COMMITTEE BD-025

DR AS 2870

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Draft for Public Comment Australian Standard

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BEGINNING DATE FOR COMMENT:	**10 February 2010**
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Residential slabs and footings

(Revision of AS 2870—1996)

STANDARDS Australia

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Draft for Public Comment
Australian Standard

The committee responsible for the issue of this draft comprised representatives of organizations interested in the subject matter of the proposed Standard. These organizations are listed on the inside back cover.

Comments are invited on the technical content, wording and general arrangement of the draft.

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If you know of other persons or organizations that may wish to comment on this draft Standard, could you please advise them of its availability. Further copies of the draft are available from the Publisher SAI Global at *http://www.saiglobal.com/*

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STANDARDS AUSTRALIA

Committee BD-025—Residential Slabs and Footings

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Australian Standard

Residential slabs and footings

(Revision of AS 2870—1996)

(To be AS 2870—200X)

Comment on the draft is invited from people and organizations concerned with this subject. It would be appreciated if those submitting comment would follow the guidelines given on the inside front cover.

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PREFACE

This Standard was prepared by the Standards Australia Committee BD-025, Residential Slabs and Footings to supersede AS 2870—1996.

The purpose of this Standard is to specify 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.

Notes are included for clarification and general advice only and are not part of the mandatory provisions of the Standard. 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.

The Figures are intended to show only the structural proportions of the footing system. All other details are purely illustrative.

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STANDARDS AUSTRALIA

Australian Standard
Residential slabs and footings

SECTION 1 SCOPE AND GENERAL

1.1 SCOPE

This Standard sets out the criteria 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, including 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.

For design purposes the life of the structure is taken to be 50 years.

NOTES:

1 This standard has been widely used for a number of years for the economical design of footings and slabs. Economical designs that avoid significant damage are practicable only if the soil moisture content of the foundation material under the footing or slab is stable or within reasonable limits over the design life of the house or structure. In all sites (reactive soils) except for Class A sites the moisture conditions of the foundation material under footings and slabs need to remain stable or within reasonable limits to avoid significant damage to the house or structure. (See Appendix A.)

2 Where slab on ground construction is used for long slabs and large houses particular consideration in design may be needed to avoid significant damage.

3 Information on earthquake actions is included in AS 1170.4. Information on wind actions is included in AS/NZS 1170.2

1.2 APPLICATION

To comply with this standard—

(a) all sites shall be classified in accordance with Section 2; and

(b) footing system design shall be by either—

(i) prescribing a standard design in accordance with Section 3, or

(ii) applying the engineering principles described in Section 4; and

(c) all design and construction shall comply with Sections 5 and 6.

Residential footing system design, detailing and construction shall also comply with AS 3600 except that, where in conflict, AS 2870 shall take precedence.

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1.3 PERFORMANCE OF FOOTING SYSTEMS

1.3.1 General

Buildings supported by footing systems designed and constructed in accordance with this Standard on a normal site (see Clause 1.3.2) that 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 site foundation 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 that are classified as one of the Classes A, S, M, H1, H2 and E in accordance with Section 2 of this Standard and where foundation moisture variations are those caused by seasonal and regular climatic effects, effect of the building and subdivision, and normal garden conditions without abnormal moisture conditions. (See Clause 1.3.3.) Compliance with the recommendations in Appendix B is deemed to provide normal garden conditions.

1.3.3 Abnormal moisture conditions

Abnormal moisture conditions are those that result in foundation moisture variations beyond those for normal sites (see Clause 1.3.2). Buildings constructed on sites subject to abnormal moisture conditions have a higher probability of damage than those given in Clause 1.3.1.

In the following examples, the identified factor may result in abnormal moisture conditions where the feature is sufficiently close to affect the ground moisture under the building and/or the event was sufficiently recent that the effect on ground moisture will be present at the time of construction.

Examples of abnormal moisture conditions existing prior to construction include the following:

(a) Removal of an existing building or structure likely to have significantly modified the soil moisture conditions under the footprint of the footing system of the building.

(b) Removal of trees prior to construction.

(c) Presence of trees.

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

Examples of abnormal moisture conditions resulting from construction include the following:

(i) Failure to provide adequate site drainage.

(ii) Failure to detail or construct drainage in accordance with this Standard.

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Examples of abnormal moisture conditions developing after construction include the following:

(A) The effect of trees too close to a footing.

(B) Excessive or irregular watering of gardens adjacent to the building.

(C) Failure to maintain site drainage.

(D) Failure to repair plumbing leaks.

(E) Loss of vegetation from near the building.

1.4 DESIGN CONDITIONS

1.4.1 General

The design conditions below apply for beams and slabs supported by the foundation on normal sites.

For other than normal sites the design of the footing system shall be by engineering principles. Other design considerations particular to the site shall be considered and the performance criteria in Clause 1.3 apply.

1.4.2 Design action effects

Design for serviceability and safety against structural failure or bearing failure shall be based on design actions due to—

(a) permanent action +0.5 imposed action; and

(b) foundation movement.

Permanent and imposed actions shall be in accordance with AS/NZS 1170.1

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

Design for uplift shall be based on design action effects due to 0.9 permanent action + wind action in accordance with AS/NZS 1170.2 or AS 4055.

Reactive soil movements and soil settlements shall be determined from permanent action + 0.5 imposed action. Design bearing strength, including uplift, shall be determined using a geotechnical strength reduction factor of 0.33 applied to the ultimate bearing capacity.

Soil parameters shall be taken as mean values for each soil stratum.

1.4.3 Other design considerations

The design of footing systems shall consider the following:

(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) Foundation bearing properties.

