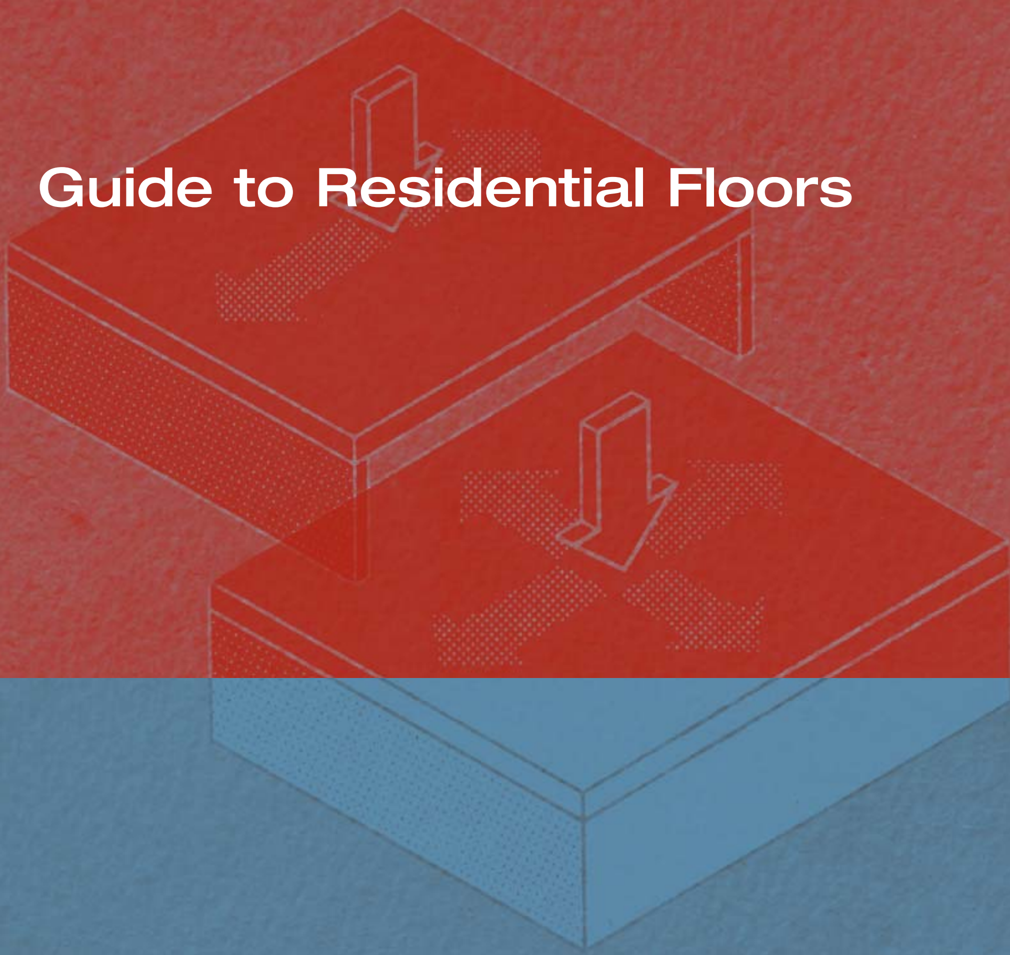
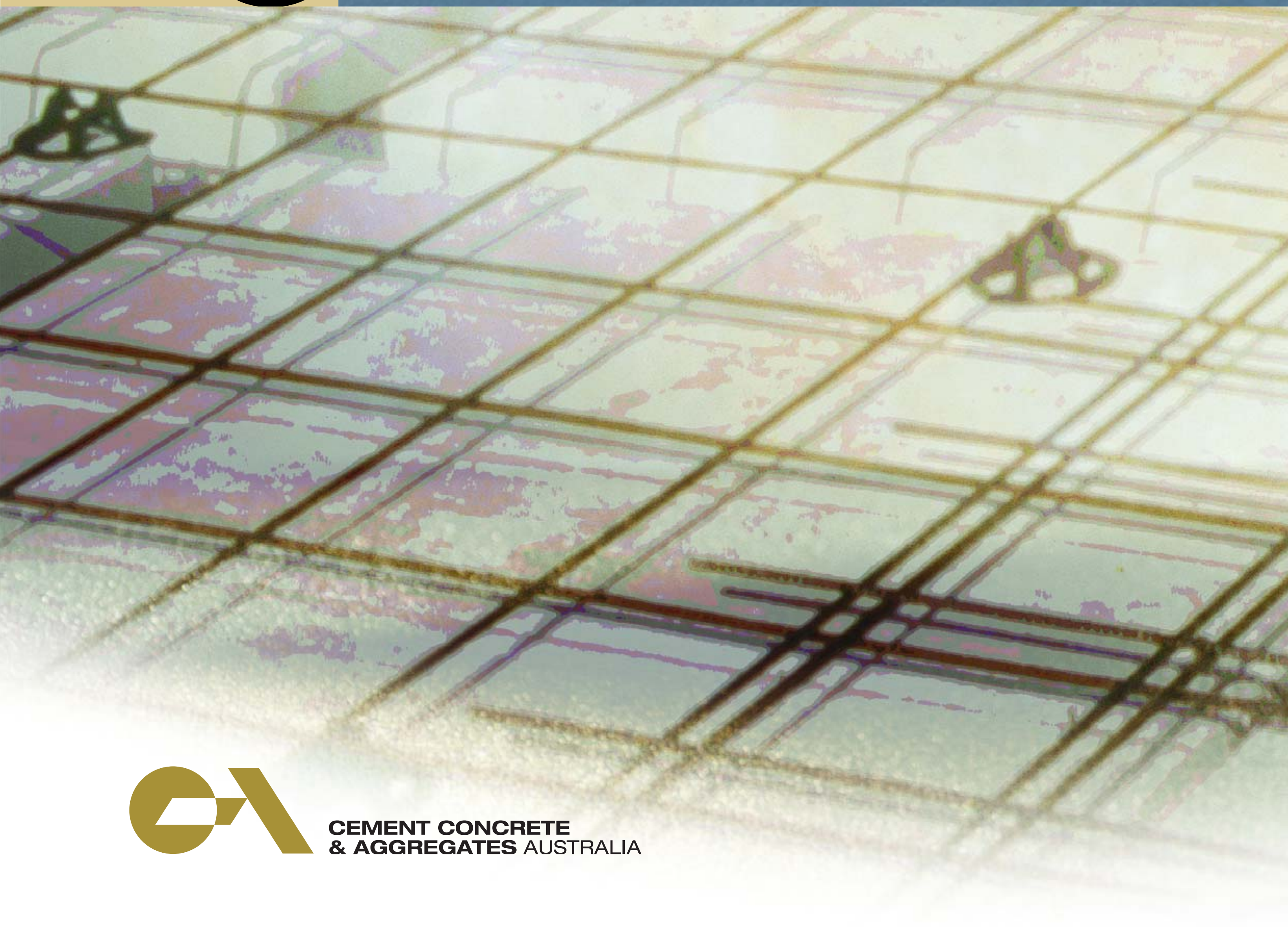
CCAA T49-2003

Guide to Residential Floors

Guide





CEMENT CONCRETE
& AGGREGATES AUSTRALIA

Guide to Residential Floors

Guide

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Cement Concrete & Aggregates Australia is a not-for-profit organisation established in 1928 and committed to serving the Australian construction community.

The Association is acknowledged nationally and internationally as Australia's foremost cement and concrete information body – taking a leading role in education and training, research and development, technical information and advisory services, and being a significant contributor to the preparation of Codes and Standards affecting building and building materials.

The Association's principle aims are to protect and extend the uses of cement, concrete and cement-based products by advancing knowledge, skill and professionalism in Australian concrete construction and by promoting continual awareness of products, their energy-efficient properties and their uses, and of the contribution the industry makes towards a better environment.

Cement Concrete & Aggregates Australia
ABN 34 000 020 486

SYDNEY OFFICE:
Level 6, 504 Pacific Highway
St Leonards NSW Australia 2065

POSTAL ADDRESS:
Locked Bag 2010
St Leonards NSW 1590
TELEPHONE: (61 2) 9437 9711
FACSIMILE: (61 2) 9437 9470

BRISBANE OFFICE:
Level 14, IBM Building
348 Edward Street
Brisbane QLD 4000
TELEPHONE: (61 7) 3831 3288
FACSIMILE: (61 7) 3839 6005

MELBOURNE OFFICE:
2nd Floor, 1 Hobson Street
South Yarra VIC 3141
TELEPHONE: (61 3) 9825 0200
FACSIMILE: (61 3) 9825 0222

PERTH OFFICE:
45 Ventnor Avenue
West Perth WA 6005
TELEPHONE: (61 8) 9389 4452
FACSIMILE: (61 8) 9389 4451

ADELAIDE OFFICE:
Greenhill Executive Suites
213 Greenhill Road
Eastwood SA 5063

POSTAL ADDRESS:
PO Box 229
Fullarton SA 5063
TELEPHONE: (61 8) 8274 3758
FACSIMILE: (61 8) 8373 7210

Extractive Industries Office:
PO Box 243
Henley Beach SA 5022
TELEPHONE: (61 8) 8353 8151
FACSIMILE: (61 8) 8353 8151

TASMANIAN OFFICE:
Extractive Industries Office:
PO Box 246
Sheffield TAS 7306
TELEPHONE: (61 3) 6491 2529
FACSIMILE: (61 3) 6491 2529

WEBSITE: www.concrete.net.au
EMAIL: info@ccaa.com.au

Preface

When first released in 1998, this publication covered slab-on-ground floors in detail but contained only a limited outline of the alternatives available for suspended floors. Comprehensive information on the latter was at that time provided in the Association's companion publication *Guide to Suspended Concrete Floors for Houses* (T40) published in 1991.

Both earlier publications are now superseded by this second edition of *Residential Floors*. It covers both slab-on-ground and suspended floors in similar detail to that found in its predecessors. The content has been completely updated to reflect changes in statutory requirements, site practices and available products.

The target audience is building designers, architects and engineers. However, the general information on both slab-on-ground and suspended floors is presented in such a way as to give building owners and owner-builders an understanding of what is involved, enabling them to participate in the selection process.

The permission of the National Precast Concrete Association Australia (NPCAA) to use material from its *Precast Concrete Handbook* in the preparation of Sections 5.7–5.10 is gratefully acknowledged.

Contents

1 Introduction

1.1 General

Concrete offers the flexibility of a structural material that can be cast into almost any desired shape and size or made in a factory in predetermined sizes. Concrete construction can respond to the many specific requirements and design considerations found in modern building.

More than 80% of housing incorporates concrete flooring of one type or another; either in slab-on-ground floors/footings or in suspended floors. The reasons for choosing a concrete flooring system are many and varied and will differ from one project to the next. Some of the advantages concrete flooring offers are:

- Durability – a properly constructed concrete floor will outlast most of the other components of the house.
- Stiffness – concrete floors designed to carry the imposed loading will generally possess adequate stiffness and will not deflect under the applied load so as to create problems in non-structural elements, eg doors.
- Energy efficiency – concrete floors possess high thermal mass and this can be used to improve the internal environment within the dwelling and reduce the energy demand for thermal comfort.
- Acoustic performance – concrete floors can meet the acoustic performance requirements set out in the Building Code of Australia (BCA)[1].
- Speed of construction – concrete floors can be constructed quickly. The adoption of concrete floor/footings speeds the completion of the ground floor. Precast flooring systems have the added advantage of reducing the amount of labour required on site.

Concrete slab-on-ground floor/footings also provide a pleasing transition between indoor and outdoor living areas, a very important consideration in Australia's vast temperate regions. The change of level is minimal, making for easy negotiation by the very young and the elderly alike. Further, with the design flexibility inherent in the system and construction methods, a sloping site is not a deterrent. One of the options on such a site is to use a cut-and-fill approach and deepen the perimeter beams to economically retain the fill.

1.2 Definitions

The terms ‘footing’ and ‘foundation’ are used variously within the technical literature to refer to something that supports a building. In this Guide the terms have the meaning ascribed to them in AS 2870[2], as shown below. Foundations can be either stable or reactive depending on the soil properties, and a footing can be anything from a strip footing through to a waffle raft.

Fill

Controlled fill Material that has been placed and compacted in layers by compaction equipment within a defined moisture range to a defined density requirement in accordance with Clause 6.4.2(a) of AS 2870 and AS 3798[3].

Rolled fill Material compacted in layers by repeated rolling with an excavator in accordance with Clause 6.4.2(b) of AS 2870.

Uncontrolled fill Fill other than the above

Fill depth

For a slab, depth of fill is measured from the underside of the slab panel to the natural surface level or excavated surface in natural material. For a strip or slab footing system, the depth of fill is measured from the finished ground level to the natural surface level.

Footing

The construction that transfers the load from the building to the foundation, eg supporting ground.

Foundation

The ground that supports the building.

Geotechnical survey

A survey, undertaken by geotechnical engineers (or a geologist in some States), to determine the soil profile of a building site. It establishes soil type, moisture content, bearing capacity and possible reactivity of soil when subjected to the climatic conditions likely to be encountered at the site, thus enabling the site classification to be made. The resulting report enables appropriate footing and slab details to be designed that comply with the requirements of AS 2870.

Piers and piles

A structural member that is driven, screwed, jacked, vibrated, drilled or otherwise installed in the ground so as to transmit loads to the soil or rock. *Note: Driven piles may be a problem in urban areas with vibration affecting adjoining property.*

Bored Formed by auguring the foundation soil to form a cylinder and filling with concrete (an economical method of providing adequate founding and bearing capacity for footings and slabs constructed on filled sites, unstable or suspect soils or to attain bridging for distribution of loads over underground services).

Driven Formed by driving a concrete, steel or treated timber section into the ground to a specific depth or until a certain level of resistance is reached.

Mass concrete Locally deepened sections of the footing trenches into natural or acceptable foundation into which concrete is poured to provide adequate bearing capacity for footings and slabs.

Reactive site

A site consisting of a clay soil which swells on wetting and shrinks on drying by an amount that can damage buildings on light strip footings or unstiffened slabs. *Note: Sites classified as S, M, H, or E in accordance with Clause 2.1 of AS 2870 are reactive.*

Sediment control plan

An approval document required indicating the measures to be taken to control soil and silt run-off from a construction site whereby installed catchment fencing or other devices to prevent or limit sediment entering the stormwater system.

Slab

Infill slab A slab cast on the ground between walls. *Note: The walls are generally of masonry supported on strip footings.*

Slab-on-ground (SOG or sog) A concrete floor supported on the ground and incorporating integral internal and edge beams. Note: The term is used to refer collectively to stiffened rafts, footing slabs and waffle rafts.

Slab panel The part of the slab between beams.

Wall

Articulated A masonry or clad wall in which planned joints are designed to accommodate movement due to foundation movement without cracking in the wall panels between the joints. *Note: Clay brick walls also require joints to allow for 'brick growth'. Typically joints are required at 6- to 8-m centres and 'brick growth' can be as much as 1 mm per m.*

Loadbearing Any wall imposing on the footing or slab a service load greater than 10 kN/m. *Note: Internal walls less than 3.0-m high in single-storey buildings are deemed to be non-loadbearing.*

2 Scope

This Guide describes and illustrates the various types of concrete slab-on-ground floor systems and suspended floors suitable for residential buildings ranging from single, detached houses to medium density buildings of apartments and flats.

For slab-on-ground floors it provides an understanding of the footing/slab selection, design, detailing and construction requirements contained in AS 2870 and the Housing Provisions of the BCA. The requirements of AS 3660.1[4] are also covered.

For suspended floors it covers both upper floors and those at ground level where a slab-on-ground may not be suitable. Forms of construction include insitu concrete (using either temporary or permanent formwork) and precast concrete (normal-weight and lightweight). It provides an understanding of the design approach, span-load charts to enable a selection of appropriate floor types, and design details and identifies various manufacturers/suppliers where appropriate.

The Guide provides general information giving an appreciation of the relevant issues and Standards to be considered when planning and designing concrete floors. Alternative reinforced concrete floor systems and general site issues (eg slope, drainage) are discussed to assist in selecting the most practical footing/floor for a particular site. The information provides the basis for the selection by the designer; architect, engineer or building consultant of an appropriate floor system for a particular project.

The Guide will in no way replace the services of professional consultants.

For information on site supervision and recommended work practice for reinforced concrete floor construction readers are referred to *The Housing Concrete Handbook* [5].

3 Responsibility for Design

The design of concrete structures including suspended floors needs an appreciation of many factors and therefore must be carried out by a designer (usually a structural engineer) experienced in such design and who may have to be registered. The BCA provides a simplified and uniform set of regulations designed to establish essential construction standards for structural adequacy, fire resistance, public health and general amenity. The technical requirements of this code refer to AS 3600[6], which sets the minimum requirements for the design and construction of safe, serviceable and durable concrete structures, as well as to other Standards such as AS 1170 *Structural design actions* which sets out the various design actions to be considered.

In any structural design of buildings including housing, one designer must be responsible for the overall structural design including stability, robustness, movement joints, fire resistance and durability even if more than one designer is involved in the design process.

The design process is an iterative procedure for all concrete structures where preliminary sizes are initially assumed and then checked for various design criteria. In the case of a suspended concrete floor, if the thickness is inadequate then a greater thickness is chosen and the process repeated until an appropriate thickness of slab is found which meets all of the design requirements.

AS 3600 is a significant document defining the design requirements. It specifies design criteria for both:

- Serviceability – by limiting deflections to tolerable values and designing for durability/exposure conditions and
- Strength – by defining appropriate section details to resist applied loads.

4 Slab-on-Ground Floor/Footings

4.1 The Function of Footings

The function of the footing is not only to distribute vertical loads from the building to the foundation, but to ensure that the building superstructure performs satisfactorily, particularly when it is on a foundation subject to movement due to moisture changes (reactive clay sites), settlement, etc.

The most common movements arise as a result of moisture changes in reactive clay soils. As clay soils become wet, they swell or increase in volume, and as they dry out, they shrink. This is why cracks appear in clay soils during periods of prolonged dry weather. The more reactive the clay or the deeper the soil is affected, the larger will be the surface movement.

Constructing a concrete slab on the ground is like covering the ground with an impermeable membrane. Any moisture rising beneath the slab can no longer evaporate from the surface. The soil in the centre of the slab will therefore remain damp and the moisture content may even increase and, if reactive, will swell. However, around the edges of the slab, moisture will be able to evaporate during dry periods and permeate back under the slab during wet periods. Thus the edges of the slab will be subject to periods of heave and periods of loss of support when the slab has to cantilever out from the centre mound. It is important to determine how reactive a site is, and to what depth the soil will be affected. The amount of movement to be designed for can then be determined, and thus a footing provided that will adequately support the building superstructure and limit the movement that the superstructure has to accommodate.

It is important to understand that AS 2870 is not intended to provide damage- or crack-free performance of superstructures. Footing systems designed, detailed and constructed in accordance with AS 2870 are not intended to prevent cracking of the walls constructed on them due to possible foundation movement, but merely to limit cracks to a generally acceptable width and number, and at an acceptable cost.

4.2 Footing Types

Common footing systems include the following:

4.2.1 Footing slab (Figure 4.1)

A footing slab consists of a concrete floor supported on the ground with a separately poured strip footing. It minimises the time excavations are left open and does not require extensive formwork, although two concrete pours are required. Depending on the site classification and the requirements for termite protection the edge beam may be tied to the slab by fitments. Generally, the footing slab system adapts well to sloping sites. It is particularly suited to unreactive and S sites.

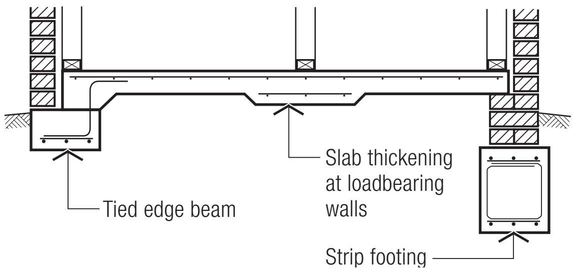


Figure 4.1 Footing slab

4.2.2 Stiffened raft (Figure 4.2)

A stiffened raft consists of a concrete slab on ground stiffened by integral edge beams and a grid of internal beams. It is also referred to as a slab-on-ground footing. The floor slab is placed at the same time as the external and internal beams all of which are reinforced. Internal beams are not required on stable sites while for more-reactive sites the beam sizes and quantity of reinforcement are increased to suit foundation conditions. Stiffened raft footings generally require only one concrete pour, are economical in material and labour use. On uncontrolled fill sites they can be adapted to be supported on mass concrete piers/piles founded in natural material.

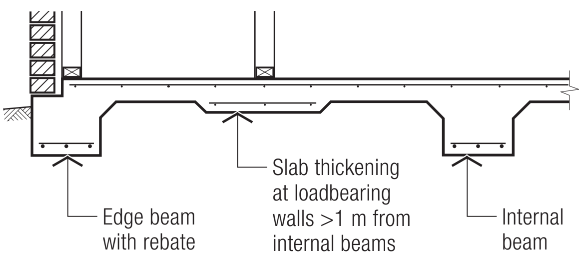


Figure 4.2 Stiffened raft

4.2.3 Stiffened raft with deep edge beams (Figure 4.3)

In this case the stiffened raft incorporates deep edge beams. It is suitable for sloping sites where cut-and-fill excavation is not appropriate. The deep edge beams (which may be of reinforced masonry) retain the controlled or rolled fill under the slab.

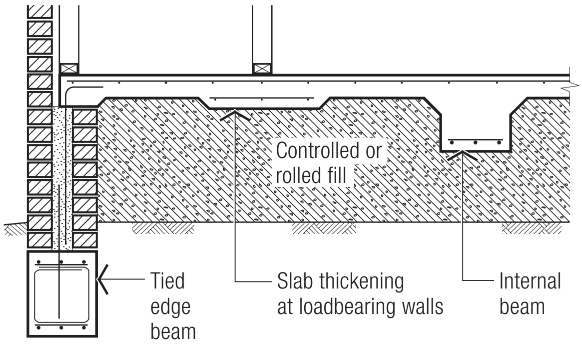


Figure 4.3 Stiffened raft with deep edge beams

4.2.4 Waffle raft (Figure 4.4)

A waffle raft is a stiffened raft with closely spaced ribs constructed on the ground and with slab panels suspended between the ribs. It is constructed on a level site using cardboard or polystyrene void formers to produce a close grid of reinforced concrete ribs, which support the slab panels. As the footing system is cast on the surface using forms, rather than trenched into the foundation, site preparation is minimised and reduced concrete and reinforcement is required. Waffle rafts, as with stiffened rafts, can be designed to be supported on piers/piles.

