Foundations and footings

Introduction

The base of a building consists of:

- floor—timber, steel framing, or concrete
- sub-floor support—columns, piers, continuous walls
- footings – strip footings, isolated pad footings, or slab footing

The ground on which the building sits is referred to as the foundations.

The base of a building provides a stable support and link for the remainder of the structure to prevent it falling over, falling apart or blowing away. It also prevents surface water from entering the building and forms the principle barrier against termite infestation from below the ground.

The areas applying to the base of buildings that are important as part of the building design and documentation are:

- footing design by a structural engineer
- protection from subterranean termites
- water and moisture entry
- ventilation for sub-floor spaces
- fixing of member to member for stability of the structure in relation to bracing and tie-down requirements

Foundations and Footings

The foundation is the earth or strata upon which the footings for a building are constructed. For buildings the bearing capacity of the soil or foundation is very important as well as any settlement of the soil/foundation that may occur.

The footings are constructed immediately on the foundation. They both support the building and spread the weight of the building across the foundation. The footings, so to speak, are the meat in the sandwich.

In reactive soils like clay, footings protect the building from expansion and contraction due to moisture changes in the foundation. Footings must be rigid enough to protect the building from foundation movement and spread the weight of the building evenly over the foundation.

Generally, if the surface is capable of adequately supporting the structural loads, pad footings, strip footings or a raft slab is usually used. However, if the surface cannot support the structure, piles or piers are used to transmit the load to a foundation at a greater depth that can support the loads. The foundation level should be below the seasonally affected levels of shrinkage and swelling.
Footing systems

A footing is that portion of a building which rests directly on the foundation and is used to support the walls above. Footings are designed to distribute the loads on the foundation below. The width, depth and type of footing will depend on the foundation below and the building that is to go on the foundation.

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Footings other than simple pad footings for small loads are required to be designed by structural engineers.

The essential requirements for footings for buildings are that:

- any settlement shall be as small as possible, and
- any settlement shall be uniform.

The possible causes of failure are:

- unequal settlement
- incorrect design
- scour or the removal of part of the foundation by water
- the effect of moisture on reactive soils

AS 2870–2011 Residential slabs and footings is the Australian Standard that can be used to design standard footings for residential construction. If the footing does not fall into the standard site classification or building type then it must be designed by a structural engineer. Councils generally require that any reinforced concrete construction is designed and documented by a structural engineer for construction approval.

The vast majority of footing systems for houses complying with AS 2870–2011 and constructed on Class A, Class S or Class M sites could be described as shallow footings of the following types

- Spread (pad) footings
- Continuous footings - they include strips, footing slabs/raft slabs, stiffened slabs.

When foundations are of a poor material and cannot support the load of the structure, piers are used to bear the footings on better foundation deep down and can be used in combinations of pier and beam, pier and slab, etc.

Section 3 of AS 2870–2011 sets out the requirements for standard designs of footing systems. It also allows for the modification by engineering principles of the standard designs.

Strip footings consist of a continuous strip under all walls to distribute the weight of the wall to the foundation material. The most common material for strip footings is reinforced concrete although brick and stone have been used in the past. Concrete and strip footings are used in domestic buildings where sectional size is governed by AS 2870. A description of the different types of footing follows.
Spread (pad) footings

Spread footings are usually square or round, and support a concentrated load. They include pad footings. Pad footings for houses comprise a pad used to support a pier or stump. See Figure below:

Continuous footings

Continuous footings may take the form of a slab or strip that supports an essentially uniformly distributed load usually used for walls. They include:

- strips
- footing slabs
- stiffened slabs.
Continuous Footings – In sections and details, continuous footings can look like this. This is an example of a stiffened slab continuous footing.

Stumps and Piers

Where footings are used on fill, unstable soils (subject to slip), low bearing capacity soils, etc. the footings (and slab) will need further support which may be provided by:

- **Bulk piers**—using a backhoe or excavator to dig down to firm ground at regular intervals. Bulk piers are generally poured at the same time as the footing.
- **Bored piers**—either reinforced or unreinforced depending on diameter, length, side movement expected, etc. These are usually dug and poured prior to digging the footings.
- **Driven pile footings**—timber, concrete, steel piles are mechanically driven prior to work commencing on the footings.
- **Screw piles**—propriety systems using specially built steel columns which are mechanically screwed into the soil prior to work commencing on the footings. Screw piles can also be used as stumps for a building with a raised floor. No concrete footing is required when they are used for this purpose.

When used under the footing the top of the bored pier or the driven pile is generally left flush with the bottom of the footing or just protruding. The footing is then dug and poured so that it is directly supported by the pier or pile. With poured in-situ reinforced piers, the reinforcement is usually left long and tied to the footing reinforcement. Driven reinforced piles may be left long and the concrete removed down to the bottom of the footing and the exposed reinforcement is tied to the footing reinforcement.
Steel stumps

Steel stumps are usually made from hollow section steel such as CHS (Circular Hollow Section), SHS (Square Hollow Section) or RHS (Rectangular Hollow Section).

