Australian Standard®

Residential slabs and footings—Construction

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PREFACE

This Standard was prepared by the Standards Australia Committee BD/25 on Residential Slabs and Footings to supersede AS 2870.1 —1988 and AS 2870.2—1990.

The purpose of this Standard is to establish performance requirements and specific designs for footing systems for foundation conditions commonly found in Australia and to provide guidance on the design of footing systems by engineering principles. Although a wide range of conditions is covered, this Standard places particular emphasis on the design for reactive clay sites susceptible to significant ground movement due to moisture changes. The Standard takes account of the following:

(a) Swelling and shrinkage movements of reactive clay soils due to moisture changes.
(b) Settlement of compressible soils or fill.
(c) Distribution to the foundation of the applied loads.
(d) Tolerance of the superstructure to movement.

The Notes to the Figures in Section 3 form part of the mandatory provisions of this Standard. The Figures are intended to show only the structural proportions of the footing system. All other details are purely illustrative.

The terms ‘normative’ and ‘informative’ have been used in this Standard to define the application of the appendix to which they apply. A ‘normative’ appendix is an integral part of a Standard, whereas an ‘informative’ appendix is only for information and guidance.
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STANDARDS AUSTRALIA

Australian Standard

Residential slabs and footings—Construction

SECTION 1 SCOPE AND GENERAL

1.1 SCOPE This Standard sets out the requirements for the classification of a site and the design and construction of a footing system for a single dwelling house, townhouse or the like which may be detached or separated by a party wall or common wall, but not situated vertically above or below another dwelling. Such houses include buildings classified as Class 1 and 10a under the Building Code of Australia.

The Standard may also apply to other forms of construction including some light industrial, commercial and institutional buildings if they are similar to houses in size, loading and superstructure flexibility. The footing systems for which designs are given include slab-on-ground, stiffened rafts, waffle rafts, strip footings, pad footings and piled footings. This Standard gives no advice on detailing of the connection of superstructures to the footing systems for wind loads or earthquake loads.

This Standard shall not be interpreted so as to prevent the use of materials or methods of design not referred to herein. Specifically, this Standard shall not be used to prevent the use of locally proven designs, or alternative designs in accordance with engineering principles.

NOTE: This Standard does not include design details for Class P sites. Some advisory material is included in the commentary.

1.2 APPLICATION The Standard requires that all sites shall be classified in accordance with Section 2 and that footing system designs shall be prepared either by prescribing a standard design in accordance with Section 3, or by the engineering principles described in Section 4. In either case, all construction shall comply with Sections 5 and 6.

Residential footing system design and construction shall comply with AS 3600 except that, where in conflict, this Standard shall take precedence.

NOTE: The functions of the various parties involved in the design and construction of residential slabs and footings are normally as described in Appendix A.

1.3 PERFORMANCE OF FOOTING SYSTEMS

1.3.1 General The footing systems complying with this Standard are intended to achieve acceptable probabilities of serviceability and safety of the building during its design life. Buildings supported by footing systems designed and constructed in accordance with this Standard on a normal site (See Clause 1.3.2) which is—

(a) not subject to abnormal moisture conditions; and

(b) maintained such that the original site classification remains valid and abnormal moisture conditions do not develop (see Note 1);

are expected to experience usually no damage, a low incidence of damage category 1 and an occasional incidence of damage category 2 (see Note 2). Damage categories are defined in Appendix C.

NOTES:
1 Appendix B provides information and guidance on the maintenance of foundation site conditions.
2 Class A sites (as defined in Section 2) are not reactive to moisture and may have a lesser risk of damage.

1.3.2 Normal sites Normal sites are those which are classified as one of the Classes A, S, M, H and E in accordance with Section 2 of this Standard and where foundation moisture variations are caused by seasonal and climatic changes, effect of the building and subdivision
and normal garden conditions, without abnormal moisture conditions (see Clause 1.3.3). Compliance with the recommendations in CSIRO 10-91 is deemed to provide normal garden conditions.

1.3.3 Abnormal moisture conditions  Where the following factors are present, footings will have a higher probability of damage than that given in Clause 1.3.1:

(a) Recent removal of an existing building or structure likely to have significantly modified the soil moisture conditions under the proposed plan of the building.

(b) Unusual moisture conditions caused by drains, channels, ponds, dams or tanks which are to be maintained or removed from the site.

(c) Recent removal of large trees prior to construction.

(d) Growth of trees too close to a footing.

(e) Excessive or irregular watering of gardens adjacent to the house.

(f) Lack of maintenance of site drainage.

(g) Failure to repair plumbing leaks.

1.4 DESIGN CONDITIONS

1.4.1 General  For the purpose of this Clause, the design conditions below apply for normal sites. Where abnormal sites or abnormal environmental conditions apply, the design of the footing system shall be by engineering principles which may be beyond the scope of those set out in Section 4.

1.4.2 Load effects  Design for serviceability and safety against yield of concrete or bearing failure shall be based on design actions due to—

(a) dead load + 0.5 live load; and

(b) foundation movement.

Design for uplift shall be based on action effects due to 0.8 dead load + wind load.

Settlements and bearing capacity of the foundation shall be determined from dead load + 0.5 live load. Settlement may be determined directly using the above load. Bearing and uplift failures shall be determined using a strength reduction factor of 0.3.

Foundation movement shall be assessed as the level which has less than 5% chance of being exceeded in the life of the structure, which may be taken as 50 years. Design soil suction profiles shall be based on this concept and the values given in Section 2 shall be deemed to comply with this requirement.

Soil parameters shall be taken as mean values of available results for each soil horizon or particular soil.

1.4.3 Other design considerations  The design of footing systems shall consider:

(a) Effective drainage of the site.

(b) Past satisfactory performance of similar footings on similar sites.

(c) Control, but not prevention of, shrinkage cracking.

(d) Control, but not prevention of, cracking due to footing movement.

(e) Stiffness and ductility of the footing system.

(f) Strength of the wall system.

(g) Tolerance of the wall system to movement.

(h) Allowable bearing pressure.
1.5 **DEEMED-TO-COMPLY STANDARD DESIGNS** The standard designs given in Section 3 shall be deemed-to-comply with the performance expectations described in Clause 1.3.

1.6 **REFERENCED DOCUMENTS** The following documents are referred to in this Standard:

- AS 1289 Methods of testing soils for engineering purposes
- 1289.7.1.1 Determination of the shrinkage index of a soil—Shrink swell index
- 1289.7.1.2 Determination of the shrinkage index of a soil—Loaded shrinkage index
- 1289.7.1.3 Determination of the shrinkage index of a soil—Core shrinkage index (subsidiary method)
- 1289.F3.3 Part F—Soil strength and consolidation tests—Determination of the penetration resistance of a soil with a Perth sand penetrometer
- 1302 Steel reinforcing bars for concrete
- 1304 Welded wire reinforcing fabric for concrete
- 1379 Specification and supply of concrete
- 1650 Hot-dipped galvanized coatings on ferrous articles
- 1684 National Timber Framing Code
- 1720 Timber structures (known as the SAA Timber Structures Code)
- 2159 Rules for the design and installation of piling (known as the SAA Piling Code)
- 2870 Supp1 Residential slabs and footings—Construction—Commentary (Supplement to AS 2870—1996)
- 3600 Concrete structures
- 3660 Protection of buildings from subterranean termites
- 3660.1 Part 1: New buildings
- 3700 Masonry in buildings (known as the SAA Masonry Code)
- 3798 Guidelines on earthworks for commercial and residential developments
- 3958 Ceramic tiles
- 3958.1 Part 1: Guide to the installation of ceramic tiles
- AS/NZS 4347 Damp-proof courses and flashings—Methods of test
- 4347.6 Method 6: Determining impact resistance (falling dart impact test)
- 4347.9 Part 9: Determining thickness

**Australian Building Code Board**

- BCA Building Code of Australia
- Cement and Concrete Association of Australia
- TN 61 Articulated walling

**CSIRO, Division of Building, Construction and Engineering**

- 10-91 A Guide to Home Owners on Foundation Maintenance and Footing Performance

1.7 **DEFINITIONS** For the purpose of this Standard, the definitions below apply.

1.7.1 **Allowable bearing pressure**—the maximum bearing pressure that can be sustained by the foundation from the proposed footing system under service loads over the design range of soil moisture conditions. Allowable bearing pressure shall take into consideration both the site conditions and the ability of the building system to accommodate settlement.
1.7.2 Articulated full masonry—full masonry construction in which special provision is made for movement by articulation.

1.7.3 Articulated masonry veneer—masonry veneer construction in which the provisions for articulated masonry have been applied to the masonry veneer.

1.7.4 Braced stump—a stump that resists horizontal loads from bracing that connects to the stump at less than or equal to 150 mm from ground level. The stump may also support vertical loads.

1.7.5 Bracing stump—a stump that, in addition to vertical loads, resists horizontal loads applied more than 150 mm above ground level.

1.7.6 Bored pier—in-situ concrete cylindrical load support element.

1.7.7 Bulk pier—in-situ concrete load support element excavated by backhoe or similar.

1.7.8 Characteristic surface movement ($y_s$)—the movement of the surface of a reactive site caused by moisture changes from characteristic dry to characteristic wet condition in the absence of a building and without consideration of load effects.

1.7.9 Clad frame—timber or metal frame construction with the exterior wall clad with timber or sheet material not sensitive to minor movements. Includes substructure masonry walls up to 1.5 m high.

1.7.10 Clay—fine-grained soil with plastic properties when wet. Includes gravelly, sandy or silty clays.

1.7.11 Collapsing soil—weakly-cemented soil subject to large settlements under load as a result of degradation by water on the cementing action.

1.7.12 Concrete wall panel—a precast (including tilt-up) or in situ concrete wall designed to act as a unit and separated from adjacent walls by a joint.

1.7.13 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) and AS 3798.

1.7.14 Edge beam—beam at the edge of a slab-on-ground or stiffened raft.

1.7.15 Edge footing—footing at the edge of a footing slab.

1.7.16 Extension—additional construction to and abutting an existing building.

1.7.17 Fill depth—for a slab, depth of fill is measured from the underside of the slab panel to the natural surface level. For a strip or pad footing system, the depth of fill is measured from the finished ground level to the natural surface level.

1.7.18 Finished ground level—ground level adjacent to the footing system at the completion of construction and landscaping.

1.7.19 Fitment—tie, ligature or stirrup reinforcement.

1.7.20 Footing—construction which transfers the load from the building to the foundation.

1.7.21 Footing slab—concrete floor supported on the ground with a separately poured edge strip footing.

1.7.22 Footing system—general term used to refer to slabs, footings, piers and pile systems that transfer load from the structure to the foundation.

1.7.23 Foundation—ground which supports the building.

1.7.24 Framed double-leaf masonry—construction with masonry double-leaf external wall and framed internal walls.
1.7.25 **Full masonry**—construction with masonry double-leaf external walls and masonry single-leaf internal walls without full articulation.

1.7.26 **Gilgai**—soil surface feature associated with reactive clay sites, characterized by regularly spaced and sized depressions on virgin land. Gilgais are formed by extreme reactive soil movements. Soil profiles may vary markedly across sites with gilgais.

1.7.27 **House**—detached single dwelling constructed as Class 1, or Class 10a as defined in the Building Code of Australia, with limitations as stated in this Standard.

1.7.28 **Infill slab**—slab cast on the ground between walls.

1.7.29 **Landslip**—foundation condition on a sloping site where downhill foundation movement or failure is a design consideration.

1.7.30 **Load-bearing wall**—any wall imposing on the footing a service load greater than 10 kN/m.

1.7.31 **Masonry**—stone, brick, terracotta block, concrete block, or other similar building unit single or in combination assembled together unit by unit.

1.7.32 **Masonry veneer**—house construction consisting of a load-bearing frame clad with an outer leaf of masonry.

1.7.33 **Maximum differential footing movement**—the maximum movement of a footing relative to a line joining the ends of the footing system (or, in the case of double curvature, joining the points of contraflexure).

1.7.34 **Mine subsidence**—settlement, curvature, slope and lateral strain produced at the surface as a result of underground mining.

1.7.35 **Mixed construction**—building consisting of more than one form of construction, particularly in double-storey houses.

1.7.36 **Natural site**—site which has not been subjected to cut or fill.

1.7.37 **One-storey**—construction with wall height, excluding any gable, not exceeding 4.2 m and including only one trafficable floor.

1.7.38 **Outbuilding**—detached building such as a carport, private garage, shed or the like.

1.7.39 **Pad footing**—concrete footing used to support a pier or stump.

1.7.40 **Pier-and-beam**—footing system incorporating bored piers, bulk piers or piles and reinforced concrete beams supporting a building where the floor is not integral with the beams.

1.7.41 **Pier-and-slab**—footing system incorporating bored piers, bulk piers or piles supporting a suspended slab and including a slab partly supported on piers and partly supported on ground.

1.7.42 **Pile**—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.

1.7.43 **Qualified engineer**—a professional engineer with academic qualifications in geotechnical or structural engineering who also has extensive experience in the design of footing systems for houses or similar structures.

1.7.44 **Reactive site**—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. Includes sites classified as S, M, H or E in accordance with Clause 2.1.

1.7.45 **Reinforcement**—steel bars, wire or mesh. (See Clauses 1.9, 5.3.2, 5.3.7 and 5.4.2).
1.7.46 **Reinforced single-leaf masonry**—outer wall constructed of concrete blocks with some vertically reinforced cores at not greater than 2.0 m centres lapped with steel starter bars set in concrete beams or footings and a bond beam.

1.7.47 **Rock**—strong material including shaley material and strongly cemented sand or gravel that does not soften in water or collapse under the combination of loading and wetting. Material that cannot readily be excavated by a backhoe may be taken to be rock.

1.7.48 **Rolled fill**—fill compacted by rolling with an excavator as defined in Clause 6.4.2.

1.7.49 **Sand**—granular soil that may contain a small proportion of fines including silt or clay. The amount of fines may be assessed as small by a visual inspection or if the amount that passes a 75 µm sieve is 15% or less. Material with a higher proportion of fines shall be treated as silt or clay.

1.7.50 **Shall**—indicates that a statement is mandatory.

1.7.51 **Should**—indicates a recommendation.

1.7.52 **Silt**—fine-grained soil that is non-cohesive and non-plastic when wet and can include some sand and clay.

1.7.53 **Single-leaf masonry**—outer walls constructed with a single thickness of masonry units.

1.7.54 **Slab**—general term used to refer to slab-on-ground, stiffened rafts, footing slabs, stiffened footing slabs and waffle rafts.

1.7.55 **Slab-on-ground**—concrete floor supported on the ground and incorporating integral edge beams.

1.7.56 **Slab panel**—part of a slab between beams.

1.7.57 **Soft site**—site consisting of soils for which the allowable bearing pressure is less than that required by the proposed footing system.

1.7.58 **Stiffened raft**—concrete slab on ground stiffened by integral edge beams and a grid of internal beams.

1.7.59 **Strip footing**—footing of rectangular section.

1.7.60 **Stump**—element supported on a footing used for the support of a frame construction.

1.7.61 **Two-storey**—construction with wall height, excluding any gable, not exceeding 8.0 m and including two trafficable floors.

1.7.62 **Veneer**—construction of either masonry veneer or articulated masonry veneer.

1.7.63 **Waffle raft**—a stiffened raft with closely spaced ribs constructed on the ground and with slab panels suspended between ribs.

1.8 **NOTATION** The symbols used in this Standard are as follows:

\[ B_w = \text{width of stem of edge, or internal beam} \]

\[ D = \text{overall depth of a footing or beam} \]

\[ D_t = \text{depth of strip footing from finished ground surface level} \]

\[ D_s = \text{depth of pad footing from finished ground surface level (see Figure 3.6)} \]

\[ d = \text{differential movement} \]

\[ e = \text{edge distance (see Section 4)} \]

\[ H_s = \text{depth of design suction change (Table 2.4)} \]
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\( h \) = maximum height of masonry wall retaining structure as shown in Figure 6.3

\( I_{ps} \) = shrinkage index or instability index without lateral restraint or loading of soil

\( I_{pt} \) = effective instability index including allowance for lateral restraint and vertical load

\( k \) = soil stiffness for soil-structure models

\( L \) = footing or slab length in the design direction

\( L_s \) = minimum distance from internal stump or pier to perimeter stump, pier or wall (see Figure 3.6)

\( M_{cr} \) = cracking moment capacity

\( M_u \) = ultimate bending moment capacity

\( M^* \) = design moment

\( t \) = thickness of slab or pad footing

\( W_f \) = shape factor for edge heave

\( y_m \) = differential mound movement

\( y_s \) = characteristic surface movement

\( \alpha \) = coefficient relating \( I_{pt} \) to \( I_{ps} \)

\( \Delta \) = differential footing movement (Clause 4.4)

\( \Delta u \) = change in suction

\( \phi \) = strength reduction factor

1.9 REINFORCEMENT DESIGNATION

1.9.1 Trench mesh For the purpose of this Standard, trench mesh is designated as x-8TM, x-11TM or x-12TM, where x is the number of main longitudinal wires required of the appropriate trench mesh F8TM, F11TM or F12TM. Trench mesh shall comply with AS 1304.