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1.5 DEEMED-TO-COMPLY STANDARD DESIGNS

The standard designs given in Section 3 are deemed to comply with the performance criteria in Clause 1.3.

1.6 ARTICULATION REQUIREMENTS

Where the standard designs given in Section 3 are for articulated masonry veneer and articulated full masonry, articulation joints shall comply with the requirements of TN 61.

1.7 NORMATIVE REFERENCES

The following referenced documents are indispensable for the application of this document. Documents referenced for informative purposes are listed in Appendix I.

AS

1289	Methods of testing soils for engineering purposes	
1289.6.3.3	Method 6.3.3:	Soil strength and consolidation tests—Determination of the penetration resistance of a soil—Perth sand penetrometer test
1289.7.1.1	Method 7.1.1:	Soil reactivity tests—Determination of the shrinkage index of a soil—Shrink swell index
1289.7.1.2	Method 7.1.2:	Soil reactivity tests—Determination of the shrinkage index of a soil—Loaded shrinkage index
1289.7.1.3	Method 7.1.3:	Soil reactivity tests—Determination of the shrinkage index of a soil—Core shrinkage index
1379	Specification and supply of concrete	
3600	Concrete structures	
3660	Termite management	
3660.1	Part 1: New building work	
3700	Masonry structures	
3798	Guidelines on earthworks for commercial and residential developments	
4055	Wind loads for housing	

AS/NZS

1170	Structural design actions
1170.1	Part 1: Permanent, imposed and other actions
1170.2	Part 2: Wind actions
4347	Damp-proof courses and flashings—Methods of test
4347.6	Method 6: Determining impact resistance (falling dart impact test)
4347.9	Method 9: Determining thickness
4671	Steel reinforcing materials
4773	Masonry in small buildings
4773.2	Part 2: Construction

Australian Building Code Board
BCA Building Code of Australia

Cement Concrete and Aggregates Australia
TN 61 Articulated walling

CSIRO, Division of Building, Construction and Engineering
Method for the determination of the penetration resistance to falling aggregate

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1.8 DEFINITIONS

For the purpose of this Standard, the definitions below apply.

1.8.1 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 load-related settlement.

1.8.2 Articulated full masonry

Full masonry construction incorporating articulation of external and internal walls.

1.8.3 Articulated masonry veneer

Masonry veneer construction incorporating articulation of the masonry veneer.

1.8.4 Articulation

Provision for movement in walls through mainly caused by incorporation of permanent control joints.

1.8.5 Braced stump

Stump that forms part of a bracing element that resists lateral loads through diagonal members attached between two or more stumps.

1.8.6 Bracing stump

Stump that, in addition to vertical loads, resists horizontal loads applied more than 150 mm above ground level.

1.8.7 Bored pier

Cast in place concrete cylindrical load support element.

1.8.8 Bulk pier

Cast in place concrete load support element excavated by backhoe or similar machinery.

1.8.9 Characteristic surface movement (y_s)

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.

1.8.10 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.

1.8.11 Clay

Fine-grained soil with plastic properties when wet. Includes gravelly, sandy or silty clays.

1.8.12 Collapsing soil

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

1.8.13 Concrete wall panel

Precast (including tilt-up) or in situ concrete wall designed to act as a unit and separated from adjacent panels or walls by a control joint.

1.8.14 Controlled fill

Fill that will be required to support structures or associated pavements, or for which engineering properties are to be controlled.

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1.8.15 Earth wall construction

Unfired earth bricks and unfired rammed earth wall construction.

1.8.16 Edge beam

Beam at the edge of a slab-on-ground or stiffened raft.

1.8.17 Edge footing

Footing at the edge of a footing slab.

1.8.18 Engineering principles

Principles of geotechnical and structural engineering as applicable for the purposes of this Standard.

NOTE: This means engineering principles that are commonly accepted by qualified engineers.

1.8.19 Extension

Additional construction abutting an existing building.

1.8.20 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.

1.8.21 Finished ground level

Ground level adjacent to the footing system at the completion of construction and landscaping.

1.8.22 Fitment

Tie, ligature or stirrup reinforcement.

1.8.23 Footing

Construction that transfers the load from the building to the foundation.

1.8.24 Footing slab

Concrete floor supported on the ground with a separately poured edge strip footing.

1.8.25 Footing system

General term used to refer to slabs, footings, piers and pile systems that transfer load from the structure to the foundation.

1.8.26 Foundation

Ground that supports the building.

1.8.27 Framed double-leaf masonry

Construction with masonry double-leaf external wall and framed internal walls.

1.8.28 Full masonry

Construction with masonry double-leaf external walls and masonry single-leaf internal walls without full articulation.

1.8.29 Gilgai

Soil surface feature associated with reactive clay sites, characterized by regularly spaced and sized depressions on virgin land.

NOTE: Gilgais are formed by extreme, reactive soil movements. Soil profiles may vary markedly across sites with gilgais.

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1.8.30 Infill slab

Slab cast on the ground between walls.

1.8.31 Load-bearing wall

Wall imposing a load on the slab, factored in accordance with Clause 1.4.2, greater than 10 kN/m.

1.8.32 Masonry

Stone, brick, terracotta block, concrete block, or other similar building unit single or in combination assembled together unit by unit.

1.8.33 Masonry veneer

Construction consisting of a load-bearing frame clad with an outer leaf of masonry.

1.8.34 Maximum differential footing movement

Maximum movement of a footing relative to a straight line joining the ends of the footing system or, in the case of double curvature, joining the points of contraflexure.

1.8.35 Mine subsidence

Settlement, curvature, tilt and lateral strain, either individually or in combination, produced at the surface as a result of underground mining.

