm through a slab or wall must be fully detailed and trimmer bars shown.

To avoid openings, bars must be moved sideways because indiscriminate cutting will cause a reduced strength. If some areas of concrete are therefore left unreinforced, additional bars must be specified.

Even if openings are not shown on the drawings, it can be an advantage if typical details are given to show what to do should an unplanned hole be required during construction.

An example of a Standard Detail for penetrations is shown in **Clause 14.13 Standard Detail 14.6**.

14.10 STANDARD DETAIL DRAWINGS FOR SLABS

This Clause provides a drawing office with the opportunity to prepare their own standard details for slabs of various types. They are based on various sources, and should not be regarded as the only method to be used. Any such system should be used as an “office standard”, not as an individual person’s standard. The Standard Details are shown in **Clause 14.13** and range from **Standard Detail 14.1** to **14.8**, although not all apply to slabs.

14.10.1 One-Way and Two-Way Slabs

The plan-view requirements given in **Clauses 14.2.6** and **14.2.7** are shown in a Standard Detail as cross-sections in **Standard Details 14.2**.

14.10.2 Flat-Slab and Flat-Plate Slab Systems

The design principles described in **Clause 14.2.8** are given in **Standard Details 14.3** and **14.4**. For both slab-systems, the details are nearly identical.

For bottom steel, 50% of bottom steel must be lapped $25 d_b$ near column centrelines; ie alternate pieces of mesh strips, or bars. This lap need not be centred over the column centreline, but may be located where steel lengths can be rationalised. The cut-off point of the remainder is an extension of $25 d_b$ past a drop panel face for flat slabs or, for flat plates, termination no further than 0.1 times the clear span from the column-face line.

Top steel details are also nearly identical. Make sure 25% of the total negative moment is resisted by steel centred over the column. See **Clause 14.2.2**.

Points of difference occur at drop panels as noted above.

Standard Details 14.3 and **14.4** are “design drawings” showing only one layer in one direction. The design drawings (probably accompanied with a reinforcement schedule) gives steel quantities such as the size and number of pieces in each placing strip. The method of staggering the bars, etc, is shown on an additional “construction drawing”.

Elevations on **Standard Details 14.3** and **14.4** show the required cut-off points.

Most projects will provide the standard details for a flat-slab system using drop panels, or the standard details for a flat-plate system without drop-panels.

In either case, the full set of “design drawings” will show the complete floor plan and reinforcement layout in two directions, in addition to these standard details.

Note that, to improve readability of drawings, it is common practice not to draw the additional tie bars needed for support of top steel at edges and in middle strips (see **Clause 14.3.9**).

14.10.3 Band-Beam and Slab Systems

Standard Details for these systems allow the beam and slab steel to be shown together because there is room on the plan-view to define the beam reinforcement.

Both top and bottom band-beam bars can be distributed over the width of the beam. Two-bar bundles may be used to reduce steel congestion.

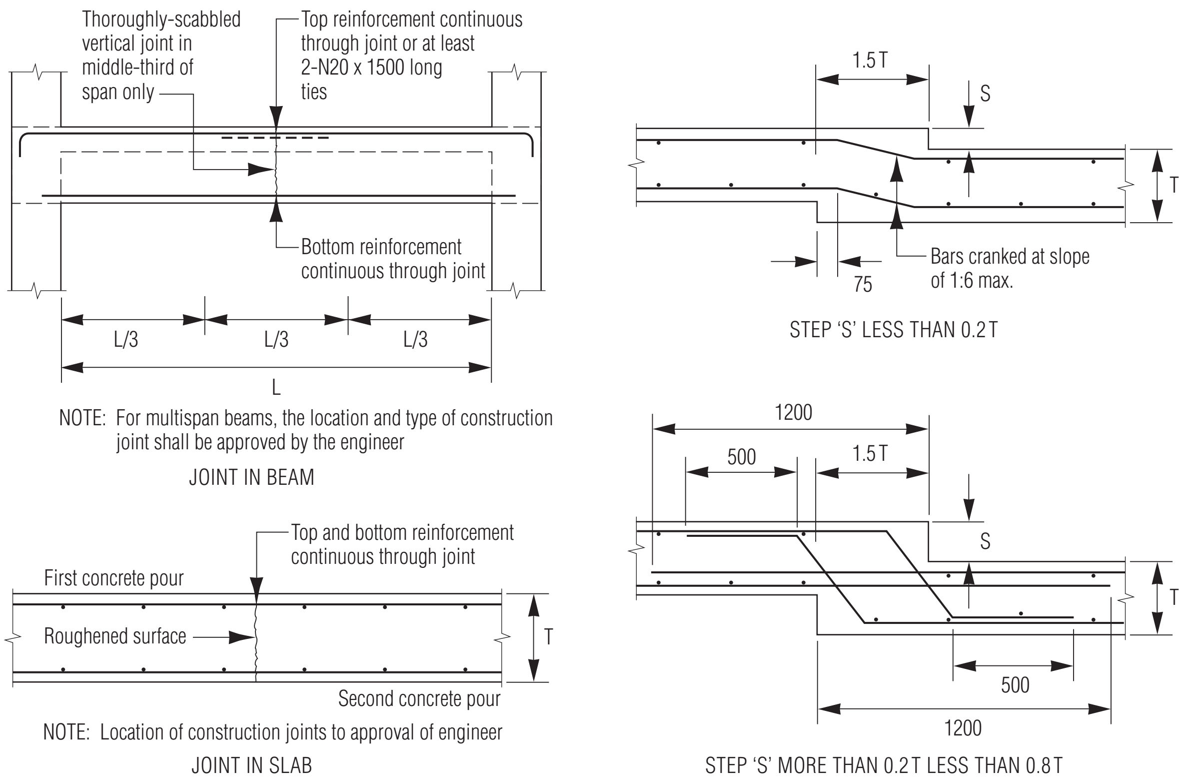
Checks for shear reinforcement must also be made; an extra cage over a short length of the span near the support will supplement the minimum shear steel requirements.

The **Standard Detail 14.5** relates the design requirements shown on the plan-view (perhaps with a reinforcement schedule) to the actual reinforcement arrangement on the formwork (staggered ends, etc). Standard detail of the band-beam in elevation is provided in **Standard Details 14.5**.

14.11 JOINTS AND SET-DOWNS IN SUSPENDED SLABS

Figures 14.14(a) and **14.14(b)** illustrate steel arrangements for various situations. They are illustrative only to indicate the problems associated with reinforcing complex concrete shapes. A design check is recommended before adoption.

The on-site complications are considerable. Check that adequate space exists for reinforcement thickness and cover. Accuracy of scheduling and steel bending is essential.



(a) CONSTRUCTION JOINTS IN BEAMS AND SLABS **(b) SETDOWNS IN SUSPENDED SLABS**

Figure 14.14 *Typical Arrangements for Joints and Set-Downs in Suspended Floors*

14.12 DETAILING FOR SEISMIC (INTERMEDIATE MOMENT-RESISTING FRAMES)

14.12.1 General

It has generally been found that insitu floor slabs spanning in either one or both directions and acting monolithically with the supporting beams are more than capable of acting as a diaphragm unless the number of large openings is excessive. The detailing requirements for slab reinforcement for moment resisting frame systems in Appendix C of AS 3600 are essentially the same as for beams (eg provisions of reinforcement, continuity, anchorage, lapping).

14.12.2 Flat Slabs

Flat-slab construction has additional requirements due to the need to ensure ductility and continuity conditions are met at column and middle strips along the line of support.

Appendix C of AS 3600 sets out the following criteria:

- All reinforcement resisting the portion of the slab moment transferred to the support is to be placed within the column strip.
- A proportion of this reinforcement is to be evenly distributed in a narrower zone measuring 1.5 times the thickness of the slab or drop panel beyond the face of the column or capital. This proportion is the greater of 0.5
  or
  $1/1 + 2/3\sqrt{(b_1 + d_o)/(b_t + d_o)}$
  where
  b_1 = the size of rectangular (or equivalent) column, capital or bracket, measured in the direction of the span for which moments are being determined.
  b_t = the size of rectangular (or equivalent) column, capital or bracket, measured transversely to the direction of the span for which moments are being determined.
- At least 25% of the top reinforcement at the support in the column strip is to be run continuously through the span.
- At least 33% of the area of top reinforcement at the support in the column strip is provided in the bottom of the strip, again running continuously through the span.
- At least 50% of all bottom reinforcement at mid-span is to be continuous through the support such that its full yield strength is developed at the face of the support.
- At discontinuous edges of the slab, all top and bottom reinforcement at a support is to be capable of developing its yield strength at the face of the support. These requirements are illustrated in **Figure 14.15**.

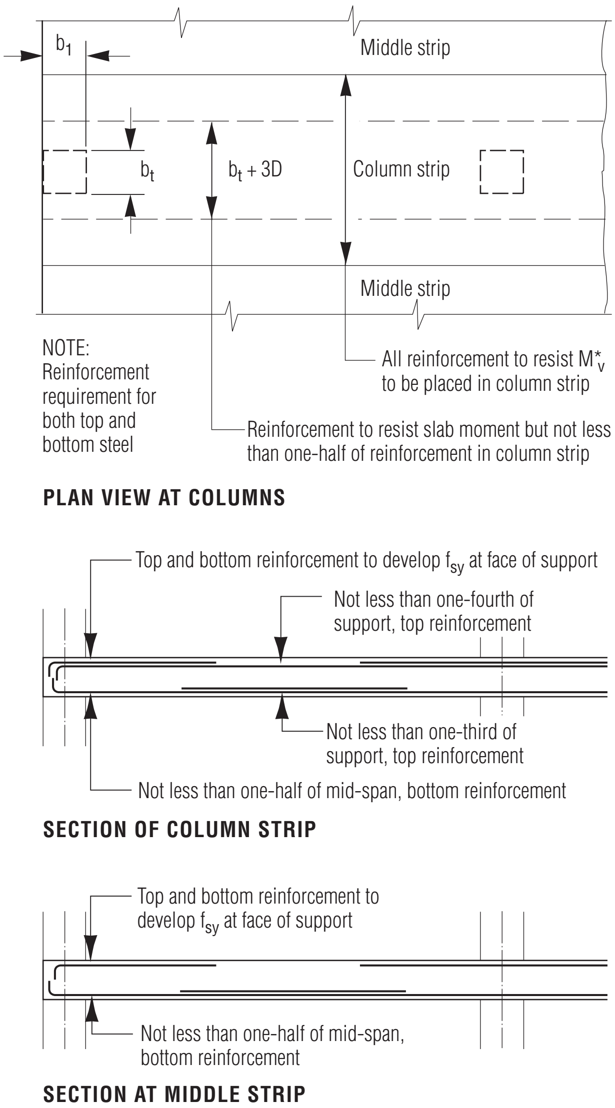


Figure 14.15 *Reinforcement Detailing for Flat Slabs in Accordance with AS 3600 Appendix C*

With flat-slab construction, it is important to ensure that the slab/column connection can withstand the deformation and moments arising from the drift of the primary lateral force resisting system without shear failure and subsequent collapse. Booth reports that failure occurs in the slab close to the column rather than in the joint zone.

(See as a Reference: Booth, E. (ed) *Concrete Structures in Earthquake Regions: Design and Analysis* Longman, 1994).

The most important factor influencing the inelastic deformation that can be sustained in the slab is the level of axial load to be transferred to the column at the joint zone. As the magnitude of axial load increases, so the available ductility decreases. This failure can be brittle in character, leading to the possibility of progressive collapse.

To prevent this, secondary reinforcement should be placed in the bottom of the slab at the column/slab intersection to resist the gravity loads in a tensile membrane action. See **Figure 14.16**.

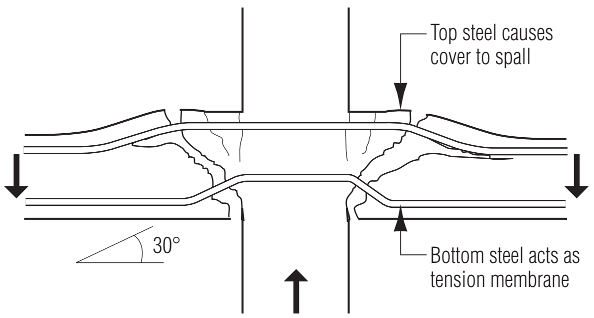


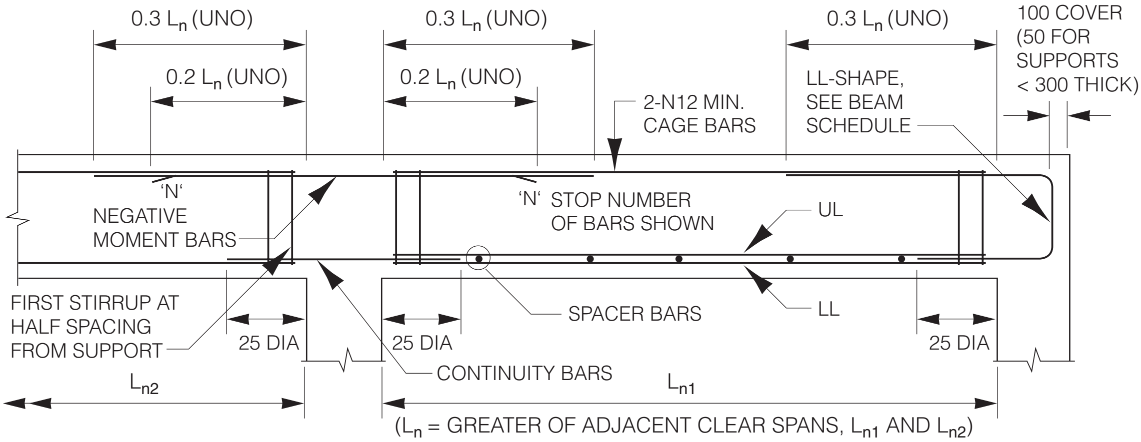
Figure 14.16 *Tensile Membrane Steel at Column-Slab Intersection*

14.12.3 **Band Beams**

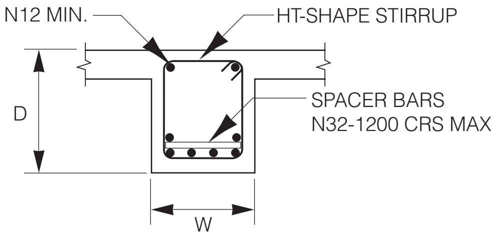
Shallow beams with large principal reinforcement ratios and correspondingly large joint shears will often give rise to problems in placing all the required joint ties. Irvine and Hutchinson (see details of Reference in **Clause 12.10.4**) report that in fully-ductile frames, the joint ties would usually be placed with one tie set directly on top of the next set with no clear space between, and recommend that for frames of limited ductility, the principal beam ratios (A_s/bd) be restricted to 0.02 or less, so as to reduce the problems of placing the beam/column joint ties. This needs to be considered especially at band beam/external column joint connections to ensure sufficient ductility in the column to prevent a plastic hinge and potential collapse mechanism forming in the column. If this proves impractical, the mechanism shown in **Figure 10.1(c)** may be considered, provided rigorous analysis and careful detailing are employed.

14.13 **STANDARD DETAILS**

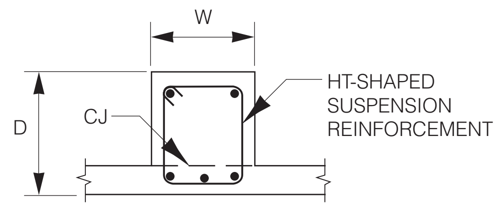
14.13.1 **Standard Details 14.1 – Beams and Beam Schedules**



ELEVATION



DOWNTURNED BEAM



UPTURNED BEAM

NOTES

1. FOR REINFORCEMENT DIMENSIONS, SEE ELEVATION AND BEAM SCHEDULE.
2. BEAM DIMENSION GIVEN AS DEPTH X WIDTH.
3. ALL BEAMS ARE DOWNTURN UNLESS NOTED AS UPSTAND.
4. BARS TO BE IN ONE LAYER UNLESS SPECIFICALLY NOTED AS UPPER LAYER (UL) OR LOWER LAYER (LL).
5. SPACER BARS ARE NOT INCLUDED IN BEAM SCHEDULE.
6. BEAM STIRRUPS ARE NOTED AS FOLLOWS - NUMBER, SIZE AND SPACING TO BEAM CENTRELINE. WHEN ONLY SIZE AND SPACING IS NOTED, STIRRUPS SHALL BE EQUALLY-SPACED THROUGHOUT BEAM LENGTH.
7. PROVIDE N12-200 OR N16-300 EACH FACE FOR BEAMS GREATER THAN 750 DEEP.
8. TERMINATE BOTTOM CAGE BARS WITHIN CLEAR SPAN.
9. LOCATE CONTINUITY BARS INSIDE COLUMN BARS.
10. NUMBER OF NEGATIVE MOMENT REINFORCEMENT BARS TERMINATED MUST BE SPECIFIED.
11. REFER ALSO TO STANDARD NOTES.