1.9.2 Square fabric F62, F72, F82, F92 or F102 fabric or equivalent, where specified, shall comply with AS 1304. F53 and F63 refer to square fabric similar to those specified in AS 1304, but with 5 mm wires at 300 mm centres and 6 mm wires at 300 mm centres respectively.

1.9.3 Reinforcing bars Reinforcing bars shall comply with AS 1302 and are specified as x-Y12, x-Y16 or x-Y20, where x is the number of bars.

1.9.4 High strength steel Where fabric of higher strength than 450 MPa or bars of higher strength than 400 MPa are to be substituted for the specified reinforcement in the standard designs in Section 3, a proportional reduction in reinforcement area is permitted, provided that the substitute steel has a uniform elongation of at least 1.5% and that test certificates are available to substantiate this value. This reduction in reinforcement area is not permitted where reinforcement is less than 6 mm diameter. Use of reinforcing steel with yield strength greater than 500 MPa is not covered by this Standard.

1.10 INFORMATION ON DRAWINGS The site classification, selected footing systems and any special sitework and site drainage shall be documented for reactive sites.

NOTE: The footing specification relies on specific site drainage performance.
SECTION 2 SITE CLASSIFICATION

2.1 GENERAL

2.1.1 Classification Site classification is performed to allow the selection of standard footing designs presented in Section 3 or for the design of footing systems by engineering principles as described in Section 4.

Natural sites shall be classified into one of the classes given below in accordance with Clauses 2.2, 2.3 and 2.4 for both the expected extent of soil movement and the depth to which this movement extends. In the classification account shall be given to the possibility of a Class P site caused by conditions described in Clause 1.3.3(a), (b) or (c). For the effects of fill on classification see Clause 2.4.6.

NOTE: Site classification may require consideration of factors beyond the boundaries of the subject site.

2.1.2 Definitions Site classes shall be designated for the expected level of site movement shown in Table 2.1.

<table>
<thead>
<tr>
<th>Class</th>
<th>Foundation</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Most sand and rock sites with little or no ground movement from moisture changes</td>
</tr>
<tr>
<td>S</td>
<td>Slightly reactive clay sites* with only slight ground movement from moisture changes</td>
</tr>
<tr>
<td>M</td>
<td>Moderately reactive clay or silt sites, which can experience moderate ground movement from moisture changes</td>
</tr>
<tr>
<td>H</td>
<td>Highly reactive clay sites, which can experience high ground movement from moisture changes</td>
</tr>
<tr>
<td>E</td>
<td>Extremely reactive sites, which can experience extreme ground movement from moisture changes</td>
</tr>
<tr>
<td>A to P</td>
<td>Filled sites (See Clause 2.4.6)</td>
</tr>
<tr>
<td>P</td>
<td>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</td>
</tr>
</tbody>
</table>

* For examples of clay sites classified as Class S, refer to Appendix D.

For Classes M, H and E further division based on the depth of the expected movement is required. For deep-seated movements, characteristic of dry climates and corresponding to a design depth of suction change, \( H_s \), equal to or greater than 3 m, the classification shall be M-D, H-D or E-D as appropriate.

NOTE: For example, H-D represents a highly reactive site with deep moisture changes and H represents a highly reactive site with shallow moisture changes.

2.2 METHODS FOR SITE CLASSIFICATION

2.2.1 General For sites that do not qualify as Class P sites, site classification shall include one or more of the following methods:

(a) Identification of the soil profile and either—
   (i) established data on the performance of houses on the soil profile; or
   (ii) interpretation of the current performance of existing buildings on the soil profile.

(b) Estimation of the characteristic surface movement \( (y_s) \).
2.2.2 Identification of the soil profile  Identification of the soil profile and a classification from established data on the performance of houses on the soil profile are as follows:

(a) The typical soil profile data given in Appendix D shall be used. Where no data are provided in Appendix D, local knowledge where available shall be applied.

NOTE: The soil type and site conditions should be inspected at footing excavation stage by the classifier to confirm the soil profile.

(b) Identification of the soil profile and interpretation of the current performance of existing buildings.

Identification of the soil profile and interpretation of the performance of existing residential footing systems within the region which are not less than 10 years old and are founded on a similar soil profile shall be assessed in accordance with Table 2.2.

NOTE: The soil type and site conditions should be inspected at footing excavation stage by the classifier to confirm the soil profile.

### TABLE 2.2

**SIMPLE CLASSIFICATION BY INTERPRETATION OF FOOTING PERFORMANCE**

(Damage categories are given in Appendix C)

<table>
<thead>
<tr>
<th>Wall construction</th>
<th>Performance of walls of existing buildings on lightly stiffened strip footings or slabs on ground</th>
<th>Primary classification of site</th>
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<tbody>
<tr>
<td>Clad frame</td>
<td>Buildings with differential movements, $d$ (lowest to highest points on perimeter of building)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$d \leq 15$ mm</td>
<td>$S$</td>
</tr>
<tr>
<td></td>
<td>$15 &lt; d \leq 30$ mm</td>
<td>$M$</td>
</tr>
<tr>
<td></td>
<td>$30 &lt; d \leq 50$ mm</td>
<td>$H$</td>
</tr>
<tr>
<td></td>
<td>$d &gt; 50$ mm</td>
<td>$E$</td>
</tr>
<tr>
<td>Masonry (veneer or full)</td>
<td>Damage Category 0 to Category 1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Damage often Category 1 but rarely Category 2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Damage often Category 1 and 2, but rarely Category 3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Damage often Category 3 or more severe and area usually well known for damage to houses and structures</td>
<td></td>
</tr>
</tbody>
</table>

NOTES:

1. Where performance of existing buildings indicates Class H, H-D, E, or E-D, a further investigation is suggested for buildings other than small extensions, garages or out-buildings.

2. Timber subfloor structures in clad-frame buildings may have settled due to biodegradation of the timber structure and not only ground movement.

3. Lightly stiffened footings can be taken to be footings as detailed in this Standard for Class A and S sites.

2.2.3 Estimation of the characteristic surface movement  Estimation of the characteristic surface movements ($y_s$) shall be used to prescribe site class by applying the limits in Table 2.3.
TABLE 2.3
CLASSIFICATION BY CHARACTERISTIC
SURFACE MOVEMENT

<table>
<thead>
<tr>
<th>Surface movement</th>
<th>Primary classification of site</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 mm &lt; $y_s$ ≤ 20 mm</td>
<td>S</td>
</tr>
<tr>
<td>20 mm &lt; $y_s$ ≤ 40 mm</td>
<td>M</td>
</tr>
<tr>
<td>40 mm &lt; $y_s$ ≤ 70 mm</td>
<td>H</td>
</tr>
<tr>
<td>$y_s$ &gt; 70 mm</td>
<td>E</td>
</tr>
</tbody>
</table>

The value of $y_s$ shall be determined using soil shrinkage indices ($I_{ps}$) appropriate to the soil profile of the site and suction change profiles which represent the design moisture changes (see Note 1).

Soil shrinkage indices shall be derived using one or more of the following methods:
(a) Laboratory tests for soil reactivity (AS 1289.7.1.1, AS 1289.7.1.2, AS 1289.7.1.3).
(b) Correlations between shrinkage index ($I_{ps}$) and other clay index tests for the soil type.
(c) Visual-tactile identification of the soil by an engineer or engineering geologist having appropriate expertise and local experience.

NOTES:
1 The general principles of calculating $y_s$ are given in AS 2870 Suppl (Commentary, Clause C2.2.3).
2 The estimation of surface movement shall be based on sufficient soil data to adequately describe the soil profile. Estimations based on a single test result to describe a full soil profile may be misleading.
3 As a guide to designers, the values of design suction changes are given in Table 2.4 for those locations where data are available. The designer may extrapolate to other areas if due consideration is given to the climate and soil fabric. Alternatively, published values of $H_s$ based on consideration of regional Thornthwaite moisture indices, using the general principles in Appendix D and based on at least 20 years of climate data, may be used. Where a watertable is encountered within the depth $H_s$ from the surface, the suction change shall be modified in accordance with Figure 2.1. Shallow bedrock shall be treated as a non-reactive soil layer, having no effect on the design suction change as shown in Figure 2.1. Where the soil profile indicates deep and open shrinkage cracking, the depth ($H_s$) given in Table 2.4 shall be increased to not less than the depth of cracking.

$\Delta u$ and $H_s$ are to be taken from Table 2.4 (except that $H_s$ = depth of watertable if it is less than the value in Table 2.4)

FIGURE 2.1 EFFECT OF BEDROCK OR WATERTABLE ON DESIGN SUCTION CHANGE PROFILES

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### TABLE 2.4
RECOMMENDED SOIL SUCTION CHANGE PROFILLES FOR CERTAIN LOCATIONS

<table>
<thead>
<tr>
<th>Location</th>
<th>Change in suction at the soil surface ($\Delta u$) pF</th>
<th>Depth of design suction change ($H_s$) m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adelaide</td>
<td>1.2</td>
<td>4.0</td>
</tr>
<tr>
<td>Albury/Wodonga</td>
<td>1.2</td>
<td>3.0</td>
</tr>
<tr>
<td>Brisbane/Ipswich</td>
<td>1.2</td>
<td>1.5 to 2.3 (See Note)</td>
</tr>
<tr>
<td>Hobart</td>
<td>1.5</td>
<td>2.0</td>
</tr>
<tr>
<td>Hunter Valley</td>
<td>1.5</td>
<td>2.0</td>
</tr>
<tr>
<td>Launceston</td>
<td>1.2</td>
<td>2.0</td>
</tr>
<tr>
<td>Melbourne</td>
<td>1.2</td>
<td>1.5 to 2.3 (See Note)</td>
</tr>
<tr>
<td>Newcastle/Gosford</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Perth</td>
<td>1.2</td>
<td>3.0</td>
</tr>
<tr>
<td>Sydney</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Toowoomba</td>
<td>1.2</td>
<td>1.8 to 2.3 (See Note)</td>
</tr>
</tbody>
</table>

NOTE: The variation in $H_s$ depends largely on climatic variation.

### 2.3 SITE INVESTIGATION REQUIREMENTS

#### 2.3.1 General
Where a site investigation is required for the purpose stated in Clause 2.3.2, the requirements in Clauses 2.3.3 to 2.3.5 shall be met.

#### 2.3.2 Purpose
The purpose of site investigation is to provide sufficient information to enable a site classification to be made, and to include information on the presence and depth of fill material, natural soil profile, and soil reactivity where required.

#### 2.3.3 Depth of investigation
The soil profile shall be examined to a minimum depth equal to 0.75 times the depth of the suction change, $H_s$, as given in Table 2.4, but not less than 1.5 m, unless rock is encountered or in the opinion of the classifier, further drilling is unnecessary for the purpose of identifying the soil profile in accordance with Clause 2.2.1(a).

#### 2.3.4 Minimum number of exploration positions
For house sites, either of the following shall apply:

(a) A minimum of one borehole or pit per house site (see Note 1).

(b) A minimum of three boreholes per site in areas with deep-seated movements ($H_s > 3.0$), and areas where the soil profile is known to be highly variable (see Notes 1 and 2).

NOTES:

1. The total number of boreholes across a housing subdivision may be reduced if soil profiling indicates uniform soil conditions which are predictable from soil maps. The presence of gilgais in an area is evidence of highly variable soil profiles within a site.

2. For sites for extensions and outbuildings, essentially rectangular in plan, with walls articulated at the junction with any other building and not longer than 9 m in either direction, only one borehole is required if the original site classification for the house has proved satisfactory.

#### 2.3.5 Assessment of allowable bearing pressure
Class A, S, M, H and E sites shall have adequate allowable bearing pressure. Adequate allowable bearing pressure is as follows:

(a) The allowable bearing pressure at foundation level shall be not less than 100 kPa for strip and pad footings, and under the edge footing of footing slabs used without tie bars between the edge footing and slab.
(b) The allowable bearing pressure at foundation level shall be not less than 50 kPa under all beams and slab panels and support thickenings for slab construction.

Determination of allowable bearing pressure shall consider the weakest state of the foundation under normal site conditions; local knowledge shall be used.

NOTE: Inadequate allowable bearing pressure is not common except for some sites with loose sand, collapsing soils or swampy deep silt deposits.

2.4 ADDITIONAL CONSIDERATIONS FOR SITE CLASSIFICATION

2.4.1 General Site classes shall be determined according to the provisions of Clauses 2.4.2 to 2.4.6. Filled sites shall be classified as Class P except where the conditions of Clauses 2.4.6(c) and 6.4.2 allow another classification.

2.4.2 Sites consisting predominantly of sand or rock Sites consisting predominantly of sand or rock, as defined in Clause 1.7, shall be classified as Class A.

NOTE: Loose sands may not have adequate bearing capacity for strip or pad footings. See Clause 2.4.4.

2.4.3 Natural sand sites underlain by clay Where clay occurs at a greater depth than $0.75 \ H_s$ the effect of the clay on the classification can be disregarded. Refer to Clause 2.4.5.

2.4.4 Class P sites Sites shall be classified as Class P if—

(a) the allowable bearing pressure is less than specified in Clause 2.3.5;

(b) excessive foundation settlement may occur due to the effects of fill loading on the foundation;

(c) the sites contain uncontrolled fill or certain controlled clay fill as stipulated in Clause 2.4.6;

(d) the sites are subject to mine subsidence, landslip, collapse activity or coastal erosion; or

(e) the sites are subject to moisture changes due to extreme site conditions significantly more severe than the reasonable site conditions described in Clause 1.3.2.

2.4.5 Effect of site works on classification The classification of a site shall take into account the effect of site works when these are known at the time of classification. Where the effect of site works is not taken into account, the classification shall be reconsidered if—

(a) the depth of cut on an S, M, H or E site exceeds 0.5 m; or

(b) the depth of fill exceeds the limits provided in Clause 2.4.6.

2.4.6 Effect of fill on classification The following shall be observed:

(a) Controlled fill

(i) Shallow fill The classification of a site with controlled fill up to 0.8 m deep for sand and 0.4 m deep for material other than sand shall be the same as the natural site, prior to filling.

(ii) Deep fill The classification of a site with controlled sand fill deeper than 0.8 m shall not require a more severe Class than the natural site classification, but may be used to justify by engineering principles a less severe reactive site classification. The effect of the fill on the settlement of the underlying soil shall be taken into account. The classification of a site with controlled fill of material other than sand and deeper than 0.4 m shall be Class P (refer Item (c) regarding reclassification).
(b) **Uncontrolled fill**

(i) **Shallow fill** The classification of a site with uncontrolled fill up to 0.8 m deep for sand and 0.4 m deep for material other than sand shall be Class P, unless all footings (i.e. edge beams, internal beams and load support thickenings) are founded on natural soil through the filling.

(ii) **Deep fill** The classification of a site with uncontrolled fill deeper than 0.8 m for sand and 0.4 m for material other than sand shall be Class P.

(c) **Reclassification of filled sites** A site filled with controlled fill and classified as Class P can be given an alternative site classification if assessed in accordance with the following engineering principles:

(i) The assessment shall consider the movement of the fill and the underlying soil from the as-constructed condition to the long-term equilibrium moisture conditions. Allowance shall be made for construction variations of moisture conditions. Alternatively, the movement may be estimated by reference to established knowledge of the behaviour of similar fills in a similar area.

(ii) The depth of the cracked zone should be taken as zero for reactive clay in controlled fill placed less than 5 years prior to building construction.

**NOTES:**

1 Long term equilibrium moisture conditions may be taken as—

   (a) marginally wet of optimum moisture condition (standard compactive effort) in the eastern coastal area; or

   (b) marginally dry of optimum moisture condition (standard compactive effort) in arid areas.

2 Equilibrium moisture conditions may be estimated by reference to similar clays that have stabilized near the centre of large sealed surfaces.

3 The reclassification should not be less severe than the natural site classification, unless the controlled fill consists of non-reactive material and is deeper than one metre or $0.5H_s$, whichever is greater.
SECTION 3  STANDARD DESIGNS

3.1 SELECTION OF FOOTING SYSTEMS

3.1.1 Selection procedure Standard designs for footing systems shall be selected from Figures 3.1 to 3.6. The design in Figure 3.2 makes provision in Western Australia for a reduction in slab thickness to 85 mm. Where this provision is utilized, the slab shall be specified by an appropriate qualified engineer. These designs shall not apply to—

(a) Class E or P sites;
(b) buildings longer than 25 m;
(c) slabs containing permanent joints, e.g. contraction or control joints;
(d) two-storey construction with a suspended concrete floor at the first floor level except in accordance with Clause 3.5;
(e) two-storey construction in excess of the height limitations. See Clause 1.7.61;
(f) support of columns or fireplaces not complying with Clause 3.6;
(g) buildings including wing walls or masonry arches unless they are detailed for movement in accordance with TN 61;
(h) construction of three or more storeys; or
(i) single-leaf earth or stone masonry walls greater than 3 m height.

NOTE: The use of proprietary suspended floor systems based on composite design with precast beams and insitu concrete is not precluded by this Clause.