1.8.36 Mixed construction

Building consisting of more than one form of construction.

1.8.37 Natural site

Site which has not been subjected to cutting or filling.

1.8.38 Outbuilding

Detached building such as a carport, private garage, shed or the like.

1.8.39 Pad footing

Concrete footing used to support a pier or stump.

1.8.40 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.

1.8.41 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.

1.8.42 Pile

Structural member that is driven, screwed, jacked, vibrated, drilled or otherwise installed in the ground such as to transmit loads to the underlying soil or rock and provide a footing component for a structure.

1.8.43 Reactive site

Site consisting of a clay soil that 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, H1, H2 or E in accordance with Clause 2.1.

1.8.44 Reinforcement

Steel bars, wire or mesh.

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1.8.45 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.

1.8.46 Rock

Strong material including shaly 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 is deemed to be rock.

1.8.47 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.

1.8.48 Silt

Fine-grained soil that is non-cohesive and non-plastic when wet and can include some sand and clay.

1.8.49 Single-leaf masonry

Outer walls constructed with a single thickness of masonry units.

1.8.50 Single-storey

Construction with wall height, excluding any gable, not exceeding 4.2 m and including only one trafficable floor.

1.8.51 Slab

General term used to refer to slab-on-ground, stiffened rafts, footing slabs, stiffened footing slabs and waffle rafts.

1.8.52 Slab-on-ground

Concrete floor supported on the ground and incorporating integral edge beams.

1.8.53 Slab panel

Part of a slab between beams.

1.8.54 Soil suction

Negative pore water pressure in soils, expressed in pF units.

NOTE: pF = 1+log(u), where u = total suction in kPa.

1.8.55 Stiffened raft

Concrete slab on ground stiffened by integral edge beams and, commonly, a grid of internal beams.

1.8.56 Strip footing

Footing of rectangular section.

1.8.57 Stump

Element supported on a footing used for the support of a frame construction.

1.8.58 Superstructure

Portion of a completed building that is supported by the selected footing system including slab where applicable.

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1.8.59 Two-storey

Construction with wall height, including any gable, not exceeding 8.5 m and including two trafficable floors.

1.8.60 Veneer

Construction of either masonry veneer or articulated masonry veneer.

1.8.61 Waffle raft

A stiffened raft with closely spaced ribs constructed on the ground and with slab panels suspended between ribs.

1.9 NOTATION

The symbols used in this Standard are as follows:

A1, A2, B1, B2	=	exposure classification, reinforced or pre-stressed concrete members (per AS 3600)
B_w	=	width of stem of edge, or internal beam
D	=	overall depth of a footing or beam
D_f	=	depth of strip footing from finished ground surface level
Di	=	ground movement influence distance of a tree or trees (see Paragraph G2)
D_s	=	depth of pad footing from finished ground surface level (see Figure 3.6)
Dt	=	distance of tree to the building (see Paragraph G2)
d	=	differential movement
EC_e	=	saturated electrical conductivity in deciSimens per metre
e	=	edge distance (see Section 4)
H_s	=	depth of design suction change (Table 2.4)
H_t	=	maximum design drying depth close to a tree or trees (see Paragraph G2)
HT	=	design height of single tree (see Paragraph G2)
HT_σ	=	design height of a group of trees (see Paragraph G2)
h	=	maximum height of masonry wall retaining structure as shown in Figure 6.3
h_h	=	drop height of the hammer for driven piles
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 strength
M^*	=	design moment
R_{ug}	=	ultimate geotechnical strength of a pile

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S	=	pile set in metres for driven piles
S^*	=	design action effect on a pile due to all imposed loads
T_i	=	installation torque for screw piles
t	=	thickness of slab or pad footing
W_f	=	shape factor for edge heave
W_h	=	hammer weight for driven piles
y_m	=	differential mound movement
y_s	=	characteristic surface movement
$Y_{t\ max}$	=	maximum potential tree movement for the tree induced suction change in addition to the normal design suction change
α	=	lateral restraint factor
Δ	=	differential footing movement (Clause 4.4)
Δu	=	change in suction
Δu_{base}	=	maximum extra suction change caused by the vegetation at the maximum design drying depth
u	=	total soil suction
ϕ	=	strength reduction factor

1.10 REINFORCEMENT DESIGNATION

1.10.1 Trench mesh

For the purposes of this Standard, trench mesh is designated as x–L8TM, x–L11TM or x–L12TM, where x is the number of main longitudinal bars required of the appropriate trench mesh L8TM, L11TM or L12TM. Trench mesh shall comply with AS/NZS 4671.

1.10.2 Square mesh

SL62, SL72, SL82, SL92 or SL102 shall comply with AS/NZS 4671. SL53 and SL63 refer to square meshes similar to stock meshes specified in AS/NZS 4671, but with 5 mm bars and 6 mm bar at 300 mm centres respectively, and with the bars complying with the requirements for grade 500L in accordance with AS/NZS 4671.

1.10.3 Reinforcing bars

Reinforcing bars shall comply with AS/NZS 4671 Grade 500N, and are specified as x–N12, x–N16, or x–N20, where x is the number of bars.

1.10.4 Substitution of reinforcement

The ductility and strength requirements of reinforcement specified in the standard designs of Section 3 shall not be reduced except as provided in Clause 3.7.

1.11 INFORMATION IN DOCUMENTS

1.11.1 Classification report

For class P sites the classification report shall include the reason for the P classification and recommendations for further investigation as required to provide adequate data for footing system design.

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1.11.2 Design documents

The site classification shall be stated on the drawings. The selected footing systems and any required sitework and required site drainage shall be documented.