Timber stumps

Timber stumps can be supplied using:

- ‘natural’ finish poles—have the bark removed and vary in size from one end to the other.
- machined poles—are the same size from end to end. They have either been sawn to give a multi-faced finish or turned to give a cylindrical surface.
- machined posts—are generally square in section. However, rectangular section posts are sometimes used but usually in pairs with bolted spacer blocks. Paired rectangular posts are used where long lengths of posts are required such as on steep blocks where the post is to go from footing right up to the roof in one continuous length.
Masonry piers and continuous walls

Masonry piers and continuous walls are usually either brick or concrete block. Masonry sub-floor walls can be either pier-and-brick, cavity, single skin or double thickness.

Stone

Stone foundation walls used as a support for a residential building are common in older houses. Stone sub-walls are built using mainly cleaned natural stone held together with cement mortar.
Various methods of footing construction

**Slab footings**

There are two main types of flooring system:

1. those in contact with the ground
2. suspended floors.

A slab on ground forms both the footing and the floor of the building. Pad footings and strip footings provide a sub-floor space that creates a raised or suspended floor. Suspended floors are generally framed with stumps or piers, and bearers and joists and are described in the next section. Slabs are formed on the ground. The final flooring material may be laid onto the concrete, but the slab creates a continuous footing.
Floors in contact with the Ground

This generally means a slab-on-ground. A slab on ground can be one of a number of different types of slab such as a raft slab, waffle pod slab, slab with dropped edge beams or a reinforced slab on fill.

The main faults that arise with a slab are cracking due to ground movement and keeping out the damp and the cold. Another important component of a slab footing is the termite protection but this will be discussed later.

To stop moisture/water in the ground penetrating into the building it is necessary to waterproof the slab. This is usually in the form of a plastic membrane. See figure below.
Note the black plastic vapour barrier that will line the underside of the slab to be poured. This is a stiffened raft slab with a step separating two different floor levels. You can see the grid pattern of beams.

This type of construction is particularly popular in housing construction around Australia.

The slab-on-ground combines all the elements that make up the base of a building, in a compact low profile system. Slab-on-ground construction needs special attention paid to the control of surface water flow around the building and also to the prevention of access to the building by subterranean termites.

Slab-on-ground systems include:

a) Combined slab/footing (thickened edge slabs)—where the edge of the slab is deepened thus replacing the need for a separate footing. The slab, with the thickened edge, is poured all-in-one.

b) Separate slab/footing or footing slab—footings and slab are poured at different times and so a construction joint occurs. The construction joint may vary from direct concrete to concrete contact to several or many courses of masonry. The slab may be suspended or poured on the ground.

c) Raft slabs—these are slabs with large beams (similar to strip footings) that form a grid under the slab and are tied to the slab with reinforcement bars to allow the slab panels and beams to act as one unit. The grid beams are normally poured at the same time as the slab panels.
A raft slab showing the grid pattern of beams

d) Waffle raft slabs (sometimes called waffle pod slabs)—these are like raft slabs but have purpose made forms to create voids under the slab with a series of thin grid beams.

In this case the slab and the grid beams (formed by leaving gaps between the void forms) are formed and poured sitting on top of the ground. Later the ground level may be raised around the edge of the slab.
e) Post-tensioned slabs—in these slabs the mesh reinforcement is replaced by a series of cables which are tightened after the slab is poured to enhance the slabs structural performance. The cables form an open grid, usually between 1.2 m centres and 2.5 m centres depending on soil conditions. The slab is poured and after the designated time to allow the slab to set, the cables (which are inside sleeves) are tensioned in two or three stages over a period of several days. When the full tension is achieved the sleeves and the open ends are filled with grout. Post-tensioned slabs can be designed as thick plate slabs of between 150 mm to 180 mm deep with no internal beams required. A post-tensioned slab will generally have reduced visual cracking as the slab is slightly compressed due to the effect of the tension cables. This type of slab would not be used in standard residential construction.
Different types of slab

- **Thickened edge slab**: Poured in one pour.
- **Concrete slab**: Reinforced with steel mesh.
- **Footing slab**: Separate footing poured first.
- **Raft slab**: Stiffened by a grid of integral beams.
- **Waffle-pod slab**: Used for reactive soils.
- **Post-tensioned slab**: Cables tightened and clamped after concrete sets.
Termites

Termites live in underground colonies, travelling up to 100 metres from the nest in continuous mud tunnels or galleries, searching for food. They live on cellulose, predominantly found in timber. They favour wet and dark conditions and being blind, smell out food from a long distance.