3.1.2 Design for single-leaf masonry, mixed construction and earth masonry The proportions for the selected footing system for single-leaf masonry, mixed construction and earth masonry shall comply with Clause 3.1.1 using the equivalent construction set out below in Table 3.1.

### TABLE 3.1  EQUIVALENT CONSTRUCTIONS

<table>
<thead>
<tr>
<th>Actual construction</th>
<th>Equivalent construction</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>External walls</strong></td>
<td><strong>Internal walls</strong></td>
</tr>
<tr>
<td>Single leaf masonry</td>
<td>Articulated masonry on</td>
</tr>
<tr>
<td>Reinforced single-leaf masonry</td>
<td>Articulated masonry or reinforced single leaf masonry</td>
</tr>
<tr>
<td>Reinforced single-leaf masonry</td>
<td>Masonry</td>
</tr>
<tr>
<td>Articulated single-leaf masonry</td>
<td>Articulated masonry</td>
</tr>
<tr>
<td>Other single-leaf masonry</td>
<td>Framed</td>
</tr>
<tr>
<td>Other single-leaf masonry</td>
<td>Masonry</td>
</tr>
<tr>
<td><strong>Mixed construction</strong></td>
<td>Framed</td>
</tr>
<tr>
<td>Full masonry</td>
<td>Framed</td>
</tr>
<tr>
<td>Articulated full masonry</td>
<td>Framed</td>
</tr>
<tr>
<td>Earth masonry:</td>
<td>Framed</td>
</tr>
<tr>
<td>Infill panels of earth masonry</td>
<td>Framed earth masonry</td>
</tr>
<tr>
<td>Load bearing earth masonry</td>
<td>Load bearing earth masonry</td>
</tr>
</tbody>
</table>

NOTE: Articulated internal walls shall comply with TN 61.
3.1.3 Construction with framed party walls For construction involving framed party walls for the purpose of this Section, the building shall be taken as equivalent to masonry veneer construction or design shall be based on engineering principles.

3.1.4 Design for masonry feature walls Masonry feature walls can be used in basically masonry veneer construction on footings appropriate for masonry veneer provided that the wall is straight, one-storey, less than 4 m in length between joints and is supported by either—

(a) an internal beam in a stiffened raft; or
(b) an internal strip footing continuous from external strip footing to external strip footing.

3.1.5 Design for outbuildings and extensions to dwellings The footing system design given in this Section shall be used for outbuildings and extensions and—

(a) outbuildings of clad framed construction can use footing systems appropriate for one class of reactivity less severe than for a house; and
(b) walls of masonry extensions, or masonry veneer extensions, shall be articulated at the junction with the existing building.

Footings of similar proportions and details to those used in an existing house on the same allotment can be used, provided that the performance of the existing house has been satisfactory and there are no unusual moisture conditions.

3.1.6 Design for rock outcrops Where a footing or edge beam encounters a single local rock outcrop or floater over a length less than 1 m, the depth of the footing or edge beam can be reduced by up to one-third provided that the amount of top and bottom reinforcement is doubled and extended 500 mm past the section with reduced depth. Alternatively, the footing can be stepped or raised provided the structural stiffness is preserved.

3.1.7 Design for partial rock foundation Where part of the footing is on rock and part is on soil, provision for movement at the change between the two types of foundation shall be made by articulation of the superstructure or strengthening of the footing system.

On M and H sites where part of the footing is on rock and part is on soil, the design shall be in accordance with engineering principles.

3.1.8 Design for complete rock foundation Where the edge beam or footing is to be founded entirely on rock, the footing or beam can be replaced by a levelling pad of concrete or mortar.

3.2 PIER-AND-BEAM, PIER-AND-SLAB OR PILE SYSTEMS Generally a pier-and-beam, pier-and-slab or piled footing system shall be designed in accordance with engineering principles.

The waffle raft for a one-storey house for clad frame or masonry veneer on M, M-D, H or H-D sites may be supported on piers as follows without structural design of the waffle raft:

(a) Piers shall be located on the intersection of every third rib.
(b) An additional Y12 bar at the top shall be provided in the ribs intersecting the piers, but no shear fitments are required.
<table>
<thead>
<tr>
<th>Site class</th>
<th>Type of construction</th>
<th>Edge and internal beams (see Note 1)</th>
<th>Slab fabric</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Depth (D) mm</td>
<td>Bottom reinforcement</td>
<td>Maximum spacing centre to centre (m)</td>
</tr>
<tr>
<td>Class A</td>
<td>Clad Frame</td>
<td>300</td>
<td>3-8TM</td>
</tr>
<tr>
<td></td>
<td>Articulated masonry veneer</td>
<td>300</td>
<td>3-8TM</td>
</tr>
<tr>
<td></td>
<td>Masonry veneer</td>
<td>300</td>
<td>3-8TM</td>
</tr>
<tr>
<td></td>
<td>Articulated full masonry</td>
<td>400</td>
<td>3-8TM</td>
</tr>
<tr>
<td></td>
<td>Full masonry</td>
<td>400</td>
<td>3-8TM</td>
</tr>
<tr>
<td>Class S</td>
<td>Clad frame</td>
<td>300</td>
<td>3-8TM</td>
</tr>
<tr>
<td></td>
<td>Articulated masonry veneer</td>
<td>300</td>
<td>3-8TM</td>
</tr>
<tr>
<td></td>
<td>Masonry veneer</td>
<td>300</td>
<td>3-11TM</td>
</tr>
<tr>
<td></td>
<td>Articulated full masonry</td>
<td>400</td>
<td>3-11TM</td>
</tr>
<tr>
<td></td>
<td>Full masonry</td>
<td>450</td>
<td>3-11TM</td>
</tr>
<tr>
<td>Class M</td>
<td>Clad frame</td>
<td>300</td>
<td>3-11TM</td>
</tr>
<tr>
<td></td>
<td>Articulated masonry veneer</td>
<td>400</td>
<td>3-11TM</td>
</tr>
<tr>
<td></td>
<td>Masonry veneer</td>
<td>400</td>
<td>3-11TM</td>
</tr>
<tr>
<td></td>
<td>Articulated full masonry</td>
<td>500</td>
<td>3-12TM</td>
</tr>
<tr>
<td></td>
<td>Full masonry</td>
<td>800</td>
<td>3-12TM</td>
</tr>
<tr>
<td>Class M-D</td>
<td>Clad frame</td>
<td>400</td>
<td>3-11TM</td>
</tr>
<tr>
<td></td>
<td>Articulated masonry veneer</td>
<td>400</td>
<td>3-11TM</td>
</tr>
<tr>
<td></td>
<td>Masonry veneer</td>
<td>500</td>
<td>3-12TM</td>
</tr>
<tr>
<td></td>
<td>Articulated full masonry</td>
<td>625</td>
<td>3-12TM</td>
</tr>
<tr>
<td></td>
<td>Full masonry</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Class H</td>
<td>Clad frame</td>
<td>400</td>
<td>3-11TM</td>
</tr>
<tr>
<td></td>
<td>Articulated masonry veneer</td>
<td>500</td>
<td>3-12TM</td>
</tr>
<tr>
<td></td>
<td>Masonry veneer</td>
<td>700</td>
<td>3-16</td>
</tr>
<tr>
<td></td>
<td>Articulated full masonry</td>
<td>1000</td>
<td>4-16</td>
</tr>
<tr>
<td></td>
<td>Full masonry</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Class H-D</td>
<td>Clad frame</td>
<td>500</td>
<td>3-11TM</td>
</tr>
<tr>
<td></td>
<td>Articulated masonry veneer</td>
<td>600</td>
<td>3-12TM</td>
</tr>
<tr>
<td></td>
<td>Masonry veneer</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Articulated full masonry (See Note 6)</td>
<td>1200</td>
<td>4-16</td>
</tr>
<tr>
<td></td>
<td>Full masonry</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

**FIGURE 3.1 (in part) STIFFENED RAFT SITE CLASSES A, S, M, M-D, H, H-D**

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NOTES:
1 Internal and external edge beams shall form an integral structural grid in accordance with Clauses 5.3.8 and 5.3.9.

2 A 10% increase in these spacings is permitted where the spacing in the other direction is 20% less than specified.
   Where the number of beams in a particular direction satisfies the requirements of the maximum spacing given above, the spacing between individual beams can be varied, provided that the spacing between any two beams does not exceed the spacing given in the above Figure by 25%.
   These allowances for increased beam spacings do not override the maximum spacings between edge beams and first internal beams as required by Clause 5.3.9.

3 Where external beams are wider than 300 mm, an extra bottom bar or equivalent of the same bar size is required for each 100 mm additional width.

4 For a particular class of site, if a beam depth greater than that given for the type of construction is selected, the bottom reinforcement specified for the deeper beam is to be used.

5 Except on site Classes M-D or H-D, a horizontal construction joint is permitted in the edge and internal beams, provided the concrete-to-concrete joint is at least 150 mm wide and traversed by R10 fitments at 600 mm centres or equivalent (see alternative edge beam detail).

6 Construction details are given in Clauses 6.4 and 6.6.

7 If shrinkage crack control is a design consideration, then refer to Clause 5.3.7.

8 For Class M, M-D, H and H-D sites, alternative reinforcement, as follows, may be selected in lieu of the slab fabric specified in the Table above:

<table>
<thead>
<tr>
<th>Alternative slab fabric</th>
<th>Specified slab fabric</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F102</td>
</tr>
<tr>
<td>Additional reinforcement at top of beams</td>
<td></td>
</tr>
<tr>
<td>F92</td>
<td>3-11TM</td>
</tr>
<tr>
<td>F82</td>
<td>3-Y16</td>
</tr>
<tr>
<td>F72</td>
<td>4-Y16</td>
</tr>
</tbody>
</table>

9 Where a reinforced single-leaf masonry wall is constructed directly above, and structurally connected to, a concrete edge beam, the beam may be reduced to 300 mm wide by 300 mm deep and reinforced with 3-8TM reinforcement.

Internal beam details and spacings shall comply with this Figure 3.1. At a re-entrant corner where an external beam continues as an internal beam, the external beam details shall be continued for a length of 1 m into the internal beam.

**FIGURE 3.1 (in part)** STIFFENED RAFT SITE CLASSES A, S, M, M-D, H, H-D
NOTES:

1. In Western Australia, where specified by an appropriately qualified engineer, the slab thickness may be reduced to 85 mm with reinforcement as specified below. All other details remain the same.
   - Use F53 when maximum slab length ≤ 12 000.
   - Use F63 when maximum slab length > 12 000 and ≤ 18 000.
   - Use F62 when maximum slab length > 18 000.

2. Use F63 when maximum slab length ≤ 12 000.
   - Use F62 when maximum slab length > 12 000 and ≤ 18 000.
   - Use F72 when maximum slab length > 18 000.

3. Dune sands may require compaction.

DIMENSIONS IN MILLIMETRES

FIGURE 3.2 FOOTING SLAB FOR CLASS A SITES FOR CLAD FRAME, ARTICULATED MASONRY VENEER, MASONRY VENEER, ARTICULATED FULL MASONRY OR FULL MASONRY
NOTES:

1 The proportions for the tied edge beam apply only where there is a structural connection by concrete-to-concrete contact tied with fitments.

2 Where the edge beam supports but is not tied to the slab such as is shown for the alternative edge beam treatment above, the footing proportions and footing reinforcement shall comply with Figure 3.6.

3 Construction details are given in Section 6. In particular, for the alternative edge treatment, the retaining wall details are given in Clause 6.4.5.

4 Fitments shall be adequately anchored above and below the joint.

DIMENSIONS IN MILLIMETRES

FIGURE 3.3 FOOTING SLAB FOR CLASS A AND FOR CLASS S SITES FOR CLAD FRAME, ARTICULATED MASONRY VENEER, MASONRY VENEER, ARTICULATED FULL MASONRY OR FULL MASONRY
**Site class and type of construction**

| Class A | Clad frame, articulated masonry veneer and masonry veneer  | 260 | Y12 | F72 |
| Class A | Single-storey articulated full masonry and single-storey full masonry | 310 | Y12 | F72 |
| Class S | Clad frame, articulated masonry veneer and masonry veneer | 260 | Y12 | F72 |
| Class S | Single-storey articulated full masonry | 310 | Y12 | F72 |
| Class M | Clad frame, articulated masonry veneer and masonry veneer | 310 | Y12 | F72 |
| Class M-D | Clad frame and articulated masonry veneer | 310 | Y12 | F72 |
| Class H | Clad frame | 310 | Y12 | F72 |
| Class H | Articulated masonry veneer | 385 | Y12 | F82 |
| Class H-D | Clad frame | 385 | Y16 | F72 |
| Class H-D | Articulated masonry veneer | 385 | Y16 | F82 |

**DIMENSIONS IN MILLIMETRES**

**FIGURE 3.4 (in part) WAFFLE RAFT**
NOTES:

1 The minimum stem width shall be 110 mm. The minimum width of the base of an external beam shall be 110 mm for clad frame, single-storey articulated masonry veneer and single-storey masonry veneer and 300 mm for two-storey articulated masonry veneer, two-storey masonry veneer, single-storey articulated full masonry and single-storey full masonry. Additional reinforcement shall be provided for all beams where the stem width exceeds 150 mm. The total number of reinforcement bars in beams shall be as follows:

<table>
<thead>
<tr>
<th>Stem width mm</th>
<th>Top steel (additional to slab fabric)</th>
</tr>
</thead>
<tbody>
<tr>
<td>110 to 150</td>
<td>0</td>
</tr>
<tr>
<td>151 to 220</td>
<td>1</td>
</tr>
<tr>
<td>221 to 330</td>
<td>2</td>
</tr>
<tr>
<td>331 to 440</td>
<td>3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Beam base width mm</th>
<th>Bottom steel</th>
</tr>
</thead>
<tbody>
<tr>
<td>110 to 150</td>
<td>1</td>
</tr>
<tr>
<td>151 to 220</td>
<td>2</td>
</tr>
<tr>
<td>221 to 330</td>
<td>3</td>
</tr>
<tr>
<td>331 to 440</td>
<td>4</td>
</tr>
</tbody>
</table>

2 The alternative rebate can be used.

3 85 mm slab thickness can be used in garage areas.

4 Construction details are given in Clauses 6.4 and 6.6. See in particular Clause 6.4.3.

DIMENSIONS IN MILLIMETRES

FIGURE 3.4 (in part) WAFFLE RAFT
NOTES:
1 The reinforcement of the cavity shall consist of Y12 bars at 400 centres in each direction anchored into both the footing and the slab. The cavity shall be filled with well compacted 20 MPa concrete, or grout in accordance with AS 3700. Single-leaf reinforced masonry can also be used.
2 Horizontal construction joints are permitted between the beams and the slab provided the concrete-to-concrete joint is at least 150 mm wide and is traversed by R10 fitments at 600 mm centres.
3 Beams shall be spaced in accordance with Figure 3.1.
4 Where local practice indicates satisfactory performance, the internal stiffening beams can be omitted when all internal partition walls are of non-load-bearing framed construction.
5 Construction details are given in Section 6.