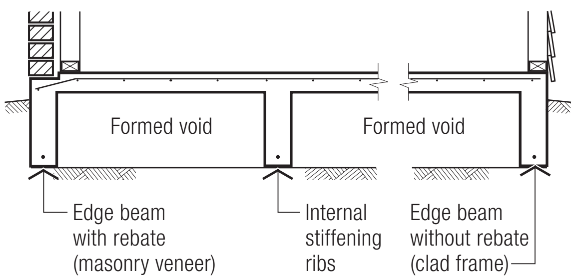


Figure 4.4 Waffle raft

4.2.5 Strip and pad footings (Figure 4.5)

Strip footings are rectangular in section and are generally used to support continuous walls. Pad footings are used to support piers, columns or stumps that support a framed structure. Strip and pad footings can be used independently or in combination to support a range of suspended flooring options common on sites with steep slopes. Concrete infill slabs may be supported on controlled or rolled fill between walls constructed on strip footings.

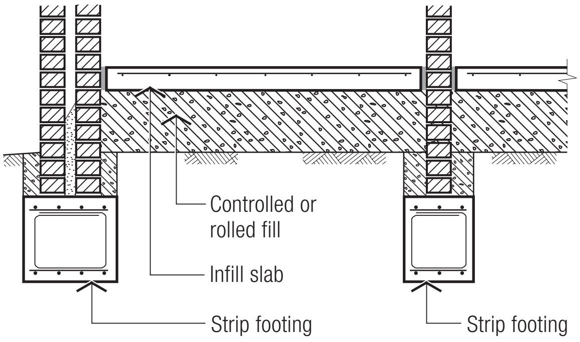


Figure 4.5 Strip and pad footings

4.2.6 Pier/pile and slab (Figure 4.6)

On highly reactive sites and areas of collapsing or uncontrolled fill, piers or piles may be used to support a concrete slab-and-beam floor. Piers are excavated and then poured before casting a slab-and-beam floor system on top of a compressible void-former to provide space for soil expansion. Piles are usually concrete, steel or treated timber of a specific depth. The piles are cut off at the required level for casting of the floor system.

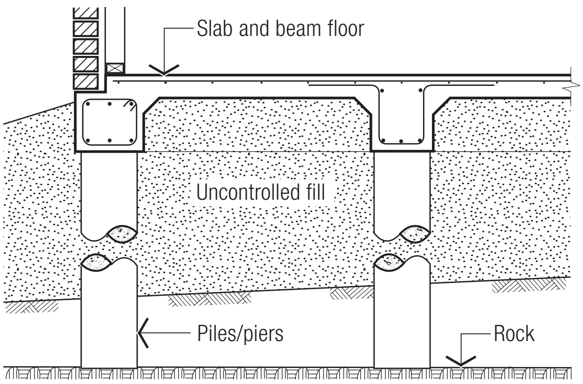


Figure 4.6 Pier/pile and slab

4.3 Slab on Ground and Footing Design

4.3.1 General

The design of a floor/footing for a residential building requires an appreciation and consideration of many factors ranging from architectural to environmental to materials. The first, and perhaps major, consideration is to distribute vertical loads from the building to the foundation and ensure that the building superstructure performs satisfactorily.

All buildings, including domestic structures, have to comply with Performance Requirements as set out in the BCA. The Approving Authority, ie Local Council or Private Certifier, certifies that the plans conform to the requirements of the BCA. This usually means that the details comply with the relevant Australian Standard. However, where an alternative solution is proposed it is necessary to demonstrate that the solution meets the Performance Requirements. This can be time consuming and is why the deemed-to-satisfy route is usually chosen. For this reason, the Guide follows AS 2870, ie it takes the deemed-to-satisfy route.

Local Authorities do not always require an engineer to be involved in the design of domestic slab/footings. Nevertheless, the engagement of an engineer to prepare the design is recommended. Note that this will usually mean that the engineer does not have to prepare a one-off design, but simply use engineering knowledge in determining the site classification, making a selection from the alternatives for floor/footings given in AS 2870 and determining suitable beam layouts and details.

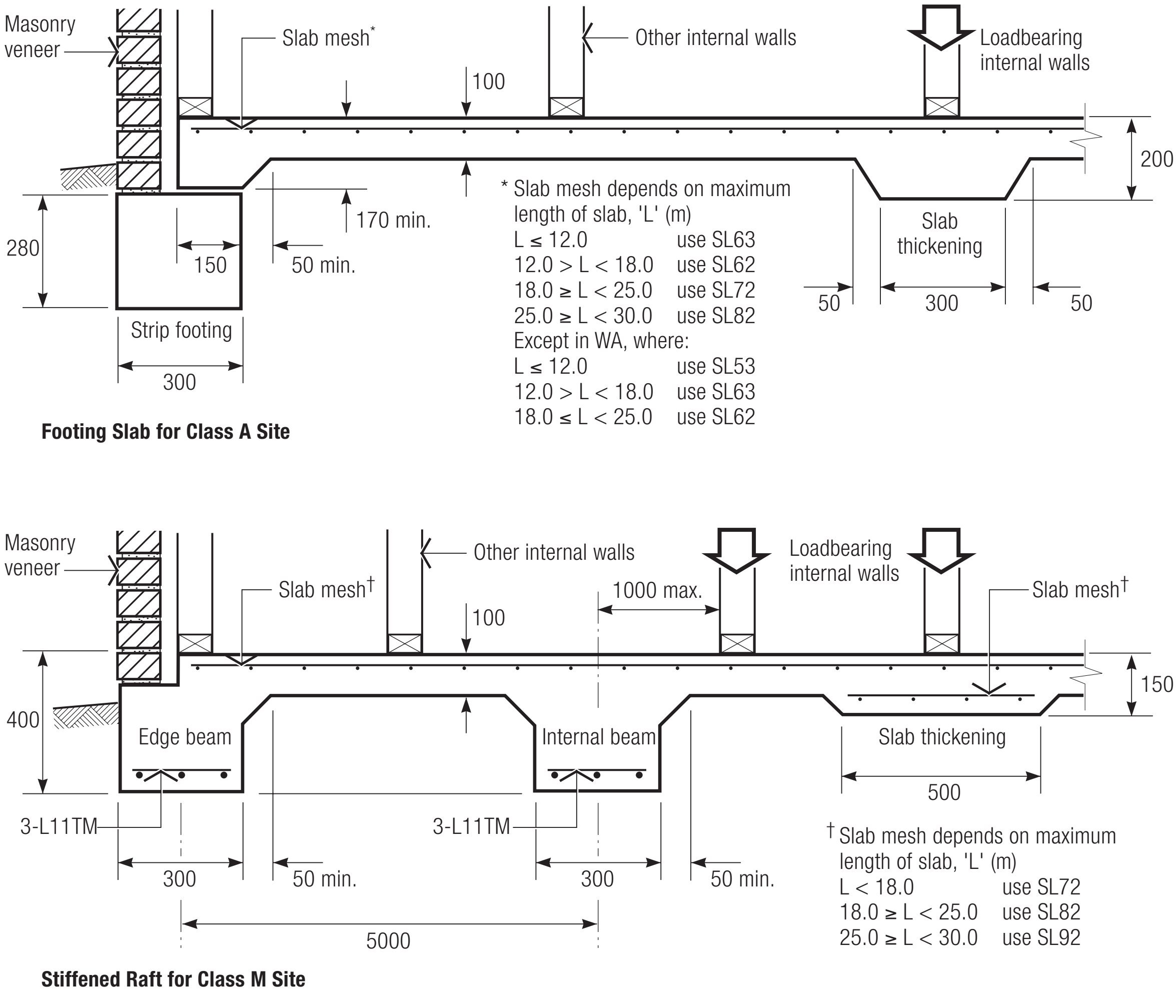


Figure 4.7 Typical details from AS 2870

4.3.2 AS 2870 Design Procedure

This section covers the selection and detailing of domestic house floors/footings, including strip footings, (placed on the natural ground or on fill), for the usual range of site conditions (soil types and slopes) based on AS 2870, typical information from which is shown in **Figure 4.7**. It also covers other design considerations where appropriate.

The five main steps in the design of a suitable footing system are:

Step 1 Classification of the Site

Step 2 Assessment of the Topography

Step 3 Selection of Footing and Wall Types

Step 4 Assembly of the Details

Step 5 Preparation of the Documentation, including calculations, specification and drawings or sketches, etc.

Each of these is discussed below.

4.3.3 Classification of the site

Classifying the site to determine if the foundation is stable or reactive and, if the latter, to what extent, is the first step. The importance of getting the site class correct cannot be over-emphasised, as no selection of footing details from the tables within AS 2870 will guarantee acceptable performance if the classification is wrong.

For this reason, AS 2870 is quite specific on the methods used to classify sites, and on the qualifications of those carrying out site classifications. Different States/Authorities have varying requirements in relation to site classification. In Victoria for example, each site is individually classified by a geotechnical engineer who determines the soil profile, eg from a bore log, and carries out soil tests on the various layers.

AS 2870 lists site classes by foundation material and the expected level of ground movement as shown in **Table 4.1.**

Table 4.1 Site classes by foundation material (from AS 2870)

Site class	Foundation material and expected ground movement from moisture changes
A	Most sand and rock sites with little or no ground movement
S	Slightly reactive clay sites with only slight ground movement
M	Moderately reactive clay or silt sites, which can experience moderate ground movement
H	Highly reactive clay sites, which can experience high ground movement
E	Extremely reactive sites, which can experience extreme ground movement
P	Sites which include soft soils, such as soft clay or silt or loose sands; landslip; mine subsidence; collapsing soils; soils subject to erosion; reactive sites subject to abnormal moisture conditions or sites which cannot be classified otherwise
A to P	Filled sites

The procedure given in Clause 2.2.3 of the Standard, used to classify the site, implies that surface movements of the order shown in **Table 4.2** can be expected for the varying site classes.

Table 4.2 Likely surface movement for various site classes (from AS 2870)

Site class	Surface movement (mm)
S	0 to ≤ 20
M	20 > to ≤ 40
H	40 > to ≤ 70
E	more than 70

Where soils in Class M, H and E sites are subject to movement at depths greater than 3 m (known as deep-seated movement and typically occurring in dry climates), a further division of the Class is required, ie M-D, H-D and E-D respectively. The shape of the soil profile under the slab is affected, increasing the required stiffness in the footings.

The above rules for assessment of the site are based on normal site conditions. Because moisture changes in reactive soils cause ground movements, the following abnormal moisture conditions may result in problems, and need to be considered in the design:

- **Building over the site of a recently-removed structure** If previous structures such as tennis courts and slabs for large sheds/other buildings are removed to allow construction of the dwelling, then uneven ground movements may result since possible ground movements due to moisture changes may have already occurred under the removed slab. Such conditions should be identified at the time of the site inspection, and allowed for in the design.
- **Drains, channels, ponds, dams, or tanks** The ground around this type of feature will normally be quite wet and any ground movement due to moisture would probably have already occurred. Again, if building over these areas, differential ground movements and the possible loss of bearing capacity should be allowed for in the design and detailing of the building.
- **Trees** Trees draw moisture out of the ground, causing reactive soils to shrink. When they are removed, the soil slowly regains its natural moisture content, and swells. In reactive soil areas, eg Class M-P, if trees are removed to construct the slab then the soil in the root area should also be removed and replaced with soil at a moisture content typical for the site, to avoid uneven swelling of the ground under the new slab.
- **Gardens** The establishment and maintenance of a garden changes the moisture condition of the soil. Watering the garden increases moisture in the soil that can lead to swelling. Plants also draw moisture out of the soil, particularly during long dry spells, and this can cause the soil to shrink. To avoid excessive moisture variations in the soil around the house, it is necessary to plan the garden so that only lightly watered areas such as lawns and small garden beds are located in close proximity to it **Figure 4.8**. It is preferable to have a path, patio or paved area alongside the house so that any planting is at least 1.2 m away from the slab edge. Heavy watering alongside the house

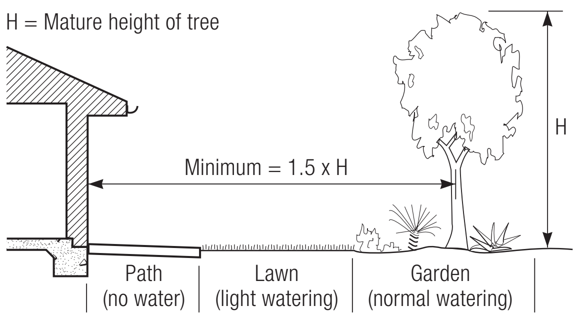


Figure 4.8 Suggested garden plan for a reactive site

should be avoided, although uniform, consistent watering can be beneficial to prevent undue shrinkage and consequent damage during long dry spells.

Trees and large shrubs can affect footings in two ways. Firstly, roots can actually lift footings by growing underneath them. Secondly, they can cause the footings to subside, as moisture is removed from the soil immediately beneath the footing and the soil shrinks. Because trees and large shrubs require large amounts of water, a tree's root system can spread quite extensively in search of moisture – up to one and a half times the height of the mature tree. To minimise the risk of damage to footings, trees and shrubs should be no closer to the house than one and a half times their mature height **Figure 4.8**. Before selecting trees and shrubs and finalizing the garden layout, it is desirable to obtain information about the species proposed for the given location on the site and to follow the advice contained in *Guide to Home Owners on Foundation Maintenance and Footing Performance*[7].

- **Fill** Fill, especially deep clay that has been compacted dry of optimum, can often cause increased ground movements when moisture is taken up underneath a new slab. If the fill is too dry, it is possible to over-compact it when placing it, resulting in considerably more movement than the amount that the site classification indicates. This in turn can cause problems with cracking if the slab has not been designed to allow for such movements.
- **Cut-and-fill** This is a typical method of achieving a level platform to allow the construction of a slab-on-ground. In terms of ground movements, the cut side will usually be wetter than the filled side. In reactive sites (Class M and H) this may result in swelling on the cut side. This is not a problem as long as adequate drainage of the cut side is provided.
- **Paving** Paths, driveways and other paving all act as impermeable membranes in terms of soil moisture and, similar to the house slab, will cause ground movements due to moisture changes in the soil. Paving provides an excellent 'buffer zone' around the house that assists in reducing moisture variations around the footings. However, to work effectively, it is essential that paving has sufficient crossfall away from the house for the expected reactivity or ground movement of the site **Figure 4.9**. If laying pavements in summer, care should be taken to ensure that crossfalls are adequate to accommodate soil swelling in winter.

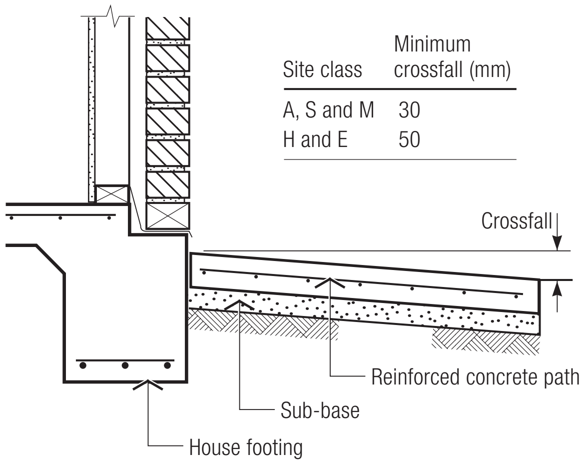


Figure 4.9 Minimum crossfall of paving for given site classifications

All surface water should be drained to the stormwater system.

Variations in paving between one side of the house and the other should be minimised, as this may cause differential movement of the footings. Further, if it is not possible to construct any planned paving immediately, then plastic sheeting with gravel spread on the top, graded away from the house, provides a practical temporary measure to facilitate the reaching of stable moisture conditions.

- **Aggressive soils** Apart from the classification of the site in terms of the surface movement of the soil due to moisture changes, the site also should be assessed in terms of the aggressiveness of the soil with respect to concrete. Some soils and/or site conditions are aggressive to concrete. For example sulfate soils soften the concrete reducing the capacity of the member and exposing the reinforcement to corrosion. For guidance on appropriate measures to be taken in sulfate soils reference should be made to *Sulfate Resisting Cement and Concrete*[8] *and Sulfate and Acid Resistance of Concrete*[9].

Other similar site conditions that need to be recognised are rising salt damp and saline soils where the salinity of the soil is likely to lead to the deposition of salt in the pores of the concrete. In affected areas the local council may prescribe preventative measures to minimise damage. These may include: the specification of damp-proof membranes, minimum concrete strength, cement type and admixtures and cover to reinforcement. In some States, maps are available at the local council delineating areas where precautions need to be taken.

4.3.4 Assessment of the topography

The second step, a thorough assessment of the site topography, can result in a significant reduction in the cost of construction and in a more comfortable and practical house. The careful location of the building footprint in relation to site slopes and boundaries can reduce the depth of cut-and-fill required, thus minimising the extent of retaining walls and site drainage. Alternatively, depending on the slope, it may be more economical to adopt a split-level approach or to use one of the suspended concrete slab options (see Chapter 5). The extent of cut-and-fill and retaining walls (other than those needed for the dwelling itself) should be considered from the outset, as most Councils require these site works to be completed at the same time as the dwelling itself. Topographical matters that should be considered include:

- **Orientation of the site** and possible alternative orientations of the house on the site. What is the predominant orientation of any site slope? Do other topographical features shade the house? Is it exposed to hot/cold winds? Is there a view and in what direction? Can the house be orientated to take advantage of passive solar design principles? See *Energy Saving Using Passive Solar Design*[10].
- **Direction of any slope** in relation to the front boundary. Is the site above or below street level? If below the street level, will the front still have an outlook? Where is the vehicular access? Will the slope allow access to a garage?
- **Maximum depth of cut** A cut into a slope for a slab supported on ground usually needs to extend about one metre beyond the slab, and if the face of the cut is over about 600 mm high, it will require appropriate stabilisation treatment, eg batters or retaining walls.
- **Flood-prone sites** In locations prone to flooding, the local Council may impose a minimum floor level and this may dictate the height of fill required at the house location. In other locations the Council may impose restrictions on the minimum level of floor wastes and other sewerage fittings and fixtures to minimise the risk of back-flow up the sewer lines and into the dwelling. There may also be minimum sewer gradients to ensure the lines are self-cleansing.
- **Maximum depth of fill.** If fill is required under any part of a slab-on-ground, it must be controlled or rolled fill. AS 2870 Clause 6.4.2 details the methods required to achieve adequate compaction for fill up to 800 mm deep in stable or sandy soil and 400 mm in reactive or clay soil. For greater depths, the use of an alternative footing system (eg pier and beam) or a suspended slab may be required but engineering advice will be needed.
- **Extent of fill** The fill should extend one metre beyond the slab and then be battered down at a slope not steeper than 2 (horizontal) to 1 (vertical).
- **Retaining walls** A wide variety of retaining wall types is available, giving choice of material, surface texture, wall contour and colour. Design guides are available for some types, eg segmental concrete masonry[11]. Drainage needs to be provided to the ground behind retaining walls while their design requires engineering input.
- **Drainage** How will any earthworks affect natural site drainage? What measures will need to be taken to keep water away from footings? To minimise variations in moisture content in the foundation, especially under the footing, an effective drainage system must be installed and maintained for the site and building. This involves directing both surface and subsurface water away from the house. This is particularly pertinent when cuts are involved with slabs supported on ground. The minimum requirement will be that the ground be sloped away from the slab with a dish drain at the base of the batter or retaining wall to take surface water away from the high side of the house. On clay sites, sealed surface drains should be used since subsoil drains may introduce moisture into the foundation. Dish drains on the high side of unprotected batters may also be required if the face is likely to be eroded by run-off.

  Stormwater is the greatest source of surface runoff and large quantities are collected by the roof of a house. To ensure effective drainage, all downpipes need to be connected to an adequate stormwater system and directed away from the house, generally to the street or other stormwater drain. (Note: Some authorities prefer drainage to be retained on site where possible or held for a time before discharging into stormwater.) Similarly, paved areas should be graded to collection points that are connected to the stormwater system and are accessible for cleaning.

  Individual sites, especially cut-and-fill sites, will have specific drainage requirements which should be detailed on a site or drainage plan prepared by the engineer or builder. On cut-and-fill sites, all batters and drainage should ensure adequate site drainage, spoon/dish drains and/or agricultural drains will generally be required to prevent surface and subsurface water draining towards the house **Figure 4.10**. Agricultural drains are also used in low-lying areas or on sites that have a tendency to collect excessive water.

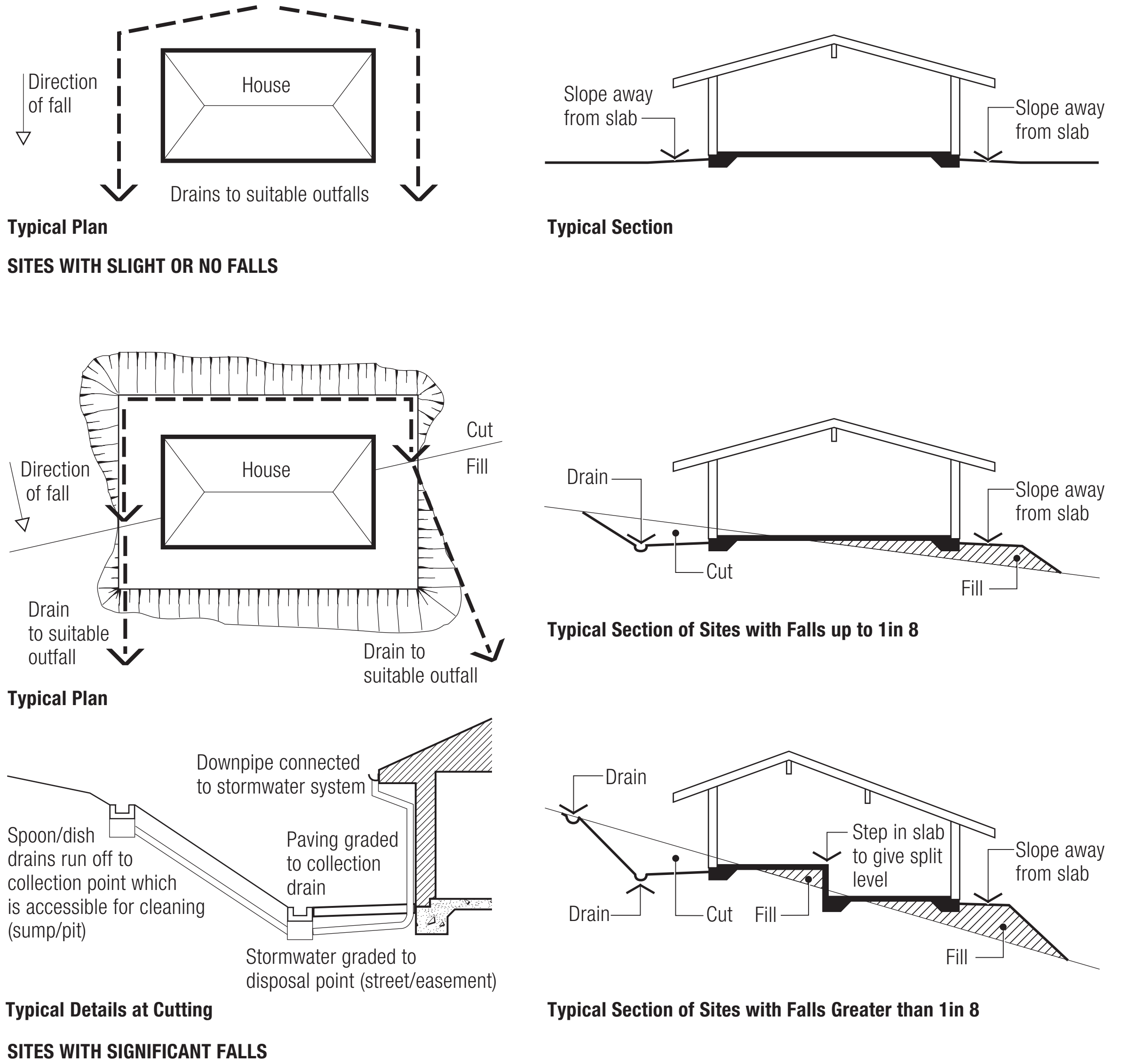


Figure 4.10 Stormwater drainage

4.3.5 Selection of footing and wall types

Once the site class and the maximum depth of any required fill have been established, the footing system and wall type to be used can be determined.