STANDARD BEAM DETAILS

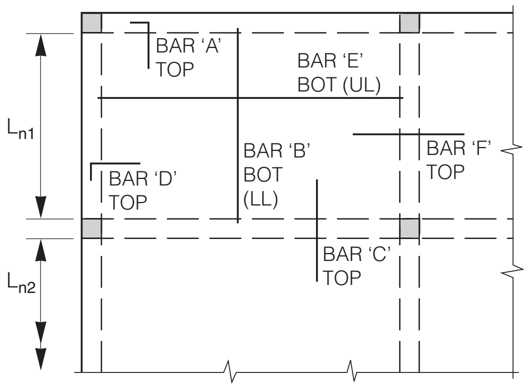
SAMPLE BEAM SCHEDULE

BEAM MARK (D X W)		SUPPORT	**MAIN REINFORCEMENT** L_n 0.3 L_n		0.3 L_n	SUPPORT		**STIRRUP SPACING** TYPE	LEFT	REMAINDER	RIGHT	TOP COVER
B1 700 X 450	150 COG			2-N24 3-N24			500		6-N12-100 THEN 300 TO CL.		6-N12-100 THEN 300 TO CL.	65
B2 1320 X 300	150 COG			2-N24 3-N24	2-N32				6-N12-100 THEN 300 TO CL.		6-N12-100 THEN 300 TO CL.	65
B3 1320 X 300				2-N32 3-N28	2-N28		1000		N12-300 THROUGHOUT			65
B4 1000 X 250			3-N32	2-N16 3-N32	3-N32				N12-300 THROUGHOUT			65

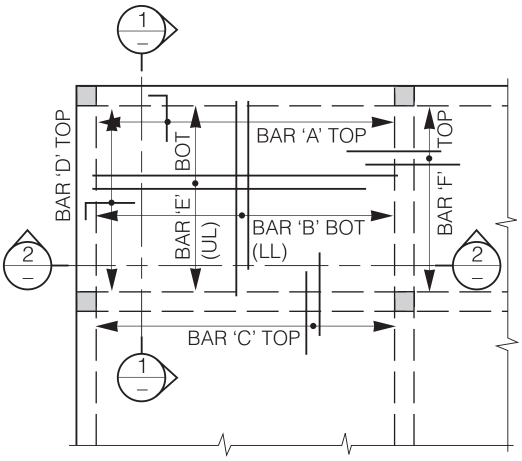
NOTE SAMPLE BEAM SCHEDULE DOES NOT APPLY TO STANDARD BEAM DETAILS ABOVE

STANDARD DETAILS 14.1 –

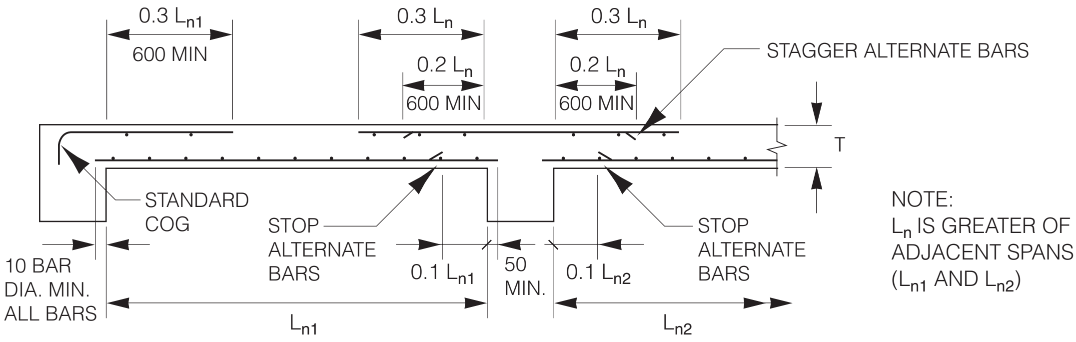
14.13.2 **Standard Details 14.2 – One and Two-Way Slab and Beams**



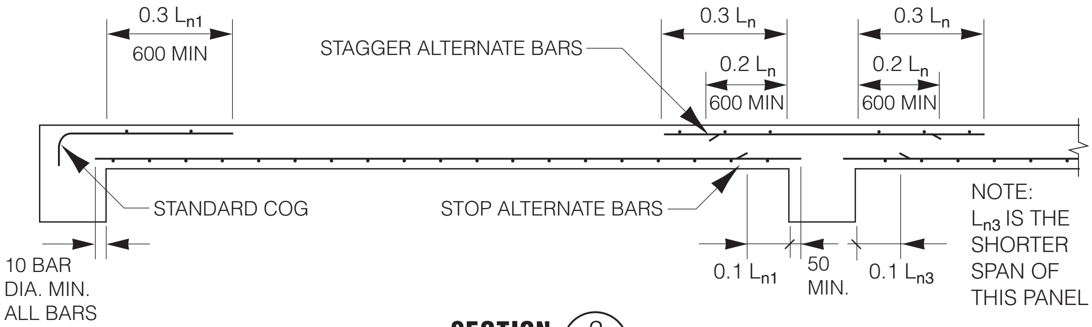
REINFORCEMENT PLAN AS DESIGNED



REINFORCEMENT PLAN AS DETAILED



SECTION 1



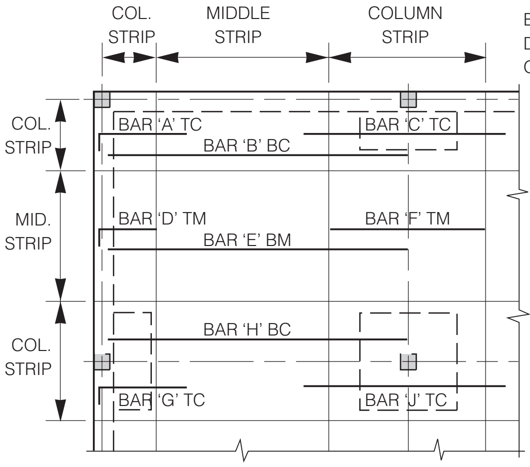
SECTION 2

NOTES

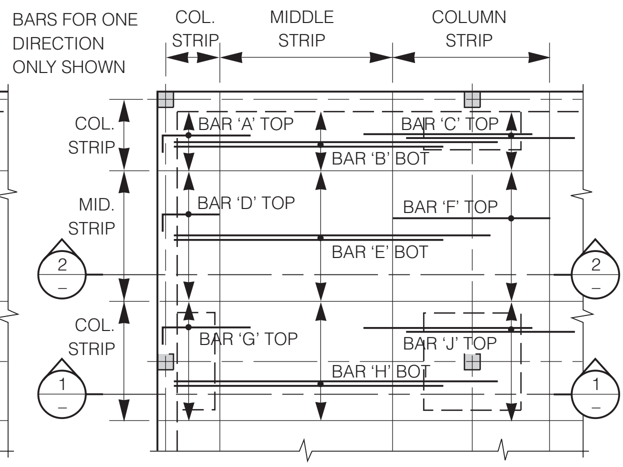
1 FOR REINFORCEMENT DIMENSIONS, SEE PLANS.
2 ALL DISTRIBUTION BARS NOT SHOWN ON PLANS TO BE N12 - 450 LAPPED 400 WITH MAIN TOP BARS.
3 FOR SLABS REINFORCED WITH BOTTOM MESH, THE MESH SHALL BE ONE PIECE IN THE DIRECTION OF THE SHORTER SPAN AND MAIN WIRES IN THE LOWER LAYER.
4 BAR LAYERS ON PLANS INDICATED AS UPPER LAYER (UL) OR LOWER LAYER (LL).
5 DETAILS ABOVE APPLY UNLESS SHOWN OTHERWISE ON THE PLANS.
6 REFER ALSO TO STANDARD NOTES.

STANDARD DETAILS 14.2 –

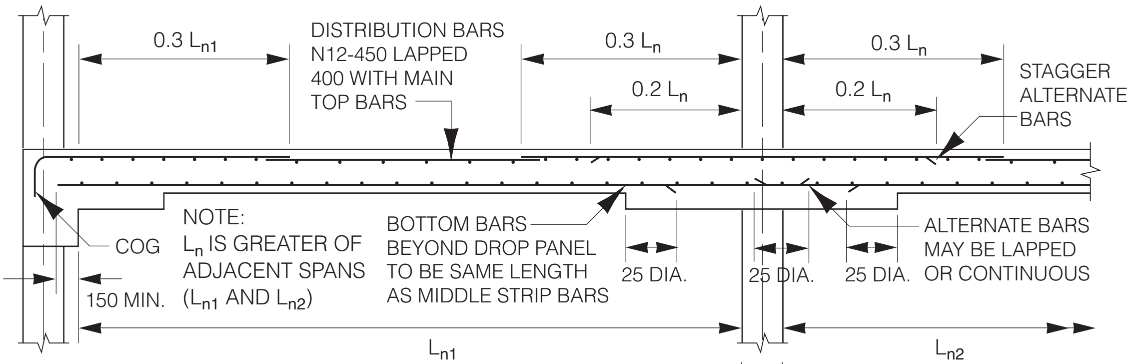
14.13.3 **Standard Details 14.3 – Flat Slab**



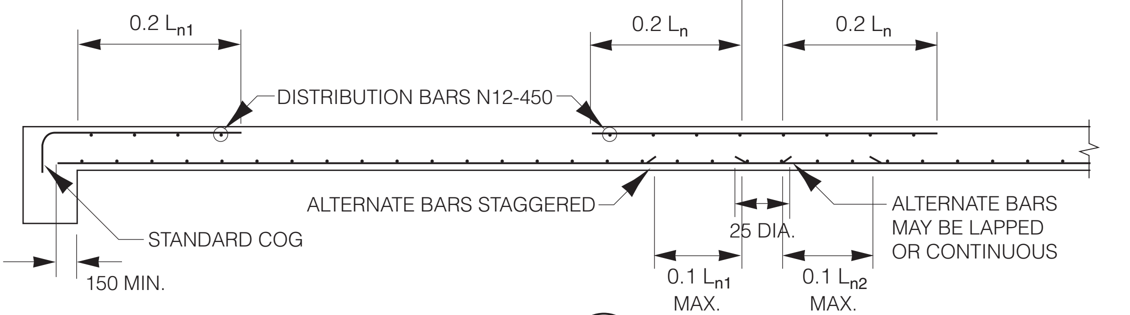
REINFORCEMENT PLAN AS DESIGNED



REINFORCEMENT PLAN AS DETAILED



SECTION 1/–



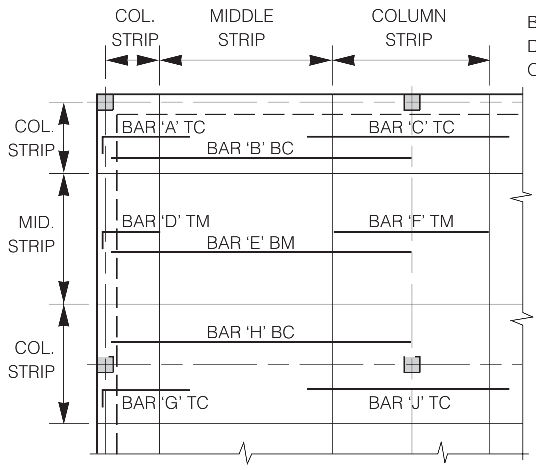
SECTION 2/–

NOTES

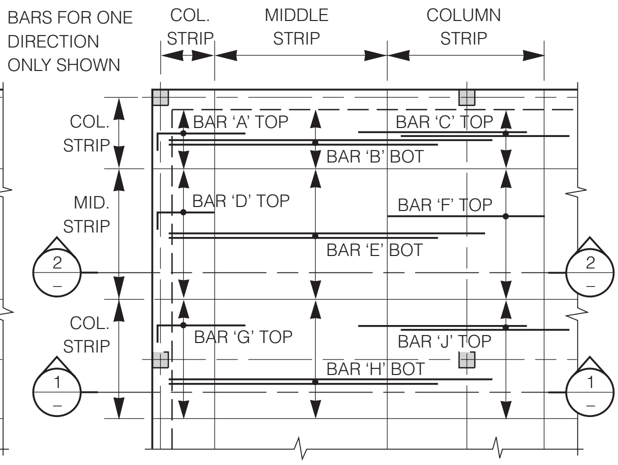
1 FOR REINFORCEMENT DIMENSIONS, SEE PLANS.
2 BARS ARE TO BE EVENLY SPACED WITHIN THEIR RESPECTIVE STRIP WIDTHS AS DIMENSIONED ON PLANS.
3 LONG AND SHORT BARS ARE TO BE PLACED ALTERNATELY, ODD BARS ARE TO BE LONG BARS.
4 BAR LAYERS ON PLANS INDICATED AS UPPER LAYER (UL) OR LOWER LAYER (LL).
5 ALL DISTRIBUTION BARS NOT SHOWN ON PLANS TO BE N12 - 450 LAPPED 400 WITH MAIN TOP BARS.
6 DETAILS ABOVE APPLY UNLESS SHOWN OTHERWISE ON THE PLANS.
7 REFER ALSO TO STANDARD NOTES.

STANDARD DETAILS 14.3 –

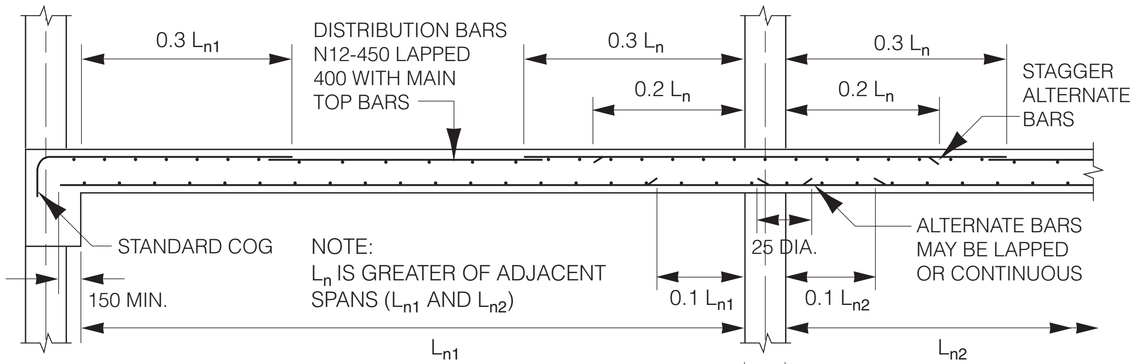
14.13.4 **Standard Details 14.4 – Flat Plate**



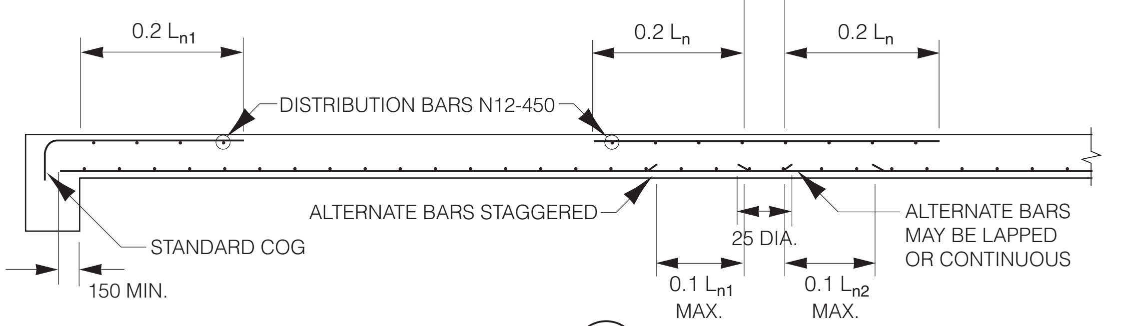
REINFORCEMENT PLAN AS DESIGNED



REINFORCEMENT PLAN AS DETAILED



SECTION 1/–



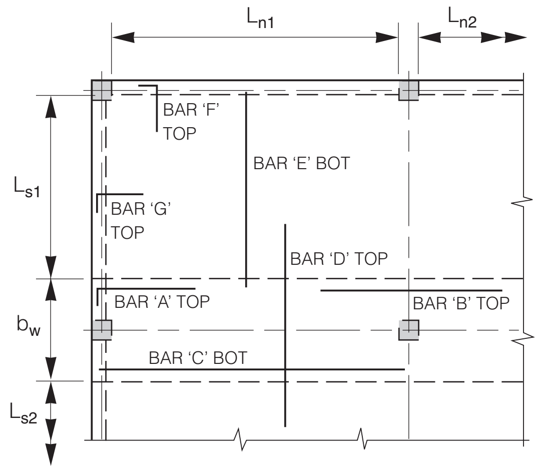
SECTION 2/–

NOTES

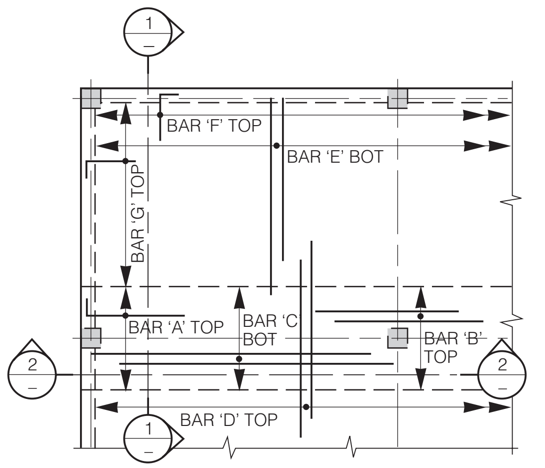
1 FOR REINFORCEMENT DIMENSIONS, SEE PLANS.
2 BARS ARE TO BE EVENLY SPACED WITHIN THEIR RESPECTIVE STRIP WIDTHS AS DIMENSIONED ON PLANS.
3 LONG AND SHORT BARS ARE TO BE PLACED ALTERNATELY, ODD BARS ARE TO BE LONG BARS.
4 BAR LAYERS ON PLANS INDICATED AS UPPER LAYER (UL) OR LOWER LAYER (LL).
5 ALL DISTRIBUTION BARS NOT SHOWN ON PLANS TO BE N12 - 450 LAPPED 400 WITH MAIN TOP BARS.
6 DETAILS ABOVE APPLY UNLESS SHOWN OTHERWISE ON THE PLANS.
7 REFER ALSO TO STANDARD NOTES.