DIMENSIONS IN MILLIMETRES

FIGURE 3.5 STIFFENED SLAB WITH DEEP EDGE BEAM FOR MASONRY VENEER AND ARTICULATED MASONRY VENEER CLASS M SITE
(i) Masonry veneer or articulated masonry veneer

(ii) Clad frame on stumps or piers

(iii) Clad frame on base or dwarf wall

(a) Suspended floors (timber or concrete single-storey construction < 4 kPa dead load)

(b) Infill floor Class A and Class S sites

FIGURE 3.6 (in part) STRIP FOOTING SYSTEMS
DIMENSIONS IN MILLIMETRES

FIGURE 3.6 (in part) STRIP FOOTING SYSTEMS

(c) Example of footing system with re-entrant corners
<table>
<thead>
<tr>
<th>Site class and type of construction</th>
<th>D (mm)</th>
<th>B (mm)</th>
<th>Reinforcement</th>
<th>$D_\text{s}$ (mm)</th>
<th>$L_\text{s}$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Class A</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clad frame</td>
<td>300</td>
<td>300</td>
<td>3-8TM</td>
<td>400</td>
<td>—</td>
</tr>
<tr>
<td>Articulated masonry veneer</td>
<td>300</td>
<td>300</td>
<td>3-8TM</td>
<td>400</td>
<td>—</td>
</tr>
<tr>
<td>Masonry veneer</td>
<td>300</td>
<td>300</td>
<td>3-8TM</td>
<td>400</td>
<td>—</td>
</tr>
<tr>
<td>Articulated full masonry</td>
<td>300</td>
<td>400</td>
<td>4-8TM</td>
<td>400</td>
<td>—</td>
</tr>
<tr>
<td>Full masonry</td>
<td>300</td>
<td>400</td>
<td>4-8TM</td>
<td>400</td>
<td>—</td>
</tr>
<tr>
<td><strong>Class S</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clad frame</td>
<td>400</td>
<td>300</td>
<td>3-8TM</td>
<td>400</td>
<td>—</td>
</tr>
<tr>
<td>Articulated masonry veneer</td>
<td>400</td>
<td>300</td>
<td>3-8TM</td>
<td>400</td>
<td>—</td>
</tr>
<tr>
<td>Masonry veneer</td>
<td>400</td>
<td>300</td>
<td>3-8TM</td>
<td>400</td>
<td>—</td>
</tr>
<tr>
<td>Articulated full masonry</td>
<td>400</td>
<td>400</td>
<td>4-11TM</td>
<td>400</td>
<td>—</td>
</tr>
<tr>
<td>Full masonry</td>
<td>500</td>
<td>400</td>
<td>4-11TM</td>
<td>400</td>
<td>—</td>
</tr>
<tr>
<td><strong>Class M</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clad frame</td>
<td>400</td>
<td>300</td>
<td>3-11TM</td>
<td>500</td>
<td>—</td>
</tr>
<tr>
<td>Articulated masonry veneer</td>
<td>450</td>
<td>300</td>
<td>3-11TM</td>
<td>500</td>
<td>—</td>
</tr>
<tr>
<td>Masonry veneer</td>
<td>500</td>
<td>300</td>
<td>3-12TM</td>
<td>500</td>
<td>—</td>
</tr>
<tr>
<td>Articulated full masonry</td>
<td>600</td>
<td>400</td>
<td>4-12TM</td>
<td>500</td>
<td>—</td>
</tr>
<tr>
<td>Full masonry</td>
<td>900 (Note 2)</td>
<td>400</td>
<td>4-12TM</td>
<td>500</td>
<td>—</td>
</tr>
<tr>
<td><strong>Class M-D</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clad frame</td>
<td>500</td>
<td>300</td>
<td>3-11TM</td>
<td>800</td>
<td>—</td>
</tr>
<tr>
<td>Articulated masonry veneer</td>
<td>550</td>
<td>300</td>
<td>3-12TM</td>
<td>800</td>
<td>—</td>
</tr>
<tr>
<td>Masonry veneer</td>
<td>700 (Note 2)</td>
<td>300</td>
<td>3-Y16</td>
<td>800</td>
<td>—</td>
</tr>
<tr>
<td>Articulated full masonry</td>
<td>1 100 (Note 2)</td>
<td>400</td>
<td>4-Y16</td>
<td>800</td>
<td>—</td>
</tr>
<tr>
<td><strong>Class H</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clad frame</td>
<td>500</td>
<td>300</td>
<td>3-11TM</td>
<td>1 000</td>
<td>≥2.4 m</td>
</tr>
<tr>
<td>Articulated masonry veneer</td>
<td>600</td>
<td>300</td>
<td>3-12TM</td>
<td>1 000</td>
<td>≥2.4 m</td>
</tr>
<tr>
<td>Masonry veneer</td>
<td>850 (Note 2)</td>
<td>300</td>
<td>3-Y16</td>
<td>1 000</td>
<td>≥2.4 m</td>
</tr>
<tr>
<td>Articulated full masonry</td>
<td>1 100 (Note 2)</td>
<td>400</td>
<td>4-Y16</td>
<td>1 000</td>
<td>≥2.4 m</td>
</tr>
</tbody>
</table>

NOTES:
1 All masonry walls shall be supported on strip footings
2 For all beams 700 mm or deeper, as specified in the table above, internal footings shall be provided at no more than 6 m centres, and at re-entrant corners to continue the footings to the opposite external footing (see Figure 3.6).
   Internal strip footings shall be of the same proportions as the external footing and run from external footing to external footing.
   ‘Side slip joints’ consisting of a double layer of polyethylene shall be provided at the sides of the footing only.
3 The size and thickness of pads for stumps or piers shall be selected using AS 1684. Sizes for larger loads may be selected using Appendix E.
4 Bracing forces and uplift forces to stumps may be provided for, using the details in Appendix E.
5 If strip footings deeper than those required are used, the reinforcement shall be increased to match that specified for the deepened proportions.
6 Infill floors in Figure 3.6(b) shall only be used for Class A and S sites, and may be concrete slabs, brick paving, stone flags or compacted or stabilized earth. For concrete slab infill panels, mesh may be required to control shrinkage in slab panels and around openings or restrained regions. F62 should normally be provided (see also Clause 5.3.7).
7 Where footings are wider than the specified width, an extra bar of the same bar size, or equivalent, is required top and bottom for each 100 mm additional width.
8 $D_f \geq D + 75$ mm.
9 For site Classes M-D and H, a provision shall be made by methods such as an adequate crawl space to allow for future re-levelling due to drying effects.

FIGURE 3.6 (in part) STRIP FOOTING SYSTEMS

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3.3 REINFORCEMENT EQUIVALENCES  The bar sizes given in Table 3.2 shall be deemed to comply with the requirements for trench mesh reinforcement in beams and footings. F11TM and F12TM may be replaced by F1118 or F1218 fabric respectively. Two layers of F8TM may be used as a replacement for F11TM. Where a single layer of trench mesh would be too wide for the footing or beam, multiple layers or equivalent reinforcement shall be used. Where bars are specified in this Standard, trench mesh of equivalent force capacity (in multiple layers if required) may be used.

Alternative arrangements of beam or footing reinforcement, including trench mesh placed vertically, may be used if the flexural strength of the section is unimpaired.

### TABLE 3.2

<table>
<thead>
<tr>
<th>Trench mesh</th>
<th>Area $\text{mm}^2$</th>
<th>Reinforcing bar alternative</th>
<th>Trench mesh* alternative</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-8TM</td>
<td>101</td>
<td>2-Y12</td>
<td>not applicable</td>
</tr>
<tr>
<td>3-8TM</td>
<td>151</td>
<td>2-Y12</td>
<td>not applicable</td>
</tr>
<tr>
<td>4-8TM</td>
<td>201</td>
<td>3-Y12</td>
<td>2-11TM</td>
</tr>
<tr>
<td>5-8TM</td>
<td>252</td>
<td>4-Y12</td>
<td>3-11TM</td>
</tr>
<tr>
<td>2-11TM</td>
<td>197</td>
<td>2-Y12</td>
<td>4-8TM</td>
</tr>
<tr>
<td>3-11TM</td>
<td>295</td>
<td>3-Y12</td>
<td>6-8TM</td>
</tr>
<tr>
<td>4-11TM</td>
<td>395</td>
<td>4-Y12</td>
<td>8-8TM</td>
</tr>
<tr>
<td>2-12TM</td>
<td>245</td>
<td>2-Y16</td>
<td>3-11TM</td>
</tr>
<tr>
<td>3-12TM</td>
<td>368</td>
<td>2-Y16</td>
<td>4-11TM</td>
</tr>
<tr>
<td>4-12TM</td>
<td>491</td>
<td>3-Y16</td>
<td>5-11TM</td>
</tr>
</tbody>
</table>

* Where necessary two layers of mesh may be used.

3.4 SUSPENDED CONCRETE FLOORS IN ONE-STOREY CONSTRUCTION

Suspended concrete floors in one-storey construction shall be designed in accordance with engineering principles except that for short span floors on Class A and S sites the following guidelines may be used for design:

(a) Fill used as temporary support need not be compacted, but clay fill shall be placed at a moisture content that will minimize subsequent swell.

(b) Internal concrete slabs that are suspended between at least two opposite walls and do not support walls or columns may be constructed of 125 mm thickness with F72 top and F72 bottom minimum reinforcement, with 20 mm cover top and bottom, for clear spans up to 4.0 m length.

(c) Such floors can be supported on dwarf masonry walls on strip footings.

3.5 FOOTING SYSTEMS FOR TWO-STOREY CONSTRUCTION WITH SUSPENDED CONCRETE FLOOR  For a two-storey building with a suspended concrete floor at the first floor level, the footing system designs given in Figures 3.1 to 3.6 for Class A and S sites can be used provided that for the suspended floor—

(a) the thickness is not greater than 165 mm, or the dead load per unit area is not greater than 4 kPa;

(b) the span is less than 5 m; and

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(c) the support is on masonry walls at each end with openings not greater than 2.5 m.

In addition, the width given in those figures for the edge beams and footings shall be increased by 100 mm and where reinforcement is specified the reinforcement both top and bottom shall be increased by one wire of the same diameter.

Where the suspended floor is supported through an internal wall onto the slab panel on the ground, the thickness of the slab panel shall be increased to 200 mm for a width of 500 mm and where reinforcement is specified an extra strip containing three wires of the slab fabric placed in the bottom of the thickened section shall be provided.

3.6 FOOTINGS FOR CONCENTRATED LOADS

3.6.1 Footings for columns Loads from columns shall be supported by either—
(a) pad footings, which can be integral with a slab, of the proportions in Figure 3.6;
(b) edge beams or strip footings; or
(c) slab panels for supported areas less than 10 m².

On reactive clays, concentrated loads from columns shall be supported directly on an edge or internal beam or edge footing, provided that the supported area is not greater than 20 m² (see Note 2, Figure E1).

On sites Class M, M–D, H and H–D separate footings shall not be used unless the construction supported is structurally isolated from the rest of the building.

3.6.2 Footings for fireplaces on Class A and S sites Fireplaces shall be supported on a pad footing 150 mm thick for one-storey construction or 200 mm thick for two-storey construction reinforced top and bottom with F72 and extending 300 mm past the edges of the masonry except for any edge flush with the outer wall. This footing can be integral with a slab.
SECTION 4 DESIGN BY ENGINEERING PRINCIPLES

4.1 GENERAL Slabs or footings designed in accordance with engineering principles shall be designed in accordance with the following Clauses and AS 3600 (except where more specific provisions are given here).

Engineering principles may be used to extend the range of validity of the deemed-to-comply designs or to modify the designs set out in Section 3 of this Standard.

The general requirements for footings for rafts designed under this Clause shall be in accordance with Clause 3.1, Figure 3.1 and the relevant sections of Clause 4.4 and Section 5 of this Standard.

4.2 DESIGN LOADS Slabs and footings and associated superstructures, shall be designed to achieve the performance requirements set out in Clause 1.3 when subjected to the loads noted therein.

4.3 DESIGN OF FOOTING SYSTEMS Footing systems shall be designed in accordance with one of the following—
(a) raft footing systems supporting a superstructure that relies entirely on the raft to resist cracking, (see Clause 4.4 or 4.6);
(b) footing systems for walls which are able to cantilever without cracking, (see Clause 4.7); or
(c) other footing systems (see Clause 4.6).

4.4 RAFT FOOTING SYSTEMS A stiffened raft footing system which supports a superstructure that relies entirely on the footing system or raft stiffness to resist movement and cracking shall be proportioned as follows:
(a) For rafts with beams embedded deeper than 1 m in depth, or with connected piers greater than 1 m in depth, the analysis shall consider the influence of skin friction on the sides of the beams or piers according to engineering principles. The uplift resistance of connected piers or anchors shall be taken into account.
(b) The tolerable limits for relative differential movement depend on the form of construction, surface finish and the actual detailing of the superstructure, and in the absence of more specific information shall be taken from Table 4.1.

<table>
<thead>
<tr>
<th>Type of construction</th>
<th>Absolute maximum differential footing movement, $\Delta$, as a function of span, mm</th>
<th>Maximum differential footing movement $\Delta$, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clad frame</td>
<td>$\leq L/300$</td>
<td>40</td>
</tr>
<tr>
<td>Articulated masonry veneer</td>
<td>$\leq L/400$</td>
<td>30</td>
</tr>
<tr>
<td>Masonry veneer</td>
<td>$\leq L/600$</td>
<td>20</td>
</tr>
<tr>
<td>Articulated full masonry</td>
<td>$\leq L/800$</td>
<td>15</td>
</tr>
<tr>
<td>Full masonry</td>
<td>$\leq L/2000$</td>
<td>10</td>
</tr>
</tbody>
</table>

NOTE: Bed joint reinforcement of articulated full masonry can be used to increase the allowable movement. Bed joint reinforcement consists of at least three layers of pairs of 3 mm wires galvanized to AS 1650 with an average coating mass of not less than 300 g/m².
(c) The effective total width of the flange for slab beams shall be determined as follows:

(i) In sagging mode (edge heave), the effective total width shall be taken as $B_w + 0.1 L$ for an edge beam and $B_w + 0.2 L$ for an internal beam.

(ii) In hogging mode (centre heave), the effective total width shall be assessed by the designer as between $B_w + 0.1 L$ and $2 m$ for an edge beam, and $B_w + 0.2 L$ and $4 m$ for an internal beam.

In no case shall the flange width be taken as greater than the distance halfway to the adjacent beams.

(d) From the soil-structure analysis using the loads given in Clause 1.4, the design moment ($M^*$) and the required stiffness ($EI$) may be determined. The structural design for strength of the cross-section shall satisfy the requirement that—

$$M^* \leq \phi M_u \ldots 4.4$$

where $M_u$ is the ultimate strength calculated in accordance with AS 3600

$\phi$ is the strength reduction factor given in AS 3600.

NOTE: Two acceptable methods of design (Walsh and Mitchell) using soil structure interaction for stiffened rafts are described in Appendix F.

(e) The stiffness, $EI$, of the slab shall be not less than that required by the analysis. In the determination of $EI$ the value of $E$ shall be taken as 15,000 MPa for N20 concrete and $I$ shall be as defined in AS 3600.

(f) To ensure ductility, the cross-section shall be reinforced so that the ultimate strength calculated on the basis of a reinforced section ($M_u$) is 20% greater than the cracking moment capacity ($M_c$), where $M_c$ may be determined for sagging moments for 20 MPa concrete using a tensile strength of 2.7 MPa and for hogging moments 1.8 MPa.

(g) Shear reinforcement need not be provided in raft beams unless the calculated shear force exceeds the design strength of the unreinforced section. Side face reinforcement is not required in deep raft beams.

### 4.5 MODIFICATION OF STANDARD RAFT DESIGNS

#### 4.5.1 Application

This Clause may be used provided that the design parameters are within the following range:

<table>
<thead>
<tr>
<th>Design parameter</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>$y_s$</td>
<td>10 mm to 70 mm if $H_s &gt; 3 m$ or 80 mm if $H_s &lt; 3 m$</td>
</tr>
<tr>
<td>$\Delta$</td>
<td>5 mm to 50 mm</td>
</tr>
<tr>
<td>Span</td>
<td>5 m to 25 m</td>
</tr>
<tr>
<td>Beam spacing</td>
<td>$\leq$1.25 values in Figure 3.1 (see also Clause 5.3.9)</td>
</tr>
<tr>
<td>Beam depth</td>
<td>250 mm to 1000 mm</td>
</tr>
<tr>
<td>Minimum depth of any beam</td>
<td>$\geq$0.7 max. beam depth</td>
</tr>
<tr>
<td>Beam width</td>
<td>110 mm to 400 mm</td>
</tr>
<tr>
<td>Average load</td>
<td>to 15 kPa</td>
</tr>
<tr>
<td>Edge line load</td>
<td>to 15 kN/m</td>
</tr>
</tbody>
</table>

This Clause may be used to modify the standard raft designs in Section 3 where the value of $y_s$ is lower than the upper limit in Section 3, or where the beam layout provides a...
spacing less than the minimum required. It may be used to override the beam spacing and reinforcement provisions provided that the slab fabric is not less than F72 for slab spans \( \leq 18 \) m and F82 for spans 18 m to 25 m and provided that the ductility requirements of Clause 4.4(e) are satisfied. It shall not be necessary to use a design stronger than the standard design for the site classification nor is it permitted to use a design weaker than the design given for the next lower site Class.

For types of construction outside the range of that given in Figure 3.1 and Table 3.1 for which no standard design is appropriate this method may be used.

4.5.2 Modification procedure The value of \( \frac{y}{\Delta} \) shall be determined where \( \Delta \) is the permissible maximum differential movement given in column 3 of Table 4.1 for the appropriate construction. From Figure 4.1 and the value of \( \frac{y}{\Delta} \), the design shall provide in each direction the stiffness parameter \( \log \left\{ \sum \left( \frac{B_w D^3}{12} \right)/W \right\} \) where the summation is determined over all the edge and internal beams and \( B_w \) is the beam web width in millimetres, \( D \) is the overall depth of the beam in millimetres and \( W \) is the overall width of the slab in metres normal to the direction of the beams being considered. The strength shall be provided by the satisfaction of the ductility requirements of Clause 4.4(e). For non-rectangular plans the design shall be based on overlapping rectangles.

4.5.3 Detailing and construction requirements Except as modified in Clause 4.5.2, detailing and construction shall be in accordance with the requirements of Sections 5 and 6.