The common types are :

Footing Systems
- Footing slab
- Stiffened raft
- Stiffened slab with deep edge beam
- Waffle raft
- Strip footings.

Wall Types – from most flexible to least flexible
- Clad frame
- Articulated masonry veneer
- Masonry veneer
- Articulated full masonry
- Full masonry.

The choice of the type of footing system is usually based on the site class, topography, the type of house, material and form of construction.

The selection of details will need to also take account of the type of external and internal wall construction to be used, which is chosen by either the owner or builder. Footing systems for which standard designs are provided in AS 2870 are as given in **Table 4.3**.

Table 4.3 Footing systems for which standard designs are provided in AS 2870.

Footing system	Site class A or S	M	H
Footing slab	✓		
Stiffened raft	✓	✓	✓
Stiffened slab with deep edge beams	✓	✓	
Waffle raft	✓	✓	✓
Strip footings	✓	✓	✓

As can be seen, for any particular site classification there will be more than one suitable type of footing system. Each will perform satisfactorily and the final choice will be influenced by such things as:

- local experience with a particular type of footing system;
- the builder's experience in preparing filled sites;
- the builder's preference for a particular type of footing system.

Site Classes E and P are not included since footing systems on these extremely reactive and problem sites will always need to be designed by an engineer. Other circumstances where specific engineering advice should be sought are where:

- there are concentrated loads from columns;
- the depth of edge beams exceeds 1500 mm;
- the slab is longer than 30 m;
- the depth of fill exceeds the limits allowed for the type of material being used.

Note that by introducing a step in the floor-slab (split-level house) it may be possible to reduce the maximum depth of fill to within the limits for builder-supervised fill as detailed in AS 2870 Clauses 6.4.2 and 6.4.5.

When selecting the wall type, it is important to realise that different types have different stiffnesses or degrees of flexibility. The more rigid or stiff a wall, the less it is able to tolerate ground movement without cracking. For a given soil reactivity, as the wall stiffness increases, the footing stiffness also has to increase to allow it to control the amount of foundation movement that has to be tolerated by the walls above. This is why footing beams become deeper (and hence stiffer or more rigid) the more rigid the walling type is, or the more reactive the foundation. The maximum movement that the walls are able to accommodate without unacceptable cracking occurring is indicated by the maximum footing movements that the Standard sets. These are listed (from most flexible to most rigid) in **Table 4.4**.

Having classified the site and selected the footing and wall types based on the topography and house design, the footing system requirements can be obtained from the figures referred to in AS 2870 Clause 3.1.1. This includes the slab and beam dimensions, beam spacing and reinforcement requirements.

From the tables, it can be seen that some masonry wall types are not suitable for Class M and H sites. This is because the stiffness of the walls makes it uneconomical to provide a rigid enough footing system to prevent the walls from cracking unacceptably with the movements associated with these sites. This problem can be overcome by providing articulation joints in the masonry walls.

All types of wall construction can be supported. However, with Class H, E or P sites, consideration should be given to articulating the walls, ie dividing long runs of wall into shorter panels, usually at door or window openings **Figure 4.11**. Jointing materials or timber-framed infills are often used as the dividers. This method of construction allows each panel of masonry to move independently, thus reducing the possibility of cracks developing in the walls due to foundation movement and the consequent deflection of the footing beams. (*See Articulated Walling*[12].)

Table 4.4 Maximum footing movements that can be accommodated by various wall types (from AS 2870).

Type of construction	Absolute maximum differential footing movement as a function of span (mm)	Max. differential footing movement (mm)
Clad frame	≤ L/300	40
Articulated masonry veneer	≤ L/400	30
Masonry veneer	≤ L/600	20
Articulated full masonry	≤ L/800	15
Full masonry*	≤ L/2000	10

* Where full clay masonry is used, control joints for ‘brick growth’ must be provided at 6- to 8-m centres. Where mixed construction or earth masonry are used, AS 2870 Clause 3.1.2 gives the equivalent construction (ie a standard walling type with a similar stiffness) for use in the selection of a standard design for a footing system.

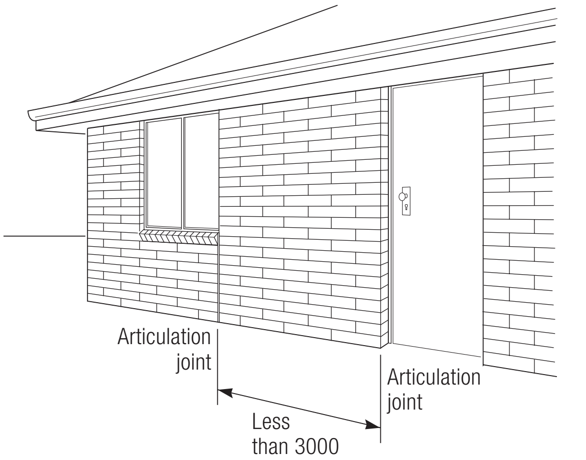


Figure 4.11 Articulated walling is desirable on Class H, E or P sites

4.3.6 Assembly of the details

Having determined the footing requirements, various details need to be finalised:

Building on fill Fill can be either controlled or rolled fill depending on its height and the requirements of the footing system (*see 4.3.4 Assessment of the topography*). For depths beyond the limits given in the Standard, engineering advice will be necessary.

Termite barriers The various physical and chemical barrier systems, eg woven stainless steel mesh, graded stone particles and chemical soil barriers, are outlined in AS 3660.1. Generally, the concrete slab/footing will form part of the barrier system and the details adopted have to conform to the requirements of AS 3660.1.

The aim of any termite protection system is to both minimise termite access and, just as importantly, to make any access that does occur easy to detect by virtue of its being visible. Thus, protection of the building throughout its life depends on good maintenance of the chosen protection system and regular inspections.

The nomination of the concrete slab as a barrier against concealed incursion from subterranean termites will require that:

- it is constructed in accordance with AS 2870;
- appropriate reinforcing, concreting and curing practices are adopted to control cracking;
- supplementary protection is provided in the zones shown in **Figure 4.12** by one of the methods listed in AS 3660.1. Appendix 1 outlines the procedure for using a concrete slab as part of the termite barrier.
- Slab edge exposure – Where perimeter protection using the exposed edge of the concrete slab or edge beam is selected, it is essential that good off-the-form finishes are achieved by casting against good clean and tight formwork to minimise grout loss. It is essential to compact this concrete to eliminate voids that could provide concealed access for termites. A minimum clearance of 75 mm above the finished ground or pavement level is required of the exposed vertical slab or beam edge.
- Suspended concrete floors – Concrete floors constructed on a masonry base structure must conform to the requirements of AS 3660.1 ensuring that both the inner and outer sides are accessible for inspection. The base walls require a continuous shield placed throughout the masonry

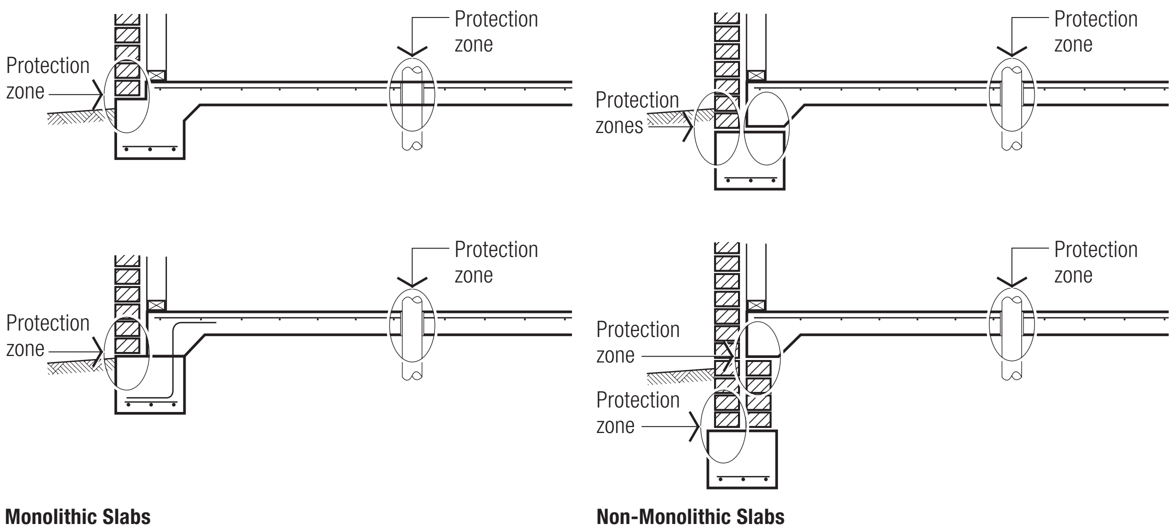


Figure 4.12 Termite protection zones

extending across the entire width of the wall. Concrete and sealed metal columns are exempt from ant capping only if they remain fully exposed for inspection. All adjoining attachments including stairs and ramps that are not protected must be either isolated from the main structure or attached to the main structure below the shielding level.

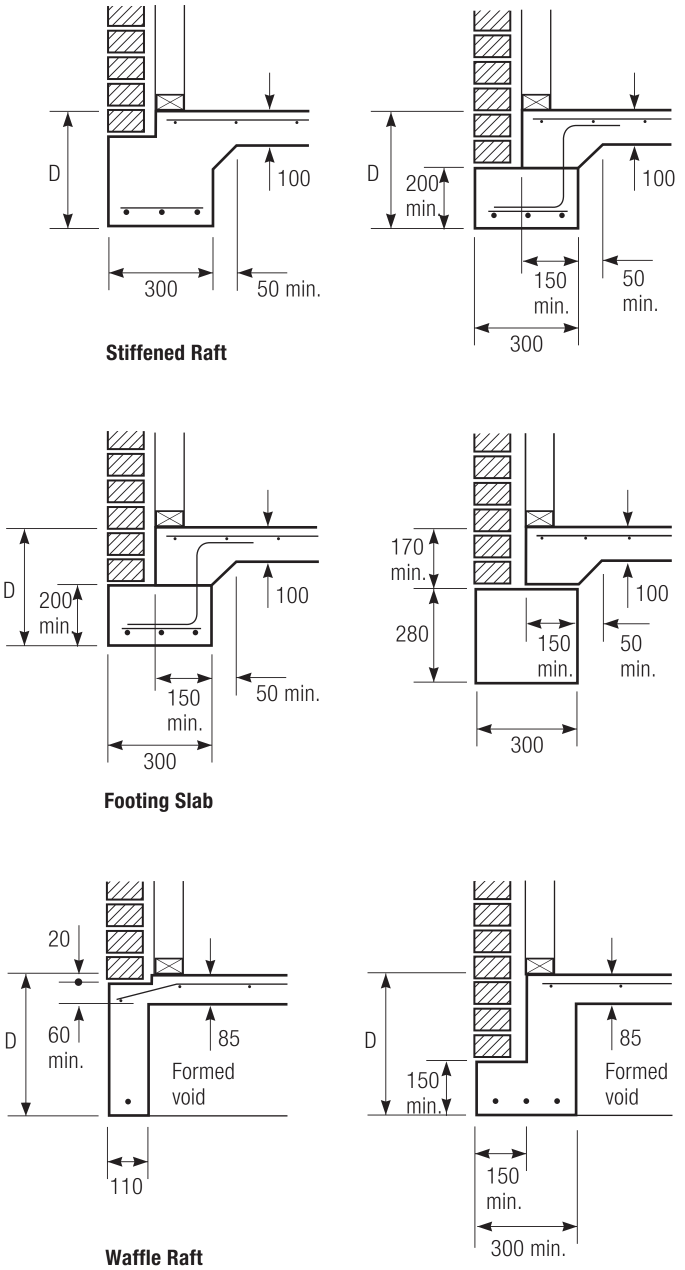


Figure 4.13 Slab edge details (reinforcement and depth 'D' obtained from AS 2870) *Note: Cavity flashing and membrane not shown*

Slab edge/step-down details Each footing method and structural design will create differing slab edge and step-down details as shown in **Figures 4.13** and **4.14**: Note that:

- Edge rebates should extend to the inside of any wall cavities.
- Weepholes to perpends should discharge above finished ground level.
- When the slab is being used as part of a termite barrier system, detailing must meet AS 3660.1 requirements. Note that if pathways are to be placed later, additional termite barriers may need to be included in slab/footing construction detailing.
- At external step-downs for garages, etc the edge beam should also be stepped to maintain the required beam depth.
- Edge dampness should be avoided by adopting the principles set out by the Concrete Institute of Australia[13].

Slab reinforcement – the minimum cover to reinforcement specified in AS 2870 Clause 5.3.2 depends on the exposure condition of the slab/edge-beam face **Table 4.5**.

Table 4.5 Minimum cover to reinforcement (from AS 2870)

Exposure of concrete surface	Minimum cover (mm)
In contact with the ground	
- unprotected	40
- protected by a membrane	30
Exposed to the weather	40
Protected from the weather	20

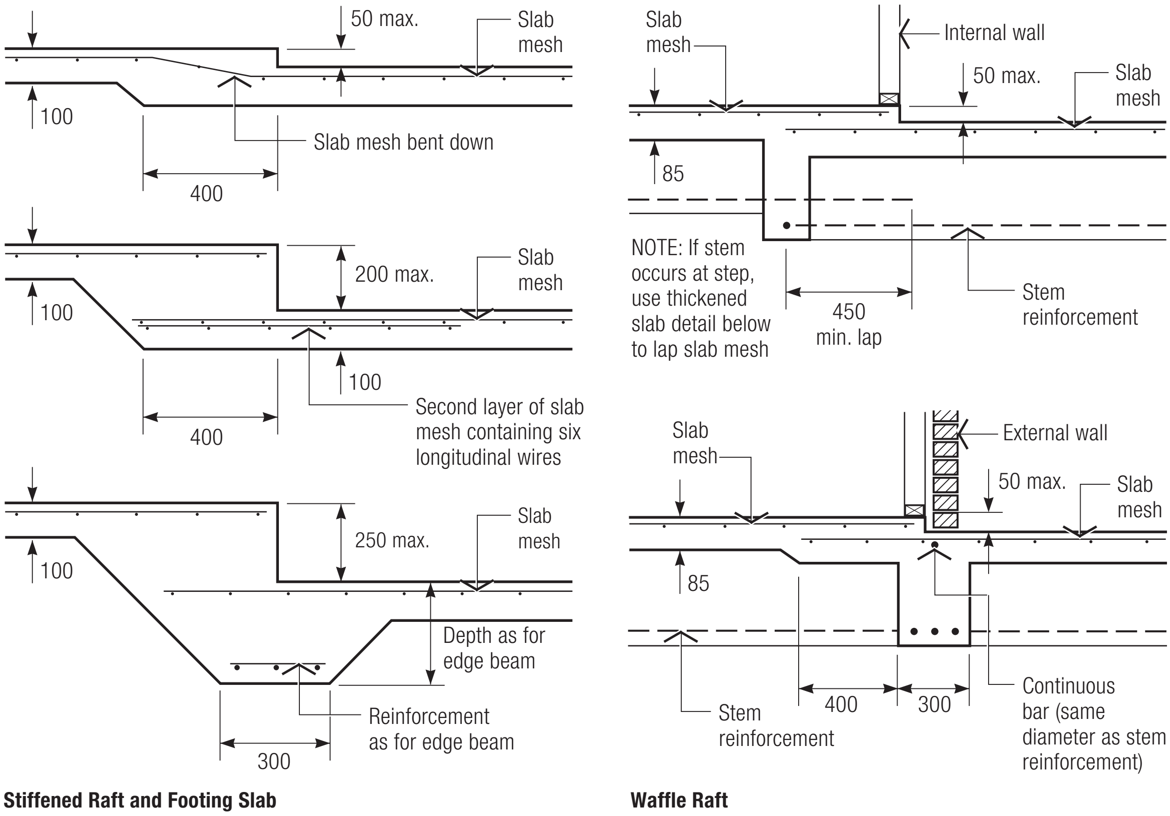


Figure 4.14 Slab step-down details *Note: Cavity flashing and membrane not shown*

Where brittle floor coverings such as ceramic tiles are to be used, the amount of reinforcement in the slab may need to be increased to control shrinkage cracking. Alternatively, the laying of tiles (with flexible adhesive) should be delayed for at least 90 days or a flexible bedding mortar used. Construction joints should be designed not to pass through areas to receive a brittle floor finish since this will result in ragged cracks roughly following the line of the joint below.

With vinyl tiles, timber boards, parquetry, etc it should be noted that it takes about one month for every 25 mm of slab thickness for the moisture content of the concrete to stabilise. An average 100-mm-thick slab should be left for four months prior to the adhesive fixing of this flooring, unless special adhesives are used.

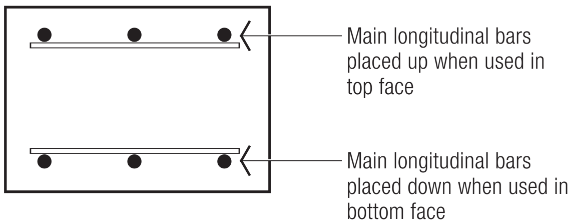
Strip-footing reinforcement Trench mesh is often used and should be placed as shown in **Figure 4.15** (which also shows how slopes and steps are detailed).

Top and bottom layers of reinforcement in strip and raft footings will require to be adequately supported during concreting and to provide the correct cover. Trench mesh in the bottom of beams will require either proprietary trench mesh supports or ligatures and bar chairs. If bars are used they will need ligatures and bar chairs or similar to support them. In both cases, these supports or ligatures and bar chairs are typically spaced at 600- to 900-mm centres depending on the rigidity of the reinforcement.

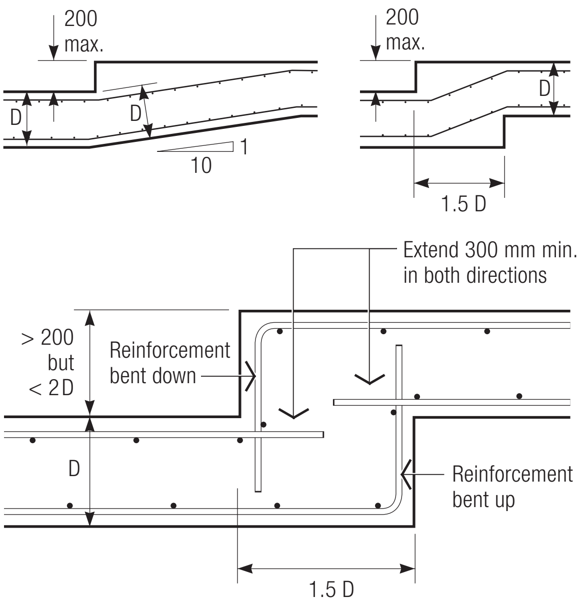
Laps in reinforcement The requirements for lapping of reinforcement are as follows in accordance with AS 2870 Clause 5.3.2:

- Steel mesh should be lapped as shown in **Figure 4.16**, ie the two outermost cross-wires of one sheet should overlap the two outermost wires at the other.
- Trench mesh should be lapped 500 mm.
- At 'T' intersections the reinforcement should lap the full width of the intersection **Figure 4.17**.
- Bars should be lapped not less than 500 mm.
- Bars at 'L' intersections should be lapped in one of the ways shown in **Figure 4.18**.

Additional reinforcement should be provided at re-entrant corners **Figure 4.19**.

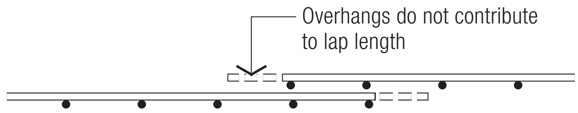


Positioning of Trench Mesh in Strip Footings

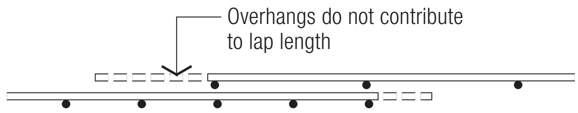


Steps in Strip Footings

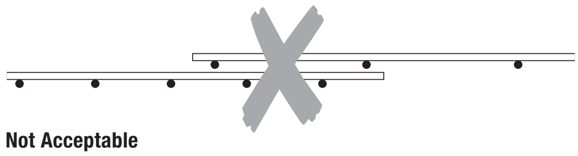
Figure 4.15 Reinforcement details for strip footings



Cross-wires with Same Spacing



Cross-wires with Different Spacing



Not Acceptable

Figure 4.16 Laps in mesh reinforcement

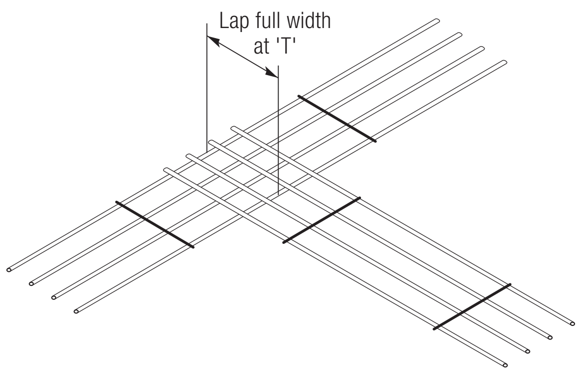
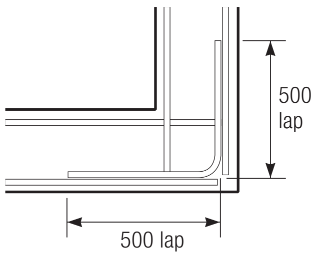
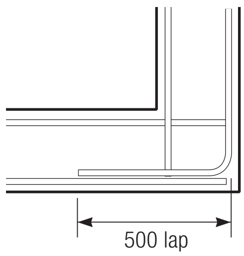


Figure 4.17 Lapping of trench mesh at a 'T' intersection



Separate L-Bar Lapped on Each Leg



One Outer Bar Bent and Lapped

Figure 4.18 Lapping of bars at intersections

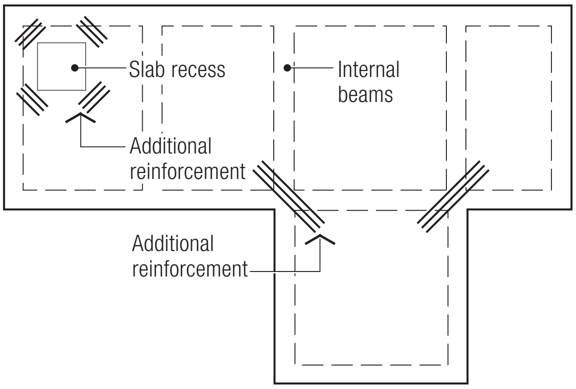


Figure 4.19 Diagonal reinforcement at re-entrant corners

Services – where service pipes penetrate the floor, footing or walls, provision should be made for movement of these elements, particularly on Class M, H or above sites. This can be achieved by lagging with a cellular and compressible material. Where penetrations pass through a footing, the footing may need to be deepened sufficiently for the penetration to occur in the middle third of the footing depth **Figure 4.20** (alternatively, the footing could be stepped down to enable the service pipe to pass over it). Where the slab is being used as part of the termite barrier system, protection as required by AS 3660.1 will also need to be provided.