STANDARD DETAILS 14.4 –

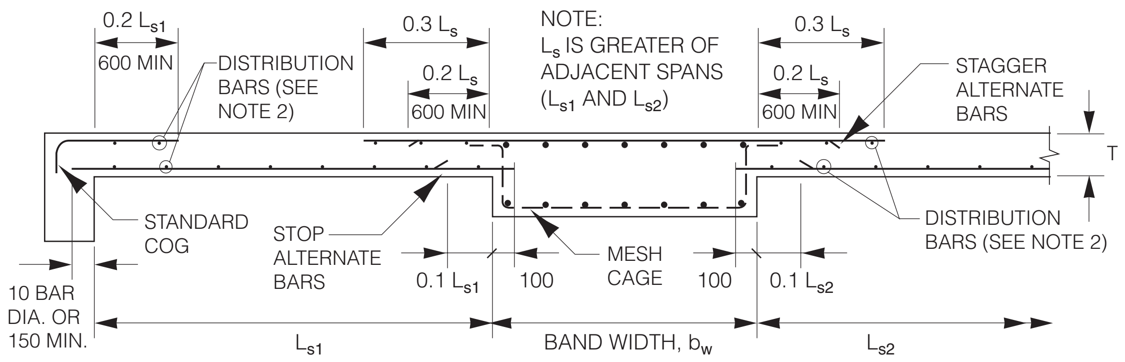
14.13.5 **Standard Details 14.5 – Band Beam and Slab**



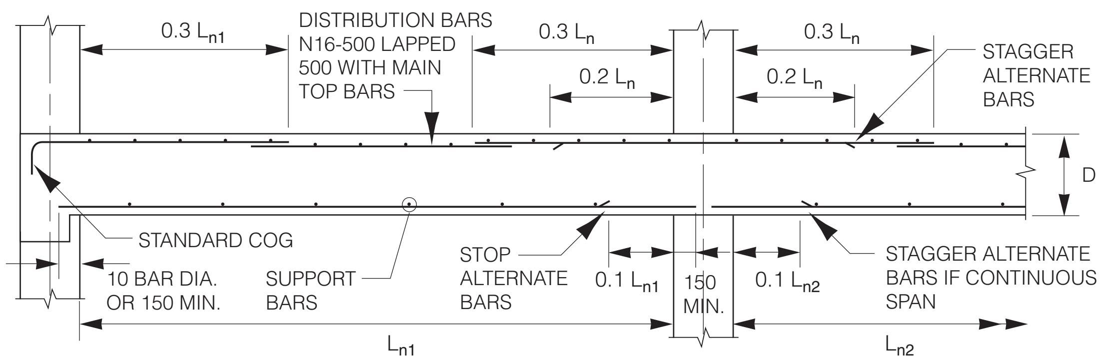
REINFORCEMENT PLAN AS DESIGNED



REINFORCEMENT PLAN AS DETAILED



SECTION 1



SECTION 2

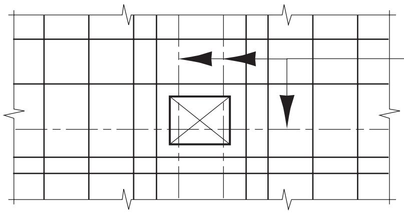
L_n IS GREATER OF ADJACENT SPANS (L_{n1} AND L_{n2})

NOTES

1 FOR REINFORCEMENT DIMENSIONS, SEE PLANS.
2 ALL DISTRIBUTION BARS NOT SHOWN ON PLANS TO BE N16 - 500 LAPPED 500 WITH MAIN BARS.
3 BARS MAY BE ADJUSTED SIDEWAYS TO AVOID COLUMN BARS.
4 BAR LAYERS ON PLANS INDICATED AS UPPER LAYER (UL) OR LOWER LAYER (LL).
5 LONG AND SHORT BARS ARE TO BE PLACED ALTERNATELY, ODD BARS ARE TO BE LONG BARS.
6 DETAILS ABOVE APPLY UNLESS SHOWN OTHERWISE ON THE PLANS.
7 REFER ALSO TO STANDARD NOTES.

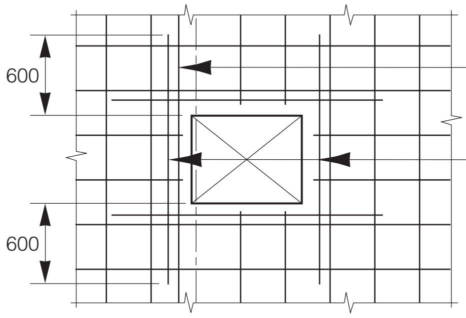
STANDARD DETAILS 14.5 –

14.13.6 **Standard Details 14.6 – Penetrations in Slabs**



MOVE BARS WHICH ALIGN WITH HOLE TO NEAREST SIDE (WATCH COVER)

HOLES LESS THAN 300 x 300



BOTTOM BARS

BARS WITHIN 50 mm OF HOLE EDGE TO BE MOVED NOT CUT

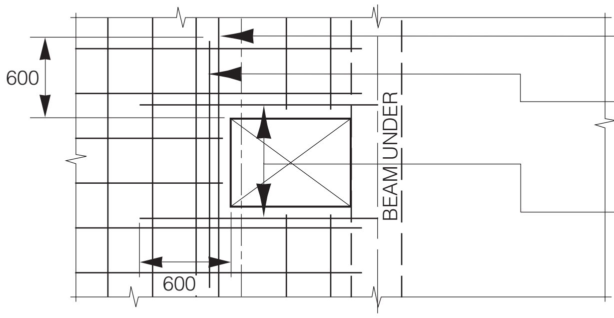
FOR EACH TWO BARS STOPPED BY THE HOLE, ADD ONE BAR EACH SIDE, OF SAME SIZE AND GRADE, EXTENDING 600 mm BEYOND THE HOLE

TOP BARS

WHERE TOP BARS ARE USED, APPLY SAME DETAILS AS FOR BOTTOM BARS.

IF TOP BARS ARE NOT USED, ADD 1-N16 TOP BAR EACH SIDE OF HOLE EXTENDING 600 mm BEYOND HOLE

(a) HOLES IN SLAB INTERIOR

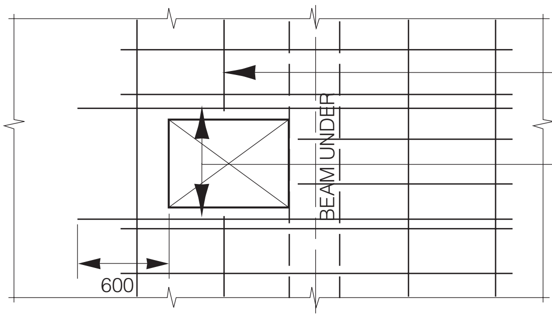


BARS WITHIN 50 mm OF HOLE EDGE TO BE MOVED NOT CUT

FOR EACH TWO BARS PARALLEL TO THE BEAM, STOPPED BY THE HOLE, ADD ONE BAR OF SAME SIZE AND GRADE TO THE EDGE AWAY FROM THE BEAM, EXTENDING 600 mm BEYOND THE HOLE

FOR EACH TWO BARS PERPENDICULAR TO THE BEAM, STOPPED BY THE HOLE, ADD ONE BAR OF SAME SIZE AND GRADE TO EACH SIDE, EXTENDING 600 mm BEYOND THE HOLE

(b) BOTTOM BARS AT HOLES IN SLAB ADJACENT BEAM



DISTRIBUTION BARS MAY BE CUT AT THE HOLE

FOR EACH TWO TOP BARS STOPPED BY THE HOLE, ADD ONE BAR OF SAME SIZE AND GRADE TO EACH SIDE, EXTENDING THE SAME LENGTH AS TOP BARS OR 600 mm BEYOND THE HOLE, WHICHEVER IS THE GREATER

(c) TOP BARS AT HOLES IN SLAB ADJACENT BEAM

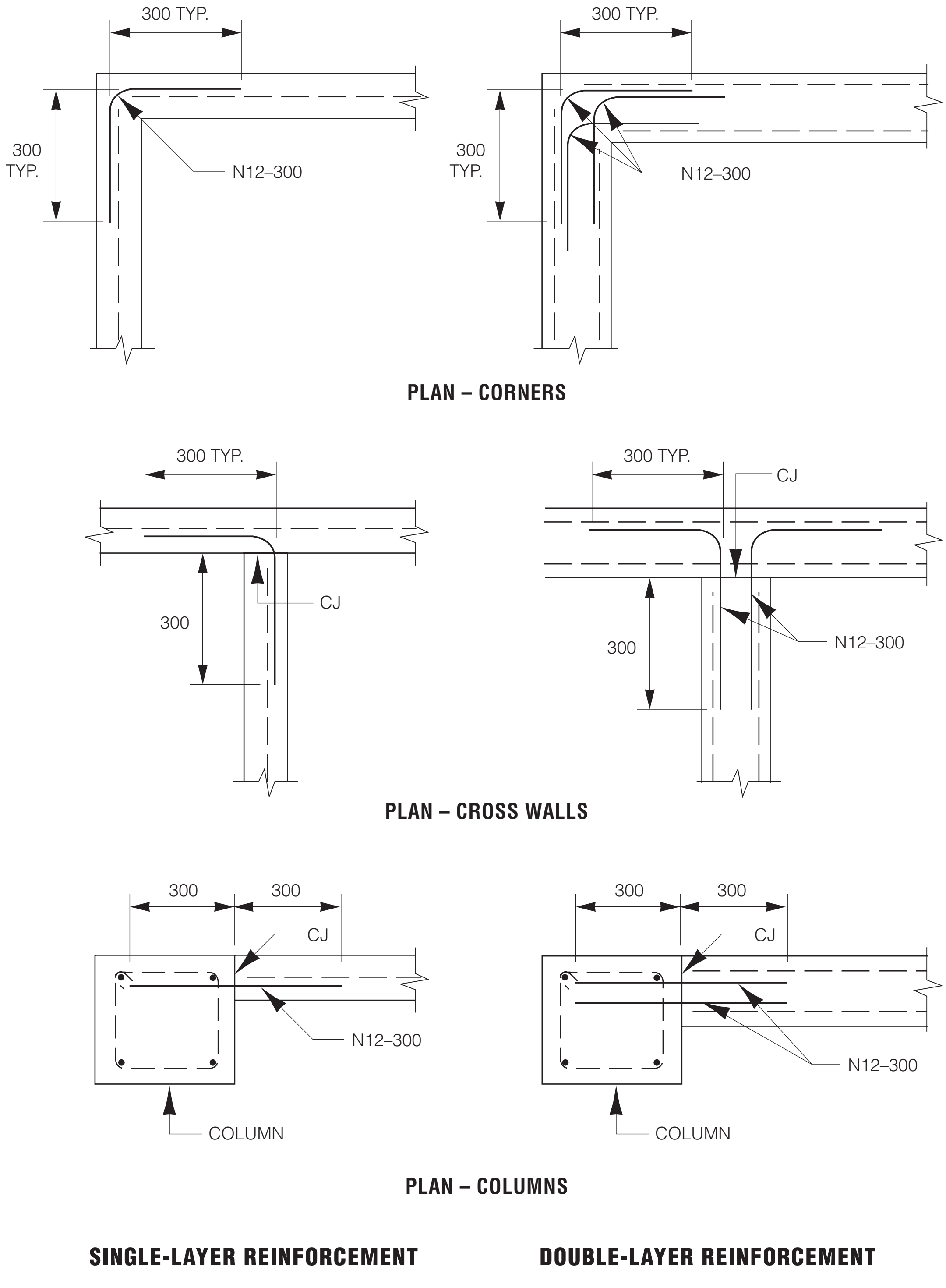
HOLES BETWEEN 300 x 300 AND 1000 x 1000

NOTES

1 FOR HOLES GREATER THAN 1000 x 1000, REFER TO ENGINEERS PLANS.
2 LOCATION OF HOLES TO BE APPROVED BY THE ENGINEER.
3 REFER ALSO TO STANDARD NOTES.

STANDARD DETAILS 14.6 –

14.13.7 **Standard Details 14.7 – Reinforced Concrete Wall Intersections**

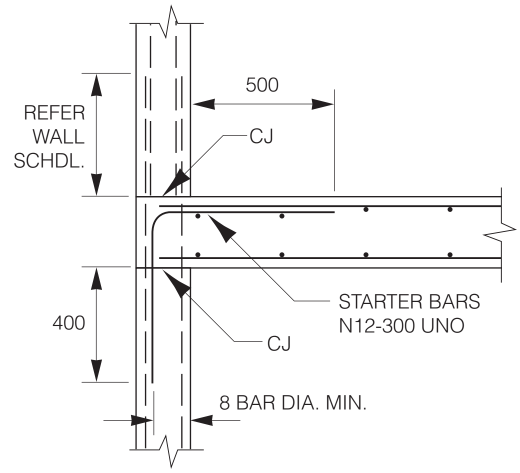


NOTES

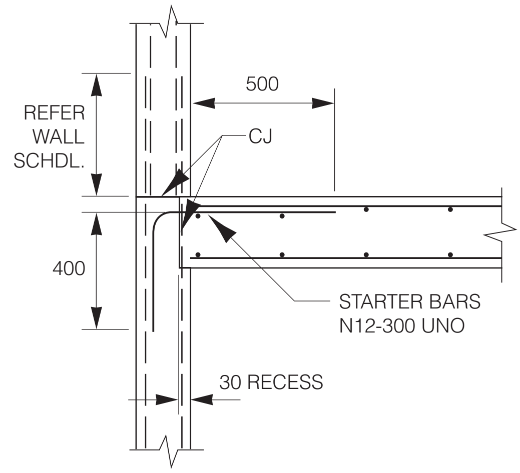
1 N12-300 BARS ASSUMED AS AN EXAMPLE (LAP LENGTHS WOULD CHANGE IF BAR SIZE CHANGES).
2 DETAILS ABOVE APPLY UNLESS SHOWN OTHERWISE ON THE PLANS.
3 REFER ALSO TO STANDARD NOTES.

STANDARD DETAILS 14.7 – IV

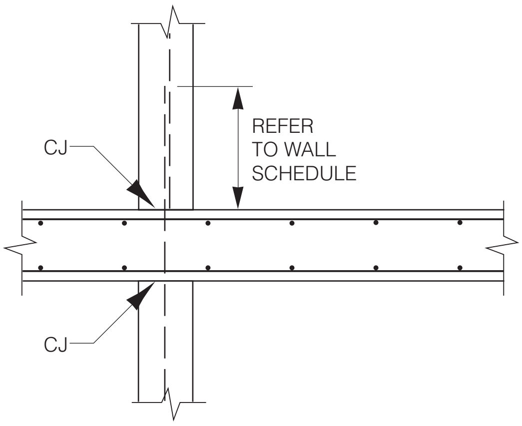
14.13.8 **Standard Details 14.8 – Reinforced Concrete Wall/Slab Intersections**



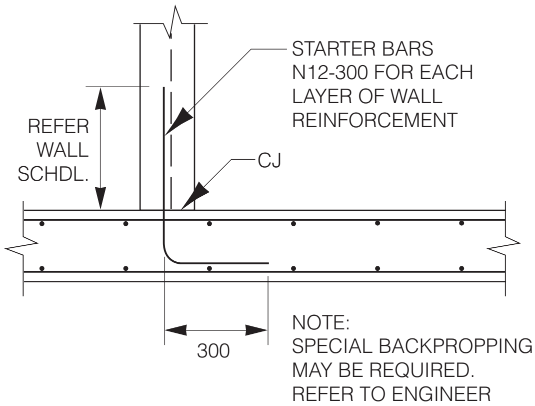
CONTINUOUS PERIMETER WALL



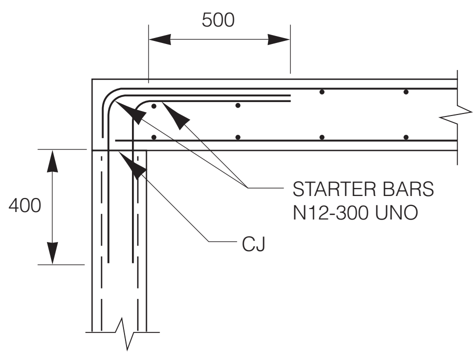
CONTINUOUS PERIMETER WALL WITH RECESS



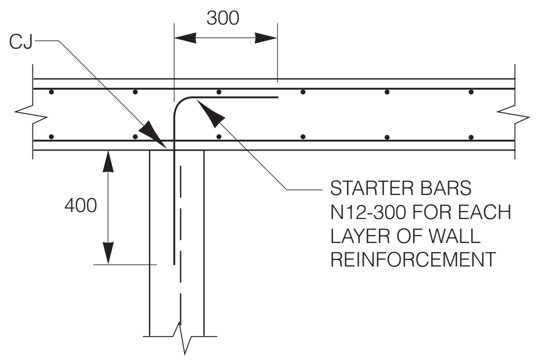
CONTINUOUS INTERNAL WALL



INTERNAL WALL OVER



PERIMETER WALL UNDER



INTERNAL WALL UNDER

NOTES

1 N12-300 BARS ASSUMED AS AN EXAMPLE (LAP LENGTHS WOULD CHANGE IF BAR SIZE CHANGES).
2 DETAILS ABOVE APPLY UNLESS SHOWN OTHERWISE ON THE PLANS.
3 REFER ALSO TO STANDARD NOTES.