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SECTION 2 SITE CLASSIFICATION

2.1 GENERAL

2.1.1 Classification

Site classification is based on the expected ground surface movement and the depth to which this movement extends. Sites shall be classified in accordance with Clauses 2.1.2 and 2.1.3 using the techniques and principles specified in Clauses 2.2, 2.3, 2.4 and 2.5.

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

2.1.2 Site classification based on soil reactivity

Sites where ground movement is predominantly due to soil reactivity under normal moisture conditions shall be classified based on the expected level of ground movement as nominated in Table 2.1.

TABLE 2.1

CLASSIFICATION BASED ON SITE REACTIVITY

Class	Foundation
A	Most sand and rock sites with little or no ground movement from moisture changes
S	Slightly reactive clay sites*, which may experience with only slight ground movement from moisture changes
M	Moderately reactive clay or silt sites, which may experience moderate ground movement from moisture changes
H1	Highly reactive clay sites, which may experience high ground movement from moisture changes
H2	Highly reactive clay sites, which may experience very high ground movement from moisture changes
E	Extremely reactive sites, which may experience extreme ground movement from moisture changes

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

For Classes M, H1, H2 and E further classification may be required based on the depth of the expected moisture change. For sites with deep-seated moisture changes 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, H1-D, H2-D or E-D as appropriate.

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

2.1.3 Classification of other sites

Sites with inadequate bearing strength or where ground movement may be significantly affected by factors other than reactive soil movements due to normal moisture conditions are Class P. Class P sites include soft or unstable foundations such as soft clay or silt or loose sands, landslip, mine subsidence, collapsing soils and soils subject to erosion, reactive sites subject to abnormal moisture conditions and sites that cannot be classified in accordance with Clause 2.1.2.

A site is Class P if—

(a) the bearing strength is less than that specified in Clause 2.1.2;

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

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(c) the site contains uncontrolled or controlled fill as stipulated in Clause 2.5.3;

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

(e) the sites may be subject to moisture changes due to site conditions more severe than the normal site conditions described in Clause 1.3.2; or

(f) the site may be subject to other factors resulting in foundation movement beyond the reactive soil movements resulting from moisture changes due to the normal site conditions described in Clause 1.3.2.

The basis for classification shall be recorded on the site classification report together with recommendations for further geotechnical investigation.

2.2 METHODS FOR SITE CLASSIFICATION

2.2.1 General

Classification of sites other than Class P sites shall include one or both of the following methods:

(a) Identification of the soil profile in accordance with Clause 2.2.2.

(b) Site classification based on characteristic surface movement in accordance with Clause 2.2.3.

2.2.2 Identification of the soil profile

Site classification based on identification of the soil profile shall include one or more of the following methods:

(a) Site classification based on typical soil profile data given in Appendix D. The soil profile shall be confirmed by investigation using a borehole(s) or other excavation or sampling method in accordance with Clauses 2.4.3 and 2.4.4. The classification report shall include details of the investigation method used and significant soil profile(s).

(b) Identification of the soil profile and interpretation of the current performance of existing buildings. The soil profile shall be confirmed by inspection of soil from a borehole(s) or other excavation or sampling method in accordance with Clauses 2.4.3 and 2.4.4. Interpretation of the performance of existing residential footing systems within the region that are not less than 10 years old and are founded on a similar soil profile shall be in accordance with Table 2.2. In areas of deep-seated moisture change the site classification shall be modified by the addition of '-D' as described in Clause 2.1.2.

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TABLE 2.2

CLASSIFICATION OF NORMAL SITES BY INTERPRETATION OF FOOTING PERFORMANCE OF EXISTING BUILDINGS (Damage categories are given in Appendix C)

Wall construction	Performance of walls of existing buildings on lightly stiffened strip footings or slabs on ground	Site classification in accordance with Table 2.1
Clad frame	Buildings with differential movements, d in mm (lowest to highest points on perimeter of building)	
	$d \le 15$	S
	$15 < d \le 30$	M
	$30 < d \le 45$	H1
	$45 < d \le 55$	H2
	$d > 55$	E
Masonry (veneer or full)	Damage Category 0 to Category 1	S or M
	Damage often Category 1, but rarely Category 2	M or H1
	Damage often Category 1 and 2, but rarely Category 3	H1 or H2
	Damage often Category 3 or more severe and area usually well known for damage to buildings and structures	E

NOTES:

1 Where performance of existing buildings indicates highly or extremely reactive sites, a further investigation should be carried out for buildings other than small extensions, garages or out-buildings.

2 Timber subfloor structures in clad-frame buildings may have settled due to shrinkage or 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 Site classification based on characteristic surface movement

The characteristic surface movements (y_s) estimated in accordance with Clause 2.3 shall be used to determine the site class by applying the limits in Table 2.3. In areas of deep-seated moisture change the site classification shall be modified by the addition of '-D' as described in Clause 2.1.2.

TABLE 2.3

CLASSIFICATION BY CHARACTERISTIC SURFACE MOVEMENT

Characteristic surface movement	Site classification in accordance with Table 2.1
0 mm < y_s ≤20 mm	S
20 mm < y_s ≤40 mm	M
40 mm < y_s ≤60 mm	H1
60 mm < y_s ≤75 mm	H2
y_s >75 mm	E

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2.3 ESTIMATION OF THE CHARACTERISTIC SURFACE MOVEMENT

2.3.1 Characteristic surface movement

The characteristic surface movement (y_s) for site classification purposes shall be determined by estimating the movement of each stratum (n) within the depth of expected soil suction change and summing the movement for all layers, as follows—

$$y_s = \frac{1}{100}\sum_{1}^{n}\left(\alpha\, I_{\mathrm{pt}}\, \overline{u}\, h\right)_{\mathrm{n}} \qquad \ldots 2.3(1)$$

where

y_s = characteristic surface movement (in mm)

α = Lateral restraint factor, see Clause 2.3.2

I_{ps} = shrinkage index, see Clause 2.3.2

Δu = soil suction change at depth (z) from the surface, expressed in pF units

h = thickness of stratum n

The estimation of surface movement shall be based on sufficient soil data to adequately describe the soil profile.