4.6 DESIGN OF FOOTING SYSTEMS OTHER THAN STIFFENED RAFTS The design of shallow footing systems other than stiffened rafts shall be in accordance with the general principles outlined in Clause 4.4, modified to take into account the soil-structure interaction of the footing system. In particular, lift-off shall not be considered in strip footings deeper than 0.6 m.
FIGURE 4.1 MOVEMENT RATIO VERSUS UNIT STIFFNESS

\[
\frac{\Delta_k}{\Delta}, \text{ where } \Delta = \text{maximum differential movement} \\
\text{use Table 4.1, Column 3 for class of construction}
\]

\[
\log \left\{ \Sigma \left( \frac{B_e D^3}{12 W} \right) \right\}
\]

where

- \( B_e \) = width of beam web, in millimetres
- \( D \) = overall depth of beam, in millimetres
- \( W \) = overall width of slab, in metres
4.7 FOOTING SYSTEMS FOR REINFORCED SINGLE LEAF MASONRY WALLS
For buildings whose walls have sufficient strength to span for significant distances over sagging or hogging footings (either as a cantilever over hogging footings or simply supported over sagging footings), it shall be permissible to proportion the wall-footing system to utilize the flexural strength of the wall.

Design of the masonry shall be in accordance with AS 3700 to resist the action effects derived in this Standard. The required dimensions, reinforcement and disposition of footings shall be designed to satisfy the principles of Clause 4.4 and in accordance with Items (a) or (b) following:

(a) If the walls are not structurally connected to the footing or slab system, the length over which a particular type of wall can span before it cracks or experiences excessive deflection shall be determined and the footings proportioned to ensure that this length is not exceeded and the potential for the footing to separate from the wall is limited to 5 mm, unless specific provision is made for movement.

(b) If the walls of a building are structurally connected to the footing or slab system by means of steel starter bars, anchors or equivalent, the combined strength and stiffness of the wall and footing/slab system shall be considered to determine the length over which the particular combination can span before it cracks or experiences excessive deflection. The footings, floor and the wall shall be proportioned and reinforced to ensure that this length is not exceeded.

The joints between adjacent wall panels shall be designed to accommodate any movement resulting from footing movement. The wall configuration shall be such that each wall is prevented from tilting, twisting or distorting to an extent which limits the serviceability of the building.

In determining the spanning ability, the following points shall be considered:
(i) The effect of increased load from upper floors or roof structure in diminishing this ability to span.
(ii) The strengthening effect (if any) of joint reinforcement in masonry walls.
(iii) The strengthening effect (if any) of steel reinforcement in the cores and bond beams of reinforced or partially reinforced hollow masonry.
(iv) The strengthening effect (if any) of render, plaster, plasterboard or other veneers fixed to the wall.

4.8 DESIGN FOR TIMBER PILED FOOTING SYSTEMS
The design of timber piled footing systems may be carried out in accordance with Appendix G.
SECTION 5 DETAILING REQUIREMENTS

5.1 GENERAL The detailing of footing systems in accordance with Sections 3 and 4 shall comply with Clauses 5.2 to 5.4. For Class H or E sites, additional requirements are given in Clause 5.5. See also AS 3660.1 and AS 3700.

5.2 DRAINAGE REQUIREMENTS

5.2.1 General requirements The drainage and height of the floor level above finished ground level may be affected by factors other than structural design requirements. Such factors include the following:

(a) The local plumbing requirements, in particular the height of the overflow relief gully relative to drainage fittings and ground level.
(b) The run-off from storms and local topography.
(c) The effect of excavation or filling.
(d) The possibility of flooding.
(e) The effects of existing and post-construction landscaping.
(f) The level of existing legal point of stormwater discharge.
(g) Termite management (see AS 3660.1).

Drainage shall be designed and constructed to avoid water ponding against or near the footing. The ground in the immediate vicinity of the perimeter footing, including the ground uphill from the slab on cut-and-fill sites, shall be graded to fall 50 mm minimum away from the footing over a distance of 1 m.

Alternative drainage systems will be required on zero lot line construction. Any paving shall also be suitably sloped.

5.2.2 Specific requirements for slabs The minimum height of the slab above finished ground level shall be 150 mm, except in sandy, well-drained areas where the minimum height shall be 100 mm. These heights can be reduced locally to 50 mm near adjoining paved areas that slope away from the building.

NOTE: These minimum heights are to the top of the finished ground level after completion of paving and similar.

5.3 REQUIREMENTS FOR RAFTS AND SLABS

5.3.1 Concrete Concrete shall be not less than N20 (see AS 1379) grade, with 20 mm nominal maximum aggregate size. Slump shall be selected to suit construction requirements.

5.3.2 Reinforcement Reinforcement in rafts and slabs shall have covers and be spliced in accordance with the following:

(a) Cover for the reinforcement shall be 40 mm to unprotected ground, 40 mm to external exposure, 30 mm to a membrane in contact with the ground, and 20 mm to an internal surface. The slab fabric shall be placed towards the top of the raft or slab within the zone defined by these limits.

(b) Raft or slab fabric shall be lapped by one full panel of fabric so that the two outermost transverse wires of one sheet overlap the two outermost transverse wires of the sheet being lapped, such as shown in Figure 5.1.
(c) Trench mesh shall have all cross wires cut flush with the outer main wires. Trench mesh in beams shall be overlapped by the width of the fabric at T- and L-intersections. Trench mesh shall be spliced, where necessary, by a lap of 500 mm.

(d) Reinforcing bars shall have a lap length at splices not less than 500 mm. At T- and L-intersections, the bars shall be continued across the full width of the intersection. At L-intersections, one outer bar shall be bent and continued 500 mm, or a bent lap bar 500 mm long on each leg shall be provided.

(e) Service penetrations shall be permitted through the middle third of the edge and stiffening beams. The effect of other service penetrations shall be taken into account by the provision of extra concrete depth or reinforcement.

NOTE: The wire orientation is illustrative only.

FIGURE 5.1 ALTERNATIVE METHODS OF LAPPING OF FABRIC

5.3.3 Vapour barriers and damp-proofing membranes

5.3.3.1 General The raft or slab shall be provided with a vapour barrier, or where required, a damp-proofing membrane.

NOTE: Damp-proofing membranes are normally required in South Australia. Their use is also recommended in areas prone to rising damp and salt attack.

5.3.3.2 Materials The materials required for vapour barriers and damp-proofing membranes are as follows:

(a) 200 µm (0.2 mm) thick polyethylene film in accordance with Item (c)(i), as follows:

(i) Vapour barrier—medium impact resistance in accordance with Item (c)(ii).

(ii) Damp-proofing membrane—high impact resistance in accordance with Item (c)(ii), and resistant to puncture and penetration in accordance with Item (c)(iii).

(b) Film branded continuously ‘AS 2870 Concrete underlay, 0.2 mm—Medium (or high as appropriate) impact resistance’, together with manufacturer or distributors name, trademark or code.

(c) Criteria specified for vapour barriers and damp-proofing membranes shall be determined by the following methods:

(i) Film thickness—0.2 mm—shall be determined using the method of test outlined in AS/NZS 4347.9, except that three tests per metre width of film shall be carried out across the full width of the film, with the resulting mean average thickness to be between 180 µm and 220 µm and a maximum of only one measurement to be below 170 µm for a material pass to be recorded.

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(ii) **Impact resistance**—shall be determined using the falling dart impact test outlined in AS 4347.6 and the following:

(A) Using a load of 180 grams for medium impact film and 310 grams for high impact film and a drop height of 660 mm, one test shall be carried out on the fold of the film and the film shall not fail.

(B) Using a load of 200 grams for medium impact film and 340 grams for high impact film and a drop height of 660 mm, two tests per metre width of film shall be carried out across the full width of the body of the film and 75% of these tests shall pass for a material pass to be recorded.

(iii) **Resistance to puncturing and moisture penetration**—shall be determined using the CSIRO ‘Method for determination of the penetration resistance of water vapour barriers to falling aggregate’. Vapour permeance following this test shall not exceed 0.02 mg/N.s with no punctures or rips in the film.

5.3.3.3 **Installation** Both vapour barriers and damp-proofing membranes shall be installed as follows:

(a) The sheet shall be placed beneath the slab so that the bottom surface of the slab and beams, including internal beams, is entirely underlaid. The membrane shall extend under the edge beam to ground level, however, where justified by satisfactory local experience a vapour barrier may be terminated at the internal face of external beams as shown on Figure 5.2(a).

(b) Lapping at joints shall be not less than 200 mm for continuity.

(c) Penetrations by pipes or plumbing fittings shall be taped or sealed with a close-fitting sleeve or made continuous with the vapour barrier or damp-proof membrane by taping or by lapping according to Item (b).

5.3.4 **Edge rebates** Edge rebates for slab on ground, stiffened raft or waffle raft with masonry cavity or veneer construction shall comply with the following:

(a) The rebate depth shall be not less than 20 mm. The edge rebate may be stepped along its length.

(b) It shall be permissible to construct the exterior masonry wall past the edge of the rebate but in no case shall the overhang exceed 15 mm.

(c) The edge rebate shall be flashed and drained. If weepholes are used, they shall be spaced at not more than 1.2 m and be located above the finished ground level. Any portion of the deepened rebate that cannot be drained shall be mortar filled.

(d) Where the edge rebate exceeds 150 mm in depth, the minimum width of the edge beam at the base of the rebate shall not be less than 200 mm, except that if R10 ties at 900 mm spacings are provided to resist vertical forces, this minimum width can be reduced to 150 mm. This Clause shall not apply to waffle rafts.

(e) The depth of concrete below the edge rebate shall be not less than 150 mm.

(f) Edge rebates are not required for construction with single-leaf masonry.

(g) In areas of high salt damp, careful detailing of damp-proof courses is required.

(h) Where the edge beams are retaining more than 450 mm of fill, see Clause 6.4.5. Alternatively, the design shall be in accordance with engineering principles.

(i) Where the edge rebate depth is greater than 400 mm, the minimum stem width shall be 200 mm. The effect of the rebate shall be taken into account in accordance with engineering principles.

Permissible arrangements of the edge rebate are shown in Figure 5.2. Typical detailing for footings supporting single-leaf masonry walls is shown in AS 2870 Supplement 1.
(a) Minimum rebate for cavity masonry or veneer wall

(b) Deep edge rebate alternative

NOTE: The cavity and flashing details shown are examples only. See AS 3700.

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FIGURE 5.2 EDGE REBATE DETAILS
5.3.5 **Recesses in slab panels** Where the raft or slab surface is recessed to provide for services, the soffit of the slab shall be deepened to maintain the required thickness and the reinforcement shall be continuous or lapped as shown in Figure 5.3.

![Figure 5.3 - Slab Detail at a Recess](image)

**DIMENSIONS IN MILLIMETRES**

**FIGURE 5.3 SLAB DETAIL AT A RECESS**

5.3.6 **Heating cables and pipes** Heating cables and pipes shall be embedded in the slab as follows:

(a) Electric heating cables may be embedded in the slab without any increase in thickness or reinforcement.

(b) Hot water heating pipes may be embedded in a slab provided that the slab thickness is increased by 25 mm and an increase made in the fabric of one level, for example, F72 for F62, F82 for F72 and F92 for F82. The fabric shall be placed at a suitable level to accommodate the pipes, subject to the requirements of Clause 5.3.2(a).

5.3.7 **Shrinkage control** Shrinkage shall be controlled as follows:

(a) Where brittle floor coverings are to be used over an area greater than 16 m², extra measures shall be taken to control the effect of shrinkage cracking. Such measures shall include one of the following:

(i) The amount of shrinkage reinforcement shall be increased to F92 or equivalent throughout the affected slab panels. Alternatively, an additional sheet of slab mesh shall be placed over the affected area.

(ii) The bedding system for brittle coverings shall be selected on the basis of the expected slab movement and the characteristics of the floor covering.

(iii) The placement of floor coverings shall be delayed.

NOTE: A minimum period of three-months drying of the concrete is usually required before the placement of brittle floor coverings.

(b) At re-entrant corners, two strips of 3-8TM, or one strip of 3-11TM or 3Y12 bars, shall be placed diagonally across a potential crack. All such reinforcement shall have a minimum length of 2 m.

5.3.8 **Beam continuity in rafts** Internal beams shall be continuous from edge to edge of the slab. Where beams are at different levels, as may occur in two-pour systems, special care is required to provide continuity. Internal beams shall be located to provide continuity with the edge beams at re-entrant corners. Where one side of the re-entrant corner is less than 1.5 m, continuity of beams shall be provided by one of the details specified in Figure 5.4.
5.3.9 Beam layout restrictions For Class M and H sites, in addition to the beam spacing criterion given in Figure 3.1 at external corners, the maximum spacing between intersections of an internal beam with an external beam shall be 4.0 m. See Figure 5.5.

NOTE: S = beam spacing from Figure 3.1.

FIGURE 5.5 BEAM SPACING MEASUREMENT FOR CLASS M & H SITES
5.4 REQUIREMENTS FOR PAD AND STRIP FOOTINGS

5.4.1 Concrete Concrete shall be not less than N20 grade, with 20 mm nominal maximum aggregate size. Slump shall be selected to suit the construction conditions.

5.4.2 Reinforcement Reinforcement in pad and strip footings shall comply with the following:

(a) Trench mesh reinforcement may be replaced by the equivalent reinforcing bars.
(b) Design cover to the reinforcement shall be 40 mm.
(c) Trench mesh in footings shall be anchored by the width of the fabric at T- and L-intersections and at splices shall be lapped by 500 mm.
(d) The lap length of bar splices shall be not less than 500 mm. At T- and L-intersections, the bars shall be continued across the full width of the intersection. At L-intersections, one outer bar shall be bent and continued for 500 mm, or a bent lap bar 500 mm long on each leg shall be provided.
(e) Service penetrations shall be permitted through the middle third of the footing. The effect of other footing penetrations shall be taken into account by the provision of extra depth or reinforcement.

5.4.3 Stepping of footings The base of a strip footing shall be horizontal or at a slope of not more than 1 in 10, and the footing shall be stepped in accordance with one of the methods given in Figure 5.6.

![Figure 5.6 Acceptable Methods of Stepping Strip Footings](image-url)
5.5 ADDITIONAL REQUIREMENTS FOR CLASS H AND E SITES

5.5.1 Architectural restrictions The following aspects of superstructure design and layout shall be used to reduce the effects of movement:

(a) Masonry shall be detailed to minimize the possibility of damage.

(b) Extensions shall be isolated from the original structure by means of articulation to allow for differential movement.

(c) In masonry construction articulation joints shall be introduced at abrupt changes in construction such as at large openings or near corners except where the wall is designed to be reinforced masonry.

5.5.2 Variations in foundation material If the footing or slab is partly on rock and partly on reactive clay, structural continuity of the entire footing shall be maintained and allowance shall be made for potential movement in the superstructure near the junction of foundation types.

5.5.3 Drainage requirements Allotments containing reactive sites classified as H or E shall be provided with an adequate system of drainage designed in accordance with the following:

(a) Surface drainage of allotments for reactive sites for both footings and slabs shall be considered in the design of the footing system, and care shall be taken with surface drainage of the allotment from the start of construction. The drainage system shall be completed by the finish of construction of the house.

(b) Plumbing trenches shall be sloped away from the house and shall be backfilled with clay in the top 300 mm within 1.5 m of the house. The clay used for backfilling shall be compacted. Where pipes pass under the footing system, the trench shall be backfilled with clay or concrete to restrict the ingress of water beneath the footing system.

(c) Subsurface drains shall be free draining and shall be able to be inspected and maintained. Subsurface drains shall be protected by filters and geotextiles.

NOTE: Wherever practicable, subsurface drains should be avoided near footings.

5.5.4 Plumbing requirements Allotments containing reactive sites classified as H or E shall be provided with an adequate system of plumbing detailed in accordance with the following:

(a) Penetrations of the edge beams of a raft and perimeter strip footings shall be avoided, but where necessary shall be sleeved to allow for movement.

Closed-cell polyethylene lagging shall be used around all stormwater and sewer pipe penetrations through external footings. The lagging shall be a minimum of 20 mm thick on Class H sites and 40 mm thick on Class E sites. Sleeves allowing equivalent movements may be used as an alternative. Lagging is not required around vertical penetrations through slab panels.

(b) Connection of stormwater drains and waste drains shall include flexible connections.

(c) Septic tanks and associated soakage areas shall be located to minimize soil moisture increase within the foundation.

(d) Plumbing and drainage under a slab shall be avoided where practicable. Pipes may be encased in concrete or in recesses in the slab when provided with flexible joints at the exterior of the slab.

NOTE: Methods used should comply with local plumbing and drainage regulations.
SECTION 6 CONSTRUCTION REQUIREMENTS

6.1 GENERAL The construction of footing systems in accordance with Sections 3, 4 and 5 shall comply with Clauses 6.2 to 6.5. For Class H or E sites additional requirements are given in Clause 6.6.

6.2 PERMANENT EXCAVATIONS Any vertical or near-vertical permanent excavation within 2 m of the building and deeper than 0.6 m in material other than rock shall be adequately retained or battered. The effects of excavations on drainage or foundation drying shall be considered.

6.3 TEMPORARY EXCAVATION Any temporary excavations shall be carried out only after giving due consideration to the stability of the soil and the need to maintain support for the footing system.

Where footing systems are placed near existing services to which future access will be required, consideration shall be given to the stability of the footing systems.

NOTE: Excavations should not extend below a line drawn 30° to the horizontal for sand, or 45° to the horizontal for clay, from the bottom edge of the edge beam or footing without special consideration.