STANDARD DETAILS 14.8 – [redacted]

15

Reinforced Concrete Walls

15.1 GENERAL

Reinforced concrete walls in this Chapter include service cores.

15.1.1 Purpose

Walls have considerable breadth and height in relation to thickness. They may be subdivided into loadbearing walls, which transfer loads down the structure, and non-loadbearing walls, which act as partitions between rooms or as external facades. Walls often function as fire-separating members.

Detailers must be told of the intended purpose as load carrying capacity is critical to building safety.

15.1.2 Description of Method of Load Carrying by Walls

Section 11 of AS 3600 differentiates between the various design methods for planar walls. That section of the standard does not apply to the design of curved walls such as circular tanks or architectural features, but the recommendations for detailing which follow later can still be applied.

- *Walls subjected only to in-plane vertical forces*. Wind and other horizontal forces are not considered to be active. A braced wall would be detailed as given in this Chapter, or by **Chapter 12** if it was designed as a column. In the latter case, there would be a grid of reinforcement in each face, and ties could be required.
- *Walls subjected to in-plane vertical and horizontal forces*. Shear walls, and service cores providing that function, fall into this category. They would be detailed using this Chapter.
- *Walls subjected principally to horizontal forces perpendicular to the wall*. Where the vertical loads are small, the wall can act as a one-way or a two-way slab and would be detailed as in **Chapter 14**. Cantilever walls would also be designed as slabs, and be detailed as in **Chapters 15** and **16**.
- *Walls subjected to in-plane vertical forces and horizontal forces perpendicular to the plane of the wall*. These are designed as columns and detailed as in **Chapter 12**.
- *Walls forming part of a framed structure*. Depending on the design forces, the wall may act as a slab or as a column and would be detailed accordingly. Again, reinforcement details would accord with this Chapter.

15.1.3 Wall Reinforcement

Wall reinforcement is best described as being in the form of a grid which consists of a two-way mesh of bars, one layer placed horizontally and the other placed vertically. The grid can also consist of a single mesh sheet.

Depending on the design requirements, there may be either one or two grids in the wall. In the latter case, one grid would be placed in each face so there would be four layers of steel, two horizontally and two vertically.

Walls over 200 mm thick require two grids, as does a wall designed as a column. Horizontal ties may be required. Where the wall is designed as a slab, one grid of reinforcement may be used in each of the “positive” and “negative” bending moment zones. Termination points would also be similar to slabs. Bending can be one-way or two-way.

For a shear wall, the reinforcement contributes to the strength and the amounts required horizontally and vertically must be calculated. There are several design methods, but the reinforcement requirements of AS 3600 Clause 11.7 still apply.

15.2 AS 3600 REQUIREMENTS (Clauses 11.2, 11.6.4, 11.7)

Where the applied loads cause the wall to act as a column, **Chapter 12** may be used for detailing reinforcement in two layers with ties between them. (AS 3600 section 11.2).

15.2.1 Shear Strength Requirements (AS 3600 Clause 11.6.4)

The total steel area horizontally and vertically is calculated. These areas can then be placed in one or two grids. Most commonly, the steel is uniformly-distributed in each direction.

15.2.2 Minimum Reinforcement in Walls (AS 3600 Clause 11.7.1)

The minimum amount vertically depends primarily on the quantity needed for strength, provided it exceeds 0.15% of the cross-sectional area of the wall.

The minimum amount horizontally is 0.25% of the wall cross-sectional area. This value is larger than that for the vertical direction because shrinkage and temperature effects are more likely to cause vertical cracking than horizontal cracking.

Walls less than 2500 mm wide, and with no restraint against horizontal movement, may be used with less reinforcement in the short direction. This applies particularly to precast units such as tilt-up and prestressed hollow-core members.

The AS 3600 Clause does not mean that more steel must be used horizontally than vertically. Provided that the horizontal requirements are met, then the same size and spacing can be used vertically. Thus it is common practice to use, for example, bars "N12-200-EW" or a square mesh "SL82". Mesh tailor-made for a project can also provide for the different directional requirements.

If the wall is very thick, AS 3600 Clause 11.7.1 allows a concession for minimum horizontal reinforcement in that only the outer 250 mm thickness need be used in the calculations for each face, instead of using the total thickness. Effectively this means that for each surface of a wall over 500 mm thick, the minimum vertical reinforcement is 375 mm^2/m length and the minimum horizontal reinforcement is 625 mm^2/m height (ie each grid would be either mesh "100 x 100 - L7 x L9", or -"N12-290-VERT x N12-170-HORIZ").

15.2.3 Horizontal Reinforcement for Crack Control (AS 3600 Clause 11.7.2)

The requirements are calculated from the formulae and require a design decision to be made.

15.2.4 Spacing of Reinforcement (AS 3600 Clause 11.7.3)

The minimum clear distance between parallel bars is $3d_b$ and this may be applied to the horizontal spacing between the two grids. Maximum spacing is limited to the smaller of 2.5 times the wall thickness or 350 mm.

15.2.5 Restraint of Vertical Reinforcement

For lightly-loaded walls designed as columns, two grids of steel are still required. Ties may not be necessary for strength, but some should be specified to keep the grids in their correct location.

15.3 WALL PLAN-VIEWS

15.3.1 Location of Walls

Because lines defining a wall are drawn close together, plan-views of walls are used only to define their position in relation to other structural elements. When a slab-system is supported by walls, the outlines are shown in the plan-view as in **Figure 7.3**.

The wall thickness and other dimensions are given on sections and elevations, rather than on the plan-view.

Concrete walls defined in plan-view should be identified elsewhere in elevations and sections by the same reference number.

15.3.2 Non-Loadbearing Walls

Include any special notes above the wall, particularly when the wall is not meant to carry any load from the slab above. This is a common form of construction for masonry walls in a framed structure; the beams support the slab and the walls form solid partitions only.

All walls may be omitted if they are all non-loadbearing. If some carry loads and some do not, all walls must be shown with suitable instructions defining each type.

Masonry walls are often separated from the floors below and above by a suitable membrane. The material and method of application must be specified in the drawings.

15.3.3 Service-Core Walls

This category includes lift shafts, stair wells, air-conditioning and vertical ducts. They are often load-carrying, and location and size are critical for strength. Openings are generally not shown on this view.

- The horizontal layout of a service core is usually detailed as a cross-section incorporated with the floor plan-view.
- Variations in a wall thickness should be drawn taking special care that line separation is achieved. Dimensions are usually given in a separate larger-scale drawing.
- The inside dimensions of a core must remain constant throughout the height of the building to avoid complications with lifts and other equipment. If it is necessary, wall thicknesses are varied from the outside face.
- The requirements of slip-form or climbing-form systems must be incorporated when they are known.

15.4 WALL ELEVATIONS

15.4.1 General

Elevations of walls should show details similar to those required for plan-views of slabs. See **Clause 14.3**.

15.4.2 Wall Reinforcement – Basic Design Specification

- Specify the basic design notation (that is, the number off, type and size, spacing and placing information) for all wall reinforcement including some means of defining its shape and bending dimensions. See **Clauses 9.2** and **9.5**.
- If reinforcement is bent, the shape may be drawn on the elevation even if this is not the true shape when viewed from the side. If there is any doubt as to the shape, draw it on a separate cross-section.
- The basic design notation should be given on the extent line of reinforcement shown in elevation. See **Clause 14.3.5**.

15.4.3 Reinforcement Placing Notation

- There are always two layers of bars in each grid, or one sheet of mesh in each. See **Clause 9.7** for marking.
- The area of wall which represents the appropriate placing zone is defined by the "direction line" and the "extent line" as shown in **Figure 14.11**. Abbreviations "HORIZ" and "VERT" are recommended.
- The placing zone is generally assumed to have the same shape as the concrete outline into which the reinforcement fits. This outline must be defined; however, one label may be used even if the zone is an odd shape.
- For walls, the direction from which the elevation will be viewed must correspond with the position from which the reinforcement can be economically placed. The placing information and abbreviations EF, NF, FF, INTF, EXTF and CENTRAL are most useful. The terms "near-face" and "far-face" are purely relative to the direction of viewing. For slabs, there is no doubt that "BOTTOM" steel is against the formwork, whilst "TOP" steel will be above it; for walls, the location requires more thought.

15.4.4 Compatibility Between Drawing and Construction

The view shown in the elevation must also be the same view taken by the workmen who will build it. If a retaining wall is to be poured against the earth it is to retain, the elevation must show all details looking towards the bank. A section should always be considered as well.

If the wall surrounds a shaft or service core, each elevation must show from which side the formwork and steel will be placed. It may be necessary to use different views as the building proceeds from foundations to above ground.

Identical reinforcement layouts in each face are recommended wherever possible.

15.5 WALL CROSS-SECTIONS

15.5.1 Cross-Sections Must be Drawn

A wall elevation must always be accompanied by one or more cross-sections so that there is no possibility of misreading the reinforcement requirements.

In many cases, it may be possible to describe the walls of a structure with one standard elevation showing the layout, together with a series of cross-sections containing the design notation.

The recommendations for slab cross-sections (**Clause 14.5**) can be applied to walls also.

15.5.2 Using both Horizontal and Vertical Cross-Sections

Where both horizontal and vertical cross-sections are used, the details must be consistent so that together they show:

- Concrete outlines, dimensional thicknesses, location of construction joints, etc, which must be drawn. Horizontal construction joints are often specified by notes to the drawings.
- The location, direction and shape of all reinforcement cut by the section. To define the shape of reinforcement cut by one section, sometimes it may be necessary to draw another section at right angles, or to use an elevation.
- The location and dimensions of lap splices. This includes showing the length of reinforcement (with suitable tolerances for lapping) which will protrude from one pour so that formwork and reinforcement for a future pour can be fixed.

- The order in which bars are to be placed, if this is critical to strength. Alternatively, show the simplest method of fixing each layer in each grid. For a wall, these two recommendations are not necessarily the same. See **Clause 15.6.1**.

15.5.3 Using One Cross-Section Only

Where the elevation is used with only one cross-section (horizontal or vertical), the details suggested in **Clause 15.5.2** above must be combined.

It is more important that the direction of view of the elevation is defined on the section.

15.5.4 Restraint of Wall Reinforcement

It is very difficult to cast and compact concrete in thin walls. Reinforcement tends to obstruct the concrete. Unless the grids can be kept rigid, they can buckle under the mass of concrete. The grids should be braced from the formwork, and restrained by ties between two grids.

Specify the type, size and shape of the ties, and their horizontal and vertical spacing, at least in general terms, and permit the contractor to use a proven alternative.

15.5.4 Cover

Particularly where there is only one grid, allow for the overall thickness of the two layers in the grid when specifying cover. Ensure that the cover to the surface with the most severe exposure is correctly specified; then either omit the other cover or allow a reasonable tolerance.

15.6 SEQUENCE OF CONSTRUCTION

The sequences described below may not appear to provide the best solution for designing walls for strength in bending. However if the wall cannot reasonably be constructed, the design method must be changed. For the majority of walls which carry only vertical loads, the location of the vertical steel within the section may not be the controlling factor.

15.6.1 Fixing Vertical Bars First

It should be obvious to everyone that until vertical bars are fixed, there is no support for the horizontal bars.

- Horizontal bars should never be specified to be fixed on the far side of the verticals if they have to be lifted over the verticals or be threaded through them; this is unsafe and uneconomic.
- If there is only one grid, the verticals must be fixed first, and the horizontals fixed on the near side from which access is available.
- If there are two grids of bars with access from both sides, then the verticals can be placed first, and the horizontals are then placed on the outside from each side. This method permits good central access for vibrating equipment. See **Figure 15.1**.
- If there are two grids of bars and if access for placing forward and steel is from one side only, then the far-face verticals must be placed first, followed by the far-face horizontals; the near-face verticals come next and then the near-face horizontals. See **Figure 15.1**.

15.6.2 Fixing Mesh in Walls

Since the sheet is self-supporting, each grid can be placed as one unit. Any lap-slice between sheets should be made in the vertical direction; that is the sheets are side by side, not one above the other.

It can be an advantage to splice wall mesh through floors using either long overhangs or extra splice bars to avoid a clash with slab reinforcement.

15.7 STRAIGHT BARS PREFERRED

- Vertical bars in walls should be straight. Each lift can be lap-spliced without cranking because there is plenty of room for side-by-side laps.
- Horizontal bars between corners should be straight, but not so long that they will intrude into the concrete at a corner. Short bent bars should be used around the corners.
- If the wall is curved, it is recommended that bars over 12 mm in size should be bent to shape before lifting into place because Grade 500N bars require a considerable force to bend them.
- Mesh should always be placed in flat sheets with additional corner reinforcement fitted later. Mesh can be curved about one axis, but not about two.

15.8 REINFORCEMENT AT WALL CORNERS

Reinforcement for the corners should be short pieces of L-, LL- or U-shape. The length of each leg should be sufficient to lap with the other wall bars and allow adequate clearance between poured concrete surfaces or formwork which may still be in place. See **Clause 15.10.2**.

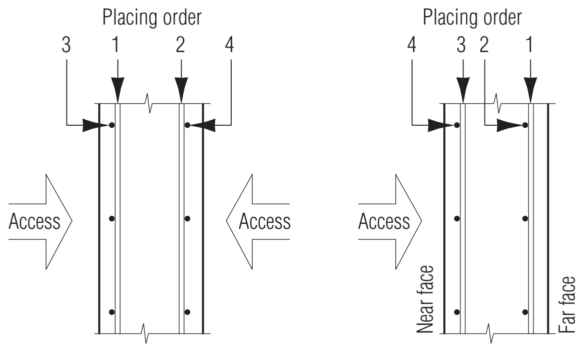


Figure 15.1 *Placing Order of Reinforcement in Walls*

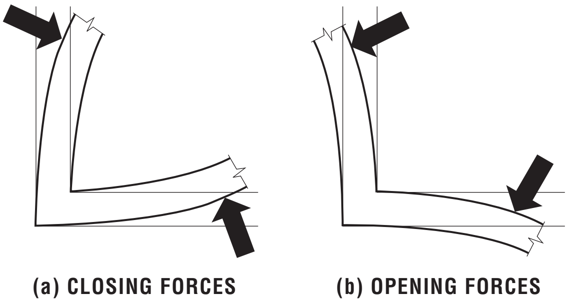


Figure 15.2 *Illustration of Closing and Opening Forces*

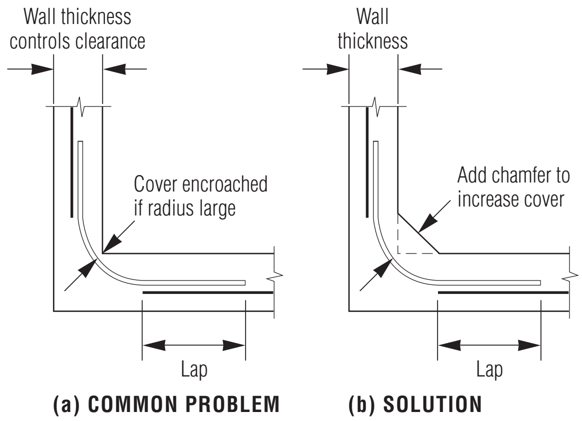


Figure 15.3 *Corner Detail for Thin Walls for Both Closing and Opening Forces*

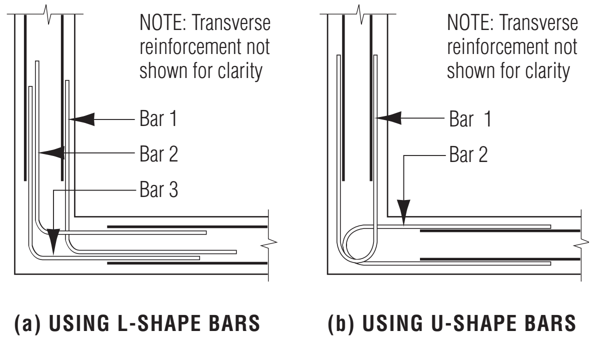


Figure 15.4 *Corner Details for Closing Forces*

The use of full-length bars of LL-shape around corners should be avoided because they are hard to fix and do not provide an adequate tolerance for construction variations.