2.3.2 Instability index

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

(a) applied stress;

(b) degree of lateral restraint; and

(c) soil suction range.

The instability index is not a constant for a particular clay, but it may be estimated from the soil shrinkage index (I_{ps}). The soil shrinkage index shall be derived using one or more of the following methods:

(d) Laboratory tests for soil reactivity (AS 1289.7.1.1, AS 1289.7.1.2, AS 1289.7.1.3).

(e) Correlations between shrinkage index (I_{ps}) and other clay index tests for the soil type.

(f) Visual-tactile identification of the soil by a suitably qualified and experienced person.

NOTE: A suitably qualified and experienced person is an engineer or engineering geologist having appropriate expertise and local experience

For Method (f) above, the suitably qualified and experienced person shall check their soil property identification against laboratory testing at a period not longer than six months and at least once in every fifty sites personally classified.

NOTE: A suitably qualified and experienced person is an engineer or engineering geologist having appropriate expertise and local experience

In the absence of more exact information the instability index shall be estimated from the shrinkage index using the following correction—

$$I_{pt} = \alpha \times I_{ps} \qquad \ldots 2.3(2)$$

α shall 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)

$$\alpha = 2.0 - z/5 \qquad \ldots 2.3(3)$$

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

In the absence of more exact information the depth of the cracked zone shall be taken as 0.5 H_s to H_s where H_s is as given in Table 2.4. In Adelaide and Melbourne the depth of cracking may be taken to be 0.75 H_s. In the Newcastle/Gosford region, in Sydney and in the Brisbane/Ipswich region the depth of cracking may be taken to be 0.5 H_s.

For reactive clay in controlled fill placed less than 5 years prior to building construction, the depth of the cracked zone shall be taken as zero. Where a site has been cut less than two years prior to building construction, the depth of the cracked zone shall be reduced by the depth of the cut.

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

2.3.3 Soil suction profile

Values of design soil suction changes are given in Table 2.4 for various locations. Where a range is given, lower values correspond to wetter climate areas, typically near the coast or in the hills. The classifier may extrapolate to other areas based on climate. Alternatively, the value of H_s may be estimated from the Thornthwaite Moisture Index ('TMI') for the region, based on at least 25 continuous years of climate data, using the relationship given in Table 2.5.

Where a permanent water table 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.