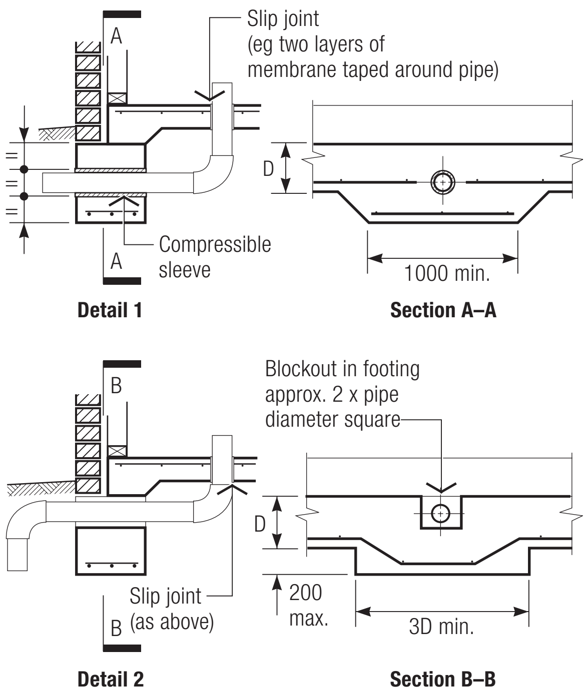


Figure 4.20 Details of pipe penetrations in slabs and footings

Vapour barriers and damp-proof membranes – underlays beneath the slab are placed over the prepared subgrade following the contours of internal beams, set downs, recesses and thickenings. The vapour barrier membrane should be a minimum 0.2 mm in thickness and all joints should be lapped 200 mm and taped. All penetrations should be taped and sealed as noted above.

In areas prone to rising damp or salt attack, a damp-proof membrane rather than a vapour barrier membrane should be laid under the slab/footing. The damp-proof membrane should be extended up to the ground level at the edges. Requirements for vapour barriers and damp-proof membranes are detailed in AS 2870 Clause 5.3.3.

Tie-downs, cyclone-prone, earthquake-prone and mine-subsidence areas – AS 1684[14], contains specific requirements for tying down the timber structure, eg walls and shear walls, to resist uplift and shear forces.

AS 2870 does not provide any details for cyclone- and earthquake-prone areas, only general guidance is given. Specific advice should be obtained from an appropriate consultant for the particular project.

- **Cyclone-prone areas** The main requirement in these areas is for the roof to be tied down to the footing with ties capable of resisting the uplift forces. Rods and flats used as tie-downs should be anchored into the footing as shown in **Figure 4.21.**
- **Earthquake-prone areas** By and large the design requirements for earthquake will not impact greatly on the footing design but can affect the design and detailing of the superstructure. The general requirements for the footing are that the superstructure is held down onto the footing so that it does not shake off under the earthquake loading. Ties should be anchored into the footing as for cyclone ties.

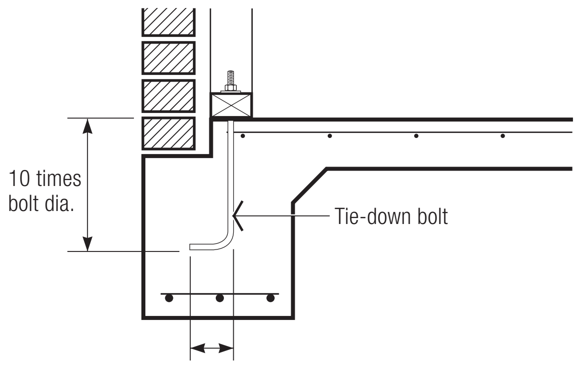


Figure 4.21 Anchorage of tie-downs to footing

- **Mine-subsidence areas** In these areas, the footings and the house itself need to be designed specifically for the anticipated movements.

4.3.7 Preparation of the documentation

Before construction of the selected floor slab/footing system can begin, the builder will require sufficient details to be drawn up so that the work can be carried out according to plan and in accordance with the Local Authority requirements.

Adequate drawings can sometimes be prepared using the information and typical details given in AS 2870. However, the requirements of the relevant Local Authority need to be checked.

Note that as foundation movement due to moisture changes in reactive clays is one of the most common causes of problems, it is recommended that details of the site drainage requirements be included on the drawings. If drainage is inadequate, and water is allowed to pond around the footings, excessive ground movements or loss of bearing capacity may occur.

4.4 Construction Issues and Maintenance

4.4.1 Earthworks

Whether or not the project requires extensive cut-and-fill or only minor earthworks, the site should be scraped clean of surface vegetation, roots and topsoil. Such material is not suitable for under-house fill and should be removed from the building site. If suitable as topsoil, it may be stockpiled for later use.

All large shrubs and trees should be removed, including taproots. When pushing stumps, the root system should be trenched with machine rippers to allow for total removal of the roots since the subgrade vegetation can house subterranean termites. As discussed above, roots from nearby trees (on both the property and neighbouring properties) may lead to excessive movement of the foundation with consequent damage to the structure. In these situations the installation of in-ground root barriers should considered.

Bulk excavations are best carried out by suitable earthmoving machinery. Where imported fill is to be utilised, it is important to seek the engineer's advice to determine type and makeup of fill and suitable compaction methods. Where fill is to be layered and compacted, traditional compaction methods should be followed, viz:

- rolled fill utilising bulk excavation machinery, placing in layers as specified;
- controlled fill - undertaken by means of a fully articulated or towed vibratory drum roller and/or a sheep's-foot vibratory roller or vibrating plate.

(Note care is needed with compacting equipment and vibrating rollers, etc to ensure excessive vibration is not transmitted to adjoining properties)

All earthworks should follow the stipulated construction requirements detailed in geotechnical surveys and reports.

4.4.2 Footing excavation and service trenches

Preparation for a concrete slab-on-ground footing should include for a nominal 50-mm thickness of bedding sand, compacted and set to maintain minimum slab thickness as specified (and to provide protection for the vapour barrier or damp-proof membrane while the slab is being placed).

After excavation, all footings should be clear of debris and have sufficient width to provide a minimum 40-mm cover for reinforcement (assuming non aggressive soils). Where piers are required under footings, they can be excavated and poured before footing excavation or they can be excavated through the cleaned-out footing and poured monolithically **Figure 4.22**.

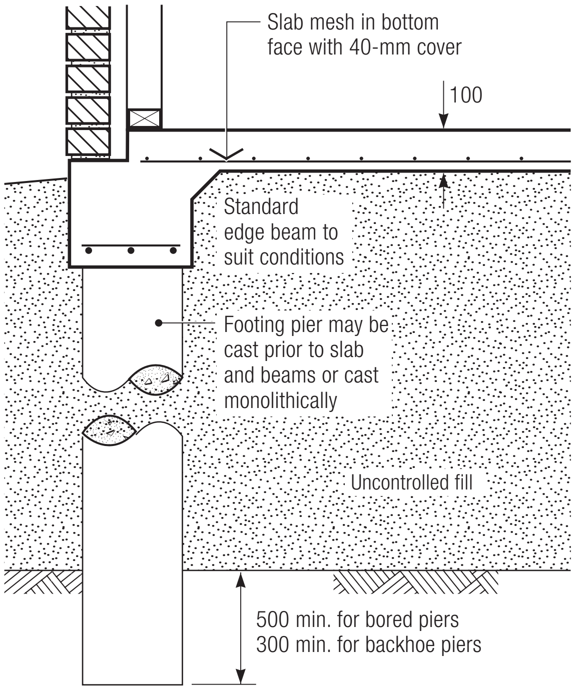


Figure 4.22 Details of piers under footings

Where service trenches are excavated along the alignment of the footings/slabs, care should be taken to ensure that the temporary excavation will not increase the chance of undermining the slab/footing **Figure 4.23**.

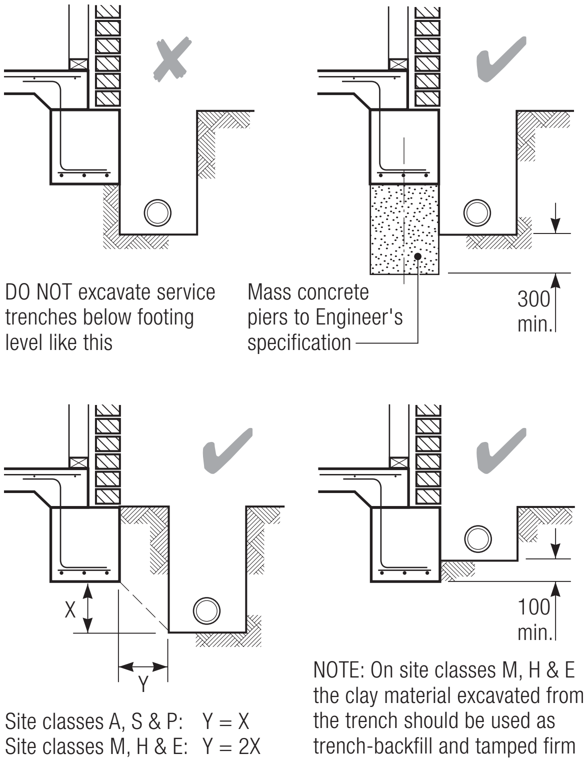


Figure 4.23 Details of service trenches alongside footings

4.4.3 Maintenance

The maintenance of the site around a new home is an important factor in the long-term performance of the footing system. The primary objective of this maintenance is to minimise the variation in soil moisture levels around the footings that could lead to excessive soil movement and possible distress of the superstructure and /or footing. When the slab forms part of the termite barrier system for the house, then it is also necessary to maintain the effectiveness of that barrier with appropriate maintenance activities.

When a concrete slab-on-ground is used as part of the termite barrier system as outlined in AS 3660.1, then it cannot be too highly stressed that regular inspections and maintenance of the slab and surroundings by a competent professional is required to ensure that any termite infestation is detected and treated promptly.

Ongoing maintenance and inspections on a regular basis is a requirement of AS 3660.1 and owners should be clearly advised of their responsibilities to ensure that their investment is properly protected.

Leaking taps, downpipes, sewers, gutters and drains can also affect the moisture content of the soil and these must be inspected regularly to ensure against damage to the footings. Similarly, gutters, downpipes and collection points can get blocked with leaves and other debris, preventing the effective drainage of stormwater away from the house. Again, regular inspections and maintenance should be carried out to prevent blockages.

It is important for the builder to make the homeowner aware of the maintenance issues associated with ensuring the long-term performance of the footing system.

5 Suspended Floors

5.1 Types of Suspended Floors

The three types of suspended concrete floor systems suitable for residential construction are insitu concrete, composite concrete/steel and precast concrete.

Insitu concrete has been used for many years but other forms of construction incorporating prefabricated components have become increasingly popular. The prime reason for the use of these prefabricated systems is to significantly reduce the cost of conventional formwork, on-site activity and construction time. The savings essentially result from the following:

- No conventional formwork, only minimal time required for the placement and removal of any temporary propping (if needed).
- An intermediate, safe working area at slab level is provided. Beneath the slab a secure, weatherproof area is achieved, suitable for possible early fit-out and/or storage.
- Only crack-control reinforcement is needed for toppings. This will generally be a light mesh reinforcement.
- Excellent dimensional accuracy of prefabricated units, with material properties being guaranteed by the manufacturer.
- Floor elements are delivered to site when required, minimising site storage.

The basic features of each system are:

- **Insitu concrete** The most flexible type in that such floors can be designed to carry walls of any type anywhere within their span, unrestricted by the position of walls (room layouts) below them. These floors are individually designed for particular projects. Support may take the form of walls or beams, themselves supported either by beams or columns.
- **Composite concrete/steel** In this type, proprietary steel decking acts as non-recoverable formwork and partial reinforcement for the floor slab. The decking spans one way and will usually be continuous over several supports. Single spans are, however, common and acceptable. Support is as for insitu floors.
- **Precast concrete.** This type uses precast concrete panels or planks, again spanning only in one direction. A concrete topping is usually required, sometimes for structural purposes (and therefore reinforced), sometimes only to provide a level surface for the application of floor finishes. As with insitu floors, support for the planks can take a variety of forms.

5.2 Terminology and Design Principles

One-way slab action (Figure 5.1)

In residential construction, suspended floors will generally be supported by loadbearing walls or sometimes beams. When the slab is to be supported on only two parallel or near parallel walls or beams it should be designed for one-way slab action, ie spanning in one direction only.

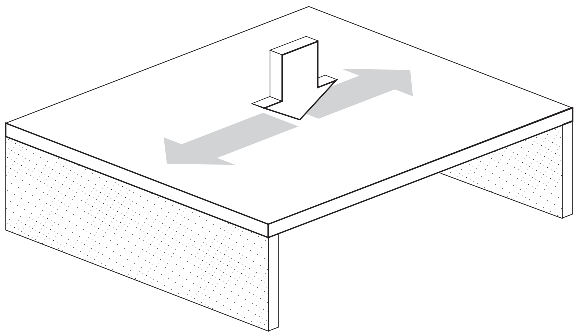


Figure 5.1 One-way slab action

Two-way slab action (Figure 5.2)

If the slab is to be supported on three or four sides and the length is not more than twice the width, then the load may be carried in two directions and the slab should be designed for two-way action.

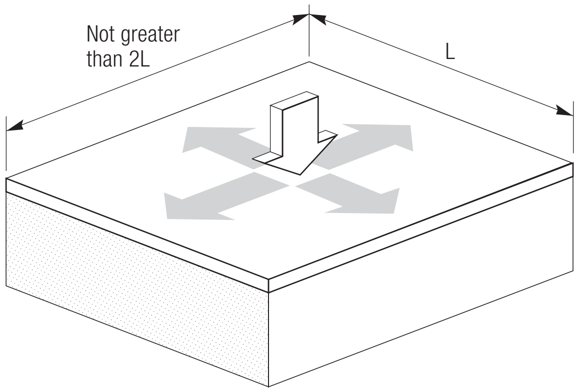


Figure 5.2 Two-way slab action

Single span (Figure 5.3)

When the suspended floor extends between only two supporting walls, the span is described as single (or simple) and the slab as one-way. In this situation, the maximum tensile stresses will occur in the underside of the suspended slab. For this reason, reinforcement designed to overcome these forces is provided in the bottom of the slab.

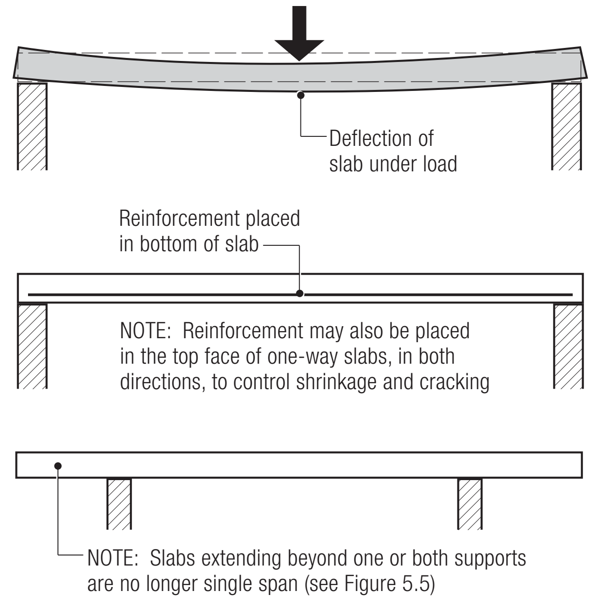


Figure 5.3 Single span

Continuous spans (Figure 5.4)

When a suspended slab extends over one or more intermediate supports, the spans are described as continuous spans (or multiple spans). In this situation, tensile forces will occur not only in the bottom of the slab between supports, but also in the top of the slab over the intermediate supports. Reinforcement additional to that required for a single span will be necessary in the top of the slab over the intermediate supports.

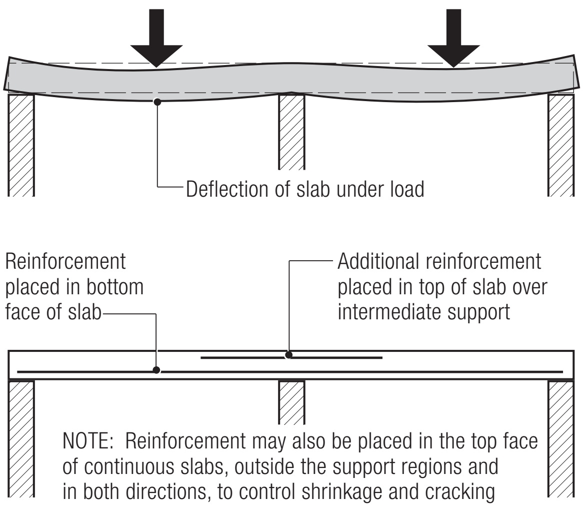


Figure 5.4 Continuous span

Cantilevers (Figures 5.5 and 5.6)

Cantilevers, such as balcony slabs, deflect downward from their support, causing maximum tensile forces in the top of the suspended slab over the support. Reinforcement should therefore be provided in the top of the cantilever slab as shown in **Figure 5.5.**

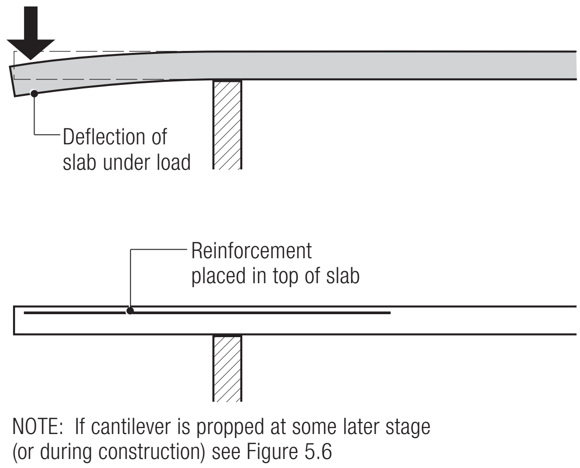


Figure 5.5 Cantilever

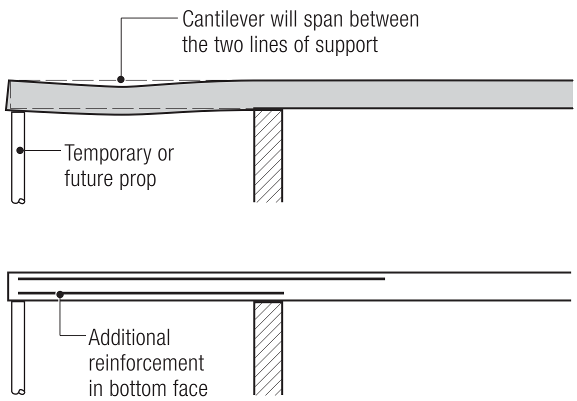


Figure 5.6 Propped cantilever

Voids

Where there is an uninhabited space or void under a suspended slab, then adequate cross ventilation will be required in accordance with the BCA.

While suspended slabs can be cast on the ground, they should generally have a minimum clearance of 400 mm to the ground below to allow air movement and access. A greater clearance will be required where access to the space is needed for the installation of services such as plumbing, or for the removal of temporary propping or formwork.

5.3 Design Procedure

As noted earlier, the BCA provides a simplified and uniform set of regulations designed to establish essential construction standards for structural adequacy, fire resistance, public health and general amenity. The technical requirements of this code refer to AS 3600 which sets the minimum requirements for the design and construction of safe, serviceable and durable concrete structures.

The design of suspended concrete floors has to comply with these documents and be verified by a suitably qualified and experienced designer, usually a structural engineer who, in some cases, may need to be registered with the Local Authority involved. The attention of the reader is drawn to the matters raised earlier in Section 3 *Responsibility for Design.*

The following list sets out the principal steps in designing a suspended concrete floor to meet the requirements of the BCA and AS 3600. While it is written for insitu floors a similar process applies for precast and composite concrete/steel decking floors.

STEP 1 Member Arrangement

Determine a feasible arrangement for the suspended concrete slabs including supporting columns, walls, beams, etc. The aim should be to arrive at a preferred option that is economical and structurally efficient. This may require preliminary design and assessment of two or more alternatives. Experience, the site constraints, the Builder's or other preferences will sometimes dictate a solution.

STEP 2 Basic Design Criteria

The following basic design criteria should then be determined (by reference to the sources indicated):

- Occupancy of the structure (BCA)
- Fire rating (BCA)
- Sound transmission (BCA)
- Exposure classification and durability requirements (AS 3600)
- Any other special design criteria that may be required (eg heavy loads)

STEP 3 Floor Slab Sizing

Determine the minimum slab thickness from Step 2 above and with the chosen concrete strength and cover using the charts provided in this document or other information available to the designer to determine the initial suspended slab thickness.

STEP 4 Floor Thickness

Select a suitable overall thickness of floor to satisfy deflection control from the guideline values. If the slab is not thick enough then the designer will need to choose a greater thickness and repeat the design processes set out below until a suitable thickness is found.

STEP 5 Determine the Permanent and Imposed Actions (AS 1170)

This includes dead and live loads as well as wind and earthquake loads where the slabs are part of the overall structural system.

STEP 6 Calculate Design Bending Moments and Shear Forces

Determine the design actions at the critical sections in accordance with the strength requirements of AS 3600 for the chosen suspended slab system.

STEP 7 Strength Design

This requires detailed analysis of the suspended concrete slabs and detailed design including calculations and—if the slab is not adequate for strength or if the flexural reinforcement or shear reinforcement is excessive—repeating the design from Step 4 until a suitable size is determined. The final calculations are usually required to be submitted to the local authority or checked and certified by others.

STEP 8 Calculate Deflection

Check the calculated deflection or the span to depth ratio using the simplified method in accordance with AS 3600 or by more sophisticated analysis or manufacture's information as appropriate. Estimate required camber if any or repeat the design from Step 4 if deflection is excessive until a satisfactory slab thickness is found.

STEP 9 Complete Detailed Design and Documentation

This will require the preparation of calculations as well as structural drawings, sketches and details. These are required to be submitted to the Local Authority for checking or to be checked and certified by others.