6.4 CONSTRUCTION OF SLABS

6.4.1 General The construction of slab footing systems including slab-on-ground, footing slab, stiffened slab with deep edge beam, stiffened raft and waffle raft shall comply with the requirements of Section 5 and of this Clause. For Class H and E sites additional requirements are given in Clause 6.6.

The methods given for sloping sites assume that landslip is not a design consideration. Where landslip is possible the design shall be given individual consideration.

6.4.2 Filling Filling used in the construction of a slab, except where the slab is suspended, shall consist of controlled fill or rolled fill as follows:

(a) Controlled fill is material that has been placed and compacted in layers by compaction equipment within a defined moisture range to a defined density requirement. Except as provided below, controlled fill shall be placed in accordance with AS 3798.

Sand fill up to 0.8 m deep, well compacted in not more than 0.3 m thick layers by a vibrating plate or vibrating roller, shall be deemed to comply with this requirement. A satisfactory test for sand fill not containing gravel sized material is the achievement of a blow count of 7 or more per 0.3 m using the penetrometer test described in AS 1289.F3.3.

Non-sand fill up to 0.4 m deep, well compacted in not more than 0.15 m layers by a mechanical roller, shall be deemed to comply with this requirement. Clay fill shall be moist during compaction.

(b) Rolled fill consists of material compacted in layers by repeated rolling with an excavator. Rolled fill shall not exceed 0.6 m compacted in layers not more than 0.3 m thick for sand material or 0.3 m compacted in layers not more than 0.15 m thick for other material.

NOTE: The depths of fill given in this Clause are the depths measured after compaction.
6.4.3 Foundation for slabs  The foundation shall satisfy the following:

(a) Top soil containing grass roots or other organic material shall be removed from the area on which the slab is to rest.

(b) On sites subject to wind or water erosion, the foundation of the edge beam or footing shall be protected.

(c) The slab, including edge and internal beams, shall be founded as follows:

(i) Slab panels, edge beams, internal beams and load support thickenings are to be supported on natural soil with an allowable bearing pressure not less than 50 kPa.

(ii) Slab panels, internal beams and load support thickenings are to be founded on controlled or rolled fill compacted in accordance with Clause 6.4.2.

(iii) Edge beams shall not be founded on rolled fill. Edge beams may be founded on controlled fill compacted in accordance with Clause 6.4.2(a). This fill shall continue past the edge of the building by at least 1 m and shall be retained or battered beyond this point by a slope not steeper than two horizontal to one vertical.

(iv) Edge footings not tied to a footing slab (see Figures 3.2 and 3.3(b)) shall be founded in natural soil with an allowable bearing pressure of 100 kPa or may be founded on controlled sand fill on a Class A or S site.

(d) The base of edge beams and footings may be stepped or sloped not more than 1 in 10.

(e) A blinding layer of sand is not required but where used shall comply with Clause 6.4.2 if deeper than 100 mm.

6.4.4 Treatment of sloping sites  The treatment of slabs on cut-and-fill sloping sites shall comply with one of the following methods:

(a) The site shall be cut and filled and the fill (see Figures 6.1(a) and 6.1(b)) shall continue past the edge of the house by at least 1 m and shall be retained or battered beyond this point by a slope protected from erosion and not steeper than two horizontal to one vertical. The interior of the slab shall be founded on compacted material, satisfying Clause 6.4.3(c). The edge beams shall be founded on natural soil or on controlled fill or may be supported by piers designed in accordance with engineering principles.

(b) The site shall be cut and filled with fill material that satisfies Clause 6.4.3(c) and the fill shall be retained at the edge in accordance with Clause 6.4.5 as shown in Figure 6.1(c).

(c) The slab and beams may be stepped in combination with methods in Items (a) or (b) above to reduce the extent of excavation or fill. At the change in elevation, the step shall comply with the following:

(i) The ground behind the step shall be properly drained and the slab shall be waterproofed.

(ii) Care shall be taken that Clause 5.3.4 is satisfied.

(iii) Steps in stiffened rafts shall be designed to preserve the structural continuity of the system.

(iv) Steps in slabs for Class A and Class S sites shall comply with Figure 6.2 where the height of the step is less than 1.2 m. The masonry retaining wall shown in Figure 6.2 shall comply with Clause 6.4.5(b). Steps in beams shall comply with the principles of Clause 5.4.3.
The site shall be cut and filled and, where the fill does not satisfy Clause 6.4.2, the slab shall be designed as pier-and-slab in accordance with the following:

(i) The suspended slab shall be designed in accordance with AS 3600.

(ii) On Class M or H sites the strength and stiffness of the suspended slab shall be not less than required by Section 3.

Where the fill consists of reactive clay, the fill shall be placed in a moist condition and the footing system shall be designed to allow for heave.

(e) On natural slopes greater than 1:8 benching and consideration of slope stability may be required.
NOTE: Drainage provision should be made.

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FIGURE 6.2 SLAB STEP OPTIONS ON CLASS A OR S SITES

6.4.5 Retention of fill under slabs for Class A, S and M sites  At the edge of a slab (or at a step) where more than 0.45 m of fill is retained, one of the following edge treatments shall be used as follows:

(a) The fill up to a height of 750 mm shall be retained by a deepened edge beam integral with the slab and of not less than 200 mm width. If the fill is greater than 0.75 m but not more than 1.5 m depth, vertical reinforcement of centrally placed F82 fabric shall be provided. Where the height exceeds 1.5 m, the edge beam shall be designed by engineering principles.

(b) Where the fill is retained by a masonry wall, the following shall be satisfied:

   (i) The methods of construction shall be as shown in Figure 6.3. Compaction of the fill shall be undertaken in a manner that does not cause damage to the wall.

   NOTE: Clay fill should be avoided but if used shall be placed in a moist condition.

   (ii) For footing slabs on Class M sites, the slab and the footing shall be tied by Y12 bars at 400 mm centres.
Wall height (h) | Wall construction
---|---
h < 450 | Single width masonry with engaged piers at 1200 mm centres
h ≤ 750 | Double width masonry wall 230 mm thick. Solid or filled concrete block wall 200 mm thick
h ≤ 1500 | Double width masonry with a 75 mm filled cavity or a 200 mm filled block wall reinforced with tied Y12 bars at 400 mm spacing horizontally and vertically. For h > 1200 mm the wall and footing shall be tied to the slab. Cavity filling shall be well compacted 20 MPa concrete or grout in accordance with AS 3700
h > 1500 | Designed in accordance with engineering principles

NOTE: Drainage provisions should be made.

DIMENSIONS IN MILLIMETRES

FIGURE 6.3 ACCEPTABLE STRUCTURAL DETAILS FOR WALLS RETAINING NON-REACTIVE FILL UNDER SLAB
6.4.6 Fixing of reinforcement  Reinforcement shall be fixed in position prior to concreting by means of proprietary spacers, bar chairs with bases, ligatures or other appropriate fixings so as to achieve the required reinforcement position and concrete covers. Reinforcement shall not be placed or located after concreting.

6.4.7 Placing, compaction and curing of concrete  The concrete shall be transported, placed, compacted and cured in accordance with good building practice.

6.4.8 Additional requirements for salt-damp areas  Where required for durability in known salt-damp areas, the concrete shall be vibrated and cured for at least three days.

6.5 CONSTRUCTION OF STRIP AND PAD FOOTINGS

6.5.1 General  The construction of strip and pad footings shall comply with Clause 6.5.2. For Class H or Class E sites additional requirements are given in Clause 6.6.

6.5.2 Foundation  For the strip and pad footing designs in Section 3 the foundation shall satisfy the following:

(a) The foundation shall provide an allowable bearing pressure of 100 kPa or the footing shall be founded on controlled sand fill on a Class A or Class S site.
(b) Topsoil containing grass roots shall be removed from the area on which the footing is to rest.
(c) On sand sites or sites subject to wind or water erosion, the minimum depth below finished ground level to the underside of the footing shall be 300 mm.
(d) Trenches shall be dewatered and cleaned prior to concrete placement so that no significant softened or loosened material remains.

6.6 ADDITIONAL REQUIREMENTS FOR CLASS H AND E SITES  For slab or strip footings on Class H or E sites, the following requirements apply to the building services and footing system in addition to Clauses 6.4 and 6.5:

(a) Any method used to minimize the damage to masonry construction caused by foundation movement shall be detailed on the drawings.
(b) Penetrations of the edge beam and footing by plumbing shall be sleeved.
(c) Water run-off shall be collected and channelled away from the house during construction.
(d) Excavations near the edge of the footing system shall be backfilled in such a way as to prevent access of water to the foundation. For example, excavations should be backfilled above or adjacent to the footing with moist clay compacted by hand-rodding or -tamping. Porous material such as sand, gravel or building rubble should not be used.
(e) Water shall not be allowed to pond in the trenches for a long period.
(f) Joints in plumbing pipes within 3 m of the house under construction shall be articulated to accommodate ground movements without leakage. Septic tanks in particular require careful detailing.
(g) Concrete in beams shall be vibrated and reinforcement shall be fixed in position by bar chairs or ligatures or both.
APPENDIX A
FUNCTIONS OF VARIOUS PARTIES
(Informative)

This Standard is based on the general assumption that one or more of the parties listed below are involved in the design and construction of residential slabs and footings, and their functions and responsibilities are as follows:

Classifier  The classifier is the person or organization responsible for classifying the site. Classification of a site should be carried out by a qualified engineer or engineering geologist, experienced in the field of geomechanics but, where there is established local knowledge, classification may be carried out by the builder, except where otherwise stated.

Designer  The designer is the person or organization responsible for the design of the footing system. Where the design consists of the selection of a design given in the Standard for a Class A, S or M site, the designer may be the builder (see below) or other person experienced in residential building construction. For Class P, H or E sites, however, the designer should be a qualified engineer experienced in the design of footing systems for houses.

Builder  The builder is the person or organization responsible for the construction of the entire building in accordance with the plans and specifications. The builder should be experienced in footing construction and where required by State legislation, should be licensed.

Owner  The owner is responsible for the maintenance of the building and the site and should be familiar with the performance and maintenance requirements set out in the CSIRO pamphlet, 10-91, ‘Guide to Home Owners on Foundation Maintenance and Footing Performance’.
APPENDIX  B
PERFORMANCE CRITERIA AND FOUNDATION MAINTENANCE
(Informative)

B1  GENERAL
The designs and design methods given in the Standard are based on the performance requirement that significant damage can be avoided provided that foundation site conditions are properly maintained. This is expressed in Section 1 by the statement that the probability of failure for reasonable site conditions is low, but is higher if extreme conditions are encountered. It is neither possible nor economical to design for the extreme conditions that could occur in the foundation if a site is not properly maintained. The expected standard of foundation maintenance is described in Paragraph B2.

Some minor cracking and movement will occur in a significant proportion of houses, particularly those on reactive clays, and the various levels of damage are discussed in Paragraph B3.

The performance requirements of a concrete floor in respect to shrinkage cracking and moisture reaction with adhesives are discussed in Paragraph B4.

A more extensive discussion of the material in Paragraphs B2 to B4 is contained in the CSIRO pamphlet, 10-91, ‘Guide to Home Owners on Foundation Maintenance and Footing Performance’ and its recommendations should be followed.

B2  FOUNDATION MAINTENANCE

B2.1  Foundation soils
All soils are affected by water. Silts are weakened by water and some sands can settle if heavily watered, but most problems arise on clay foundations. Clays swell and shrink due to changes in moisture content and the potential amount of the movement is implied in the site classification in this Standard, which is designated as follows:

(a) A means Stable (Non-reactive).
(b) S means Slightly Reactive.
(c) M means Moderately Reactive.
(d) H means Highly Reactive.
(e) E means Extremely Reactive.

Sites classified Class A and S may be treated as non-reactive sites in accordance with Paragraph B2.2. Sites classified as M, H and E should comply with the recommendations given in Paragraph B2.3.

B2.2  Class A and S sites
Sands, silts and clays should be protected from becoming extremely wet by adequate attention to site drainage and prompt repair of plumbing leaks.

B2.3  Class M, H, and E
Sites classified as M, H, or E should be maintained at essentially stable moisture conditions and extremes of wetting and drying prevented. This will require attention to the following:

(a) Drainage of the site
The site should be graded or drained so that water cannot pond against or near the house. The ground immediately adjacent to the house should be graded to a uniform fall of 50 mm minimum away from the house over the first metre. The subfloor space for houses with suspended floors should be graded or drained to prevent ponding where this may affect the performance of the footing system.

The site drainage recommendations should be maintained for the economic life of the building.
(b) **Limitations on gardens** The development of the gardens should not interfere with the drainage requirements or the subfloor ventilation and weephole drainage systems. Garden beds adjacent to the house should be avoided. Care should be taken to avoid overwatering of gardens close to the house footings.

(c) **Restrictions on trees and shrubs** Planting of trees should be avoided near the foundation of a house or neighbouring house on reactive sites as they can cause damage due to drying of the clay at substantial distances. To reduce, but not eliminate, the possibility of damage, tree planting should be restricted to a distance from the house of:

(i) \(1\frac{1}{2} \times\) mature height for Class E sites.

(ii) \(1 \times\) mature height for Class H sites.

(iii) \(\frac{3}{4} \times\) mature height for Class M sites.

Where rows or groups of trees are involved, the distance from the building should be increased. Removal of trees from the site can also cause similar problems.

(d) **Repair of leaks** Leaks in plumbing, including stormwater and sewerage drainage should be repaired promptly.

The level to which these measures are implemented depends on the reactivity of the site. The measures apply mainly to masonry houses and masonry veneer houses. For frame houses clad with timber or sheeting, lesser precautions may be appropriate.

**B3 PERFORMANCE CRITERIA FOR WALLS** It is acknowledged that minor foundation movements occur on nearly all sites and that it is impossible to design a footing system that will protect the house from movement under all circumstances. The expected performance of footing systems designed in accordance with the Standard is defined in terms of the damage classifications in Table C1, Appendix C.

Crack width is used as the major criterion for damage assessment, although tilting and twisting distortions can also influence the assessment. Local deviations of slope of walls exceeding 1/150 are undesirable. The assessment of damage may also be affected by where it occurs and the function of the building, although these effects are not likely to be significant in conventional housing. In the classification of damage, account should also be taken of the history of cracking. For most situations Category 0 or 1 should be the limit. However, under adverse conditions, Category 2 should be expected although such damage should be rare. Significant damage is defined as Category 3 or worse.

For Category 1 or 2 damage, remedial action should consist of stabilizing the moisture conditions of the clay and paying attention to repairing or disguising the visual damage. This should be regarded as part of the normal maintenance of houses on reactive clays.

Even significant masonry cracking with crack widths over 5 mm often has no influence on the function of the wall and only presents an aesthetic problem. Generally, the remedial action for such damage should start with an investigation to establish the cause of the damage. In many cases the treatment should consist of stabilizing moisture conditions by physical barriers or paths or replenishing moisture in dry foundations. This can be followed by repair of the masonry and wherever possible added articulation should be included while repairs are being effected. Structural repairs to the footing system such as deep underpinning should only be considered as the last resort.

Underpinning should generally be avoided where the problem is related to reactive clays, although it is recognized there may be occasional situations where underpinning or other structural augmentation work is appropriate. None of this structural augmentation work should be undertaken without proper engineering appraisal.
In some cases, walls may be designed to span sagging footings and cantilever beyond hogging footings. In such cases, satisfactory performance involves the wall remaining free of cracks and articulation joint movements, remaining within the limits for the particular jointing system.

**B4 PERFORMANCE CRITERIA FOR A CONCRETE FLOOR** Shrinkage cracking can be expected in concrete floors. Concrete floors can also be damaged by swelling of reactive clays or settlement of fill. The categories of damage are given in Table C2, Appendix C. In the classification, account should be taken of whether the damage is stable or likely to increase, and an allowance should be made for any deviations in level which resulted from, or during construction.

The time of attachment of floor coverings and the selection of the adhesive for them should take into account the moisture in the concrete floor and its possible effect on adhesion. Concrete floors can take a considerable time to dry (three to nine months).