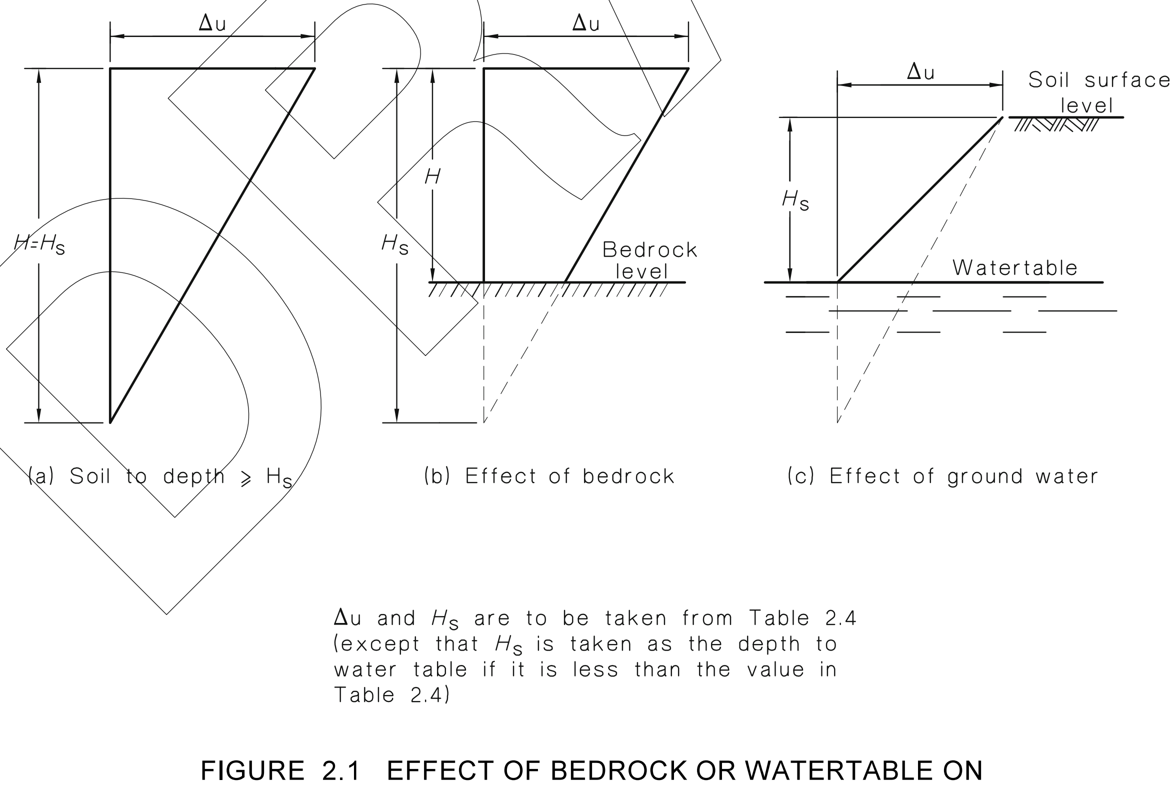

FIGURE 2.1 EFFECT OF BEDROCK OR WATERTABLE ON DESIGN SUCTION CHANGE PROFILES

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TABLE 2.4

SOIL SUCTION CHANGE PROFILES FOR CERTAIN LOCATIONS

Location	Change in suction at the soil surface (Δu) pF	Depth of design suction change (H_s) m
Adelaide	1.2	4.0
Albury/Wodonga	1.2	3.0
Brisbane/Ipswich	1.2	1.5–2.3 (see Note)
Gosford	1.2	1.5–1.8
Hobart	1.2	2.3–3.0 (see Note)
Hunter Valley	1.2	1.8–3.0
Launceston	1.2	2.3–3.0 (see Note)
Melbourne	1.2	1.8–3.0 (see Note)
Newcastle	1.2	1.5–1.8 (see Note)
Perth	1.2	1.8
Sydney	1.2	1.5–1.8 (see Note)
Toowoomba	1.2	3.0

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

TABLE 2.5

RELATIONSHIP BETWEEN TMI AND DEPTH OF DESIGN SUCTION CHANGE (H_s)

TMI	Depth of design suction change (H_s) m
>10	1.5 m
−5 to 10	1.8 m
−15 to −5	2.3 m
−25 to −15	3.0 m
−40 to −25	4.0 m
≤40	>4.0 m

2.4 SITE INVESTIGATION REQUIREMENTS

2.4.1 General

Where a site investigation is required for the purpose stated in Clause 2.4.2, the requirements in Clauses 2.4.3 to 2.4.5 shall be met. An investigation in accordance with this clause may not provide sufficient information to allow design of footings on Class P sites. If in the opinion of the classifier the investigation does not include sufficient information for the design of a footing system, a recommendation shall be made regarding further investigation.

2.4.2 Purpose

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

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2.4.3 Depth of investigation

The soil profile shall be examined to a minimum depth below the surface or below the depth of cutting where known at the time of site classification equal to 0.75 times the depth of the suction change, H_s, for the locality, but not less than 1.5 m unless rock is encountered.

2.4.4 Minimum number of exploration positions

The following requirements apply for building sites:

(a) A minimum of one borehole or pit per building site.

(b) A minimum of three boreholes per site in localities where $H_s \geq 3.0$ m, and areas where the soil profile is known to be highly variable.

The total number of boreholes across a housing subdivision may be reduced if soil profiling indicates uniform soil conditions.

The presence of gilgais in an area is evidence of highly variable soil profiles within a site.

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 building has proved satisfactory.

2.4.5 Assessment of allowable bearing pressure

Adequate bearing strength 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 bearing pressure shall consider the weakest state of the foundation under normal site conditions. Local knowledge shall be used where available.

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

2.5 ADDITIONAL CONSIDERATIONS FOR SITE CLASSIFICATION

2.5.1 Sites consisting predominantly of sand or rock

Sites consisting predominantly of sand of adequate bearing capacity or rock, as defined in Clause 1.8, shall be classified as Class A.

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

2.5.2 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 has not been taken into account, the classification shall be reconsidered if—

(a) the depth of cut on an S, M, H_1, H_2 or E site exceeds the lesser of 0.25 H_s or 0.5 m; or

(b) the depth of fill would result in a P classification in accordance with Clause 2.5.3.

2.5.3 Effect of fill on classification

For the purposes of this Standard fill that is in accordance with the technical and control requirements as specified in AS 3798 for structural fill for residential applications is controlled fill. Other fill is uncontrolled fill for the purposes of this Standard.

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The classification of sites containing fill shall be in accordance with the following clauses.

(a) *Controlled fill*

(i) *Shallow fill* The classification of a site with controlled fill not more than 0.8 m deep for sand and not more than 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 be the same as the natural site prior to filling. However, the presence of the sand 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.

(b) *Uncontrolled fill*

(i) *Shallow fill* The classification of a site with uncontrolled fill not more than 0.8 m deep for sand and not more than 0.4 m deep for material other than sand shall be Class P, unless all footings (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 with controlled fill and classified P may be given an alternative site classification in accordance with Table 2.1 if assessed in accordance with engineering principles. The assessment shall consider the movement of the fill and the underlying soil from the condition at construction to the long-term equilibrium moisture conditions.

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SECTION 3 STANDARD DESIGNS

3.1 SELECTION OF FOOTING SYSTEMS

3.1.1 Selection procedure

Standard deemed-to-comply designs shall be selected in accordance with Clauses 3.2 to 3.6. These designs shall not apply to—

(a) Class E or P sites;

(b) buildings longer than 30 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 3.9;

(e) two-storey construction in excess of the height limitations. (See Clause 1.8.58.)

(f) support of columns or fireplaces not complying with Clause 3.10;

(g) buildings incorporating 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.

On moderately and highly reactive sites, the entire footing system for a single building shall comprise only one standard design.