15.8.1 **"Opening" and "Closing" Forces**

Detailing a corner requires a knowledge of the direction of the force which acts on the wall. For descriptive purposes, the forces are called a "closing" force or an "opening" force after the effect they have on the corner. See **Figure 15.2**.

Reinforcement must not be carried around the internal corner subjected to an opening-force because the corner concrete will be "popped-out" by the forces tending to straighten the bar.

15.8.2 **For Small Forces – Opening or Closing**

Examples would be small pits, or internal bracing walls.

In many instances, the force is very small and may require only one layer of reinforcement. Such corners are detailed as in **Figure 15.3**; that is with one L-bar around the corner. The lap length should be specified in the drawings.

The bend can encroach on the corner in certain circumstances. **Figure 15.3** illustrates a detail often used to resist "small" forces; the bend radius has been exaggerated to show that the corner should be chamfered to maintain cover.

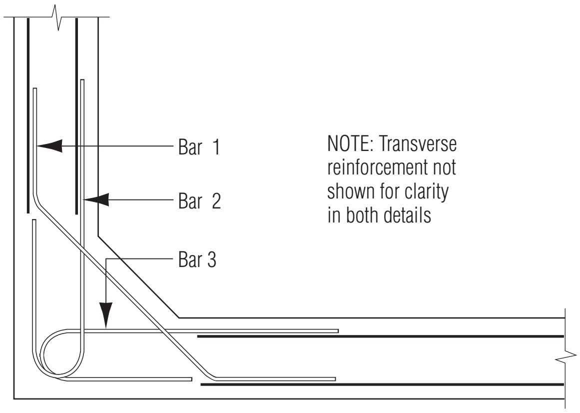
15.8.3 **For "Closing" Forces**

- Where closing forces act on the corner, no serious structural problem exists:
  - With only one grid of steel, use an L-shaped bar or mesh piece as in **Figure 15.3** to connect each wall.
  - With two grids, use a more complex arrangement as in **Figures 15.4(a)** and **15.4(b)**.
- Mesh in sheets can be used as the two grids of the wall reinforcement.
- Loose bars can be used around the corners because mesh cannot be "passed through" mesh. See **Figures 15.4(a)** and **15.4(b)**. Note how the bars at the re-entrant corner overlap into the opposite face.
- The corner bars should have the same dimensions so that they are interchangeable and thus avoid sorting time on site.

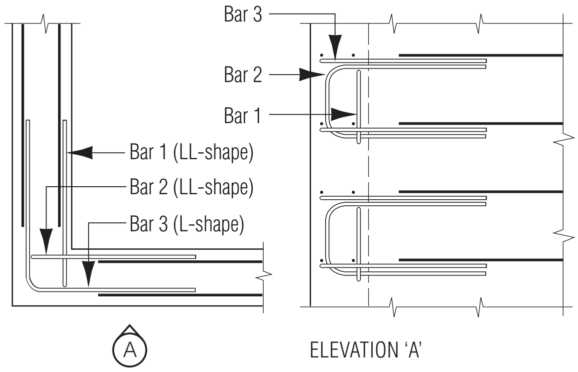
15.8.4 **For "Opening" Forces**

- Opening forces require more care when detailing. An opening corner induces tension on the inside face and can cause spalling of the concrete.
- In a thin wall, it is almost impossible to place two grids of steel and compact the concrete adequately. The method of **Figure 15.3** may be the best solution in a difficult situation.
- The method outlined in **Figures 15.4(a)** and **15.4(b)** may be used for opening corners, provided that the design tensile stress can be developed at the inside corner. In cases where the bending stress is not high, a reduced tensile stress may be used for the calculation of the development length.
- Where the re-entrant corner has a large fillet, the method of **Figure 15.5(a)** may be used, again assuming that the steel stresses can be developed at the numerous critical sections. The steel layout must permit construction joints to be made at suitable locations away from the complex corner. Note that the wall steel is shown continuing into the corner in this example; it would also require the corner bars to be placed from outside the corner. The external L-shaped bar is important as a fixing aid.
- Layouts similar to **Figure 15.5(a)** may be used for corners of any angle, or around knee-joints of members such as portal frames.
- The method of **Figure 15.5(b)** uses two identical LL-shaped bars placed vertically, from inside or outside the joint as desired. The external L-shaped bar is important as a fixing aid. The method permits a "cleaner" corner which also can be of any angle. The spacing between the legs of the LL-bar would be the same as the wall-bar spacing. For closely-spaced bars, a U-shape may be necessary. See **Clause 9.2.1** for the explanation.

Figure 15.5 gives details for strong opening forces when moment resistance and crack control are essential. Note that they are reinforced by several simple shapes which can be easily assembled. See as a reference "*Reinforced Concrete Corners and Joints Subjected to Bending Moment*", I H E Nilsson & A Losberg, J Struct Div ASCE, Vol 102, No ST6, June 1976, pp 1229-1254.



(a) DETAIL FOR STRONG OPENING FORCE



(b) DETAIL FOR LESS STRONG OPENING FORCE

Figure 15.5 *Corner Details for Walls with Strong Opening Forces*

15.9 HOLES AND OPENINGS

These act as crack initiators. Trimming bars should be located around openings for doors, ducts and windows in the same way as for slabs. See **Clause 14.9**. Generally, wall openings will be larger than those in slabs.

A standard detail of wall openings may be used, with additional information given for situations which are more critical or which require special attention.

Where there are two grids, trimming bars would be placed in each face, but concrete thickness must be sufficient to accommodate all layers of steel. Trimmer bars may be placed diagonally or parallel to the concrete corner, the only controlling factor being that the design tensile stress must be developed by the extensions beyond the corner.

Figure 15.6 illustrates a Standard Detail for penetrations through walls; such a detail can be limited to openings of a medium size without requiring reference to the designer. Any larger penetration would require further design. The amount of reinforcement will require separate consideration.

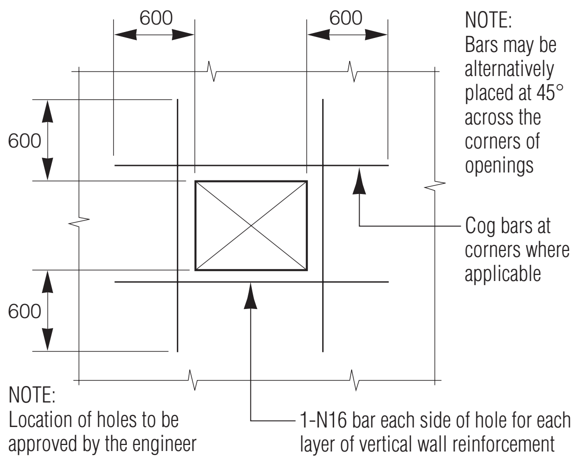


Figure 15.6 *Standard Detail for Penetrations through Walls*

15.10 STANDARD DETAIL DRAWINGS FOR WALLS

15.10.1 General

Clause 14.13 Standard Details 14.7 gives various plan-view arrangements of horizontal wall steel.

Clause 14.13 Standard Details 14.8 shows vertical cross-sections of slab and wall connections.

The size and spacing of bars stated here (N12-300 for instance) are strictly for demonstration purposes.

15.10.2 Lap-Splices

The lap lengths, where shown in **Clause 14.13 Standard Details 14.7** are based on an assumed bar size. However, it is important for schedulers to check on the method of construction when calculating actual bar lengths. Particularly at vertical corners, formwork needed at the corner and left in place while the next section is formed, may reduce the lap length. It is often an advantage to terminate the wall bars well short of the corner, and use an extended length of the L-shaped corner bar.

15.11 DETAILING FOR SEISMIC

15.11.1 Shear Walls

As AS 1170.4 assigns a low value of structural ductility factor μ divided by structural performance factor S_p (μ/S_p)to reinforced or prestressed concrete shear walls or braced frames in a bearing wall system, these elements attract higher earthquake design forces. They are therefore required to be comparatively heavily reinforced and often will have a reasonable excess of strength above that notionally required. Appendix C of AS 3600 allows elements in these systems to be designed and detailed in accordance with the main body of the code without further consideration. It must be noted by the designer, however, that the use of any μ/S_p value of greater than 1.0 results in a design earthquake force of less than the anticipated actual loading. Reinforcement will then yield once the design earthquake force is reached and plastic hinges form. Detailing must be provided to reflect this.

15.11.2 Walls in Building-Frame Systems

As building-frame systems are generally more ductile than bearing-wall systems, they are assigned a correspondingly higher μ/S_p value in AS 1170.4. The earthquake design forces are therefore lower. This may in turn result in less longitudinal and shear reinforcement. To maintain the required level of ductility, however, additional detailing is necessary.

The ductility provision requirements are as follows:

- The reinforcement ratio $P_w \geq 0.0025$ both horizontally and vertically (ie an increase from 0.0015 in the vertical direction over AS 3600 Clause 11.7.1).
- The reinforcement is to be divided between the two faces, if:

  $t_w > 200$ mm; or $øV > (A_g, f'_c)/6$

  where

  t_w = thickness of the wall

  $øV$ = design shear strength

  A_g = gross cross-sectional area

  f'_c = characteristic 28 day compressive cylinder strength of concrete

  All reinforcement terminating in footings, columns, slabs and beams must be anchored to develop yield stress at the junction of the wall and terminating member.

- Boundary elements as shown in **Figure 15.7** must be provided at discontinuous edges of shear walls and around openings where:
  - vertical reinforcement is not restrained; and
  - the extreme fibre compressive stress in the wall exceeds $0.15f'_c$.

  Note: This stress may not be the actual stress developed, but is the 'trigger value' for determining when a boundary element is required.

Restraint of the longitudinal reinforcement in boundary elements is to comply with Clause 10.7.4 or, if the extreme fibre compressive strength exceeds $0.2f'_c$ with the requirements for *Reinforced Braced Frames*.

It should be noted that the above requirements do not necessarily result in an increase in wall thickness for a boundary element, only that the areas concerned are designed and detailed to resist specified axial forces.

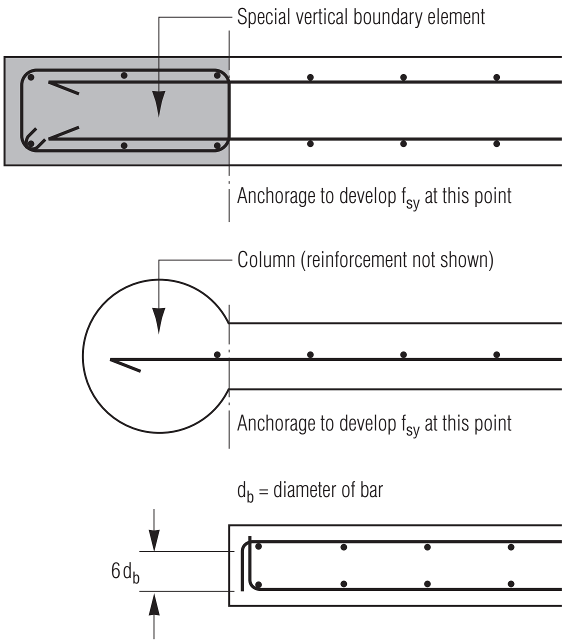


Figure 15.7 *Typical Boundary Element Details from AS 3600 Appendix C*

Cantilever Members

16.1 GENERAL

16.1.1 Concept

A cantilever is part of a member which projects beyond its support. It can include cantilever retaining walls.

16.1.2 The Support

A beam, a slab or a wall can "cantilever" over one or more of its supports. The support can be a column, a beam or a wall, or for a retaining wall, its footing.

16.1.3 Location of Tensile Stress

Using a scale rule supported as shown in **Figure 16.1**, press down at one end. To stabilise the "beam", a downward force is required at the other end. From the shape of the "beam", there is tensile stress occurring at the top face. If the load is applied between the supports, tensile stress occurs on the underside as it does with a true beam.

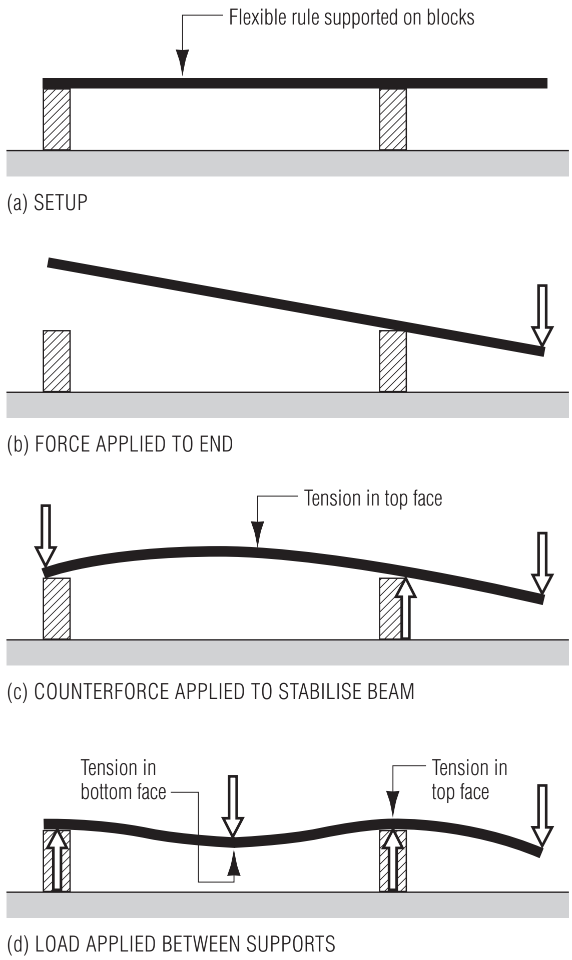


Figure 16.1 *Demonstration of Location of Tensile Stresses with a Cantilever*

16.2 AS 3600 REQUIREMENTS

There is no mention of cantilevers as such in this standard. Cantilevers are to be treated in the same way that a normal member would be designed and detailed.

Corbels, nibs and stepped joints are included in AS 3600 under the topic of "non-flexural members" in Section 12. The design requirements are such that each case must be considered independently. The general principles of this Handbook will still apply; however, specialist references should be consulted.

16.3 CANTILEVER REINFORCEMENT LOCATION

16.3.1 Examples

Figure 16.2 illustrates common combinations of cantilevers and other structural members. Note the need for reinforcement in the bottom of the internal member between the supports.

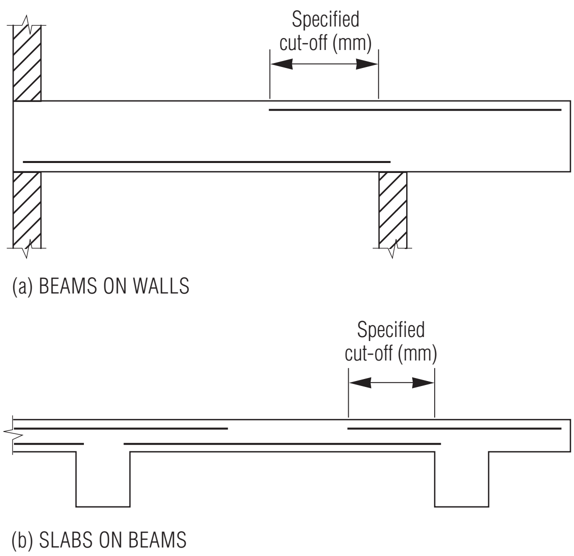


Figure 16.2 *Examples of Reinforcement Location in Cantilever Members*

16.3.2 Location and Extension of Reinforcement

There are two principal structural requirements that must be watched:

- There must always be reinforcement in the top of a cantilever beam or slab, or in the tensile face of other members; and
- Reinforcement must extend beyond both sides of the support for a distance adequate to carry all tensile forces on each side.

It is normal practice to extend reinforcement out to the end of the cantilever and back past the support face a similar distance.

How far back should it extend? This distance must be calculated by and obtained from the engineer – it cannot be guessed, it has no fixed relationship to the normal span and the cantilever may collapse if a mistake is made.

The cut-off distance into the normal span MUST be specified (in millimetres) in the drawings.

16.3.3 Effective Depth

Place cantilever reinforcement as close as possible to the top surface. The support system should be specified also.

16.4 CANTILEVER PLAN-VIEWS

16.4.1 Reinforcement Detailing

These are similar to plan-views of the elements which form the cantilevers.

For cantilever beams, the reinforcement is not shown in plan-view except in cases where the beam top steel is spread out into the slab forming the top flange. This method is particularly valuable where depth reduction and congestion should be prevented. See **Clause 14.7**.