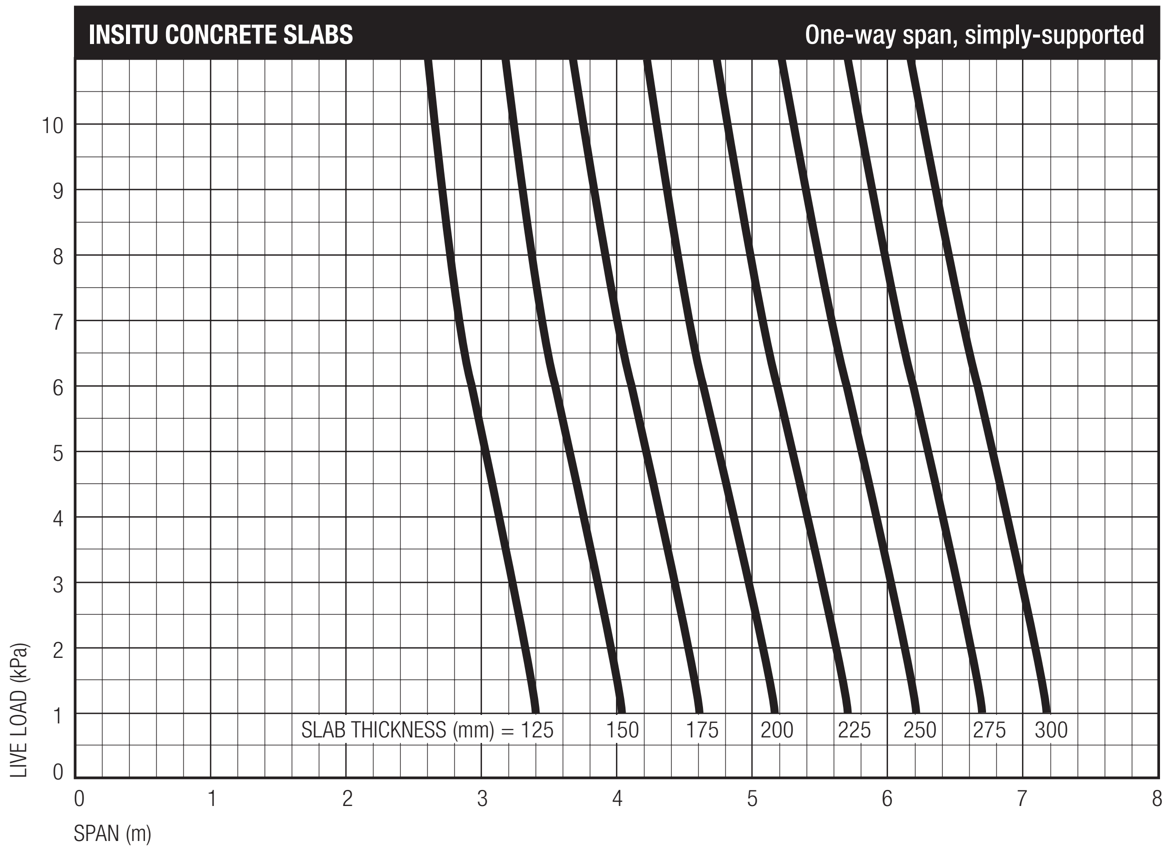


Figure 5.7 Simply-supported one-way slab

5.4 Insitu Concrete

5.4.1 General

Insitu reinforced concrete offers the flexibility of a structural material that can be cast into almost any desired shape and size.

Traditionally-formed concrete floors are cast in-place (insitu) and are not limited by site constraint, eg handling of precast floors, or architectural form. They can be designed to carry walls anywhere on their span and are not restricted by the position of walls (room layouts) in the floor below.

Of the many types of insitu floors available only two, flat plates and solid slabs, are widely used in residential buildings. Other types of insitu floors (such as band beams or post-tensioned slabs) might be appropriate in certain special situations, usually where greater structural capacity is required. Details of such floors are beyond the scope of this publication but can be found in the *Design Guide for Long-Span Concrete Floors*[15].

For preliminary design purposes, **Figures 5.7 and 5.8** provide an indication of slab thickness relative to span for a concrete strength (f'_C) of 25 MPa.

Table 5.1 Minimum times before formwork support removal (from AS 3610 Table 5.4.1)

Average ambient temperature, T, over the period (^{0}C)	Period of time before removal of all formwork supports from reinforced members (days)
T > 20	12
20 ≥ T > 12	18
12 ≥ T > 5	24

5.4.2 Typical detailing at supporting walls

The detailing of suspended concrete floor slabs is dependent on the requirements of the particular project; with reference to appropriate building regulations and Australian standards. Examples of typical construction detailing at supporting walls are shown in **Figure 5.9** for masonry walls. Similar details apply for other supporting elements.

5.4.3 Installation

Formwork

Generally, formwork supply and erection should be undertaken by a specialist subcontractor responsible to the builder. The subcontractor will be responsible for the workmanship and safety of the temporary structure, but

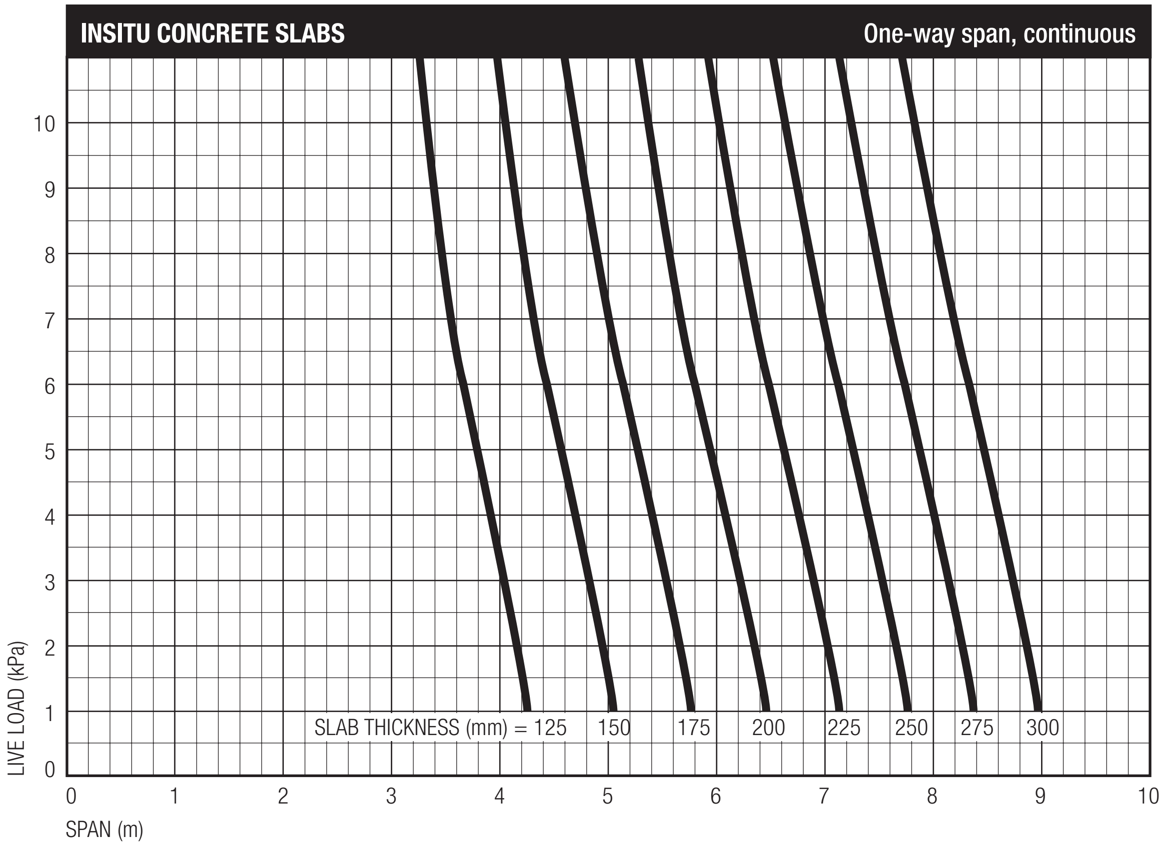


Figure 5.8 Continuous one-way slab

nonetheless the builder should ensure that his work complies with the specification, working drawings and relevant Australian standards.

The requirements for formwork are:

- Strength – to support permanent and imposed actions (dead and live loads) during steel fixing, concrete placement and subsequent early placement of building materials on the completed slab (stacking, etc).
- Stability (bracing) – to counter the eccentric loadings from concrete placement and/or lateral, wind, earthquake or impact loads.
- Grout-tightness – to prevent the loss of grout and fines from the concrete and consequently produce a surface appropriate for the specified soffit finish.

Table 5.2 Reinforcement commonly used in residential construction

Grade	Description	Usage
D500L mesh	500-MPa mesh, comprising a grid of hard-drawn wire reinforcement with longitudinal and cross wires welded together. Standard sheet size is 6.0 m (length) x 2.4 m (width). It is available in either square mesh (equal spacing of wires in both directions) or rectangular mesh.	As the top and bottom reinforcement in floor slabs SL72 is typically used.
D500N bar	500-MPa hot-rolled reinforcing bar with a deformed (ribbed) surface, available in various diameters, maximum length is 12 m.	Floor slabs; stairs, beams, columns,thickened slab sections and to reinforce openings. N12 typically used, spacing varies.
D500L bar and coil	500-MPa cold-rolled deformed bar, available in coil or bar in maximum lengths of 12 m. This grade should not be used for slab or beam reinforcement	Fitments, ie stirrups, ties and other reinforcing elements involving bends or special shapes. L8 typically used

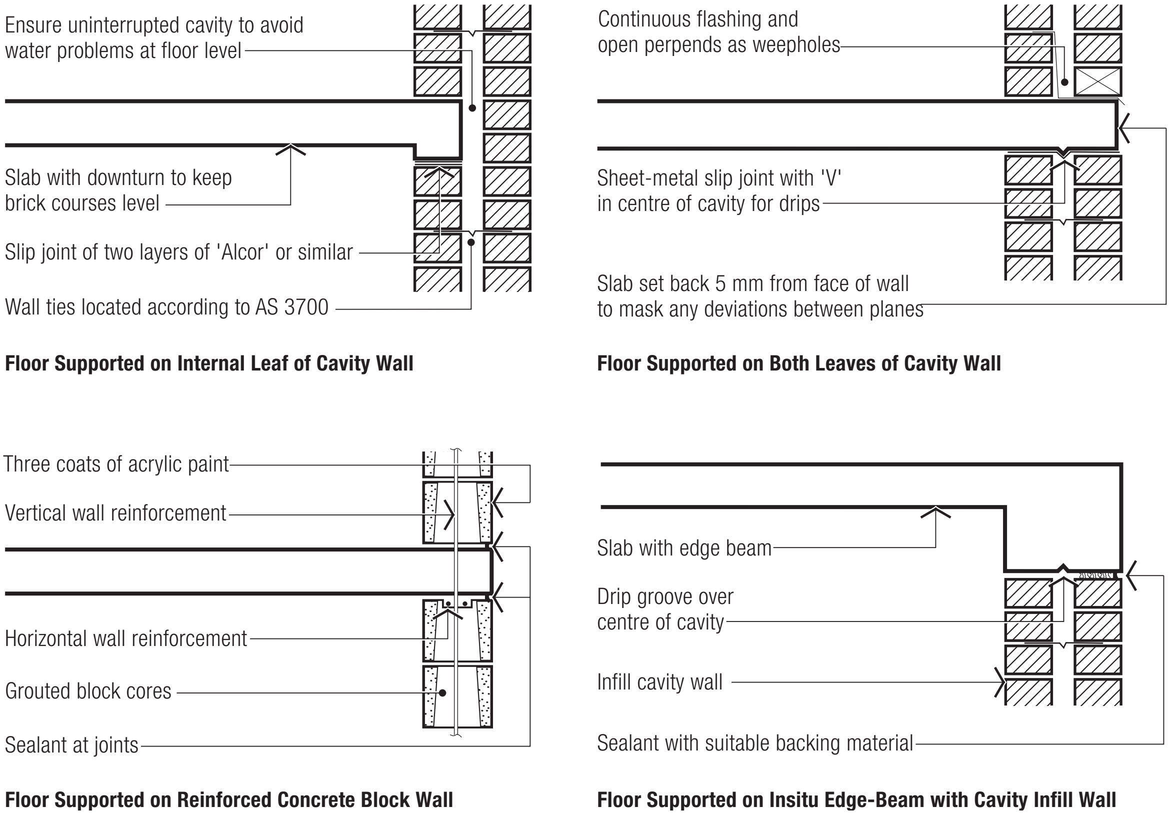


Figure 5.9 Typical detailing at walls

- Accuracy – to ensure finished floor levels and construction tolerances are achieved; formwork must accurately reflect the shape of the desired floor.

Formwork must remain in position until a significant amount of the specified strength has been achieved. The designer should advise a recommended stripping time, or make reference to AS 3610[16] and Commentary (Supplement 2)[17]. Minimum times for which formwork supports for slabs and beams not supporting structure above should remain in place are shown in **Table 5.1**.

Reinforcement

Reinforcing steel is available in Australia in a number of grades characterised by strength grade and ductility and is required to conform to AS/NZS 4671[18]. The strength grade represents the numerical value of the lower characteristic yield stress expressed in MPa. The ductility class is usually either L (Low) or N (Normal) ductility. In residential construction, three grades are commonly used as indicated in **Table 5.2**.

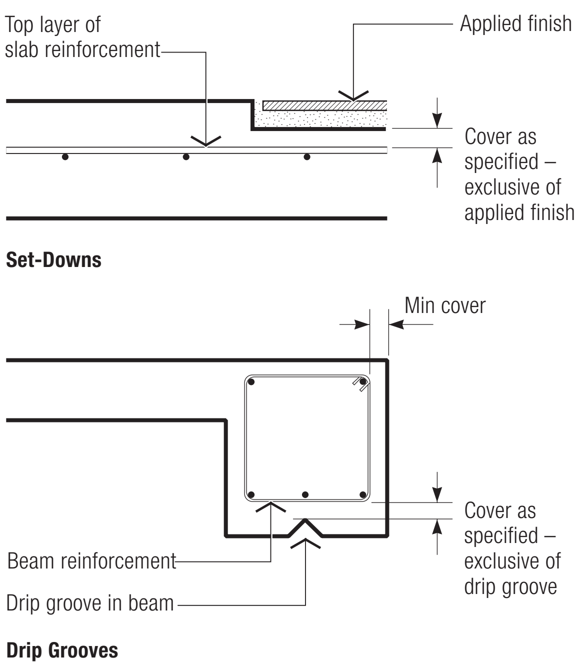


Figure 5.10 Maintaining minimum cover

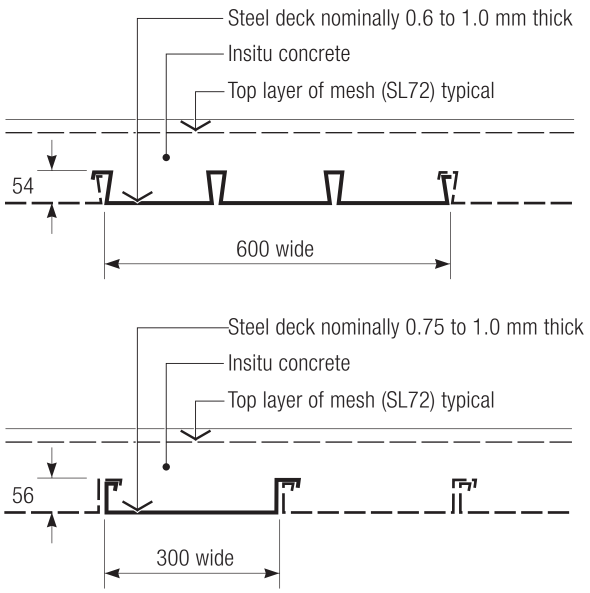


Figure 5.11 Typical profiles

Concrete cover

It is the responsibility of the designer to calculate the reinforcement required for a given project and specify the cover. The builder should ensure that the reinforcement is placed as specified, with particular attention to maintaining concrete cover in areas where set-downs and drip-grooves occur and where exposed to the weather, **Figure 5.10**.

Concrete

It is the responsibility of the designer to specify the class and strength of the concrete to be used on any given project. The specification should cover issues such as formwork accuracy, reinforcement position and cover, as well as compaction and curing.

In residential construction this concrete will almost certainly be pre-mixed and delivered to the site by a pre-mixed concrete supplier (who will need to know the method of placement).

Finishes

Finishing will be dependent upon the in-service use of the floor and the type of floor covering to be used. For ceramic tiles bedded in a mortar, the slab may be left with a screeded or broomed finish while for most other floor coverings, a mechanical trowelled finish (helicopter) is appropriate. The exception may be thin flexible coverings such as vinyl or cork tiles where a superior trowelled finish may be necessary. Also, construction joints should not be planned for areas where hard finishes such a tiles or vinyl are to be laid as small movements will occur and may damage the finishes.

5.5 Composite Concrete/Steel (Permanent Steel Formwork)

5.5.1 General

Permanent steel formwork (decking) in residential construction acts as non-recoverable formwork for insitu concrete. The decking has the advantage of providing the tensile reinforcement to the underside of the suspended floor, reducing the amount of additional reinforcement to be ordered, stored and placed by the builder.

Produced from high-tensile galvanised steel coil, it is rolled by the manufacturer to produce profiled ribs along its length. The base metal thickness (BMT), shape and size of these profiles vary with product and thicknesses of 0.6, 0.75, 0.9 and 1.00 mm are used. The sheeting has interlocking ribs. The shape and size of these profiles vary with the product. Two typical profiles are shown in **Figure 5.11**.

5.5.2 Design

Permanent steel formwork provides one-way slab action and will generally be specified by the designer to span continuously over a number of supports but single spans are common and acceptable.

Consultation with the various manufacturers is recommended to provide detailed information regarding spans, temporary propping, and thickness of insitu concrete. An indication of spanning capabilities is given in **Figures 5.12** and **5.13**. The actual design must be carried out in accordance with the particular manufacturer's design guide for the product chosen. There are some products with small triangular trusses made from reinforcing bar welded to the decking to increase the spans up to 5.5 m un-propped.

In using the charts in **Figures 5.12** and **5.13** it should be noted that:

- Propping of the composite steel formwork will be required at 2- to 3-m spacing during erection and concreting and will depend on the span and thickness of the slab. Propping must be in accordance with the manufacturer's recommendations.
- These charts have been based on 0.75-mm-thick decking in an internal environment and a concrete strength of f'_C = 25MPa and 2 or 3 rows of props.
- The charts are based on interpolated results for a particular configuration on an average of the results derived from individual design methods of the three manufacturers and smoothed to give a consistent result.
- These charts should be used only for preliminary sizing and the chosen thickness confirmed by

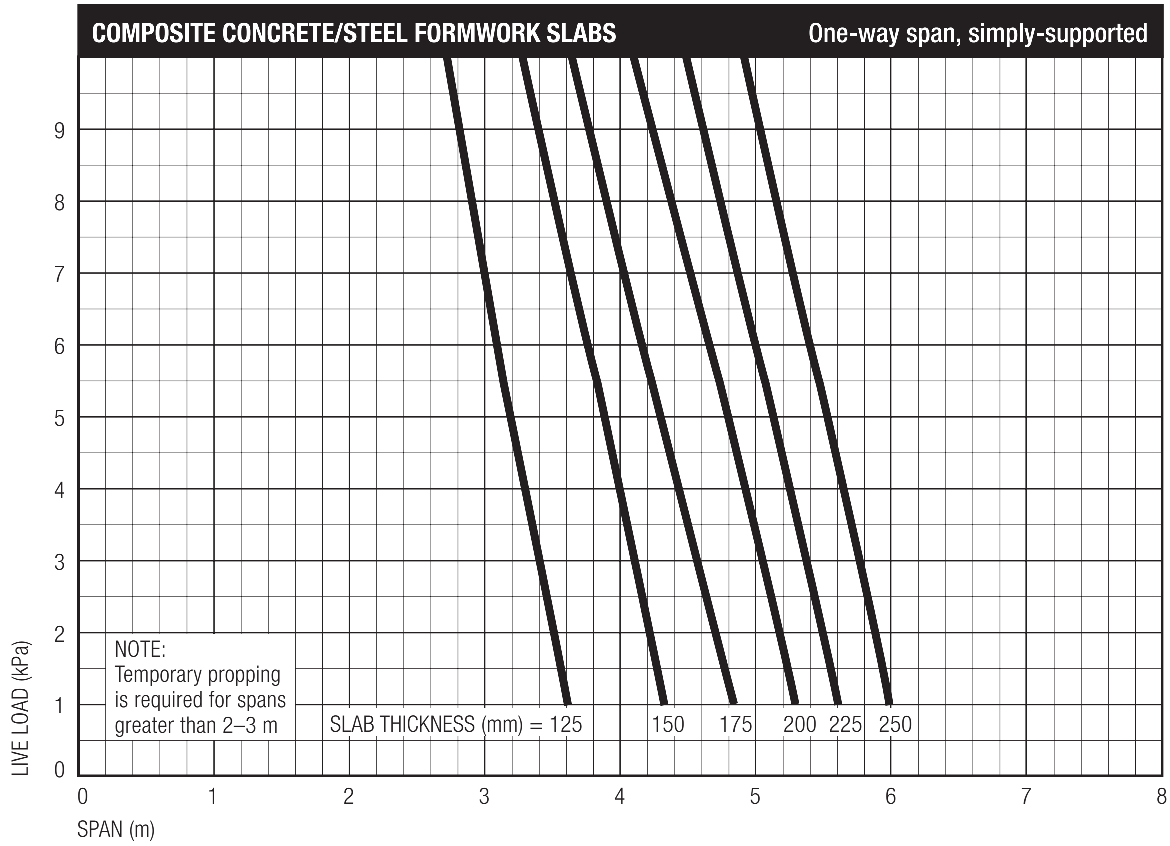


Figure 5.12 Indicative spanning capabilities – simply supported

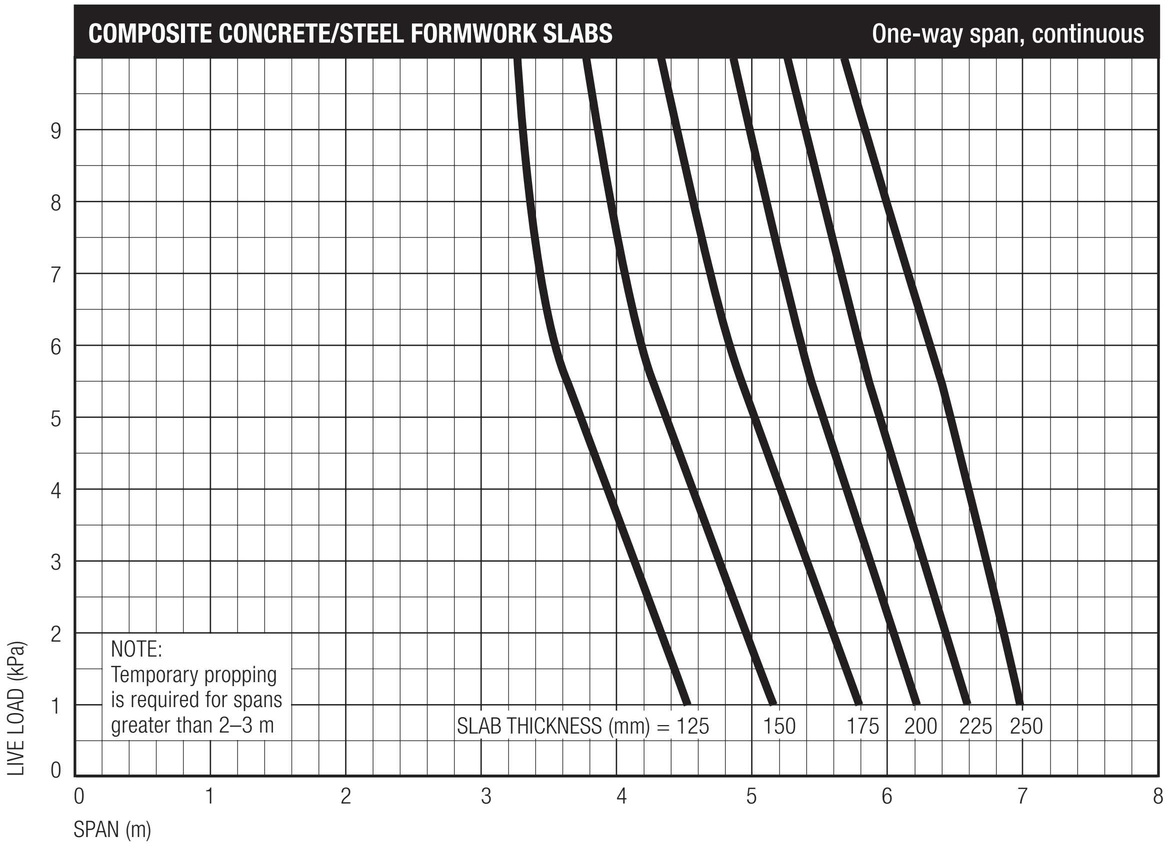


Figure 5.13 Indicative spanning capabilities – continuous

final design in accordance with the design method of the particular manufacturer.