3.1.2 Design for single-leaf masonry, mixed construction and earth wall construction

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

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TABLE 3.1

EQUIVALENT TYPES OF CONSTRUCTIONS

Actual construction		Equivalent construction
External walls	**Internal walls**	
Single leaf masonry		
Reinforced single-leaf masonry	Articulated masonry on Class A and S sites, or framed	Articulated masonry veneer
Reinforced single-leaf masonry	Articulated masonry or reinforced single leaf masonry	Masonry veneer
Reinforced single-leaf masonry	Masonry	Articulated full masonry
Articulated single-leaf masonry	Articulated masonry	Articulated full masonry
Articulated single-leaf masonry	Masonry	Articulated full masonry
Other single-leaf masonry	Framed	Articulated full masonry
Other single-leaf masonry	Masonry	Full masonry
Mixed construction		
Full masonry	Framed	Articulated full masonry
Articulated full masonry	Framed	Masonry veneer
Articulated rendered or sheet clad frame	Framed	Articulated masonry veneer
Precast concrete panels		
Reinforced concrete panel	Framed	Articulated masonry veneer
Earth masonry		
Infill panels of earth masonry	Framed earth masonry	Articulated masonry veneer
Load bearing earth masonry	Load bearing earth masonry	Articulated full masonry

3.1.3 Construction with framed party walls

For the purpose of this Section, where construction involves framed party walls 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 basic masonry veneer construction on footings appropriate for masonry veneer provided 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 main building; and

(b) walls of masonry extensions, or masonry veneer extensions, shall be articulated at the junction with the existing building.

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Footings of similar proportions and details to those used in an existing building on the same allotment may be used, provided the performance of the existing building 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 may be reduced by up to one-third provided the amount of top and bottom reinforcement is doubled and extended 500 mm past the section with reduced depth.

Alternatively, the footing may 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, H1 and H2 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 may be replaced by a levelling pad of concrete or mortar.

3.2 STIFFENED RAFT

3.2.1 General

The concrete section sizes, beam spacing and reinforcement requirements for stiffened rafts are given in Figure 3.1. Stiffened rafts shall be detailed in accordance with Clauses 3.2.2 to 3.2.4 and 5.3.

3.2.2 Beam layout

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

Where the number of beams in a particular direction satisfies the requirements of the maximum spacing given in Figure 3.1, the spacing between individual beams can be varied, provided the spacing between any two beams does not exceed the spacing give in Figure 3.1 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.

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.

3.2.3 Reinforcement

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

The slab mesh specified in Figure 3.1 may be replaced with the following:

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TABLE 3.2

ALTERNATIVE SLAB REINFORCEMENT

Alternative slab mesh	Specified slab mesh		
	SL102	**SL92**	**SL82**
	Additional reinforcement at top of beams		
SL92	3-L11TM	—	—
SL82	3-N16	3-L11TM	—
SL72	4-N16	4-L12TM	2-L12TM