For cantilever slabs, the top steel is indicated as in **Clause 14.3**.

16.4.2 Reinforcement Shape

The actual shape may be shown on the plan-view.

16.5 CANTILEVER ELEVATIONS

16.5.1 Bending of Beams

Elevations of cantilever beams must be drawn, with the reinforcement dimensions shown in millimetres.

16.5.2 Shear in Cantilever Beams

Shear requirements differ from normal span requirements. The designer must provide the detailer with location, spacing and steel size information.

16.6 CANTILEVER CROSS-SECTIONS

These must always be drawn and dimensioned.

16.6.1 Continuity of Reinforcement

Because the effective depth for strength and deflection is more critical with thin members such as slabs and walls, continuity of reinforcement through and beyond the support is essential. Laps and splices must be avoided near the support if possible, and they must always be dimensioned.

It is wise to dimension the design cantilever length also to highlight the value assumed.

16.6.2 Cantilever Balconies

The cantilever balcony causes many problems because of the many methods of support which are possible, combined with the shallow slab depths involved and the effect of weather step-downs which may also occur at the support. Other design problems are caused by the need to slope balconies outwards to shed rainwater, and the need for a balustrade at the extreme end.

Figure 16.3 illustrates wall/beam support and slab shapes, with possible reinforcement layouts.

16.6.3 Crack and Corrosion Control of Balconies

An additional mesh located in the bottom face of the balcony, on suitable non-corrodible supports, is a common practice to assist control of deflection and cracking.

Long cantilever balconies should always be subdivided by contraction joints into moderate lengths to prevent cracking from the outer edge back to the support. Whilst these cracks may not affect the strength, they will certainly detract from the appearance.

In addition to the joints, one or more extra bars located parallel to the outer edge may help to control cracks which can form due to fixings for the balustrade for instance. Such fixings and penetrations act as crack starters. AS 3600 Clause 9.4.3 on minimum reinforcement for strong control of shrinkage and temperature will provide guidelines.

A further source of trouble is the method of creating a drip groove in the soffit of the balcony. It is essential that the reinforcement is not permitted to rest on the groove form when concrete is being poured as the steel will rust here very quickly due to lack of cover.

The ends of bars or mesh must not be hooked downwards at the outer edge – this is a constant source of corrosion problems.

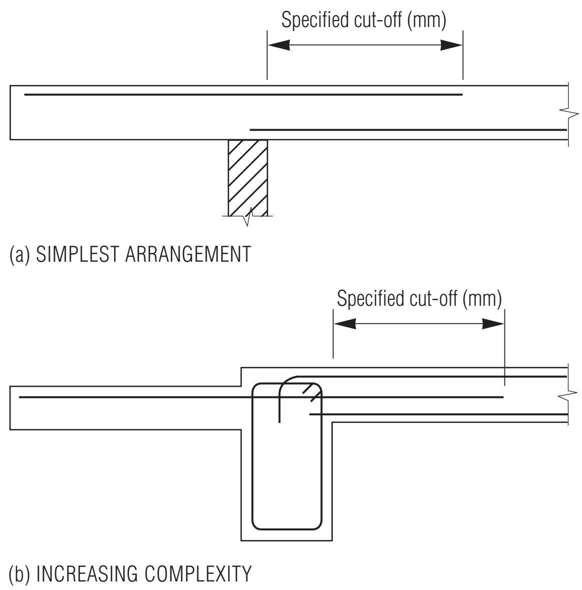


Figure 16.3 *Simple Cantilevers and their Reinforcement*

16.7 CORBELS AND NIBS

These members provide the total support for the beams or slabs which rest on them. The major requirement is that adequate bearing area is provided, and that the necessary reinforcement is located as close as possible to the bearing surface and outer edge. The loaded area must not project beyond a critical portion of reinforcement. **Figure 16.4** illustrates the problem.

AS 3600 requires considerable attention be paid to checking the anchorage of reinforcement. Welded or mechanical anchorages may be used.

Corbels are also used as fixings with precast concrete units such as façade members. See the appropriate detailing Handbooks for full information.

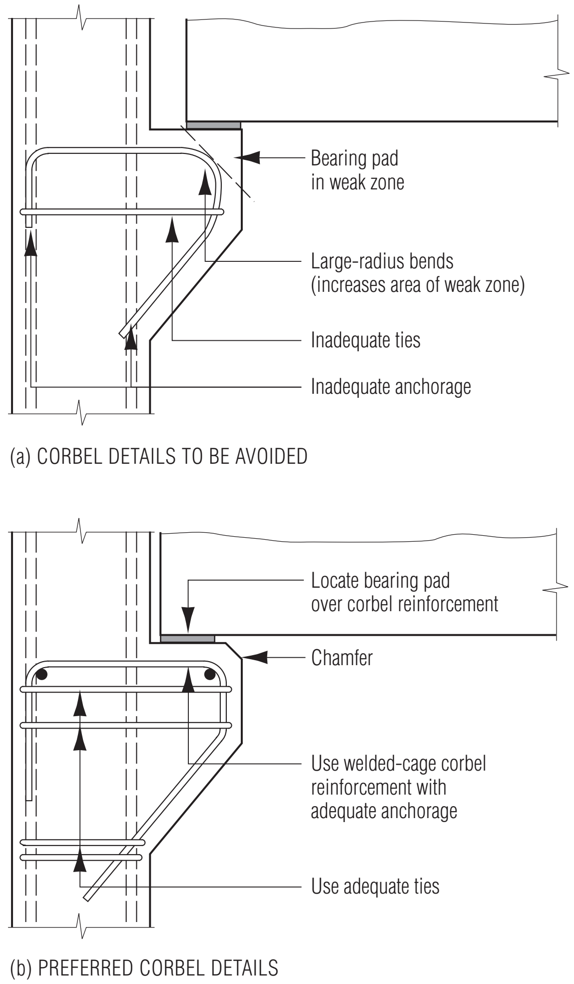


Figure 16.4 *Details of Corbels and Nibs*

16.8 CANTILEVERS AS ARCHITECTURAL FEATURES

Thin concrete members are often used as sunshades and other features of buildings. They are often thin and can be required to project from their supporting member.

The thinness causes durability problems and the specification of concrete quality and reinforcement cover must be considered with care. See **Chapter 5** and AS 3600 Section 4.

Thinness also causes problems for fins if the design does not allow for movement of the structure during its lifetime. Creep and temperature effects require realistic tolerances to be specified at the design stage.

Projection of these members means they will act as cantilevers attached to their supports. In the case of beams and horizontal sunshades, extra reinforcement for torsional strength may be required. See **Figure 16.5**.

16.9 CARE IN DETAILING

The overall problem with cantilevers and similar members is that, because of poor detailing, reinforcement congestion is not only unavoidable, but is often increased.

All of spacing, depth and cover for reinforcement must be considered.

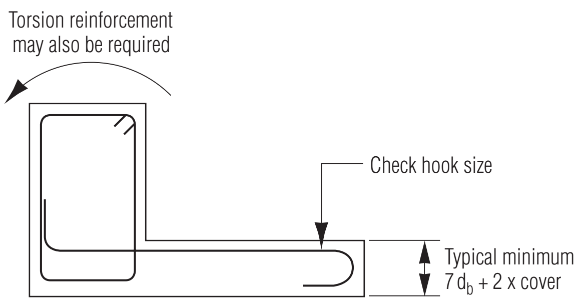


Figure 16.5 *Cantilever Acting as a Hood*

Reinforced Concrete Stairs

17.1 GENERAL

17.1.1 Terminology

Each flight of stairs consists of a sloping slab as a base.

The steps are triangular blocks attached to the top surface. A staircase can consist of one or a series of flights.

The base slab may be supported by walls or beams, or by landings which themselves are slabs.

The basic layout of a flight of stairs is shown in **Figure 17.1**.

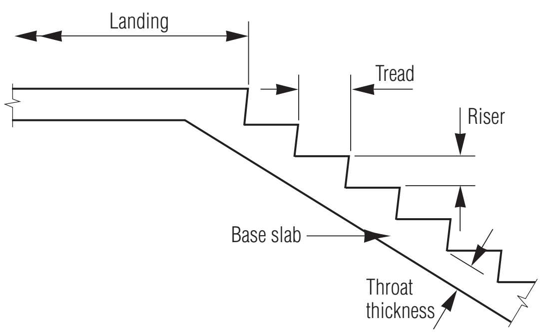


Figure 17.1 *Terminology Used with Stairs*

17.1.2 Shape of Base Slab

Since the flight is always sloped, the angles which are created require reinforcing similar to the corners of walls as discussed in **Chapter 15**.

The underside of the flight is the most critical. The bend at the lower support is a closing corner, and that at the upper support is an opening corner.

Detailing must provide a suitable arrangement of reinforcement around each bend, not only for strength, but also to allow for the construction sequence and tolerances.

17.2 AS 3600 REQUIREMENTS

Because a stair is regarded as a slab, or possibly as a beam, for design purposes, the standard has no special requirements.

Detailing of stairs would correspond with the appropriate design type.

17.3 STAIR PLAN-VIEWS

17.3.1 Location of the Staircase in the Structure

A staircase plan-view should be incorporated in the plan-view of each floor to locate it within the structure. The small scale prevents adequate reinforcement detailing.

A larger scale plan-view of stairs which have a complex outline should be considered, in which case, reinforcement layouts may be shown.

17.3.2 Information Given on the Plan-View

In general, a plan-view would show:

- The relationship of the staircase to the structure as a whole;
- The outline of the concrete forming the flights and landings;
- The edge of the treads;
- The location and type of stair supports at each end (wall, beam, slab, column);
- The location and type of support of the landings, if any; and
- The “up-and-down” direction of each flight to ensure that engineering and architectural drawings agree.

Most of the above must be obtained from the architectural drawings, together with the stair and stairwell dimensions. Stairs must comply with the Building Code of Australia which has strict requirements on width and height of steps, etc.

17.3.3 Information Required from the Job Site

This section applies particularly to formwork making and reinforcement scheduling.

Stairwell dimensions must be verified on site before formwork construction is commenced, because of unforeseen changes in dimensions of the supporting structure. For example, walls may not be in their planned position, or the landings may need to be formed and poured at a different time from the flight.

These changes can require splicing of reinforcement in positions not actually shown in the drawings, with lap-lengths left protruding through the forms. Wherever possible, reinforcement should be scheduled from the actual dimensions of the forms, but in any case detailing flexibility is strongly advisable with adequate lap allowances for tolerances and variations.

17.3.4 Landings in Plan-View

Plan-view of landings to a scale of 1:50 or 1:20 can be detailed as for plan-views of slabs. Reinforcement for landing and flights should be shown.

17.4 STAIR ELEVATIONS

These are used:

- In combination with a vertical section to show how each flight relates to those above and below; and
- As line diagrams to provide a general description of the stair and a suitable labelling method.

17.5 STAIR CROSS-SECTIONS

This is the most common method of showing structural details and would show:

- Reinforcement, detailed as for slabs.
- The basic design specification, shown on the flight. As a general rule, stair flights are approximately one metre wide and are designed as slabs.
- For bars, the notation should include the number required as well as the size and spacing to prevent an error in subsequent calculations and rounding off. The omission of one bar in ten may be serious.
- For mesh, either the number of wires or the sheet width out-to-out of the main wires will be adequate.
- The size of tie bars across the flight, and the spacing, can be given once in the drawings. They can be shown by dots on the section and numbers can be obtained by counting or calculation. Tie bars should be located where they will assist fixing, for example at bends and splices.
- For landings, the tie bar and main bar arrangement can vary depending on the degree and orientation of supports provided by walls or beams.
- Splice bars for the flight may better be detailed separately from the tie bars of the landing to permit greater flexibility.

17.6 METHODS OF SUPPORTING STAIRS AND METHODS OF CONSTRUCTION

17.6.1 Design Investigation

Two factors need to be considered in the design and detailing of stairs.

Firstly, stairs can be supported in a number of ways depending largely on the architectural requirements and structural members available to provide support.

Secondly, once the method of support is decided upon, the probable order of construction can influence the shape of the concrete outline and reinforcement layout in relation to length, splice locations, top steel, etc.

17.6.2 Methods of Support

Several methods of supporting the flights and landings are available to the engineer. Because of this, more than one may be used in a structure due to architectural requirements. Care is required to ensure that the relevant support method is quite clear to the site trades.

17.6.3 Landings – Determined by Architect

A landing should ensure that there is sufficient room to stand at the ends of the flight when opening a door or access to fire hose reels and the like. The position is the responsibility of the architect and cannot be amended unilaterally by the engineer. This means that sometimes the landing will be the support for the flight and detailed as a wide beam or thick slab.

17.6.4 Check List before Detailing

In addition to following the architectural drawings, the following may be checked:

- Is headroom adequate to permit walking under landings?
- Can walls be built to full storey-height above the stair, yet still enable landings to be supported in block-outs left in the wall?
- Do the number of risers between landings comply with building regulations? A detailing error of one extra tread may be regarded as a serious matter.
- Are treads and risers identical on all corresponding flights in each storey? If not, a separate detail for each may be required. Note: The going and risers must have the same dimensions for one flight of stairs. A maximum of 18 risers can be used before a landing is required.

- Can formwork be simplified by using flat soffits, with the necessary thickening of landings?
- Are the supporting walls, beams, slabs and columns clearly identified?
- Has an allowance been made for the fact that the stair may act in a manner different from that assumed in the design and shown in the drawing?
- Have extra trimmer bars been shown, particularly along the edge of a landing where up- and down-flights meet? This is a common location for a transverse crack.

17.7 REINFORCEMENT AT BENDS OF FLIGHTS

In all cases, reinforcement if it is required to be bent to a shape, should have not more than one bend. Thus shapes S and V should be adequate for most arrangements.

Flights at a common landing can consist of one opening bend and one closing bend; they will therefore create a severe shearing effect in the centre of the landing.

17.7.1 **Closing Bends**

These occur at the lower end of the flight.

- At a closing corner, bottom reinforcement may be continuous around the bend. See **Figure 17.2(b)**.
- Where the lower end of the flight forms the landing, the flight reinforcement must extend into the support. Suitable laps are permissible.

17.7.2 **Opening Bends**

These occur at the upper end of the flight. See **Figure 17.2(a)**.

- The reinforcement resembles an "opened-out" 150-degree version of a 90-degree bend at a wall corner.
- Bottom reinforcement must be carried past the line of the bend; this means that an overlap is required.
- Yield strength lap lengths are advisable, even if the design stress is less than f_{sy}. The bend angle is insufficient to act as a hook and therefore does not reduce the lap length.

17.7.3 **The Flight**

Reinforcement for the flight should be of such a length that variations due to construction can be accommodated. Thus, it should be of S-shape or V-shape – never should it have two bends.

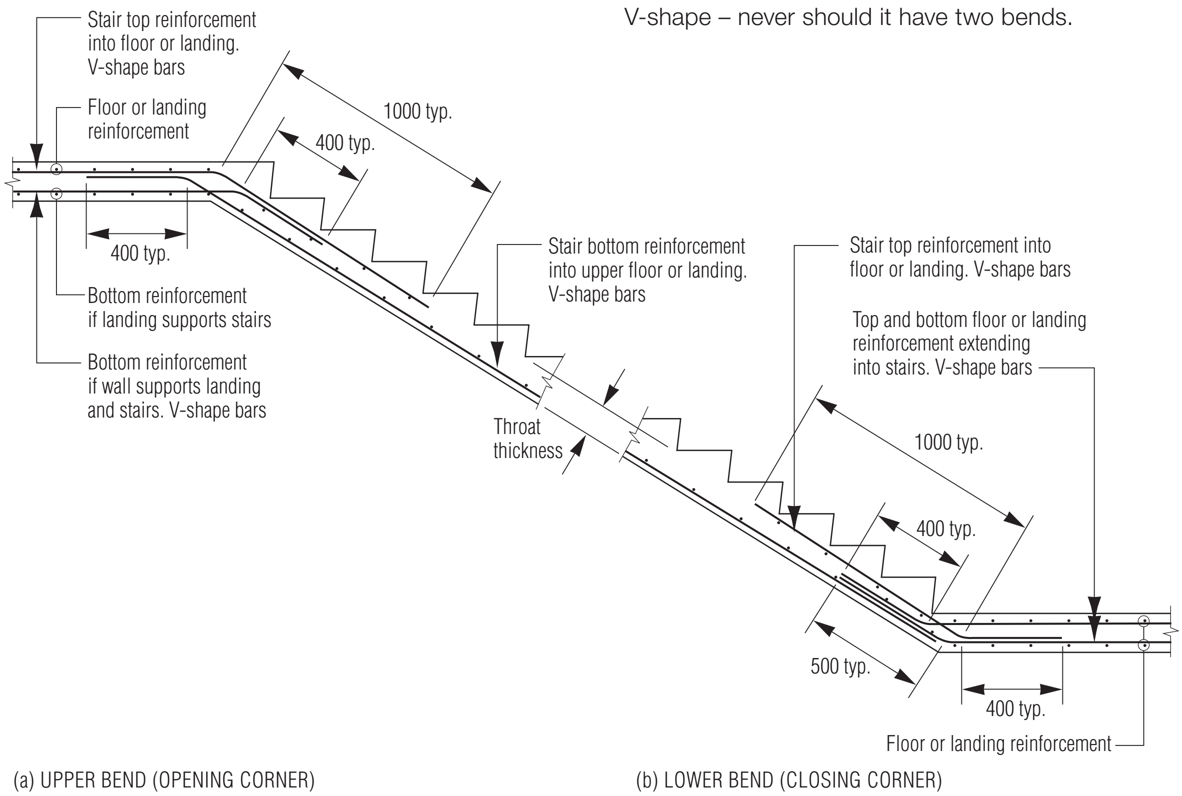


Figure 17.2 *General Detailing of Stairs including the Upper and Lower Bends and Flight.*

17.8 STANDARD DETAILS

The general arrangement of stair and landing reinforcement can be shown on a standard detail for a project. Instructions on how to handle variations to dimensions should be provided.