- The thickness of slabs considered are in the range 125 to 250 mm in 25-mm steps. Although thicknesses below 125 mm may work, these will be satisfactory only where lapping of reinforcement is not required. Above 250 mm thickness, the amount of propping and reduced spans are likely to make such thickness uneconomical.

5.5.3 Installation

Installation of permanent steel formwork does not require special skills. It will arrive on site cut to the specified lengths, generally in panel widths of 300 or 600 mm, dependent on the manufacturer. Individual panels are man-handlable and need to be restrained against uplift under strong winds.

Once in place, permanent steel formwork will provide a safe working platform with uncluttered site area directly below. Temporary propping will be necessary when indicated in the manufacturer's literature or drawings and will depend on whether simple or continuous spans have been incorporated into the design. The timing for removing props should be as for formwork under insitu concrete.

Minimum bearing on the supporting structure of 50 mm to external walls and 100 mm internally is required (but not less than recommended by the manufacturer). A slip joint should be used when bearing on brickwork or masonry.

In residential construction, a slab thickness of at least 125 mm is recommended, dependent on span.

Concrete will generally be 25 MPa, normal-class with an 80-mm slump.

5.5.4 Finishes

Finishes to top surfaces are as discussed in Section 5.4.3.

For many applications (particularly where it is not visible) the underside of the steel decking will not require additional treatment. The propping will usually leave small indentation or propping marks on the bottom of the sheet. If the soffit is exposed to view and is unpainted, the marks may be visually unacceptable. In this case the soffit should be painted with a flat paint or a plaster ceiling used with timber battens directly fixed to the soffit, to which plasterboard is then applied and set.

The void created by the battens may be utilised for services. Some profiles incorporate purpose-made clips for suspension systems for support of services and ceilings.

5.5.5 Key considerations

Lead-time Permanent steel formwork is readily available and generally would require no more than seven days lead-time in metropolitan areas.

Ordering Orders may be placed with most steel reinforcement fabricators, stating the number of panels required by their specific length. Only minor variation in length due to cutting tolerances can be expected.

Delivery Permanent steel formwork will be delivered to site tied into twenty-length bundles (maximum). Depending on the size of the order, the bundles may be opened and manually off-loaded from the transport vehicle. Mechanical lifting equipment may, however, be used if available.

Permanent steel formwork may be stored on site (refer to manufacturer's recommendations) until the builder is ready for installation and may be delivered, for example, along with the project's other reinforcement requirements.

5.5.6 Availability

The proprietary names of composite concrete/steel floor systems and their manufacturers include:

Lysaght Bondek BHP Building Products (All States and Territories)

KingFlor Fielders Australia Pty Ltd (All States and Territories)

Trussdek One Steel Reinforcing Pty Ltd

Condek Stramit Corporation Ltd (All States and Territories)

All enquiries regarding the product, design, detailing and installation should be addressed to these manufacturers, from whom technical manuals are available. Their websites also provide information.

5.6 Precast Concrete – General

5.6.1 Available systems

The different systems available include:

- Hollowcore planks, either with or without a topping
- Composite flooring using precast permanent formwork panels
- Composite flooring using precast beam and infill
- Solid slabs either reinforced or prestressed
- Autoclaved Aerated Concrete (AAC)

Specific information on each of these is provided in Sections 5.7–5.11.

5.6.2 Installation

Manufacturers will deliver precast concrete panels to the builders' time schedule, thus allowing panels to be lifted from the transport and placed directly into position. A typical precast panel for a residential project can weigh up to two tonnes. As with all precast applications, good communication between supplier and contractor is necessary, as is adequate site access for crane and transport.

While AAC is a lightweight construction material, suspended floor panels will require mechanical lifting equipment. There are, however, a number of options available to the builder due to their relatively low weight. All-terrain, boom-lift forks are one option for example, where access for larger cranes may be difficult.

Where the bearing surface for the precast panels is uneven, a 1:3 cement: sand levelling-bed may be required. Bearing strips of rubber, plastic or hardboard are frequently used to provide even bearing under the full width of each panel. End bearing width varies with panel thickness and bearing material, suggested figures for concrete and masonry are given in **Table 5.3** but in no case be less than that recommended by the precast manufacturer.

Table 5.3 Minimum bearing for precast floor panels

Panel thickness or masonry (mm)	Minimum bearing on concrete (mm)
150 and 200	80
250 and 300	120

Openings and penetrations can be readily provided – larger openings, such as for stairs, by using a header panel supported on a fabricated steel member, while smaller penetrations can be cored through the panel on site, taking care to avoid the reinforcing steel.

5.6.3 Finishes

Finishes to top Finishes to the concrete topping to all precast panels other than AAC are discussed in Section 5.4.3.

Soffit finishes Soffits of planks may be left untreated or may be treated with a textured coating. Where left exposed and painted, joints between panels may be sealed using a proprietary filler strip. Because Hollowcore panels are prestressed flat units they have a tendency to deflect upwards which may be discernable when viewed against the line of a spandrel beam or as a differential camber between adjacent units. The most suitable finish will often be directly fixed timber battens packed as required and plasterboard ceiling. Services may be carried in the void created by the battens.

5.6.4 Key considerations

Early contact At the preliminary design stage contact should be made with the precast manufacturer who will prepare a schematic proposal showing panel layout, configuration and price, providing the builder with an accurate basis for tendering. Advice on other design considerations – such as positioning of supporting walls – may be offered.

Site access In residential construction, most manufacturers will supply and erect their product. Consideration should, however, be given to cranage with particular attention to:

- Site access and topography – method of access, noting position of overhead power lines and trees.
- Site layout – to provide optimum positioning of crane and transport vehicle. As cranage is more dependent on reach than tonnage, site sheds and stockpiles should be positioned accordingly.

Erection programming When precast is delivered, bearings should have already been prepared and props (if required) should be in position.

Site activity Site activity should be programmed to coincide with the delivery and erection of precast concrete. Deliveries of other materials such as masonry and sand should be avoided at this time.

5.7 Hollowcore

5.7.1 General description

Hollowcore floor planks are precast, prestressed units produced on long-line casting beds using slide-forming (extrusion) methods. During manufacture, cores are formed throughout the unit, reducing its self-weight. Planks are usually 1200 mm wide, though some manufacturers can produce 2400-mm-wide units. These wider units may require increased crane capacity but offer greater speed of placement, less joints, grouting and sealing. Planks are identified as shown in **Figure 5.14**.

Thicknesses vary from 150 to 400 mm, in 50-mm increments, the thickness being determined by span, loading, fire rating and cover to reinforcement to satisfy exposure conditions. For residential work, planks typically in the range of 150 to 300 mm thick would normally be used. As a general rule, simply-supported floors should be limited to a span-to-depth ratio of less

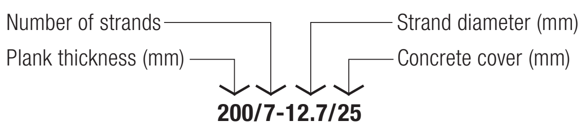


Figure 5.14 Hollowcore plank identification

than 35:1. Instances where slenderness ratios fall between 35:1 and 45:1 should be checked for vibration-resonance effects. Spans exceeding 45:1 should not be used.

The panels provide one-way slab action and require support by loadbearing walls or beams at each end only. In residential construction this will offer the builder flexibility of wall type, layout and finish for any walls specified as non-loadbearing.

Design charts in **Figures 5.15** and **5.16** are generic for preliminary sizing, actual capacities should be obtained from the manufacturer.

Planks may be used as plain sections or topped to give a composite unit. The topping increases plank capacity and fire rating. It provides a level surface or drainage falls and is recommended for residential work.

Hollowcore floor planks are ideal for single or multi-storey residential buildings, satisfying requirements for span, fire rating, sound transmission class, exposure and durability, while attaining significantly reduced construction times.

Comprehensive information on hollowcore is provided in a manual published by the NPCAA[19].

5.7.2 Component details

Precast prestressed hollowcore floor planks For economy, the structure should be dimensioned to accommodate the 1.2- or 2.4-m modular plank width. If this is not possible, planks can be sawn longitudinally by the manufacturer, or partial-widths wet cast. Planks can be supplied with block-outs and cored holes to suit openings, services, etc.

The permitted core-hole shape and number in a plank will vary with the depth and the particular proprietary forming machine. Profiled edges form shear keys between units.

Concrete used in the planks is typically special-class concrete, strength grade S40. Prestressing strand varies in diameter and number, but is typically 9.3- and 12.7-mm diameter. Planks may be left plain, given a self-levelling screed or topped with concrete after erection.

Fire rating is a function of the effective concrete thickness and the concrete cover to strand. Fire rating can be increased by the addition of a concrete topping and cover increased by application of insulating material to the soffit. In practice, however, all planks with usual topping thicknesses (except 150-mm-thick plank at 240 minutes FRP) meet fire-rating requirements.

Topping concrete The usual strength grade for topping concrete is N32. For all toppings, whether composite or to level the top surface, the plank surface should be wetted just prior to placing the insitu concrete but without pooled water. After placing and finishing the topping, standard curing practice should be followed.

Shrinkage-control reinforcement should be provided in the topping to control cracking. It should be noted that a crack of visible size usually develops at the joint between planks due to the change in section. Location of contraction joints at plank supports will be determined by the overall structure and are usually at every third or fourth support in longer structures.

Structural-continuity reinforcement may be required in both longitudinal and transverse directions. This may be placed in the topping concrete and/or the shear keys.

Shear keys These should be grouted with a 3:1 mortar mix thoroughly compacted to remove all air. Alternatively, they may be filled concurrently with the topping concrete, using a 12-mm or less aggregate.

5.7.3 Availability

The manufacturers and suppliers of hollowcore include:

Delta Corporation Ltd (WA)

Hollow Core Concrete (Vic)

Rescrete Industries Pty Ltd (NSW)

Westkon Precast Concrete Pty Ltd (Vic)

5.8 Composite Flooring – Precast Permanent Formwork

5.8.1 General

The system, known by several names depending on the manufacturer incorporates precast concrete slabs, usually 55-mm thick, with embedded reinforcement and trusses. To complete the floor, an insitu concrete topping acts compositely with the precast panels. A typical arrangement is shown in **Figure 5.17**, while a more-detailed section is shown in **Figure 5.18**. Based on the data in the latter, **Figure 5.19** provides a preliminary design chart for these floors.

The bottom reinforcement embedded in the precast panel may consist of a layer of mesh, the bottom

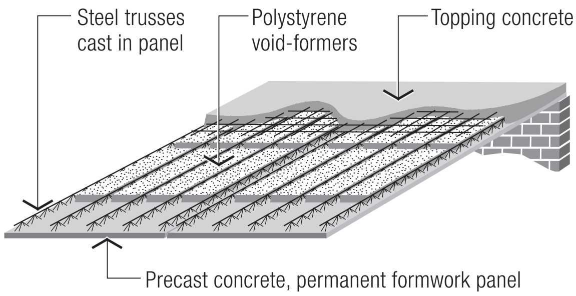


Figure 5.17 Typical permanent formwork arrangement

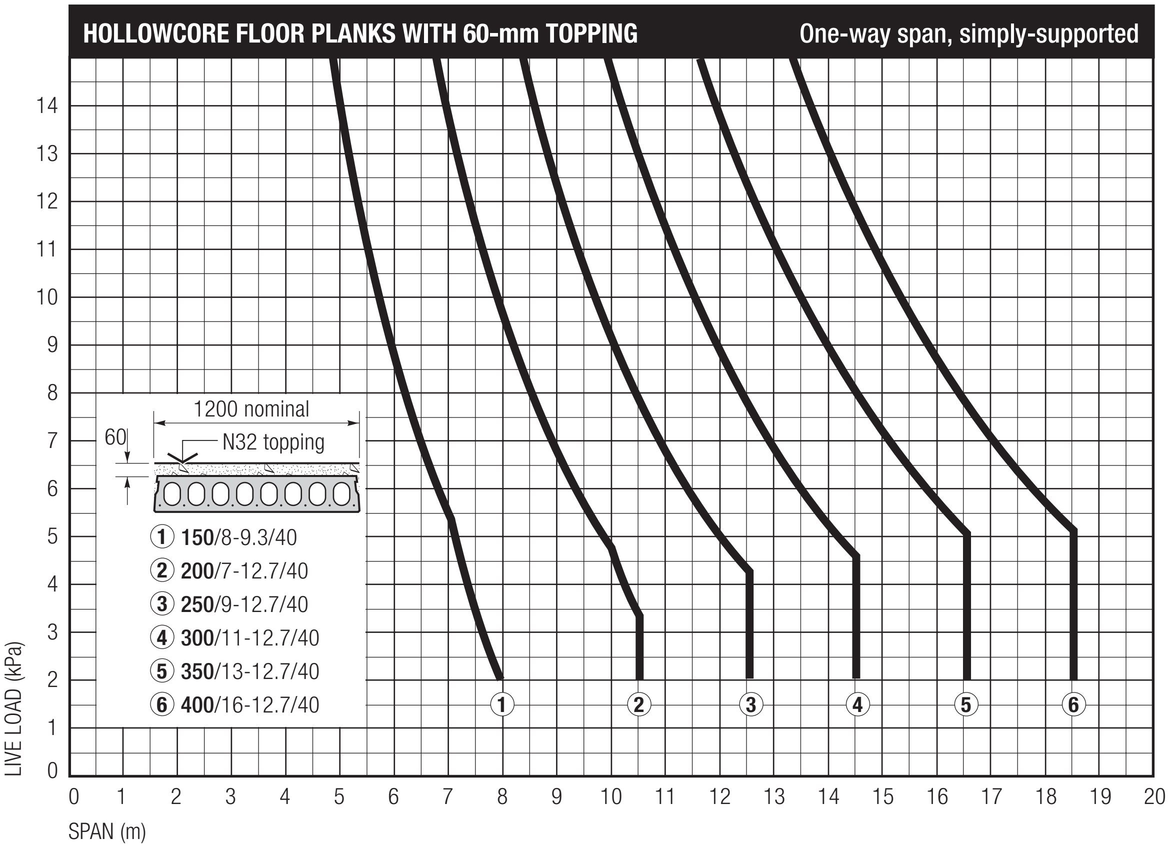


Figure 5.15 Floor planks with 60-mm topping

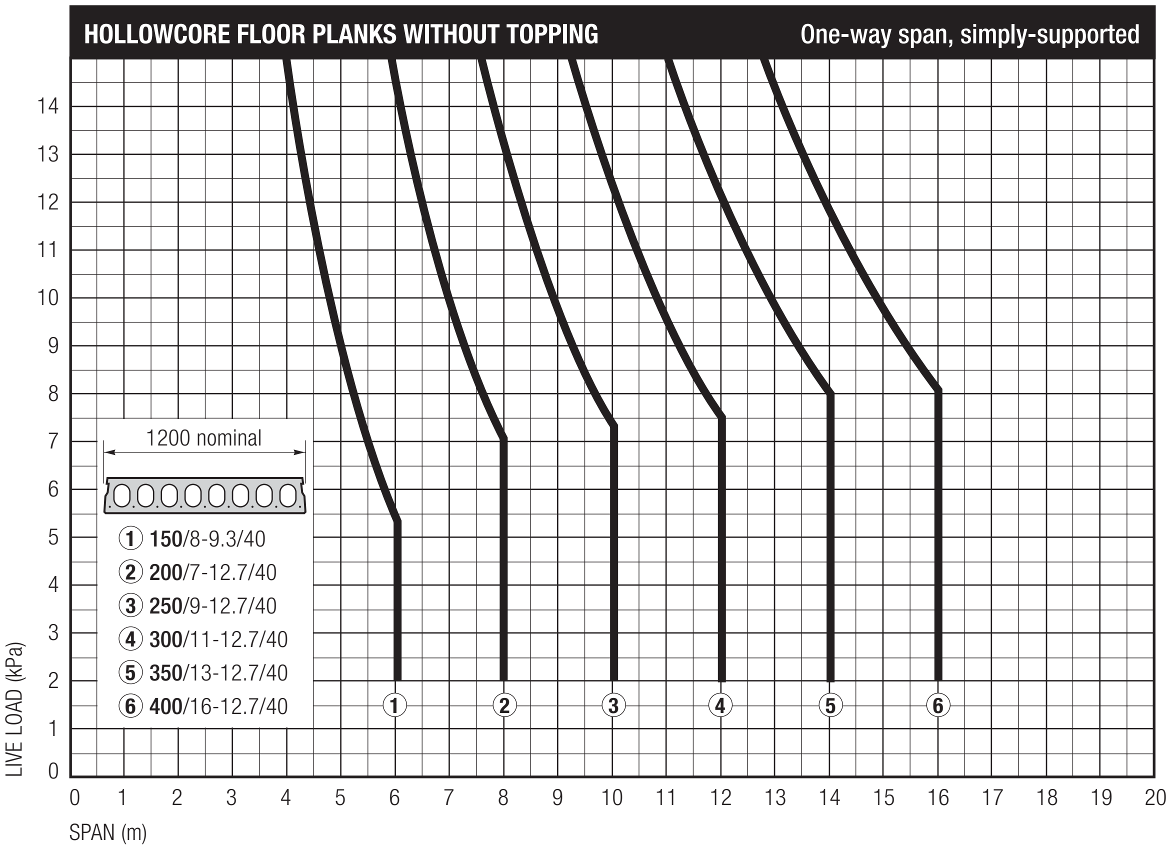


Figure 5.16 Floor planks without topping

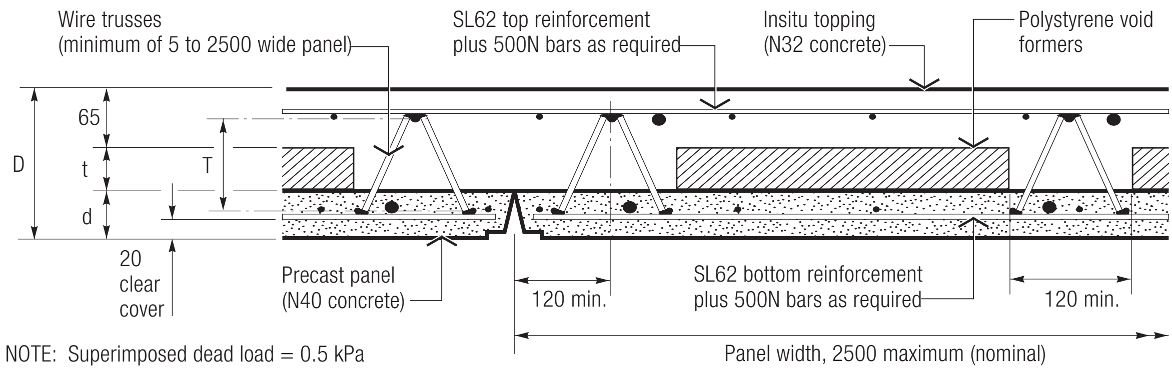


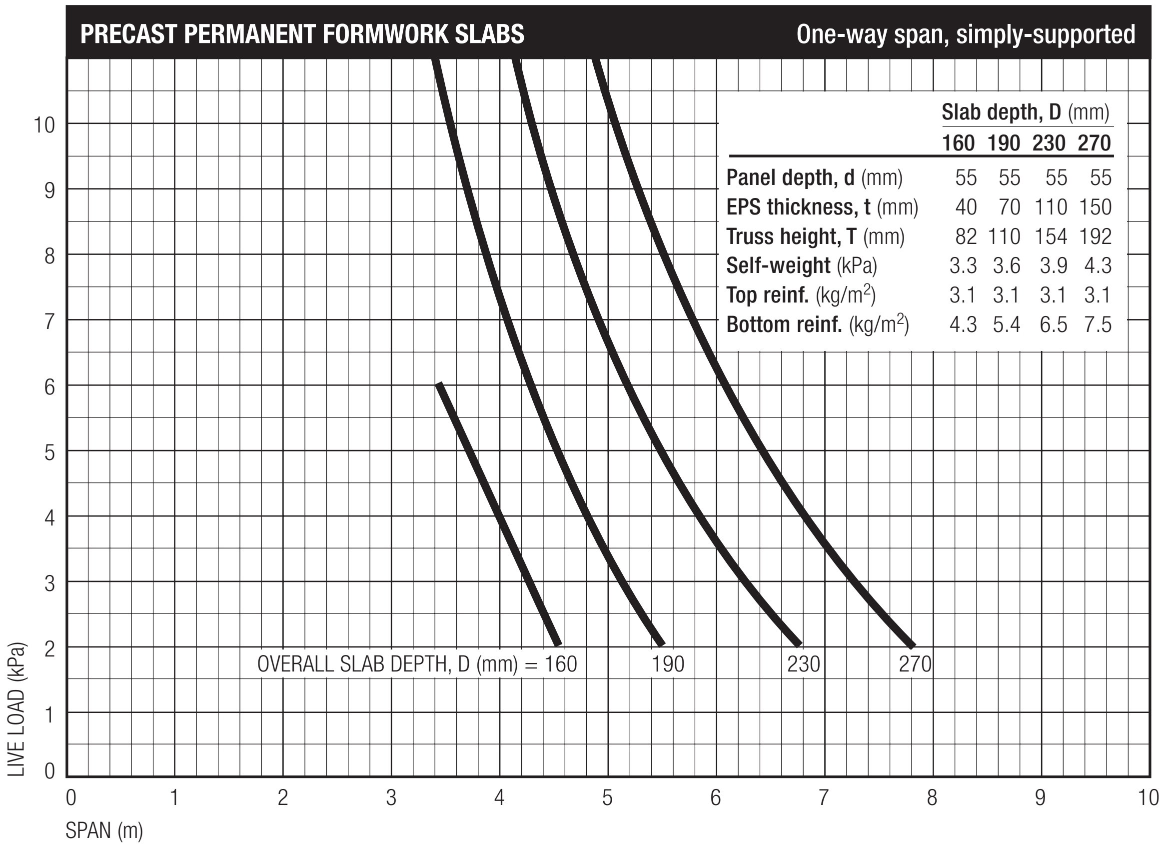
Figure 5.18 Typical permanent formwork cross section

chords of the trusses and additional reinforcing bars as required by the designer. The trusses provide strength and stiffness for handling and transport, allow panels to support construction loads with a minimum of temporary propping, contribute to the top and bottom reinforcement, and act as bar chairs to support the top reinforcement.