Floor coverings and their adhesives can be damaged by moisture in the concrete and by the shrinkage that occurs as the concrete dries. Drying could take three months or more. The time of fixing of floor coverings and the selection of the adhesive should take these factors into account (see AS 3958.1).
APPENDIX C
CLASSIFICATION OF DAMAGE DUE TO FOUNDATION MOVEMENTS
(Normative)

TABLE C1
CLASSIFICATION OF DAMAGE WITH REFERENCE TO WALLS

<table>
<thead>
<tr>
<th>Description of typical damage and required repair</th>
<th>Approximate crack width limit (see Note 3)</th>
<th>Damage category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hairline cracks</td>
<td>&lt; 0.1 mm</td>
<td>0</td>
</tr>
<tr>
<td>Fine cracks which do not need repair</td>
<td>&lt; 1 mm</td>
<td>1</td>
</tr>
<tr>
<td>Cracks noticeable but easily filled. Doors and windows stick slightly</td>
<td>&lt; 5 mm</td>
<td>2</td>
</tr>
<tr>
<td>Cracks can be repaired and possibly a small amount of wall will need to be replaced. Doors and windows stick. Service pipes can fracture. Weather tightness often impaired</td>
<td>5 mm to 15 mm (or a number of cracks 3 mm or more in one group)</td>
<td>3</td>
</tr>
<tr>
<td>Extensive repair work involving breaking-out and replacing sections of walls, especially over doors and windows. Window and door frames distort. Walls lean or bulge noticeably, some loss of bearing in beams. Service pipes disrupted</td>
<td>15 mm to 25 mm but also depends on number of cracks</td>
<td>4</td>
</tr>
</tbody>
</table>

TABLE C2
CLASSIFICATION OF DAMAGE WITH REFERENCE TO CONCRETE FLOORS

<table>
<thead>
<tr>
<th>Description of typical damage</th>
<th>Approx. crack width limit in floor</th>
<th>Change in offset from a 3 m straight edge centred over defect (see Note 6)</th>
<th>Damage category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hairline cracks, insignificant movement of slab from level</td>
<td>&lt; 0.3 mm</td>
<td>&lt; 8 mm</td>
<td>0</td>
</tr>
<tr>
<td>Fine but noticeable cracks. Slab reasonably level</td>
<td>&lt; 1.0 mm</td>
<td>&lt; 10 mm</td>
<td>1</td>
</tr>
<tr>
<td>Distinct cracks. Slab noticeably curved or changed in level</td>
<td>&lt; 2.0 mm</td>
<td>&lt; 15 mm</td>
<td>2</td>
</tr>
<tr>
<td>Wide cracks. Obvious curvature or change in level</td>
<td>2 mm to 4 mm</td>
<td>15 mm to 25 mm</td>
<td>3</td>
</tr>
<tr>
<td>Gaps in slab. Disturbing curvature or change in level</td>
<td>4 mm to 10 mm</td>
<td>&gt; 25 mm</td>
<td>4</td>
</tr>
</tbody>
</table>

NOTES:
1 Crack width is the main factor by which damage to walls is categorized. The width may be supplemented by other factors, including serviceability, in assessing category of damage.
2 In assessing the degree of damage, account shall be taken of the location in the building or structure where it occurs, and also of the function of the building or structure.
3 Where the cracking occurs in easily repaired plasterboard or similar clad-framed partitions, the crack width limits may be increased by 50% for each damage category.
4 Local deviation of slope, from the horizontal or vertical, of more than 1/100 will normally be clearly visible. Overall deviations in excess of 1/150 are undesirable.
5 Account should be taken of the past history of damage in order to assess whether it is stable or likely to increase.
6 The straight edge is centred over the defect, usually, and supported at its ends by equal height spacers. The change in offset is then measured relative to this straight edge.
APPENDIX  D

SITE CLASSIFICATION BY SOIL PROFILE IDENTIFICATION

(Normative)

In some areas, where sufficient data have been established, site classification of a reactive clay soil profile may be associated with the typical soil profiles given in sites in Tables D1, D2, D3, D4 and D5 for the regions associated with each Table. Where variable soil conditions are expected across a site, the Tables shall only be used as an aid to a site investigation. Where soil profiles are relatively consistent (e.g. Melbourne), geological or pedological maps may be used to assist in classifying a site. The soil profile shall be checked by a site visit before construction proceeds and the site classification updated if necessary.

The classification of sites for regions other than those in the Tables may be based on an appropriate Table, provided the climates and soil types and soil profiles are similar between the regions.

The levels of classification expressed in the Tables relate to ‘normal’ site conditions as defined in Clause 1.3.2 of this Standard.

NOTES:

1. ‘Depth of clay’ refers to the thickness of the clay in the soil profile within the depth of $H_s$ (Table 2.4).

2. Where a range of site Classes is given, the classification may be based on the depth of clay, the depth of a permanent water table, if present, and a visual assessment of the soil reactivity.
**TABLE D1**

CLASSIFICATION BASED ON TYPICAL PROFILES — MELBOURNE AND ENVIRONS

<table>
<thead>
<tr>
<th>Soil profiles</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BASALTIC CLAYS</strong> (Including pyroclastics and residual and alluvial clays derived from basaltic and similar volcanic rocks)</td>
<td></td>
</tr>
<tr>
<td>≤0.6 m depth of clay</td>
<td>S to M</td>
</tr>
<tr>
<td>&gt;0.6 ≤1.8 m depth of clay</td>
<td>H</td>
</tr>
<tr>
<td>&gt;1.8 m depth of clay</td>
<td>H to E</td>
</tr>
<tr>
<td>Predominantly gravelly clay (Lateritic)(see Note 2)</td>
<td>M to H</td>
</tr>
<tr>
<td><strong>NON-BASALTIC RESIDUAL CLAYS</strong> (see Note 2) (Including residual clays derived from sedimentary, metamorphic and granitic rocks)</td>
<td></td>
</tr>
<tr>
<td>≤0.6 m depth of clay</td>
<td>S</td>
</tr>
<tr>
<td>&gt;0.6 m depth of clay</td>
<td>M to H</td>
</tr>
<tr>
<td><strong>LIMESTONE CLAYS</strong> (Including clays derived from marls, and other highly calcareous sediments)</td>
<td></td>
</tr>
<tr>
<td>≤0.6 m depth of clay</td>
<td>M</td>
</tr>
<tr>
<td>&gt;0.6 m &lt;1 m depth of clay</td>
<td>M to H</td>
</tr>
<tr>
<td>&gt;1.0 m depth of clay</td>
<td>H to E</td>
</tr>
<tr>
<td><strong>QUATERNARY ALLUVIALS AND TERTIARY SEDIMENTS</strong> (Including delta, dune, lake, stream, colluvial and wind-laid deposits) (see Note 2)</td>
<td></td>
</tr>
<tr>
<td>Where predominantly silts or sands overlie clays</td>
<td></td>
</tr>
<tr>
<td>≤0.6 m silts or sands overlying clays</td>
<td>M to H</td>
</tr>
<tr>
<td>&gt;0.6 ≤1 m silts or sands overlying clays</td>
<td>S to M</td>
</tr>
<tr>
<td>&gt;1 m silts or sands overlying clays</td>
<td>A to S</td>
</tr>
<tr>
<td>Interbedded silts, sands and clay mixtures</td>
<td></td>
</tr>
<tr>
<td>(Assess on the basis of total depth of clay over $H_s$, i.e.</td>
<td></td>
</tr>
<tr>
<td>≤0.6 m total depth of clay</td>
<td>S to M</td>
</tr>
<tr>
<td>&gt;0.6 ≤1 m total depth of clay</td>
<td>M</td>
</tr>
<tr>
<td>&gt;1 m total depth of clay</td>
<td>M to H</td>
</tr>
</tbody>
</table>

**NOTES:**

1 Soil layer thicknesses shall be considered within the depth, $H_s$, which shall be taken to vary with climatic zone as follows:

<table>
<thead>
<tr>
<th>Climatic zone</th>
<th>Description</th>
<th>$H_s$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Alpine/wet coastal</td>
<td>1.5 m</td>
</tr>
<tr>
<td>2</td>
<td>Wet temperate</td>
<td>1.8 m</td>
</tr>
<tr>
<td>3</td>
<td>Temperate</td>
<td>2.3 m</td>
</tr>
<tr>
<td>4</td>
<td>Dry temperate</td>
<td>3.0 m</td>
</tr>
<tr>
<td>5</td>
<td>Semi-arid</td>
<td>4.0 m</td>
</tr>
</tbody>
</table>

Maps of regional climatic zones are presented in Figures D1 and D2.

2 These terms are explained in Geology of Victoria by J.G. Douglas & J.A. Ferguson (Geological Society of Victoria).
### TABLE D2
CLASSIFICATION BASED ON TYPICAL PROFILES—VICTORIA

<table>
<thead>
<tr>
<th>Soil profiles</th>
<th>Climatic zone</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4–5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BASALTIC CLAYS</strong> <em>(Including pyroclastics and residual and alluvial clays derived from basaltic and similar volcanic rocks)</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤0.6 m depth of clay</td>
<td>S to M</td>
<td>S to M</td>
<td>M</td>
<td>M</td>
<td></td>
</tr>
<tr>
<td>&gt;0.6 ≤1.8 m depth of clay</td>
<td>M</td>
<td>H</td>
<td>H</td>
<td>H-D to E</td>
<td></td>
</tr>
<tr>
<td>&gt;1.8 m depth of clay</td>
<td>M</td>
<td>H</td>
<td>H to E</td>
<td>E</td>
<td></td>
</tr>
<tr>
<td>Predominantly gravelly clay (Lateritic) <em>(see Note 2)</em></td>
<td>M</td>
<td>M</td>
<td>M to H</td>
<td>M-D to H-D</td>
<td></td>
</tr>
<tr>
<td><strong>NON-BASALTIC RESIDUAL CLAYS</strong> <em>(see Note 2)</em> <em>(Including residual clays derived from sedimentary, metamorphic and granitic rocks)</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤0.6 m depth of clay</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td></td>
</tr>
<tr>
<td>&gt;0.6 m depth of clay</td>
<td>M</td>
<td>M</td>
<td>M to H</td>
<td>M-D to H-D</td>
<td></td>
</tr>
<tr>
<td><strong>LIMESTONE CLAYS</strong> <em>(Including clays derived from marls and other highly calcareous sediments)</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤0.6 m depth of clay</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td></td>
</tr>
<tr>
<td>&gt;0.6 ≤1 m depth of clay</td>
<td>M</td>
<td>M to H</td>
<td>H</td>
<td>H-D</td>
<td></td>
</tr>
<tr>
<td>&gt;1.0 m depth of clay</td>
<td>H</td>
<td>H</td>
<td>H-D to E</td>
<td>E</td>
<td></td>
</tr>
<tr>
<td><strong>QUATERNARY ALLUVIALS AND TERTIARY SEDIMENTS</strong> *(Including delta, dune, lake, stream, colluvial and wind-laid deposits) <em>(see Note 2)</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Where predominantly silts or sands overlie clays</td>
<td>S to M</td>
<td>M</td>
<td>M to H</td>
<td>M-D to E</td>
<td></td>
</tr>
<tr>
<td>&gt;0.6 ≤1 m silts or sands overlying clays</td>
<td>A to S</td>
<td>S to M</td>
<td>M</td>
<td>M-D to H-D</td>
<td></td>
</tr>
<tr>
<td>&gt;1 m silts or sands overlying clays</td>
<td>A</td>
<td>A to S</td>
<td>S</td>
<td>S to M-D</td>
<td></td>
</tr>
<tr>
<td><strong>Interbedded silts, sands and clay mixtures</strong> <em>(Assess on the basis of total depth of clay over (H_s), i.e.</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤0.6 m total depth of clay</td>
<td>A to S</td>
<td>S</td>
<td>S to M</td>
<td>M</td>
<td></td>
</tr>
<tr>
<td>&gt;0.6 ≤1 m total depth of clay</td>
<td>S</td>
<td>M</td>
<td>M</td>
<td>M-D to H-D</td>
<td></td>
</tr>
<tr>
<td>&gt;1 m total depth of clay</td>
<td>S</td>
<td>M</td>
<td>M to H</td>
<td>M-D to E</td>
<td></td>
</tr>
</tbody>
</table>

**NOTES:**

1 Soil layer thicknesses shall be considered within the depth, \(H_s\), which shall be taken to vary with climatic zone as follows:

<table>
<thead>
<tr>
<th>Climatic zone</th>
<th>Description</th>
<th>(H_s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Alpine/wet coastal</td>
<td>1.5 m</td>
</tr>
<tr>
<td>2</td>
<td>Wet temperate</td>
<td>1.8 m</td>
</tr>
<tr>
<td>3</td>
<td>Temperate</td>
<td>2.3 m</td>
</tr>
<tr>
<td>4</td>
<td>Dry temperate</td>
<td>3.0 m</td>
</tr>
<tr>
<td>5</td>
<td>Semi-arid</td>
<td>4.0 m</td>
</tr>
</tbody>
</table>

Maps of regional climatic zones are presented in Figures D1 and D2.

2 These terms are explained in Geology of Victoria by J.G. Douglas & J.A. Ferguson (Geological Society of Victoria).

3 For further information, refer to AS 2870 Supplement 1.
### TABLE D3
**CLASSIFICATION OF ALL SYDNEY CLAY SOILS**

<table>
<thead>
<tr>
<th>Depth of clay in profile m</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;0.6</td>
<td>S</td>
</tr>
<tr>
<td>≥0.6 ≤2.5</td>
<td>M</td>
</tr>
<tr>
<td>&gt;2.5</td>
<td>H</td>
</tr>
</tbody>
</table>

**NOTE:** The H classification arises from the possibility of moisture changes at depths in excess of 1.5 m because of changing ground water regimes, and hence the depths of influence of Section 2 are inappropriate. Some less reactive soils do occur and if a check is desired, the methods of Section 2 may be used but with a depth of influence equal to a maximum depth of 2 m or to the depth from the surface to extremely to highly weathered rock. In addition, the crack depth should be taken as 0.5 m. The lower of H or the computed classification should be adopted.

### TABLE D4
**SITE CLASSIFICATION BASED ON LOCATION AND TYPICAL PROFILE—PERTH**

<table>
<thead>
<tr>
<th>Examples</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clays derived from weathered dolerite in Darling Range or along foothills</td>
<td>M to H</td>
</tr>
<tr>
<td>Clay material of Guildford formation</td>
<td>S to H</td>
</tr>
</tbody>
</table>

**NOTES:**
1. Actual classification of clay material of Guildford formation depends on depth of sand cover.
2. Refer to 1:50,000 Scale Environmental Geology Map Series, published by the Department of Minerals and Energy, Western Australia.

### TABLE D5
**SITE CLASSIFICATION BASED ON LOCATION AND TYPICAL PROFILE—ADELAIDE**

<table>
<thead>
<tr>
<th>Soil group</th>
<th>Typical soil types</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silts sands and gravels</td>
<td>Sand A1, DS EMS</td>
<td>A to S</td>
</tr>
<tr>
<td>Shallow clays (over rock)</td>
<td>SR</td>
<td>S</td>
</tr>
<tr>
<td>Silty and sandy clays (less reactive)</td>
<td>Clayey A1, RZ, TR, P4, SW</td>
<td>M</td>
</tr>
<tr>
<td>Podsolic and solodic soil</td>
<td>P1, P2, P3 and S</td>
<td>S to H</td>
</tr>
<tr>
<td><strong>Red brown soils</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Profiles with shallow layers of less reactive clay</td>
<td>RB2, RB4, RB6, RB7, RB9</td>
<td>M to H</td>
</tr>
<tr>
<td>Profiles with deeper layers of more reactive clay</td>
<td>RB1, RB3, RB5, RB8</td>
<td>H to E</td>
</tr>
<tr>
<td><strong>Hindmarsh or Keswick clay underlying any soil (except black earth)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depth to clay &gt; 2 m</td>
<td>H to E</td>
<td></td>
</tr>
<tr>
<td>Depth to clay from 1 m to 2 m</td>
<td>E</td>
<td></td>
</tr>
<tr>
<td><strong>Black earth</strong></td>
<td>BE</td>
<td>E</td>
</tr>
</tbody>
</table>

FIGURE D1 MELBOURNE AND ENVIRONS CLIMATIC ZONES
(Outside Melbourne inset area refer Figure D2)
APPENDIX E
STUMP PAD SIZES, BRACED STUMP UPLIFT AND HORIZONTAL LOAD CAPACITY
(Normative)

E1 GENERAL Stumps positioned beneath the floor shall be designed for vertical gravity loads, vertical uplift loads and horizontal forces (where applicable). This Appendix is applicable to braced stumps only and is not applicable to bracing stumps.

E2 VERTICAL GRAVITY LOAD CAPACITY The vertical gravity load capacity shall be calculated by the area of the footing and the assessed bearing capacity. Pad footing systems shall comply with Figure E1. Braced stumps with combined gravity loads (no net uplift) and horizontal loads shall comply with Figure E1 for gravity loads and horizontal design strength from Table E2 or E4 and no allowance need be made for combined effects.

E3 UPLIFT AND HORIZONTAL CAPACITY The uplift and horizontal design strength of braced stumps shown in Figure E2 shall be determined from Tables E1 to E4. The design action effects $U^*$ and $H^*$ due to design load for strength shall not exceed the following limits:

\[
\frac{U^*}{U} < 1.0 \text{ and } \frac{H^*}{H} < 1.0 \text{ for Class A and S sites}
\]
\[
< 0.9 \text{ for Class M site}
\]
\[
< 0.7 \text{ for Class H and M-D sites}
\]

and for combined uplift and horizontal load,

\[
\frac{U^*}{U} + \frac{H^*}{H} < 1.0 \text{ for Class A & S sites}
\]
\[
< 0.9 \text{ for Class M sites}
\]
\[
< 0.7 \text{ for Class M-D and H sites}
\]

where

\[
U^* = \text{uplift load on stump}
\]
\[
H^* = \text{design uplift capacity on stump}
\]
\[
U = \phi \ U_{ULT}, \text{ geotechnical design strength of stump in uplift, from Figure E2}
\]
\[
H = \phi \ H_{ULT}, \text{ geotechnical design strength of stump for horizontal load, from Figure E2}
\]
\[
U_{ULT}, H_{ULT} = \text{ultimate strength in uplift, horizontal loads and strength reduction factor respectively}
\]

For horizontal bracing loads applied higher than shown in Figure E2, capacity shall be determined by engineering principles.