Regardless of the type of stair, the best solution to a complex problem is to use simple concrete outlines with the least number of different pieces of steel.

18

Concrete Pavements, Floors and Residential Footings

18.1 GENERAL

More concrete is used in slabs poured on the ground than in multi-storied buildings. The need for reinforcement is complex and a simplified explanation is given as background information for detailers.

18.1.1 Purpose

Concrete pavements and floors are cast against the ground with either a natural earth surface or on a prepared sub-base. They provide a long-lasting surface for foot and wheeled traffic.

18.1.2 Method of Load-Carrying by Slabs on the Ground

They carry their applied loads directly to the foundation by bearing rather than by the bending resistance of a suspended slab.

These concrete members are used as roads and factory floors, as well as in residential housing for floor slabs, footpaths and driveways.

To carry loads over soft-spots in the foundation, bottom and top reinforcement will be necessary.

18.1.3 Causes of Lack of Serviceability

Although a heavy load such as a wheel will cause both the slab and the foundation to deflect downwards, the slab thickness should be designed so the tensile stresses due to bending are low compared to those in suspended slabs.

An even greater force can be exerted on a ground slab by vertical movements of the foundation itself. These movements are generally caused by changes to the moisture content of the soil – such as water penetration after rain or by reduction of the moisture content by the roots of trees. Vertical movements can be either up or down depending on climatic conditions.

In addition, without reinforcement, the slab will tend to crack in a random pattern due to shrinkage of the concrete or from changes in surface temperature caused by the sun, or from repeated loading (fatigue).

However, in all these cases because of the supporting sub-base and the dowel action of any reinforcement, the cracked piece cannot fall out completely.

As a result of cracking, the surface can become very uneven and will be considered as unserviceable.

18.1.4 Reinforcement for Slabs on the Ground

Slab on ground reinforcement is generally placed in one grid, the most common layout being with equal amounts of steel each way. The reasons for this are:

- Reinforcement is required to resist the bending stresses, upwards and downwards, from vertical loads of wheels and soil movements. The effect of upward forces tends to “dome” the top surface of the slab, thus creating a tensile stress zone there.

  For this type of load, the steel grid should be placed in the top of the slab.
- Shrinkage of the concrete causes uniform tensile stresses through the full depth of the slab. To resist this effect, the steel grid should be located approximately mid-depth.
- When the sun heats a slab, it has the tendency to curl at the corners and lift off the ground there. When traffic rides over the corners, it will create a tensile stress in the top of the slab because of the loss of ground support. To resist this loading, the slab should be reinforced in the top.

On balance therefore, the steel reinforcing grid is considered to be most effective when placed between mid-depth and the top of the slab. This has an advantage should the mesh be displaced downwards during concrete placement.

18.1.5 Control of Shrinkage

Plastic shrinkage of concrete can occur within the first few hours after casting; it cannot be controlled by normal reinforcement because the concrete itself is too weak to carry the induced forces.

Drying shrinkage of concrete can take place if the slab is inadequately cured. Curing generally means maintaining the water content of the concrete for several days, either by keeping the surfaces moist or by covering the surface to prevent evaporation. The effect of drying shrinkage is to cause a parallel-sided crack right through the concrete whether reinforcement is present or not. Under vertical load and without the dowel action of reinforcement, this crack can develop into a step, and the slab becomes unserviceable.

The shrinkage stresses acting on the slab can be reduced by using slabs of small size, that is the slabs are poured with closely-spaced contraction joints through which are located steel dowel bars to prevent vertical movement. Steel reinforcement may or may not be used.

Reinforcement enables larger slabs to be poured, and the amount of steel in each direction increases with length. Any reinforcement which does cross a shrinkage crack automatically acts as a dowel bar.

If a slab is much longer than it is wide, such as a road pavement, then the amount of steel in the trafficked direction will be much greater than that across the pavement. In fact, when the longitudinal steel area is approximately 0.6% to 0.7% of the concrete area, shrinkage cracking is totally controlled and the pavement does not need any contraction or expansion joints at all even over several kilometres – this is called a "*continuously reinforced concrete pavement*" or CRCP.

18.2 AS 3600 REQUIREMENTS (Sections 4, 9 and 15)

Although the previous Chapters of this Handbook also require consideration of the exposure condition of the concrete surface, slabs on the ground and pavements have needs additional to buildings.

18.2.1 Exposure Classification and Abrasion Resistance (AS 3600 Sections 4.3 and 4.6)

The flowchart in **Chapter 5 Clause 5.3** will give guidance here.

If a steel reinforced pavement is being designed, then the exposure classification is based on a reinforced member and will be subject to the various climatic conditions. If the slab is to be considered as "plain" concrete, with or without steel reinforcement as allowed in AS 3600 Section 15, the lower exposure classification of AS 3600 Table 4.3 may be applicable. In any case, exposure of the top and bottom surfaces must be determined.

Overriding the exposure conditions are the requirements for abrasion given in AS 3600 Clause 4.6. It may therefore be found that the higher strengths needed for this purpose will allow the reinforcement to play a more active part by permitting larger slab sizes, reduced jointing and better serviceability.

18.2.2 Cover (AS 3600 Clause 4.10.3.2 and Section 5.5)

Obviously the top surface will have a different exposure classification from the bottom. By detailing the steel to be in the top, this should help to provide for any differences in cover, although the thickness of the steel grid itself must be allowed for.

Table 5.1 will be used in combination with **Tables 5.2** and **5.3** as appropriate.

As a guide to steel fixers and for better depth control, it is preferable to specify the height of the support above ground rather than cover from the top surface.

Example 18.1

A reinforced slab is to be cast in the open air on a non-aggressive soil, without a "damp-proof" membrane, and in a near coastal zone.

From **Clause 5.3**, the top surface would have a B1 exposure and the bottom surface an A2 classification. A Grade 32 concrete is required for the worst situation, B1.

If the purpose of the slab is to carry traffic, Grade 32 concrete is stated as being adequate for medium to heavy vehicles.

The applicable covers with Grade 32 concrete are 40 mm top from **Table 5.1** for exposure B1, and 45 mm bottom from **Table 5.3** for exposure A2 when cast directly on the ground.

Allowing for a total thickness of the steel mesh of 20 mm, then the slab should be at least 105 mm thick. Normal pavement design may show that a greater thickness would be needed for heavy traffic.

This example illustrates the need for some care when specifying cover for slabs on the ground.

18.2.3 Crack Control for Shrinkage and Temperature Effects (AS 3600 Clauses 9.4.3 to 9.4.5)

The maximum spacing of reinforcement for control of cracking due to flexure does not apply to slabs on the ground. (See AS 3600 Clause 9.4.1).

Nevertheless, a maximum spacing of either 2D or 300 mm should be considered.

AS 3600 Clause 9.4.3 applies to slabs on the ground as well as to suspended slabs. The designer should decide the degree to which the slab will be restrained, and then calculate the amount of reinforcement required.

AS 3600 Clauses 9.4.4 and 9.4.5 may require additional reinforcement in the areas which connect the slab to a rigid restraint and where openings, discontinuities and re-entrant corners occur. Previous experience rather than calculations may be used.

18.2.4 Plain Concrete (AS 3600 Section 15)

Plain concrete may contain reinforcement for various purposes but its strength is not taken into account. It is therefore possible to use the reinforcement for shrinkage control of plain concrete without calculations being needed.

18.2.5 Concrete Pavements, Floors and Residential Footings (AS 3600 Section 16)

These are additional design considerations which involve investigation of the foundation.

Residential floors and footings designed in accordance with AS 2870 should be detailed using the examples given in that standard. They are too numerous to give in this Handbook, although the general principles given here are still applicable.

18.3 DETAILING SLABS ON THE GROUND

The same principles as for suspended slabs may be used, with modifications as necessary. Generally, plan-views are adequate with cross-sections used to give details of two layers of steel.

- Reinforcement depth. As mentioned, slab reinforcement is usually located between mid-depth and the top surface.
- Contraction and isolation joints must be defined on the plan-view to show location, shape and spacing. Sections would show the type of load transfer device (dowels or continuous reinforcement) between each slab. Edge thickening may also be shown in cross-sections. All necessary dimensions should be given in cross-sections.
- Typical details may be used provided the applicable positions are identified on the plan-view and irrelevant details are omitted.
- Cross-sections should show any "damp-proof" membrane under the slab and footings.
- Special foundation preparation can be given in a general note. For road pavements, a separate specification may be essential.

18.4 SPECIAL DETAILS FOR SLABS ON THE GROUND

18.4.1 Re-Entrant Corners and Holes

These interruptions act as crack initiators. Extra reinforcement extending a full development length past the opening should be used.

18.4.2 Separation of Ground Slabs from Columns

At the point where columns pass through the ground slab to the footing, the two elements must be separated by an isolation joint (called 'ij' in **Figure 18.1**). Such joints must not create a re-entrant corner where they intersect; if possible, they should intersect at the columns so that contraction due to shrinkage will tend to pull the slab away rather than impose a horizontal force there. See **Figure 18.1** for suitable arrangements. The slab and column concrete should be separated by a suitable membrane.

Ground slabs should also be isolated vertically from the footing to limit any additional loading, unless this is part of the footing design.

18.4.3 Location of Contraction Joints (cj)

A complete floor is generally broken up into smaller areas for casting the concrete. The pouring sequence may be specified in the drawings if an instruction is needed.

Contraction joints should be continuous across the floor or pavement. Do not allow a joint to stop at the centre of an adjacent slab or the latter will be cracked if movement or shrinkage occurs.

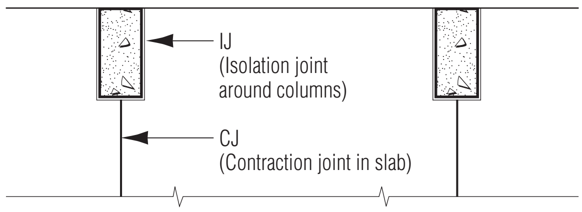
Publications of Cement Concrete & Aggregates Australia have more complete information on selecting the size of slabs and provide methods of arranging the reinforcement and joints.

18.5 MESH IN SLABS ON THE GROUND

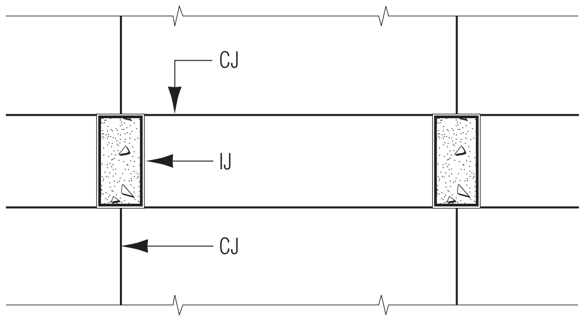
Because the stresses in these slabs are generally the same in both directions, mesh is the most common reinforcement. However, the mesh need not be limited to a square mesh if the slab dimensions require otherwise.

Mesh can be produced to fit the layout of the slabs between contraction joints or can be trimmed to shape on site. The steel area cut out for holes should be replaced by bars or a mesh strip.

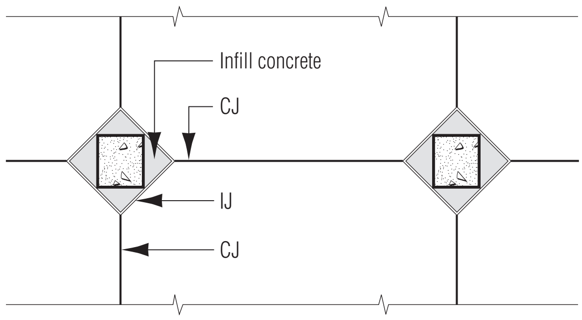
Mesh in plan view is detailed as in **Figure 14.11**. Side laps, end laps and cover should be specified in a general note. All laps should be made as shown in **Clause 6.9**, that is, a "two-wire" overlap of the transverse wires.



(a) TYPICAL DETAIL AT SLAB EDGE



(b) DETAIL AT INTERNAL COLUMNS WITH SEPARATE SLAB BETWEEN



(c) ALTERNATIVE DETAIL AT SQUARE INTERNAL COLUMNS

Figure 18.1 *Location of Contraction Joints and Isolation Joints in Slabs on the Ground*

19

Bridges – Civil Structures

19.1 GENERAL

The Australian Standard for Bridge Design was first published in 2004 as AS 5100 with Part 5 being Concrete.

19.2 REASONS FOR DIFFERENCES

The design of bridges differs from that of buildings in some of the following ways:

- The loading is heavier than in the majority of buildings.
- The loads are generally point loads, and are often considered as a series of moving point-loads.
- Structural continuity is often not available; for example, many beams are simply supported.
- The bending-moment and shear force diagrams are not for specific static load applications, but are envelopes of “worst case” scenarios for moving imposed loads.
- Important factors to be considered include impact forces, vibration, creep and shrinkage, etc, and parasitic effects of prestress, thermal loading and differential settlement in continuous bridges.
- Virtually all environments are external and in many cases aggressive external and consequently a greater emphasis is placed on concrete durability.

Because of these effects, there are no “deemed-to-comply” provisions for detailing of bridges in the Bridge Design Standard, Part 5 Concrete.

Appendix A of this Handbook gives information on variations between AS 3600:2007 and the AS 5100:2004.

Each State Road Authority has a well-established detailing standard which will take precedence over this Handbook.

A

Summary of Bridge Design Standards (Section 5) and the Concrete Structures Standard

A.1 GENERAL

Full details must be taken direct from the actual standard for either *Bridge Design* or *Concrete Structures*.

A.2 PRELIMINARY DESIGN REQUIREMENTS

A.2.1 AS 5100 Part 5 Section 1, Scope and General

Minor differences occur between Clause 1.4 of AS 3600 and the equivalent Clause 1.6.2 of AS 5100 Part 5 on the information to be shown on the drawings. A system of notation for variables is provided in Part 5 Clause 1.4.

A.2.2 AS 5100 Part 5 Clause 2.8, Cracking

Clause 2.8 is in addition to the requirements of AS 3600 and is referenced by Clauses 8.6 (beams) and 9.4 (slabs). It requires that one or both faces of concrete members are to be reinforced with a minimum area of steel of 500 mm^2 per metre of face depending on the member's thickness, spaced at 300 mm maximum.

A.2.3 AS 5100 Part 5 Clause 3.2, Load Combinations

These are covered in AS 5100 Part 2.

A.3 DESIGN FOR DURABILITY (AS 5100 Part 5 Section 4)

A.3.1 Exposure

The overall thrust of both AS 5100 and AS 3600 are very similar, but the detailed requirements differ significantly. AS 3600 Clause 4.3.2 concession for exterior exposure of a single surface does not appear in AS 5100 Part 5.

- Exposure classifications (AS 5100 Part 5 Clause 4.3) "A1" and "A2" from AS 3600 are combined into classification "A", and a new topic for "members in salt-rich desert areas – C" is added.
- Specification of concrete (AS 5100 Part 5 Clauses 4.4 to 4.8) can be regarded as similar but there are minor differences. There is no Grade 20 concrete in the AS 5100.

A.3.2 Cover (AS 5100 Part 5 Clause 4.10)

- Concrete cover for concrete placement (AS 5100 Part 5 Clause 4.10.2). Limits on spacing of reinforcement, ducts, tendons, etc, are fully defined, unlike AS 3600 Clause 4.10. More emphasis is placed on tendons and ducts. In particular, the minimum cover to the nearest steel is 1.5 times the nominal maximum size of aggregate, whereas AS 3600 Clause 10.4.2 requires 1.0 times that size.
- Cover for concrete protection (AS 5100 Part 5 Clause 4.10.3). AS 3600 Clauses 17.5.3(a), tolerances, and 17.1.3 formwork and compaction, are located in this Section because AS 3600 Section 17 is not included in AS 5100.
- Selection of cover for corrosion protection. The general procedures set out in the Reinforcement Detailing Handbook are applicable, but the principles used, and values of cover given in the AS 5100 are quire different.