Polystyrene void-formers can be bonded to the top surface of the panel between the trusses in place of the insitu concrete, resulting in a significant reduction in the self weight of the finished slab and a reduction in the amount of insitu concrete required.

Since the product is cast in a steel mould using wet-mix technology, considerable flexibility of plan shape is possible and openings for stairs and major services may be cast-in. Small penetrations for electric wiring and plumbing can be cut on site. Keyways may be cut into the polystyrene for service runs.

The system imposes few restrictions on designers because there are no standard panel sizes. The length,



	Slab depth, D (mm)			
	160	190	230	270
Panel depth, d (mm)	55	55	55	55
EPS thickness, t (mm)	40	70	110	150
Truss height, T (mm)	82	110	154	192
Self-weight (kPa)	3.3	3.6	3.9	4.3
Top reinf. (kg/m^2)	3.1	3.1	3.1	3.1
Bottom reinf. (kg/m^2)	4.3	5.4	6.5	7.5

Figure 5.19 Simply supported spans

width, thickness, plan geometry and reinforcement can be varied to suit the design requirements. The only restriction is transport limitations that generally limit maximum width to 2.5 m and maximum length to about 12 m. Special lifting frames are required for units over 8- m long.

5.8.2 Component details

Reinforcement Trusses are fabricated from grade D500L, hard-drawn wire. The diagonal wires of the truss are electrically welded to both top and bottom chords. All mesh used in panels is welded wire mesh, grade D500L and all bar reinforcement is grade D500N, each conforming to AS/NZS 4671.

Panel concrete The panel concrete is normal-class concrete. A typical concrete being: minimum strength grade, N40; maximum slump, 80 mm; maximum size aggregate, 14 mm (nominal); cement, General Purpose.

Polystyrene void formers The normal expanded polystyrene (EPS) void formers are made of a lightweight cellular plastic material comprising 98% air. Alternatively, a class SL material can be used having a density of 13.5 kg/m^3. All other physical properties of the EPS are in accordance with AS 1366.3[20].

Topping concrete It is essential that the site-placed insitu concrete is of a high quality and that placement and curing is of a satisfactory standard. Insitu concrete thickness over void formers will be governed by cover as well as quantity, size and laps of top reinforcement. A minimum thickness of 65 mm should be used.

5.8.3 Availability

The proprietary names of precast permanent formwork and their manufacturers/suppliers include:

Alice Precast (NT)

Bennetts Construction (TAS)

Cambar Precast (VIC)

Humeslab CSR Humes (QLD)

Fabcon Pty Ltd (VIC)

Rescrete Industries (NSW)

Transfloor Smorgon ARC (Licensor of *Transfloor* system)

All enquiries regarding the product, design, detailing and installation should be addressed to these suppliers, from whom technical manuals are available.

5.9 Composite Flooring – Beam and Infill

5.9.1 General

The system comprises precast, prestressed concrete inverted T-beams, spaced apart and with an infill material spanning between the flanges of the beams. This assembly provides the strength to support the weight of the (subsequently placed) insitu concrete topping. After the insitu concrete hardens, its compressive strength acts compositely with the tensile strength of the precast beams to efficiently carry the design loading on the floor. A typical arrangement is shown in **Figure 5.20**, while a more-detailed section is shown in **Figure 5.21**. Based on the data in the latter, **Figures 5.22** and **5.23** provide preliminary design charts for these floors.

In longer spans where the load of the fresh concrete would be critical, a row of temporary props can be placed under the centre of the beams during concreting. These remain in place for approximately three days until the prestressed beams are able to act compositely with the insitu concrete topping.

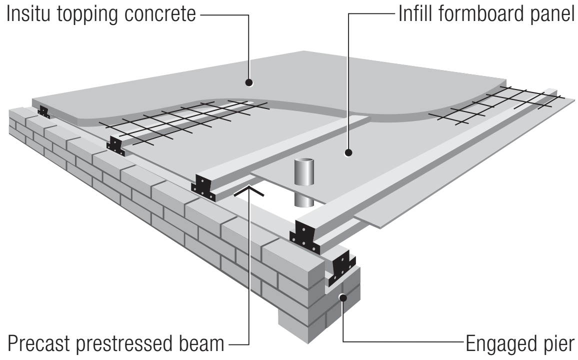
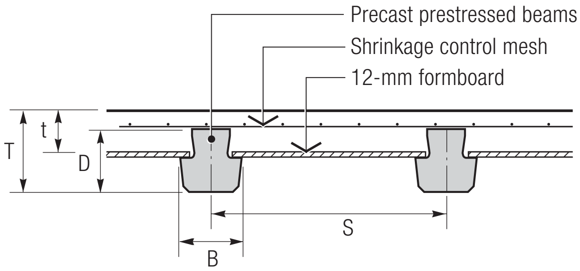


Figure 5.20 Typical composite flooring arrangement



Beam	D (mm)	B (mm)	T (mm)	t (mm)	S (mm)	Selfweight (kPa)
130R	130	130	180	98	480	2.79
150R	150	130	200	88	480	2.98
130C	130	190	180	98	540	2.90
150C	150	250	200	88	600	3.34
200C	200	250	250	88	600	3.71
250C	250	250	300	138	600	4.89

Figure 5.21 Typical composite flooring section properties

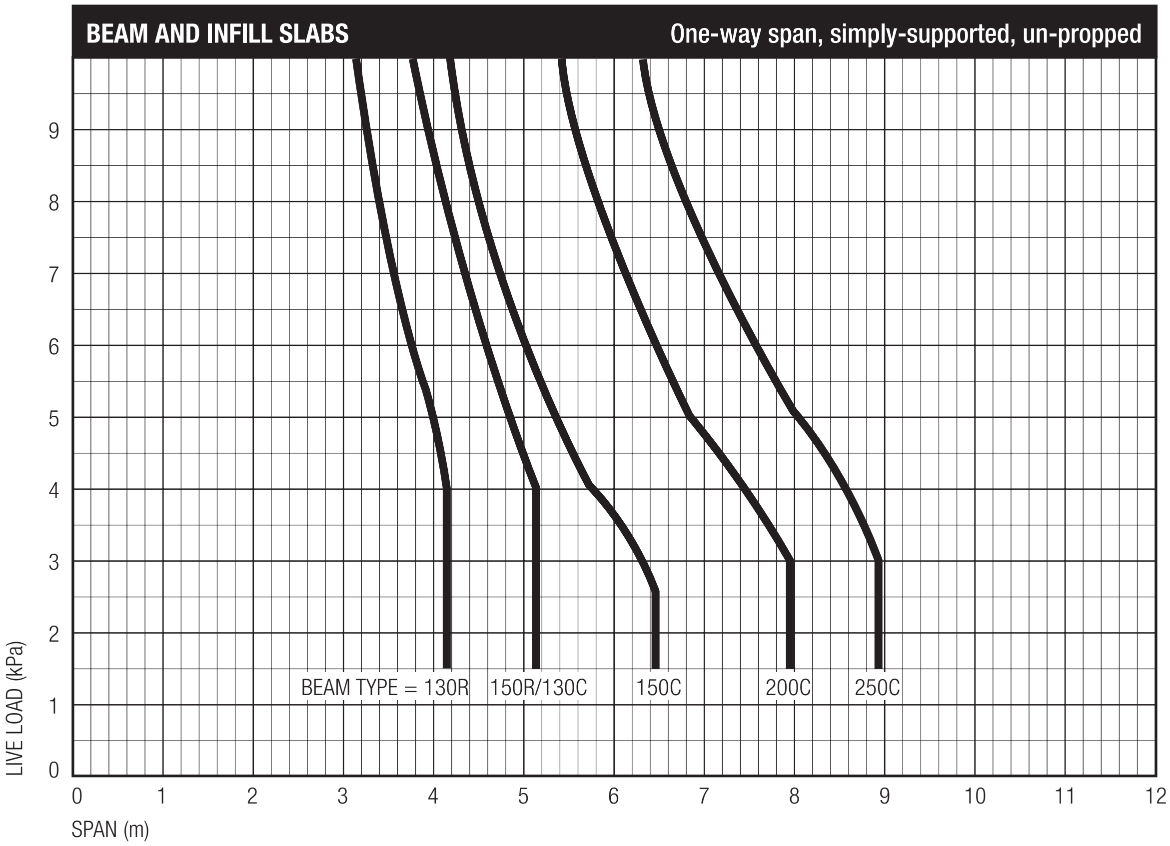


Figure 5.22 Load case 1 – Un-propped/simply supported

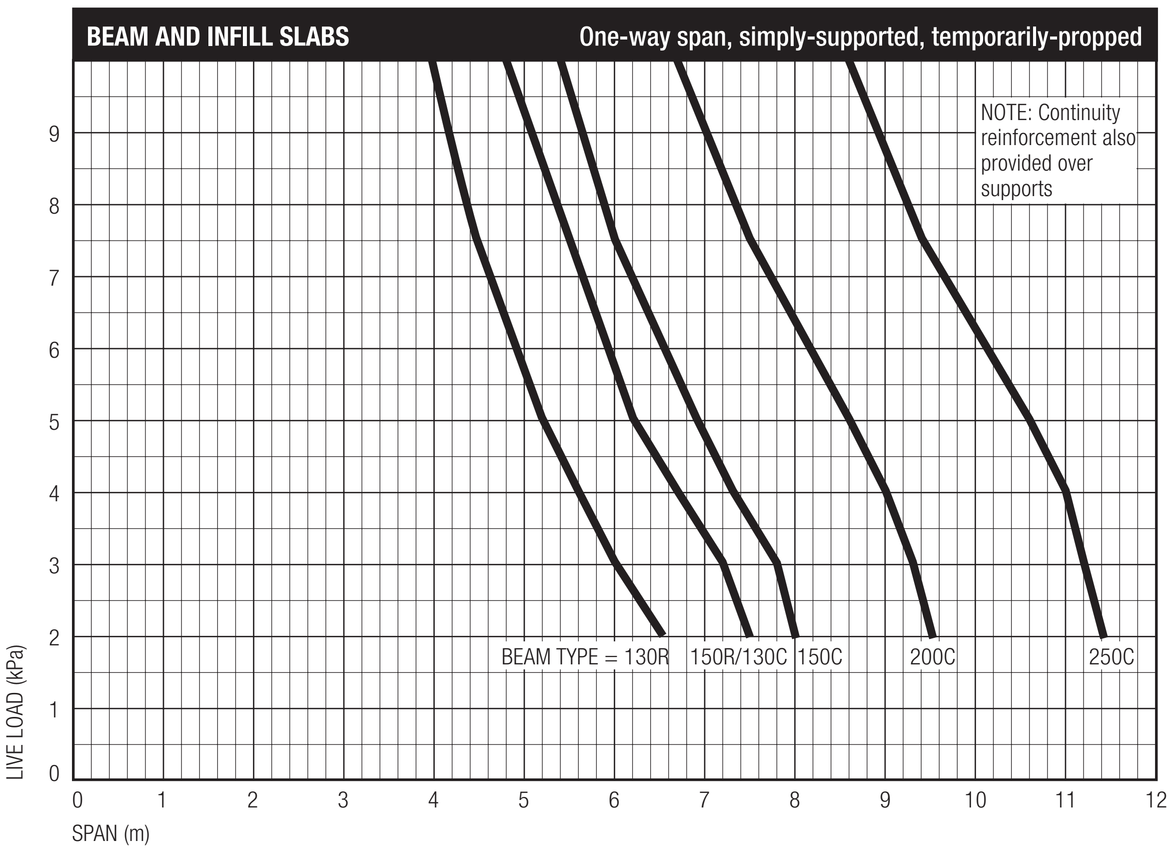


Figure 5.23 Load case 2 – Temporarily-propped with continuity reinforcement

This system has wide application in residential buildings. In addition to offering the well-established advantages of precast flooring, it has a number of further benefits, including ready accommodation of site tolerances and service penetrations (with adjustment of beam positions) and enhanced acoustic performance with appropriate detailing.

5.9.2 Component details

Precast prestressed beams There are two standard beam types, designated 'R' and 'C', with a variety of depths (see **Figure 5.21**). The 'R' series are for normal domestic and similar loadings, while the 'C' series are for heavier loads or longer spans.

The system has been tested in accordance with AS 1530.4[21] and can be used in applications that require a Fire Resistance Level of up to 120/120/120.

Infill sheeting Typically, a purpose-made fibre-cement form board product is used, although other alternatives may be considered.

Topping concrete It is important to use a high-quality concrete for topping as well as best placing and curing practices. A typical topping concrete is normal-class concrete, strength grade N32. Shrinkage control reinforcement in the form of mesh should also be provided.

5.9.3 Availability

The manufacturers/suppliers of beam-and-infill composite flooring include:

Ultrafloor Pty Ltd (NSW, Qld and Vic)

Ultrafloor and Precast Technologies (WA)

All enquiries regarding the product, design, detailing and installation should be addressed to the supplier, from whom technical manuals are available.

5.10 Precast Solid Slabs

5.10.1 General

Solid precast prestressed floor planks are wet-cast on long-line beds in unit moulds or by hollowcore equipment using slipform (extrusion) methods. The hollowcore equipment will set the width dimension usually at 1200 mm. A convenient module to suit the building layout may be selected when using unit moulds. The cross-section has similar shear key details to hollowcore planks. Thickness is also the same as hollowcore, usually 150, 200 and 250 mm. Units over 250 mm deep are likely to be too heavy for normal building purposes.

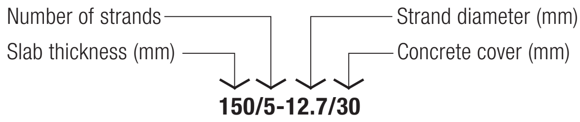


Figure 5.24 Precast solid slab identification

They are chosen in preference to hollowcore planks where:

- the loading results in high shear or there are heavy point loads; the environment is aggressive, eg in splash zones or where condensation may occur over water;
- high cover or special concrete is required;
- projecting reinforcement requires the units to be wet-cast, eg when used as a soffit beam to support hollowcore planks;
- the required width or depth module is not available in hollowcore planks.

Slabs are identified as shown in **Figure 5.24**.

5.10.2 Component details

Prestressed units will develop hog, with inevitably some differential between adjacent units. Where this is a concern, an insitu topping can be used to provide a level floor (usually normal-class N32 concrete). A grouted shear key detail is required between planks to transfer local loads to adjacent units. Typically, 50% of local loading on a plank is transferred to adjacent units through the shear keys.

Untopped units require grouted joints for fire integrity, sound insulation and to prevent long-term differential movement between adjacent planks. Topped units are not grouted separately, the width of the joint is selected to allow filling during the topping operation.

The length of support at the end of the plank will be dictated by circumstances. A bearing length of 80 mm is a normal minimum and, preferably, the length should be half the depth of the precast section. Plank lengths of less than 3 m may not develop the tensile capacity of the prestressing strand due to bond limitations. The critical section for shear usually occurs in the transmission zone of the strand.

The slenderness should not exceed an L/D of 45. This may need to be limited to 30 to 35 for applications that are sensitive to vibration.

In addition to service requirements, construction load conditions should be checked. These should include: live load on the precast unit; the topping weight plus live load on the precast section prior to developing composite action; and, stacked materials on both the precast and composite sections if this is likely to occur.

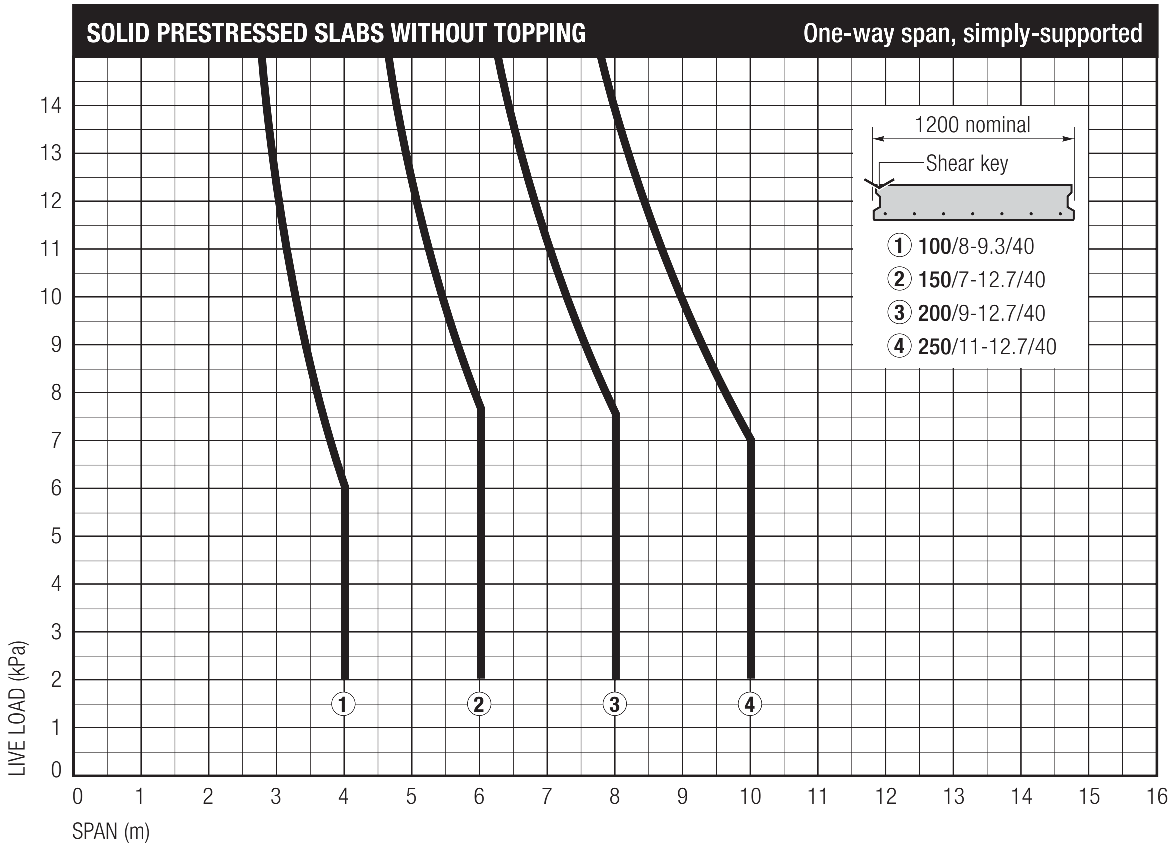


Figure 5.25 Solid slabs without topping

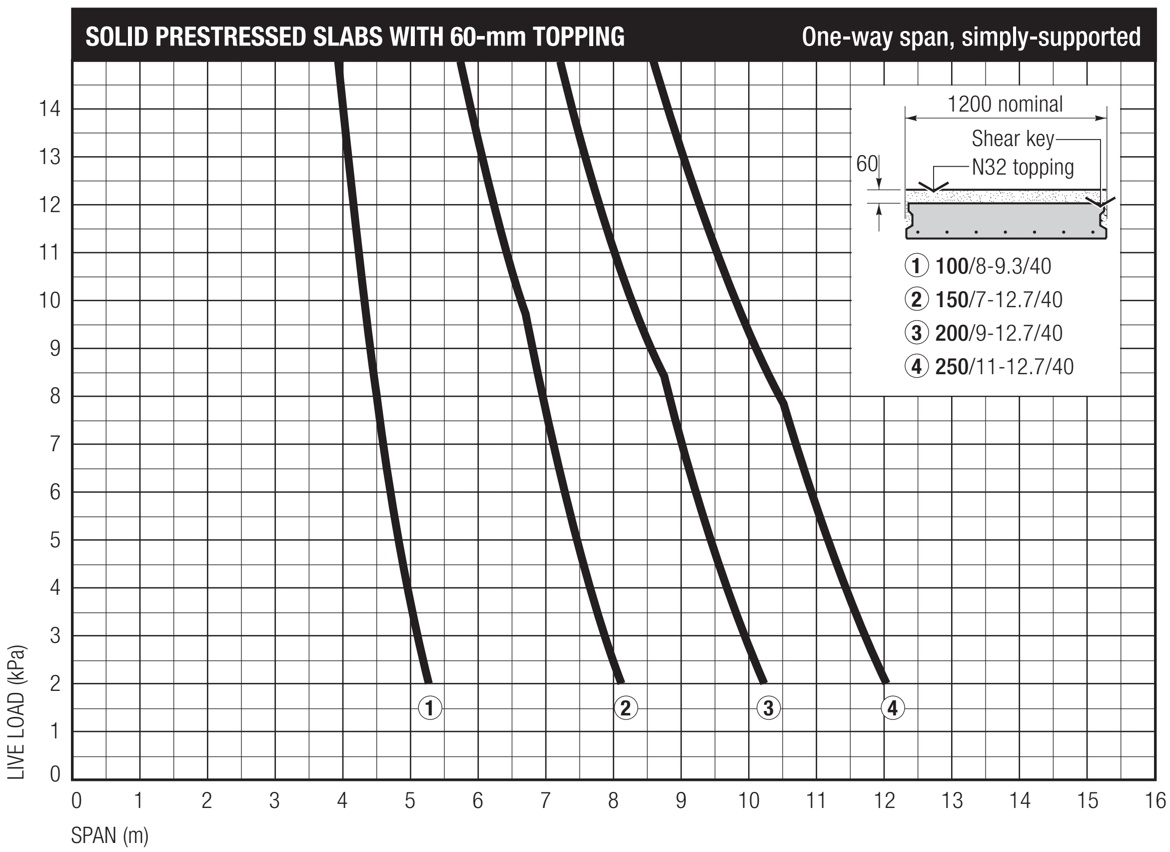


Figure 5.26 Solid slabs with 60-mm topping

5.10.3 Preliminary design

Preliminary design charts for slabs without and with topping are provided in **Figures 5.25** and **5.26** respectively.