There are more than 350 termite species in Australia of four types, of which the first (subterranean) is the most worrying for the building industry:

1. Subterranean termites - Subterranean termites’ parent colony remains concealed underground at the base of trees, beneath buildings or as a mound, with galleries to the food source.
2. Dampwood termites - Dampwood termites eat timbers affected by moisture and decay, including poorly ventilated sub-floors where timber-soil contact occurs.
3. Drywood termites - Drywood termites are tropical sub-species that do not require ground contact, active in northern Queensland.
4. Harvester termites - Harvester (grass) termites again are tropical, forage in grasses and pose no threat to buildings.


Building Code requirements

The BCA (Volume 2) Part 3.1.3 requires primary building elements (load-bearing and bracing components) to be either termite resistant or adequately protected from termites.

Common materials that are termite resistant are:

- steel
- concrete
- masonry
- fibre-reinforced cement
- naturally termite resistant timbers (Appendix A of AS 3660.1)
preservative treated timbers (Appendix B of AS 3660.1).

But this alone may not provide adequate protection. Termites can and do tunnel their way through or past structural components to eat skirting boards, cupboards and furniture, and sometimes further on walls and roofs. Therefore, acceptable construction practice includes the installation of termite barriers in accordance with AS 3660.1 ‘Protection of buildings from subterranean termites – new buildings’. This requires a notice fixed in a prominent location (typically the meter box) advising the nature of the termite protection system, plus maintenance and inspection requirements.

Concrete slabs by themselves are not accepted as adequate protection against termite attack. Too often there may be cracking in the slab or gaps where service pipes penetrate, thereby making easy access for a hungry termite to get to its food. Therefore, depending upon geographic region and severity of the termite problem, authorities will require treatment to the entire sub-slab area or in lesser risk areas, termite collars to penetrations and perimeter areas.

**Termite management**

There are three broad methods of protection, each with advantages and disadvantages:

1. physical barriers
2. chemical barriers
3. termite-resistant materials.

**Physical barriers**

These barriers protect buildings by isolating timbers from ground contact through a number of different methods.

- Metal ant-caps as traditionally used for elevated timber framing require regular inspection as termites can work around or past them.
- Stainless steel mesh (Termimesh) either to the perimeter and around service pipes, or full ground cover under slab on ground to stop them getting through the fine mesh.
- Graded granite (Granitgard) consists of crushed and angular granite particles laid and compacted under slab on ground, plus collars around service pipes to block termite access through the mass, hardness and voids between the angular stone. Perimeter and penetration installation is also an acceptable treatment where the slab is laid to AS3600.
- Combined termite and moisture barrier—Two layers of LDPE plastic have a central synthetic web chemically treated with deltamethrin, combining waterproofing and termite protection functions in one product (Kordon).
- Combined termite and moisture barrier/flashing (Alterm) uses 0.5 mm marine grade aluminium which termites cannot get through.
- Combined termite and moisture barrier/flashing (HomeGuard) uses a single layer polymer sheet containing bifenthrin.
Slab edge details

Slab edge details with termite protection systems

Typical termite shield detail for slab penetrations
A termite shield is shown around a pipe that will penetrate the slab. The shield will also be taped and then the concrete will be poured up to and around the shield as in the sketch above left as ‘alternative position’.

Chemical barriers

Since the banning in mid-1995 of organochlorines due to their toxicity and persistence in the environment (and human body), chemical sprays are now less popular. Previously, chemicals with a ‘half-life’ (half as effective) of 30 years were being sprayed sometimes every year under and around concrete slabs and buildings. These chemicals accumulate in the soil or may slowly leach out into the ground elsewhere causing toxicity and pollution of wider concern.

All chemical spray systems have implications for occupational health and safety on building sites for installers, trades and later occupants. Those of us touching the soil, the slab or anywhere else sprayed are likely to take the chemicals into our body. These chemicals remain dangerous to humans and will still be around and under most houses. Use personal protective clothing and equipment, plus personal hygiene of washing hands before eating or smoking if in any doubt.

Chemical barriers required spraying under and around slabs during construction. Their effectiveness is highly dependent upon the expertise of the installer to get the correct dosage and coverage for the particular site conditions. They are also rendered ineffective if disrupted through later alterations, pathways, new pipes or added topsoil, actions which allow termites to bridge the chemical treatment in the soil.

With the banning of organochlorines, less persistent organophosphates are now used, requiring re-treatment every 10 years under slabs and every five years around the perimeter. A newer development is a synthetic pyrethroid (Bifex). As these less hazardous treatments do not last as long, they require a system of reticulated pipes under the building to permit later pressurized retreatment into the soil.
Approximately 20% of all timber sold in Australia is treated with chemical preservatives to extend their life. All preservatives pose some risk to health and create disposal hazards (in NSW they are banned from landfill with general putrescible wastes).