The AS 5100 Part 5 values of cover in Clause 4.10.3 are from 5 mm to 20 mm greater than the corresponding values in AS 3600 Clause 4.10 or in **Chapter 5** of this Handbook due to the design life of the Bridge Design Standard being a minimum of 100 years.

A.4 METHODS OF STRUCTURAL ANALYSIS `(AS 5100 Part 5 Section 7)

No simplified methods are included. This means that the simplified and "deemed-to-comply" detailing rules of the AS 3600 are not needed either.

The use of "design strips" for slab systems is not required in bridge design, and are therefore not included.

AS 5100 Part 5 Clause 7.2.10 (equivalent to Clause 6.2.3 in AS 3600) gives more guidance on the critical Section for negative bending moments.

A.5 BEAMS (AS 5100 Part 5 Section 8)

- Spacing of reinforcement, tendons and ducts (AS 5100 Part 5 Clause 8.1.7) have more explicit rules than in AS 3600 Clause 8.1.9, where no values are specified.
- Detailing of flexural reinforcement (AS 5100 Part 5 Clause 8.1.8) requires that the extension of bars beyond the "worst-case" actual bending moment diagram is spelt out as "D + development length", ie "D + $L_{sy.t}$" or "D + $L_{sy.c}$" as applicable. One-third of the total negative tensile reinforcement extends "D + $L_{sy.t}$" past the "worst-case" point of contraflexure. There are no "deemed-to-comply" provisions for detailing.
- Displacement of tendons in ducts (AS 5100 Part 5 Clause 8.1.9) is a new Clause but is more aligned with design than detailing.
- Detailing of shear and torsion reinforcement (AS 5100 Part 5 Clauses 8.2.12 and 8.3.8) sets the maximum spacing of fitments at the smaller of 0.5D and 300 mm. The corresponding AS 3600 Clauses 8.2.12 and 8.3.8 have some similar statements but there are differences with more detail given in the AS 5100.
- Crack control of beams (AS 5100 Part 5 Clause 8.6) requires attention because of differences between design stresses and reinforcement detailing. This item is critical in bridge design. The AS 3600 under Clause 8.6 has different requirements.

A.6 SLABS (AS 5100 Part 5 Section 9)

The differences between the AS 5100 and the AS 3600 require individual comparisons.

A.7 WALLS (AS 5100 Part 5 Section 11)

Minimum reinforcement is defined in AS 5100 Clauses 11.6.1, and the maximum spacing is the lesser of $1.5t_w$ and 300 mm. (Refer Clause 11.6.3).

A.8 STRESS DEVELOPMENT (AS 5100 Part 5 Section 13)

Chapter 13 of AS 3600 on stress development and lapping of reinforcement has been completely revised in the 2009 edition of the standard including new formulae for calculation development lengths of bar both in tension and compression. Therefore AS 5100 Part 5 Section 13 is now completely different as it is a standard published in 2004 and relates to the AS 3600-2001 version.

A.9 SECTIONS NOT INCLUDED

AS 3600 Sections 16, 17 (part only) has been omitted from the AS 5100 although some parts of Section 17 are transferred elsewhere.

B

General Notes on Drawings

This Appendix contains a check list of suitable General Notes in drawings, and is for guidance purposes only. A more descriptive wording may be preferred for use in the Contract Specification.

General

G.1 Read this drawing in conjunction with Architects' and other Engineers' Drawings and Specifications and such other written instructions as may be issued.

G.2 IF IN DOUBT, ASK.

G.3 Refer any discrepancy to the Engineer/Architect before proceeding with the work.

G.4 Dimensions shall not be scaled.

G.5 Verify all setting out dimensions with the Engineer/Architect.

G.6 Materials and workmanship shall comply with the Building Code of Australia and the appropriate Australian Standards as at (*date of tender*). Copies of the following documents shall be held on site; (*list only those which are really required and their date of issue*).

G.7 Drawings are detailed in accordance with the principles set out in the CIA "Reinforcement Detailing Handbook" of (*date*).

G.8 All dimensions are in millimetres unless stated otherwise.

Foundations and Footings

F.1 Footings are designed for an allowable intensity of (*no.*) kPa founded on (*material*). Verify such foundation material and obtain approval from the (*Engineer/Local Building Authority*) before placing concrete.

F.2 Working capacity of piles shall be (*no.*) (*tonnes or kilonewtons*).

F.3 Found bored piles on (*material*) having bearing capacity not less than (*no.*) kPa.

Loading

L.1 This structure has been designed for the following superimposed loads:

(i) Permanent actions due to:

Dividing walls	(*no.*) kg/m run
Partitions	(*no.*) kg/m run
External walls	(*no.*) kg/m run

(ii) Imposed actions on:

Slabs generally	(*no.*) kPa
Stairs and landings	(*no.*) kPa
Balconies	(*no.*) kPa

L.2 The design wind criteria to AS1170.2 are as follows:

Region	(*no.*)
Terrain Category	(*no.*)
Topographic Multiplier, M_t	(*no.*)
Structural Importance Multiplier, M_i	(*no.*)
Shielding Multiplier, M_s	(*no.*)
Basic Wind Speed	
Ultimate V_u	(*no.*) m/s
Working V_s	(*no.*) m/s

L.3 The design earthquake criteria to AS1170.4 are as follows:

General Structure	(*Description*)
Acceleration Coefficient, a	(*no.*)
Site Factor, S	(*no.*)
Importance Factor, I	(*no.*)
Building Type	Type (*no.*)
Design Category	(*no.*)
Regular, Ductile Building Frame System	(*Description*)

L.4 Maintain structure in stable condition during construction.

L.5 Do not place or store building materials on concrete members without engineer's approval.

L.6 Place and trowel smooth and flat a layer of mortar (*no.*) mm thick on top of all loadbearing brick walls. Place approved non-compressible non-adhering membrane on hardened mortar before pouring concrete.

L.7 Concrete shall be separated from the top of non-loadbearing walls by an amount not less than (*no.*) mm.

Concrete

C.1 Concrete quality shall comply with AS (*no.*):(*date*) (*Complete as required. See Example C.1*).

C.2 Project assessment of concrete strength (*is not/is*) required.

C.3 Normal class concrete shall have cement of type (*list*).

C.4 Mechanically vibrate concrete in the form to give maximum compaction without segregation of the concrete.

C.5 Cure concrete as required by Section 17 of AS 3600 and as set out in the Specification.

C.6 In the drawings, the beam depth is written first and includes slab thickness if any.

C.7 Strip footing depth is written first followed by width.

C.8 Concrete sizes as drawn are minimum and do not include applied finishes.

C.9 Do not make unspecified construction joints without engineer's approval.

C.10 Do not make unspecified holes or chases without engineer's prior approval.

C.11 Do not place conduits, pipes and the like within cover concrete.

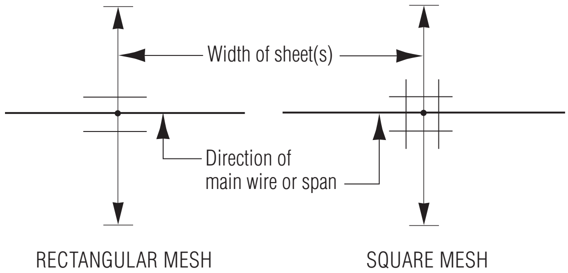
Reinforcement

R.1 Symbols in drawings for grade and strength of reinforcement are:
SL or RL denotes welded wire reinforcing mesh to AS/NZS 4671:*(date)*.
L denotes steel reinforcing bar to AS/NZS 4671:*(date)*.
N denotes hot-rolled deformed reinforcing bar to AS/NZS 4671:*(date)*.

R.2 Bar notation gives the following information in this order:
No of bars; grade; bar size (mm); spacing (mm, if required), placing information.
Eg, *20-N16-200-BOT*.

R.3 Mesh notation gives the following information in this order:
SL or RL symbol; AS reference number if standard mesh or special code if non-standard mesh; placing information.
Eg, *RL918 TOP*.

R.4 Main wires of mesh and coverage of sheets shown in plan-view and elevation thus:

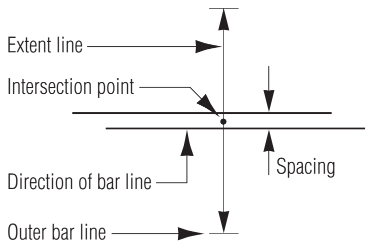


Example C.1: Specification of concrete requirements

Required properties of concrete in accordance with AS 1379

Structural Element	Exposure Classification	Class and Grade	Slump at site ± 15 mm	Nom. Max. Aggregate Size	Method of Placement	Strength at (*No.*) Days MPa
Name	*List*	*N (no.)* *S (no.)*	*mm*	*mm*	*Pump, etc*	*Value in MPa*
Examples:						
Roof Slab	B1	N32	80	20	Pump	Not required
Super-Flat Floor	U	S40	40	40	From chute	40 MPa at 28 days

R.5 Extent of bars and mesh shown thus:



R.6 Reinforcement is represented diagrammatically and not necessarily in true projection.

R.7 Reinforcement dimensions shall not be scaled.

R.8 Lap reinforcement only at locations shown in the drawings. Lap length shall comply with AS 3600. (*See Example R.8*)

Example R.8: Specification of lap splices in a drawing

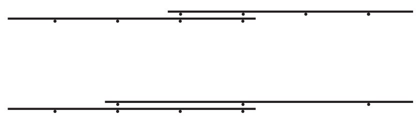
Reinforcement shall not be spliced except where shown in the drawings. The splice length of bars shall be as given in the following table, except where other dimensions are stated on the actual detail.

			Tensile lap length (mm) for Grade 500N deformed bars						
			Bar size (mm)						
Type of member	f'_c (MPa)	Cover (mm)	N12	N16	N20	N24	N28	N32	N36
Slab or	25	20	300	500	750	-	-	-	-
Wall		25	300	450	650	850	-	-	-
Other		40-45	300	400	550	800	1050	1300	1550
main bars	25	50-60	300	400	500	650	900	1100	1350

Embedment lengths for starter bars and splice lengths for column bars shall be as given in the following table, except where other dimensions are stated on the actual detail.

Bar Size (mm)	Straight embedment in footing of 20 DIA. (mm)	Splice length of 32 DIA. (mm)	Number of fitments at column bar crank
N20	400	640	1-R10 or 1-L7
N24	480	770	2-R10 or 1-L9
N28	560	900	2-R10 or 1-L10
N32	640	1030	1-N12 or 1-L11
N36	720	1160	2-N12 or 1-L12

R.9 Where lapping is specified, mesh shall be lapped such that the two outermost wires of one sheet overlap the two outermost wires of the other sheet as shown:



R.10 Welding of reinforcement including tack-welding for fixing purposes shall comply with AS 3600:*(Date)* and AS 1554.3:*(Date)*. Welding is permitted only where shown in the drawings or where otherwise approved by the engineer.

R.11 Fix distribution bars (*grade and size + spacing*) where shown unless specified otherwise.

R.12 Fix (*no, grade and size*) trimming bars around openings in (*each/top/bottom*) face of member and extending (*mm*) beyond their cross-over point.

R.13 In drawings, the following abbreviations mean:

Each way	EW
Top or top-face	T or TOP
Each face	EF
Centrally placed	CENTRAL
Near face	NF
Bottom or bottom-face	B, BOT
Far face	FF
Internal face	INTF
Horizontally	HORIZ
External face	EXTF
Vertically	VERT
At centres (bars)	CTS
Maximum	MAX
Continuous	CONT
Minimum	MIN
Typical	TYP

R.14 Reinforcement shall not be cut, bent or heated on site without the engineer's prior approval.

R.15 The deviation of reinforcement from its specified position shall not exceed the following (mm):

(a) For positions controlled by cover:

(i)	in beams, slabs, columns and walls	-5, +10
(ii)	in slabs or ground	-10, +20
(iii)	in footings cast in the ground	-20, +40

where a negative value indicates a decrease in specified cover, and a positive value indicates an increase in specified cover.

(b) For positions not controlled by cover:

(i)	the location of tendons on a profile	5 mm
(ii)	the position of ends of reinforcement	50 mm
(iii)	the spacing of bars in walls and slabs and of fitments in beams and columns	the greater of 10% of spacing or 15 mm.

R.16 Spacers and supports shall be located at centres close enough to prevent displacement of reinforcement by workmen or equipment during fixing and subsequent concrete placement within the tolerances given in R.15 above.

R.17 The cover to the reinforcement nearest the concrete surface shall not be less than the following except where specified otherwise:

Example R.17:

Member Location	Exposure Classification	Concrete f'_c (MPa)	Required Cover (mm)
Internal beams	A1	25	20 to fitments
Internal slabs	A2	25	30
External beams	B1	32	40 to fitments

Formwork

F.1 Formwork shall comply with AS 3610:(*Date*)

F.2 The contractor shall submit proposals for formwork at commencement of job.

F.3 Stripping of formwork shall comply with Section 17.6 of AS 3600:(*Date*).

F.4 Remove all props and formwork from beams and slabs before constructing walls and other supported items upon them.

Checking of Concrete Drawings

The drawings detailing the concrete along with the General Conditions of Contract, Special Conditions of Contract and the Specification are the usual documents, which form part of a contract. They therefore have legal status. Calculations are a one means of carrying out a design but they have no legal status.

Drawings are used to convey your designs onto paper so the building or civil engineering project can be built. As such, they are a vital element of any project and the quality and accuracy of drawings can make or break a project. There will never be a complete and total accurate set of documents. However, incomplete or inaccurate information is one of the greatest risks to any project.

ALL Engineers should be responsible for detailed checking of their design and checking the resultant drawings progressively to ensure their design is correctly shown on the drawings. Project Engineers should be responsible for detailed checking of all design and resultant drawings irrespective of whether they personally did the work or not.

Checking Procedure

The following checking procedure should be adopted for all jobs prior to any issue for tender or construction. If for any reason this does not appear practical, you should give early advice to your superior to enable appropriate action to be taken.

- Ensure that a set of final Architectural Drawings is available for building projects – if not, procure them before commencing – provided time allows.
- Check structural drawings to ensure they comply with architectural drawings. Start by laying the original drawings if they are in negative form (generally plans and elevations) over the Architect's drawings and checking walls, set downs and general arrangements. Also check the Architectural Sections and details for conformity being careful to note the words "*to Engineer's detail*" to ensure you have provided these items which the Architect has assumed you are showing. If your drawings say "*to Architect's detail*", make sure the Architect is aware of this.
- Fully check civil and structural drawings for content, detail, drafting and general adequacy. Pay special attention to critical detailing and connections. Every line and word should be individually checked.
- Look at the drawings and ask yourself is there enough information on the drawings to build it – dimensions, concrete strengths, section, etc. Can it be built as it is shown, with the details as drawn?

When the Project Engineer has checked the job and verified it (only then) should it be passed to a senior member of the office for an independent check and review. The project should be presented as a complete package – all drawings, computations and specification together with a checking sheet wherever possible.

Drawings ***SHOULD NOT GO OUT*** *as final drawings for tender or any other contractual purpose until this final check has been completed*.

Problem Areas

The following project or areas have been identified as high risk areas in structural design. Careful attention must be given to these by all engineers:

- Errors in reading drawings by contractor (poor documentation).
- Design errors.
- Inadequate geotechnical information.
- Inadequate survey of existing services, levels, features, etc.
- Multi-storey car parks.
- Roofs of all kinds.
- Sag and creep in reinforced concrete.
- Durability of concrete (ie cover and inadequate inspection on site).
- Post-tensioned and prestressed concrete including shrinkage.
- Factory and warehouse floors (slab-on-ground).
- Cracking of concrete.
- Fairground and amusement equipment.
- Cladding on multi-storey buildings.
- Retaining walls.
- Construction joints in concrete running through hard finishes such as tiles, vinyl, etc, resulting in unsightly cracking.
- Inadequate control joints in masonry walls for brick growth, deflection of suspended beams and ground movements.

*Remember that most professional (liability) claims come from misunderstandings created by the **Contract Drawings**.*

D

Bibliography

A number of other publications which may also be useful to obtain additional information on detailing of reinforcement in concrete structure are listed below, in no specific order.

1 *Reinforced Concrete Design Handbook* (T38) Cement Concrete & Aggregate Australia, 2002.

2 *Precast Concrete Handbook* (Z48) National Precast Concrete Association Australia and Concrete Institute of Australia, 2009

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3 *Concrete Structures*, Warner, R.F., Rangan, B.V., Hall, A.S., and Faulkes, K.A., published Longman, Melbourne, Australia,1998.

4 *Manual for the Design of Reinforced Concrete Building Structures*, The Institution of Structural Engineers and The Institution of Civil Engineers, Second Edition 2002.

5 *Structural Detailing in Concrete*, Bangash, M.Y.H. published by Thomas Telford Books, UK, 2003.

6 *Detailing Manual* (Sp66) American Concrete Institute, 2004.

7 *Standard Method of Detailing Structural Concrete : A Manual of Best Practice*, Institution of Structural Engineers and The Concrete Society (3rd Edition) 2006.

8 *Reinforced Concrete Structures*, Park, R., and Paulay, T. published by John Wiley and Sons.