5.10.4 Availability

The manufacturers/suppliers of precast solid slabs include:

Delta Corporation Ltd (WA)

Hollow Core Concrete (Vic)

Precast Concrete (Qld)

Rescrete Industries Pty Ltd (NSW)

Structural Concrete Industries (NSW)

Tilt-Tec Precast & Construction Pty Ltd (Qld)

Westkon Precast Concrete Pty Ltd (Vic)

5.11 Autoclaved Aerated Concrete (AAC)

5.11.1 General

AAC is manufactured from sand, lime and cement, to which is added a gas-forming agent (an aluminium paste). After mixing, the cement slurry is poured into a mould into which steel reinforcment has been placed for floor panels. The aluminium paste reacts with the alkaline elements in the cement and forms hydrogen gas. The liberated gas expands the mixture, forming extremely small, finely-dispersed air spaces. The product is removed from the moulds after setting and cut to size. The final curing of the product takes up to 12 hours under steam pressure in an autoclave.

AAC panels are suitable for floors, walls and roofs in domestic construction. They can be supplied in different lengths, thicknesses, widths and load-carrying capabilities. The thickness of slab should be in accordance with the designer's calculations taking into account the required span, load and deflection limit. AAC is fully workable using standard woodworking tools.

5.11.2 Component details

Panel sizes The panel configurations for floors are 600 mm maximum in width and 100- to 250-mm deep with a maximum span of 6 m depending on the thickness and load. AAC panels are about one-quarter the density of normal concrete. A typical section is shown in **Figure 5.27**.

Reinforcement After the panels are laid, reinforcing bars are placed between the panels in the recess and around the perimeter of the floor to form the ring anchor system in accordance with the manufacturer's specifications. The bars should be supported on chairs or equivalent to allow proper placing of concrete or mortar. Panels may require propping before placing the ring anchor system when subject to temporary dead load variations.

Joints The joints and ring anchor sections should be wetted, filled with minimum 15-MPa concrete or approved mortar (max slump 200 mm) and rodded. The concrete should completely cover the reinforcement. When placed accurately—and the ring anchors are poured carefully and screeded properly—the surface is level and smooth.

External use When AAC panels are used in external floor areas such as patios or balconies, it is important to use an approved waterproofing membrane.

Cutting Panels should not be cut on site unless they are identified as cuttable, either on the panel or the drawing. They should be ordered from the factory at the desired length. This is to ensure that the corrosion protection properties of the product are maintained. AAC panels are supplied ready to place. They can be simply and easily laid into position with only the joints needing to be filled. Installation is therefore largely dry and generally no formwork or bracing is necessary. The reinforcement in the panels is custom designed for each project by the manufacturer.

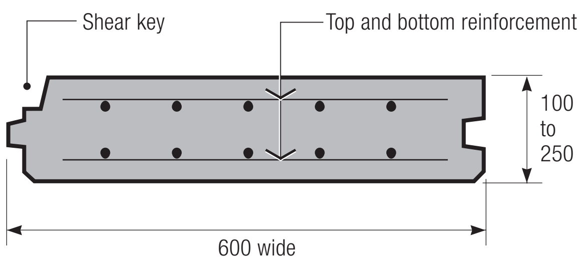


Figure 5.27 Typical AAC cross section

5.11.3 Reinforced panels – load span tables

Floor panels allow for long-term deflection of span/250.

The recommended maximum spans and thicknesses for AAC panels are given in the chart in **Figure 5.28** using working loads. These tables are for guidance purposes only. The fire resistance level of the panel should be specified at the time of ordering. For detailed design information, the manufacturer should be consulted.

5.11.4 Installation

On arrival at site, the panels may be lifted by crane directly into position. They should be placed noting minimum recommended end bearings and positioned to allow the installation of the ring-anchor system.

The minimum end bearing is typically 50 mm on concrete, 70 mm on masonry – or 1/80th of the span, whichever is greater.

The ring-anchor is an insitu ring-beam formed over loadbearing supports and acts as a perimeter tie to each section of suspended floor panels.

To transfer shear forces from panel to panel, the longitudinal panel edges have a key detail similar to a tongue and groove. This is reinforced and grouted simultaneously with the ring-anchor, creating a monolithic, fully tied suspended floor.

Grouting and positioning of reinforcement should be done by the builder to the specification of the designer.

Typical construction details for these floors are shown in **Figure 5.29**.

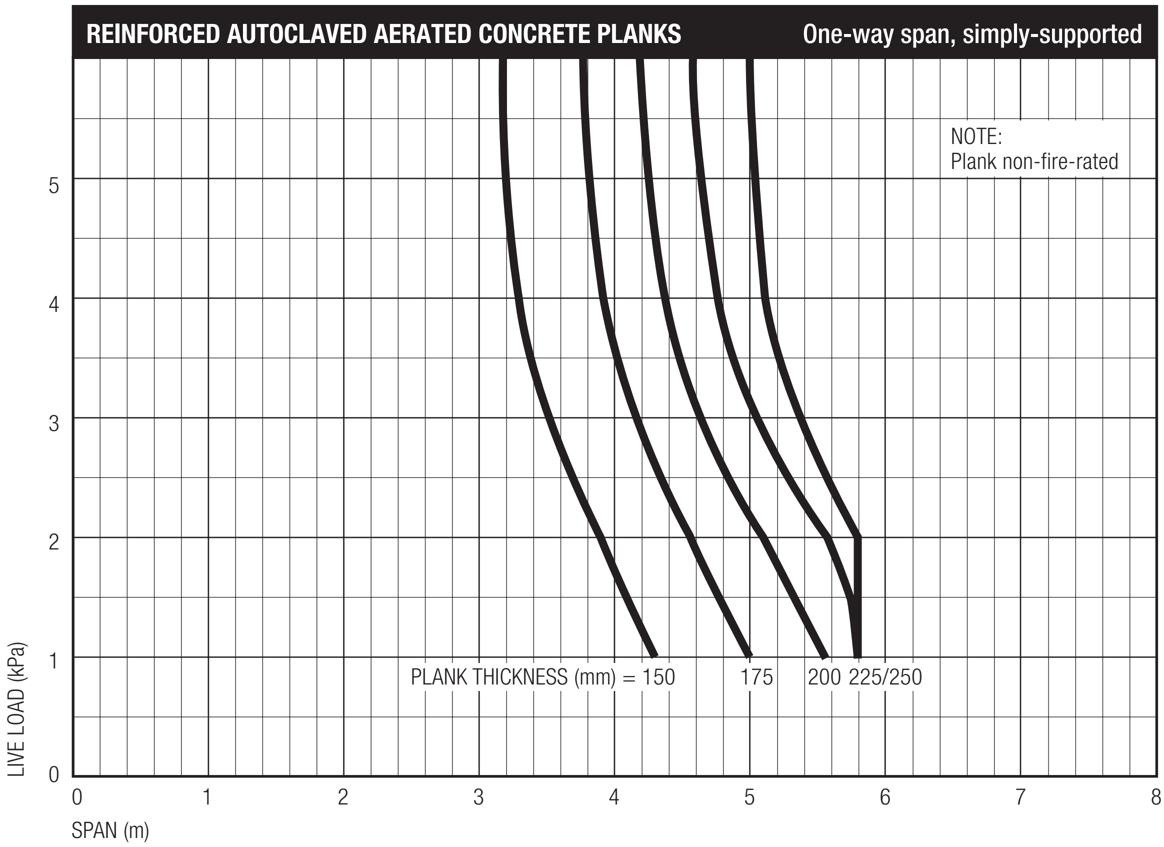


Figure 5.28 Reinforced panels – Load-span tables

5.11.5 Finishes

Generally, no toppings are required due to the dimensional accuracy of the panels. However, this will depend on the quality of the bearing surface and in some cases, the specified floor finish. Proprietary self-levelling compounds are available if required.

Ceiling linings such as plasterboard may be adhesive-fixed to the underside of the panels, with services being concealed within the top of the joints between panels.

5.11.6 Availability

The manufacturers/suppliers of AAC include:

CSR Hebel (NSW, Qld, Vic, SA)

All enquiries regarding the product, design, detailing and installation should be addressed to the manufacturers, from whom technical manuals are available.

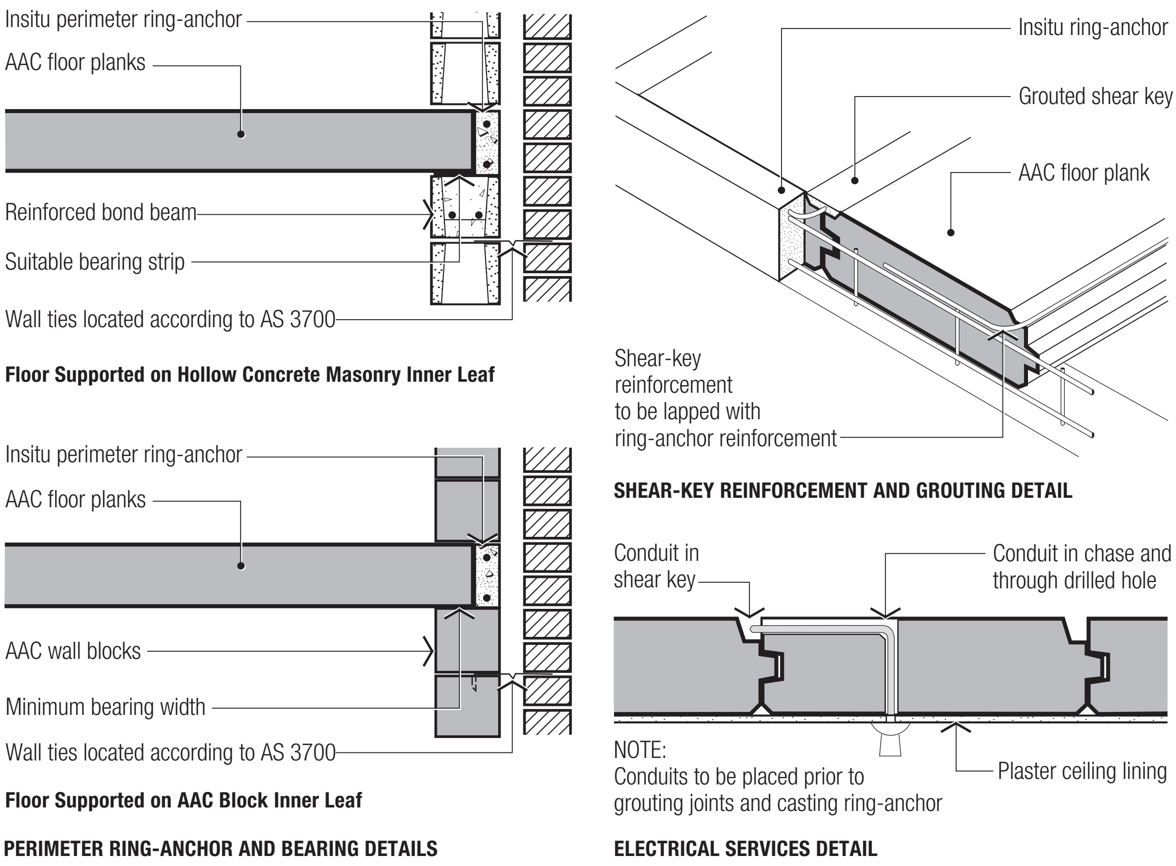


Figure 5.29 Typical details

6 REFERENCES AND FURTHER READING

1 *Building Code of Australia* Volume 2 *Class 1 and Class 10 Buildings Housing Provisions* (including Amdts. 1-11) Australian Building Codes Board, 1996.

2 AS 2870 *Residential slabs and footings – Construction* (including Amdt. 1, 2 & 3) Standards Australia, 1996.

3 AS 3798 *Guidelines on earthworks for commercial and residential developments* Standards Australia, 1996.

4 AS 3660.1 *Termite management – New building work* Standards Australia, 2000.

5 *The Housing Concrete Handbook* (T53) Cement and Concrete Association of Australia, 2000.

6 AS 3600 *Concrete structures* Standards Australia, 2001.

7 *Guide to home owners on foundation maintenance and footing performance* Sheet No. 10-91 CSIRO, revised 1996.

8 *Sulfate resisting cement and concrete* Data Sheet Cement and Concrete Association of Australia, July 2002.

9 *Sulfate and acid resistance of concrete in the ground* BRE Digest 363, Building Research Establishment, January 1996.

10 *Energy saving using passive solar design* Cement and Concrete Association of Australia, 2003.

11 *Segmental concrete reinforced soil retaining walls – Design and construction guide* (MA50/HB 156) Concrete Masonry Association of Australia and Standards Australia, 2002.

12 *Articulated walling* (TN61) Cement and Concrete Association of Australia, 1998.

13 Current Practice Note 30 *Slab Edge Dampness* Concrete Institute of Australia CPN 30 October 1998, 5p.

14 AS 1684 *Residential timber-framed construction* Standards Australia, 1999.

15 *Design guide for long-span concrete floors* (T36) Cement and Concrete Association of Australia, 1988 (currently being revised).

16 AS 3610 *Formwork for concrete* Standards Australia, 1995.

17 AS 3610 Supplement 2 *Formwork for concrete – Commentary* (Supplement to AS 3610 – 1995) (including Amdt. 1) Standards Australia, 1996.

18 AS/NZS 4671 *Steel reinforcing materials* Standards Australia, 2001.

19 *Hollowcore Floor Technical Manual* National Precast Concrete Association Australia, (2003).

20 AS 1366.3 *Rigid cellular plastics sheets for thermal insulation – Rigid cellular polystyrene – Moulded* (RC/PS – M) Standards Australia, 1992.

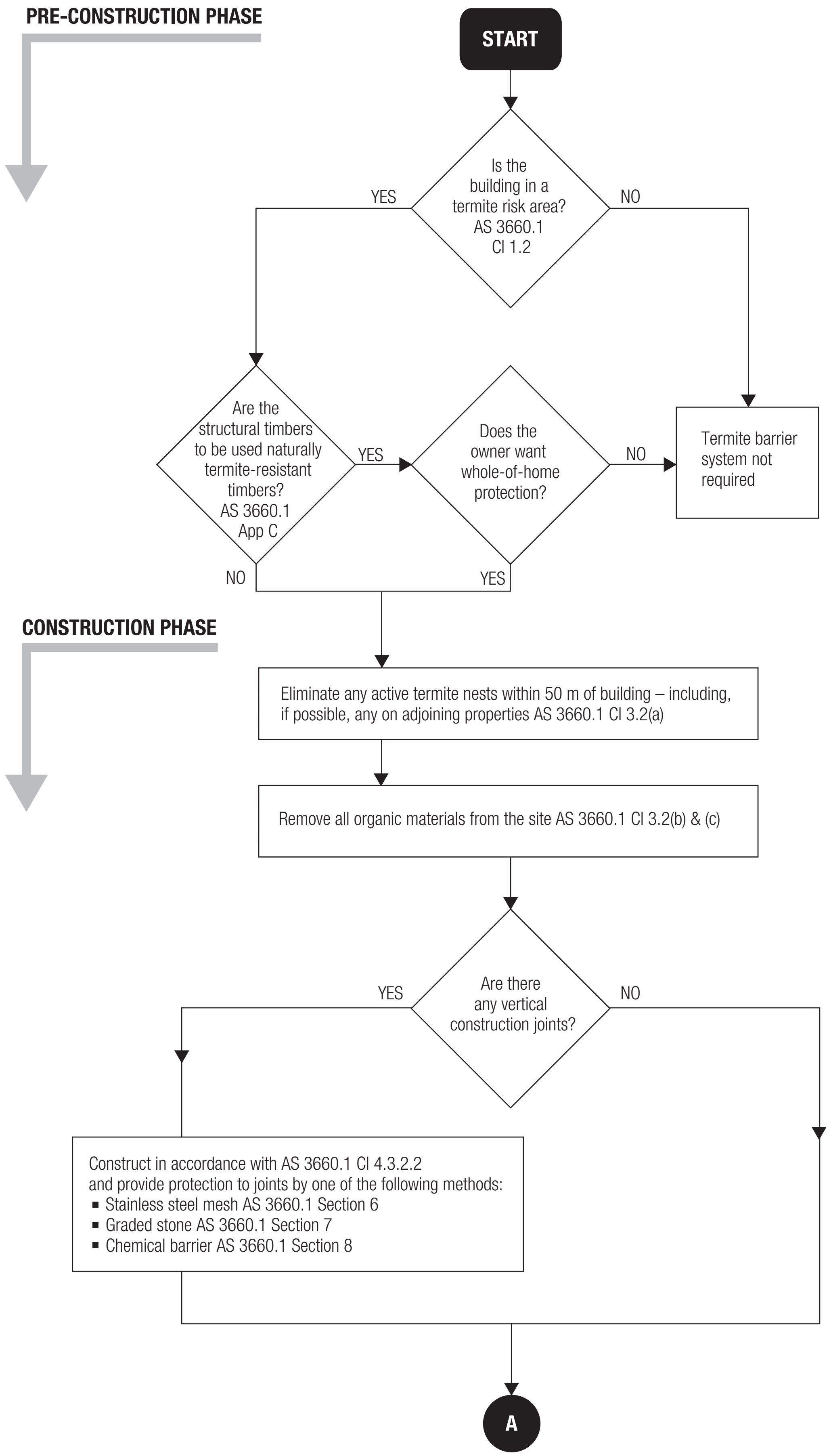
21 AS 1530.4 *Methods for fire tests on building materials, components and structures – Fire-resistance tests of elements of building construction* Standards Australia, 1997.

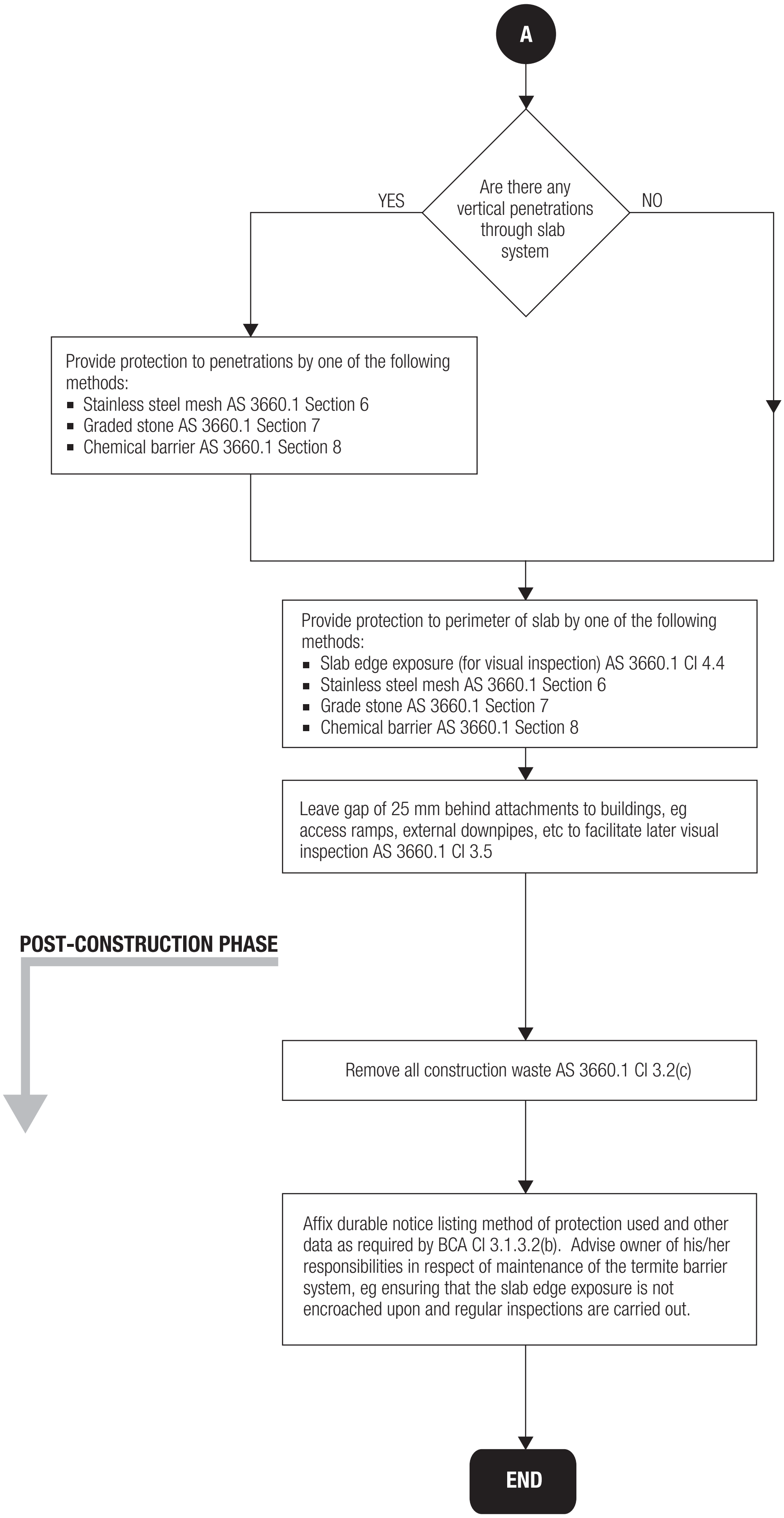
6.2 Further Reading

- Various technical publications available from the Steel Reinforcement Institute of Australia and the reinforcement suppliers.
- *Precast Concrete Handbook* National Precast Concrete Association Australia, 2002.
- Various technical publications available from precast manufacturers/suppliers.
- *Reinforced Concrete Design* Handbook Cement and Concrete Association of Australia and Standards Australia, February 2002.
- Warner, R F, Rangan, B V, Hall, A S, and Faulkes, K A *Concrete Structures* Longman, Melbourne, 1998.
- *Manual for the design of reinforced concrete building structures* The Institution of Structural Engineers and The Institution of Civil Engineers, Second Edition, 2002.
- Various publications available from the State Housing Authorities.

Appendix 1

Procedure for using a concrete slab on ground constructed in accordance with AS 2870.1 as part of the termite barrier




A
Are there any vertical penetrations through slab system
YES
NO
Provide protection to penetrations by one of the following methods:
▪ Stainless steel mesh AS 3660.1 Section 6
▪ Graded stone AS 3660.1 Section 7
▪ Chemical barrier AS 3660.1 Section 8
Provide protection to perimeter of slab by one of the following methods:
▪ Slab edge exposure (for visual inspection) AS 3660.1 Cl 4.4
▪ Stainless steel mesh AS 3660.1 Section 6
▪ Grade stone AS 3660.1 Section 7
▪ Chemical barrier AS 3660.1 Section 8
Leave gap of 25 mm behind attachments to buildings, eg access ramps, external downpipes, etc to facilitate later visual inspection AS 3660.1 Cl 3.5
POST-CONSTRUCTION PHASE
Remove all construction waste AS 3660.1 Cl 3.2(c)
Affix durable notice listing method of protection used and other data as required by BCA Cl 3.1.3.2(b). Advise owner of his/her responsibilities in respect of maintenance of the termite barrier system, eg ensuring that the slab edge exposure is not encroached upon and regular inspections are carried out.
END

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