Stump horizontal capacity (see Table E2) is for compacted soil backfill suitable for 100 kPa bearing. For soil with less than 100 kPa lateral allowable bearing pressure the horizontal capacity from Table E2 shall be reduced by multiplying by \[
\left( \frac{\text{allowable bearing pressure}}{100} \right)
\]

The structural strength of the stump and connection to pad for backfilled stumps shall not be less than defined in the design Standard appropriate for the stump material.
NOTES:
1. Footing sizes that comply with AS 1684 shall be used.
2. Footing sizes for larger loads shall be selected from the following table:

<table>
<thead>
<tr>
<th>Effective supported area (m²)</th>
<th>Width of square pad (mm)</th>
<th>Diameter of circular pad (mm)</th>
<th>Thickness (t) (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>400</td>
<td>500</td>
<td>200</td>
</tr>
<tr>
<td>20</td>
<td>500</td>
<td>600</td>
<td>200</td>
</tr>
<tr>
<td>40</td>
<td>600</td>
<td>750</td>
<td>250</td>
</tr>
</tbody>
</table>

The effective area supported by a pad footing is the sum of—
(a) the supported floor area;
(b) the supported roof area (if applicable); and
(c) half the supported wall area in elevation (if applicable).
3. The width or diameter may be reduced to one-half the above for footings on rock.
4. The pad footing may be constructed in concrete except that masonry footings can be used under masonry piers.
5. Pad footing sizes shall also apply to footings supporting roof or floor loads only.
6. The excavation shall be backfilled with manually rodded or tamped soil, or the footing thickness shall be increased.
7. Construction details are given in Clause 6.5.
8. The capacity of braced stumps may be used to detail subfloor bracing where no shear walls exist.

FIGURE E1 PAD FOOTING SYSTEM FOR CLAD FRAME, CLASS A, CLASS S, CLASS M AND CLASS H SITES
FIGURE E2  BRACED STUMPS

TABLE E1
SOIL BACKFILL BRACED STUMPS—UPLIFT CAPACITY kN

<table>
<thead>
<tr>
<th>Stump depth $D_s$ mm</th>
<th>Footing diameter $B$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>250</td>
</tr>
<tr>
<td>400</td>
<td>0.8</td>
</tr>
<tr>
<td>600</td>
<td>2.0</td>
</tr>
<tr>
<td>800</td>
<td>3.8</td>
</tr>
<tr>
<td>1 000</td>
<td>6.5</td>
</tr>
</tbody>
</table>

TABLE E2
SOIL BACKFILL BRACED STUMPS—HORIZONTAL LOAD CAPACITY kN

<table>
<thead>
<tr>
<th>Stump depth $D_s$ mm</th>
<th>Stump thickness $B$, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100</td>
</tr>
<tr>
<td>400</td>
<td>2.2</td>
</tr>
<tr>
<td>600</td>
<td>3.6</td>
</tr>
<tr>
<td>800</td>
<td>5.1</td>
</tr>
<tr>
<td>1 000</td>
<td>6.6</td>
</tr>
</tbody>
</table>

NOTE: Loose sand is not suitable for soil backfilled braced stumps; concrete backfill may be used for braced stumps.
### TABLE E3
CONCRETE BACKFILL BRACED STUMPS—UPLIFT CAPACITY kN

<table>
<thead>
<tr>
<th>Stump depth $D_s$, mm</th>
<th>Footing diameter $B$, mm</th>
<th>250</th>
<th>300</th>
<th>350</th>
<th>400</th>
<th>450</th>
</tr>
</thead>
<tbody>
<tr>
<td>400</td>
<td></td>
<td>1.0</td>
<td>1.2</td>
<td>1.5</td>
<td>1.8</td>
<td>2.2</td>
</tr>
<tr>
<td>600</td>
<td></td>
<td>2.2</td>
<td>2.6</td>
<td>3.1</td>
<td>3.6</td>
<td>4.2</td>
</tr>
<tr>
<td>800</td>
<td></td>
<td>4.1</td>
<td>4.7</td>
<td>5.4</td>
<td>6.2</td>
<td>7.1</td>
</tr>
<tr>
<td>1 000</td>
<td></td>
<td>6.8</td>
<td>7.7</td>
<td>8.7</td>
<td>9.8</td>
<td>10.9</td>
</tr>
</tbody>
</table>

### TABLE E4
CONCRETE BACKFILL BRACED STUMPS—HORIZONTAL LOAD CAPACITY kN

<table>
<thead>
<tr>
<th>Stump depth $D_s$, mm</th>
<th>Footing diameter $B$, mm</th>
<th>250</th>
<th>300</th>
<th>350</th>
<th>400</th>
<th>450</th>
</tr>
</thead>
<tbody>
<tr>
<td>400</td>
<td></td>
<td>4.0</td>
<td>4.8</td>
<td>5.6</td>
<td>6.4</td>
<td>7.2</td>
</tr>
<tr>
<td>600</td>
<td></td>
<td>6.8</td>
<td>8.2</td>
<td>9.5</td>
<td>10.9</td>
<td>12.3</td>
</tr>
<tr>
<td>800</td>
<td></td>
<td>9.8</td>
<td>11.7</td>
<td>13.7</td>
<td>15.6</td>
<td>17.6</td>
</tr>
<tr>
<td>1 000</td>
<td></td>
<td>12.8</td>
<td>15.3</td>
<td>17.9</td>
<td>20.4</td>
<td>23.0</td>
</tr>
</tbody>
</table>
APPENDIX F

SOIL PARAMETERS AND FOOTING DESIGN METHODS

(Informative)

F1 DESIGN MOVEMENT The design movement is the characteristic surface movement \( y_s \), for site classification obtained by summing the movement for each layer as follows —

\[
y_s = \frac{1}{100} \int_0^{H_s} I_{pt} \Delta u \Delta h
\]

where

- \( y_s \) = characteristic surface movement
- \( I_{pt} \) = instability index, (see Paragraph F2)
- \( \Delta u \) = suction change at depth \( z \) from the surface, expressed in pF units.

F2 INSTABILITY INDEX The instability index \( (I_{ps}) \), is defined as the percent vertical strain per unit change in suction, taking into account the expected design values of—

(a) applied stress;
(b) degree of lateral restraint; and
(c) suction range.

Thus the instability index is not a constant for a particular clay, but it may be estimated from the tests for soil shrinkage index \( (I_{ps}) \) in AS 1289.

To obtain the instability index from the test results, it is recommended that in the absence of more exact information, the following correction be used—

\[
I_{pt} = \alpha \times I_{ps}
\]

and \( \alpha \) may be taken as follows:

(i) In the cracked zone (unrestrained)
   \( \alpha = 1.0 \)

(ii) In the uncracked zone (restrained laterally by soil and vertically by soil weight)
   \( \alpha = 2.0 - z/5 \)

where \( z \) = the depth from the finished ground level to the point under consideration in the uncracked zone.

The depth of the cracked zone can be taken as 0.33 \( H_s \) to \( H_s \) where \( H_s \) is as given in Table 2.4 with other areas being assessed on the basis of climate. In Adelaide and Melbourne, the depth may be estimated as 0.75 \( H_s \). In the Newcastle/Gosford region and in Sydney, a value of 0.5 \( H_s \) is recommended. In Brisbane/Ipswich region a value of 0.5 \( H_s \) is recommended.

NOTE: The cracked zone relates to the zone in which predominantly vertical shrinkage cracks exist seasonally.

F3 DESIGN PROCEDURES FOR STIFFENED RAFTS Structural moments can be determined by an analysis which allows for an interaction of the structure with some representation of the stiffness of the foundation and the assumed mound shape. Generally, the raft should be proportioned to resist positive and negative moments of approximately the same magnitude. The recommended procedure is a computer analysis for the actual loading pattern in accordance with the Walsh and Walsh (Ref. 1) or Mitchell (Ref. 2) methods.

The analysis of non-rectangular buildings is usually on the basis of overlapping rectangles.

The analysis and design may be based on the total slab cross section.
For the Walsh method, the mound shape shall be taken as a flat section with movement occurring over an edge distance, \((e)\), as shown in Figure F1. The shape factor \((W_f)\) used to define the compound parabola in edge heave is given in Figure F2.

**FIGURE F1 IDEALIZED MOUND SHAPES TO REPRESENT DESIGN GROUND MOVEMENT (WALSH METHOD)**

(a) Centre heave mound
(b) Edge heave

**FIGURE F2 \(W_f\) FACTOR FOR WALSH MOUND SHAPE**

**F4 DESIGN PARAMETERS FOR STIFFENED RAFTS** The general procedures for the design of a stiffened raft incorporated in an engineering design method should take into account the following:

(a) **Differential mound movement** The design value of differential mound movement \((y_m)\), across the foundation may be estimated taking into account the moisture conditions at the time of construction and the influence of the footing system and edge paths on the design moisture conditions. In the absence of more accurate calculations, \(y_m\) may be taken as:

<table>
<thead>
<tr>
<th>Method</th>
<th>Centre heave</th>
<th>Edge heave on initially dry site</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walsh method</td>
<td>0.7(y_s)</td>
<td>0.5(y_s)</td>
</tr>
<tr>
<td>Mitchell method</td>
<td>0.7(y_s)</td>
<td>0.7(y_s)</td>
</tr>
</tbody>
</table>
On a site that is wet throughout the profile at the time of construction, a reduction of \( y_m \) for edge heave not exceeding 40\% may be made.

Where the slab length is less than \( 2e \), then the value of \( y_m \) may be reduced linearly with \((\text{span}/2e)\).

This movement is represented as an idealized mound, and incorporates some estimate of the edge distance (from the edge to uniform condition) as shown in Figure F1. Where the movement \( y_m \) is selected to represent an extreme moisture condition (rather than the design value described in the Standard) then the mound shape should be taken as single-sided (i.e. heave or shrinkage at one end only).

Where highly variable site conditions such as gilgais or residual soils on steeply dipping strata have been found, account should be taken of such variability in the idealization of the mound behaviour.

(b) **Edge distance** The edge distance \((e)\), is taken as:

(i) For centre heave, in metres:

\[
e = \left( \frac{H_s}{8} + \frac{y_m}{36} \right), \text{ where } y_m \text{ is in millimetres and } H_s \text{ is in metres.} \quad \ldots \quad \text{F4(1)}
\]

(ii) For edge heave, in metres:

\[
e = 0.2L \leq (0.6 + \frac{y_m}{25}), \text{ where } y_m \text{ is in millimetres.} \quad \ldots \quad \text{F4(2)}
\]

For the Mitchell method:

Mound exponent \((m)\) = \(1.5L/(D_{cr} - D_e)\) \quad \ldots \quad \text{F4(3)}

where

\[
D_{cr} = \frac{H_s}{7} + \frac{y_m}{25} \text{ m, where } y_m \text{ is in millimetres.}
\]

\[
D_e = \text{depth of embedment of edge beam from the finished ground level.}
\]

(c) **Mound stiffness** For beams in contact with swelling soil, the soil stiffness will range from \( k = 400 \text{ kPa/m} \) to \( k = 1500 \text{ kPa/m} \). The computed forces and displacements are generally not particularly sensitive to the value of \( k \) used except for certain edge heave situations.

A soil stiffness of 100 \( q \) but not less than 1000 kPa/m may be used, where \( q \) is the total building load divided by the plan area of the slab. Other values may be adopted if supported by local experience or experimental data.

For Melbourne basaltic clays, a soil stiffness of 400 kPa/m minimum or 50 \( q \) may be used.

For beams in contact with shrinking or stable soil the soil stiffness should be taken as at least 5000 kPa/m.

**F5 REFERENCES**

APPENDIX G

DESIGN OF DRIVEN TIMBER PILED FOOTING SYSTEMS

(Informative)

G1 GENERAL

G1.1 Pile systems Timber piles should be designed in accordance with this Appendix and the appropriate Sections of AS 2159. Timber piles may be used in pile systems to support all types of framed and masonry construction.

G1.2 Proportions and load capacity of piles Piles should satisfy the following requirements:

(a) For unspliced piles driven by a drop hammer, the safe working load may be calculated in accordance with:

\[ a = 0.001 \frac{bc}{s} \]

where

- \( a \) = safe working load of pile, in kilonewtons
- \( b \) = drop hammer mass, in kilograms
- \( c \) = hammer drop height, in millimetres
- \( s \) = pile set, in millimetres.

NOTE: Set is the average pile penetration per hammer impact, for five hammer impacts.

(b) Where piles are used to replace stumps and pad footings, the required safe working load (kN) of the pile may be back-calculated by multiplying the replaced pad bearing area (m²) by 100 kPa. For stump pad sizes, reference should be made to AS 1684. Otherwise the required load should be estimated by engineering principles.

(c) For piles driven by methods other than by drop hammer, the allowable load capacity should be determined by engineering principles using AS 2159.

(d) Stresses in timber piles should not exceed the allowable stresses in AS 1720.

NOTE: In some areas, there are large differences in soil strengths between wet and dry periods. In such cases, possible effects on pile capacity should be considered.

G2 PILE SYSTEMS FOR CLASS A AND S SITES Piles may be used to support framed or masonry construction on Class A and S sites. The minimum driven depth of piles shall be not less than 1 m for these sites and 1 m below the fill for filled sites or to rock.

For the support of external walls, the standard details for the piles and footing beam given in Figure G1 may be adopted. Piles should be located in all corners and steps in beams.

G3 PILE SYSTEMS FOR CLASS M AND H SITES

G3.1 Footing systems Driven timber piles may be used to support framed or masonry construction on Class M and H sites. Piles should be located in all corners and steps in beams.

G3.2 Load capacity Piles should comply with the requirements of Paragraph G1.2 for allowable load.

NOTE: Load capacity should be reduced to allow for loss of pile-soil contact due to shrinkage of reactive soils.
G3.3 Minimum depth The driven depth of the pile needs to be not less than \(4/3 \, H_s\) for framed or articulated masonry veneer construction and \(3/2 \, H_s\) for articulated full masonry construction, where \(H_s\) is given in Table 2.4.

G3.4 Standard timber pile footing system The standard pile footing system detail shown in Figure G1 may be used for Classes M and H sites. For Class E sites and full masonry construction, the pile system should be designed by a qualified engineer.

G4 PILE SYSTEMS FOR CLASS P SITES Driven timber piles may be used to support framed or masonry construction. The piles should be designed by a qualified engineer.

NOTE: Due allowance for down drag should be made in assessing pile capacity.

G5 MATERIAL AND CONSTRUCTION FOR DRIVEN TIMBER PILES

G5.1 General Driven timber piles of nominal diameter 75 mm to 200 mm used in a footing system should be constructed in accordance with Paragraphs G5.2 and G5.3 below.

G5.2 Material requirements The material used should be naturally durable or treated timber to have a specified design life. Concrete footing beams should comply with the construction requirements for strip footings in the Standard.

G5.3 Construction requirements The construction methods should comply with the following:

(a) Pile driving should conform to AS 2159 and a minimum driving mass of 250 kg should be used for drop hammers.

(b) Where steel beams are used to support masonry walls, the underside of the beam should be a minimum height of 100 mm above finished ground level. Continuous flashing should be placed between the beam and brickwork. The subfloor area should be well ventilated.

(c) In areas of high potential termite hazard, the requirements of AS 3660.1 should be taken into consideration as appropriate.

(d) The positional tolerance on piles in AS 2159 does not apply. The position of a pile measured at its cut-off level should be not more than 50\% of the pile diameter away from its design position or appropriate to the function of the pile. The vertical tolerances in AS 2159 should apply.
DIMENSIONS IN MILLIMETRES

<table>
<thead>
<tr>
<th>Site class</th>
<th>( D_l ) mm</th>
<th>( D ) mm</th>
<th>Trench mesh</th>
<th>Dowel pin diameter ( \times ) length mm</th>
<th>Minimum driven depth of pile, mm (See Note)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>400</td>
<td>500</td>
<td>3-11 TM</td>
<td>Not required</td>
<td>1 000</td>
</tr>
<tr>
<td>M</td>
<td>450</td>
<td>500</td>
<td>3-12 TM</td>
<td>Not required</td>
<td>2 000</td>
</tr>
<tr>
<td>H</td>
<td>500</td>
<td>550</td>
<td>3-12 TM</td>
<td>( 20 \times 800 )</td>
<td>2 500</td>
</tr>
</tbody>
</table>

Type of construction | Pile spacing, m
--- | ---
Clad frame | One-storey: 3.0, two-storey: 2.5
Masonry veneer | One-storey: 2.1, two-storey: 1.8
Articulated full masonry | One-storey: 1.8, two-storey: 1.5

NOTE: The above information has been based on a safe working load of 60 kN.

FIGURE G1  PROPORTIONS FOR PILED SYSTEMS UNDER PERIMETER WALLS