Preservative treatment uses a variety of chemicals for resisting particular insect pests (not just termites). The main groups are boron compounds and sodium fluorides, creosote, CCA and ACQ, and LOSP.

**Boron compounds and sodium fluorides** are mainly used against borers in internal situations as the chemicals will leach out in water.

**Creosote**, a derivative of coal tar, has been in use for 200 years. It is now known to be carcinogenic and so is banned from construction but can still be found in some agricultural uses.

**CCA** (*copper chrome arsenic*) and **ACQ** (*ammoniacal copper quaternary*) are used to treat Radiata and Hoop pine to Hazard Class up to H5 (AS 1604 – 1997). The chemical treatment gives up to eight times the longevity in ground contact than the untreated wood, but produces serious environmental and health issues in the process and at disposal. Some countries have banned these treatments.

**LOSP** (*light organic solvent preservatives*) are used for above ground timbers. They contain pyrethroid synthetic insecticides, following the banning of organochlorines in 1995.

**Termite-resistant materials**

Apart from the obvious non-organic materials listed above (steel, concrete, masonry, etc), some timbers are not attractive to termites either naturally or following chemical treatment.

Many common timber reference books list those species that have resistance to termites (which may not be the same as resistance to borers). Some of the more common naturally resistant timbers include:

- native cypress pine (*Callitris* spp.)
- river red gum (*E. corymbosa*)
- grey box (*E. moluccana*)
- yellow box (*E. melliodora*)
- ironbark (*E. siderophloia*)
• turpentine (E.Syncarpia glomulifera).

Alterations and additions
Alterations and additions commonly pose a particular challenge for termite protection because:

• existing construction may not be fully protected
• new work may bridge termite barriers
• soil (from previous chemical treatment) is moved
• termites may already be in the structure!
• termites have a way of sneaking through cavities into new work, or coming up in the join between new and old concrete slabs.

Landscaping
Even if you have taken steps during construction to protect a building from termite attack, there are a number of measures that can be taken to avoid providing conditions that suit termite activity.

• Avoid placing wood chips in garden beds against the building. This may attract termites. If possible, it is best to avoid garden beds alongside the dwelling, particularly if the dwelling has a chemical barrier at the perimeter. Topsoil and gardens may destroy the barrier, particularly when gardens are disturbed.

• If it is necessary that garden beds abut the dwelling, the beds should not be raised above the existing ground level, particularly with slab on ground construction. It is vital that the edge of the slab and the weep holes are left exposed – about 75mm below the bottom of the weepholes is a good level. If garden beds or soil levels are built up over the edge of the slab, termites can gain undetected entry into the building and break the established barriers. It is also important to choose planting that will not hide weepholes, vents in walls or the exposed edge of concrete slabs.

• It is important that areas with suspended timber floors are kept well ventilated and dry. Ensure that vents to the subfloor areas are never blocked. Ensure leaking taps, showers, pipes etc. under the dwelling or adjacent to it are repaired immediately to reduce moisture levels in the sub floor area. Any material that may contribute to termite infestation such as timber formwork, timber, tree stumps and similar materials must be kept out of the subfloor area and away from the external walls of the dwelling.

• Never use untreated timbers to form garden beds or retaining walls as these can attract termites.

• Ensure that the termite shielding is not damaged. For example, consider what trees are planted adjacent to the dwelling. If an inappropriate tree is planted, its roots may damage the termite barrier under or beside the concrete slab or cause the slab itself to crack.

• Any termite barrier can be rendered ineffective if alterations and additions are constructed. Termite protection needs to be considered for all building work, no matter what the extent.
Maintenance

The selection and installation of an effective termite protection system is the responsibility of the builder. However all systems require ongoing maintenance and regular inspections to detect any termite activity.

The type of system installed will determine the upkeep necessary to ensure its effectiveness. The following is a general list of maintenance items covering all types of systems:

- ensure good underfloor ventilation which will discourage termite activity
- do not allow timber to be stored or accumulate around or under a building
- do not build any ‘in ground’ untreated timber structures
- always follow all manufacturers’ guidelines
- do not disturb the perimeter protection system, for example by installing landscaping etc.
- any termite protection system can be made ineffective by the construction of additions, eg verandahs and pergolas
- for ‘slab on ground’ construction the weep holes must always be visible
- for suspended floor construction, all timber that may attract termites must be removed from the sub floor area
- regular inspections should be conducted of the protection system.

Further Reading

Read from Building Your own Home by George Wilkie, the following topics:

Topic 26: Footings
Topic 27: Sub-surface or agricultural drainage
Topic 28: Retaining walls
Topic 29: Ground-to-floor systems
Topic 32: Concrete slabs

You should also read relevant sections from Acceptable Standards of Construction including Parts 6, 7 & 8, relevant sections from Volume 2 of the BCA, and Sections 1, 2 and 3 of AS 2870 Residential slabs and footings.