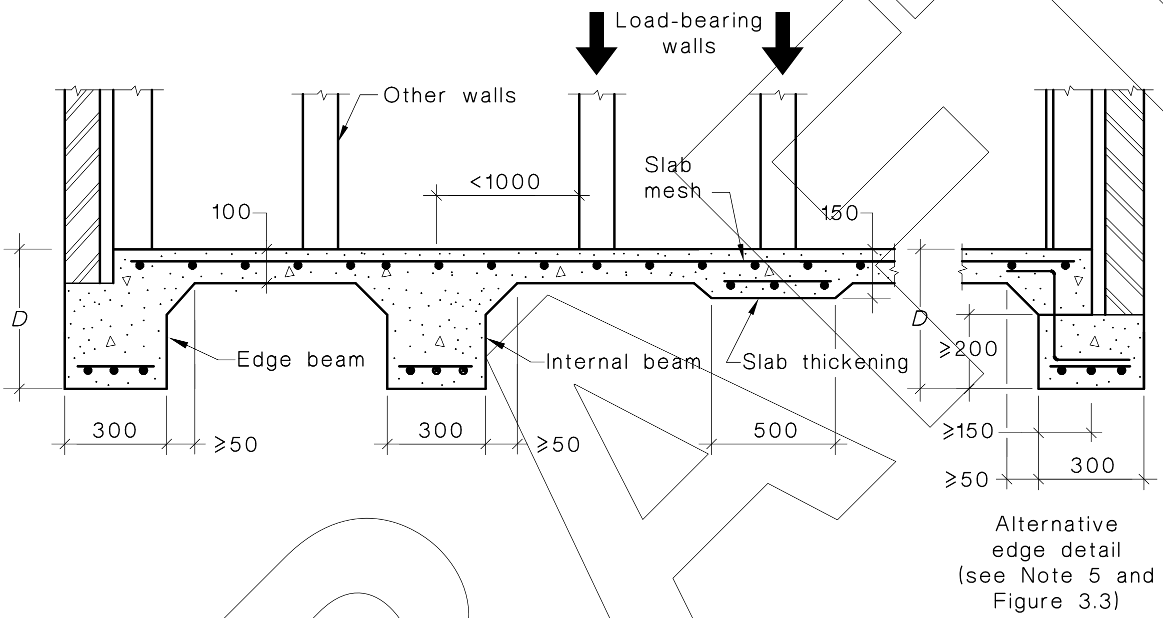

FIGURE 3.1 (in part) STIFFENED RAFT DESIGNS SITE CLASSES A, S, M, M-D, H1, H2, H1-D,H2-D

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Site class	Type of construction	Edge and internal beams (see Note 1)				
		Depth (D) mm	Bottom reinforcement		Top bar reinforce-ment	Max beam spacing cc m (see Note 2)
			Fabric mesh	Bar alternative		
Class A	Clad frame	300	3-L8TM	2N12	—	—
	Articulated masonry veneer	300	3-L8TM	2N12	—	—
	Masonry veneer	300	3-L8TM	2N12	—	—
	Articulated full masonry	400	3-L8TM	2N12	—	—
	Full masonry	500	3-L8TM	2N12	—	—
Class S	Clad frame	300	3-L8TM	2N12	—	—
	Articulated masonry veneer	300	3-L8TM	2N12	—	—
	Masonry veneer	300	3-L8TM	2N12	—	—
	Articulated full masonry	500	3-L8TM	2N12	2N12	—
	Full masonry	850	4-L11TM	2N16	2N16	5
Class M	Clad frame	300	3-L8TM	2N12	—	6
	Articulated masonry veneer	400	3-L8TM	2N12	—	6
	Masonry veneer	400	3-L8TM	2N12	—	5
	Articulated full masonry	625	3-L11TM	3N12	2N12	4
	Full masonry	950	2x3-L11TM	3N16	2N16	4
Class M-D	Clad frame	400	3-L11TM	2N12	—	5
	Articulated masonry veneer	400	3-L11TM	2N12	1N12	4
	Masonry veneer	500	3-L12TM	3N12	2N12	4
	Articulated full masonry	650	3-L12TM	2N16	2N16	4
	Full masonry	1050	2x3-L11TM	3N16	3N16	4
Class H1	Clad frame	400	3-L11TM	3N12	0	5
	Articulated masonry veneer	400	3-L11TM	3N12	1N12	4
	Masonry veneer	500	3-L11TM	3N12	3N12	4
	Articulated full masonry	750	4-L11TM	2N16	2N16	4
	Full masonry	1050	2x3-L11TM	3N16	3N16	4
Class H1-D	Clad frame	400	3-L11TM	3N12	1N12	4
	Articulated masonry veneer	500	3-L11TM	3N12	2N12	4
	Masonry veneer	650	2x3-L11TM	3N16	1N16	4
	Articulated full masonry	800	2x3-L11TM	3N16	2N16	4
	Full masonry	1100	2x3-L11TM	3N16	3N16	4
Class H2	Clad frame	550	3-L11TM	3N12	2N12	4
	Articulated masonry veneer	600	3-L11TM	3N12	2N12	4
	Masonry veneer	750	2x3-L11TM	3N16	2N16	4
	Articulated full masonry	1000	2x3-L11TM	3N16	2N16	4
	Full masonry	1200	2x4-L11TM	4N16	3N16	4
Class H2-D	Clad frame	550	2x3-L11TM	3N16	2N16	4
	Articulated masonry veneer	700	2x3-L11TM	3N16	2N16	4
	Masonry veneer	750	2x3-L11TM	3N16	2N16	4
	Articulated full masonry	1000	2x3-L11TM	3N16	2N16	4
	Full masonry	1200	2x4-L11TM	4N16	3N16	4

NOTE: Slab reinforcement for all site classes:

Slab length < 18 m	SL 72
Slab length 18 to 25 mm	SL 82
Slab length > 25 and < 30 m	SL 92

FIGURE 3.1 (in part) STIFFENED RAFT DESIGNS SITE CLASSES A, S, M, M-D, H1, H2, H1-D, H2-D

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3.2.4 Construction

Except on site Classes M-D, H1-D or H2-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 W10 or N10 fitments at 600 mm centres or equivalent (see alternative edge beam detail).

Construction details are given in Clauses 6.4 and 6.6.

Requirements for shrinkage crack control are given in Clause 5.3.7.

3.2.5 Reinforced masonry

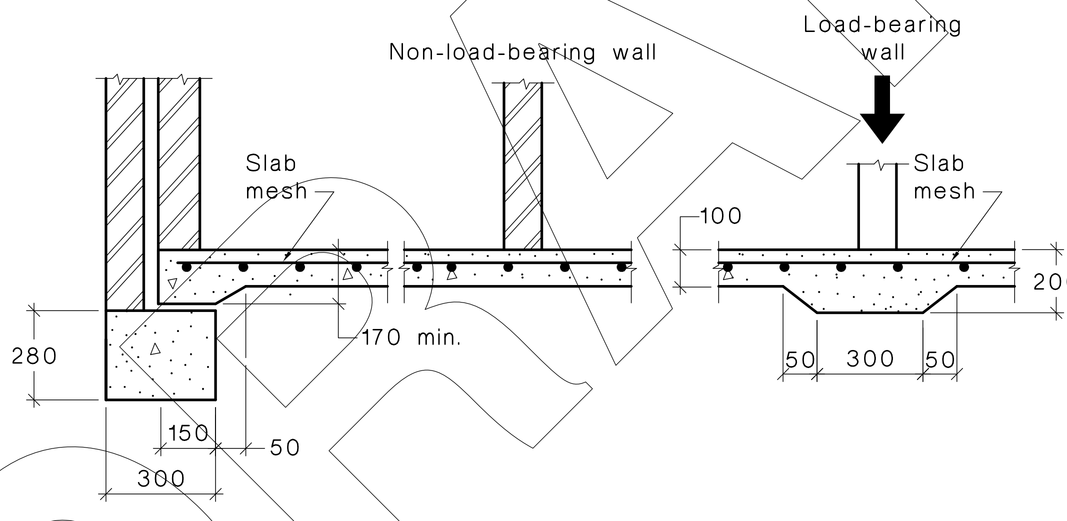
Where a reinforced single leaf masonry wall with a continuous reinforced bond beam is constructed directly above, and structurally connected to a concrete edge beam, the beam may be 300 mm wide by 300 mm deep with 3-L11TM reinforcement.

3.3 FOOTING SLAB

3.3.1 General

Footing slabs shall be selected in accordance with Figure 3.2 (Class A) or Figure 3.3 (Class A or S).

3.3.2 Unreinforced footing



NOTES:

1 Use SL63 when maximum slab length ≤12 000.
Use SL62 when maximum slab length >12 000 and <18 000.
Use SL72 when maximum slab length ≥18 000 and <25 000.
Use SL82 when maximum slab length ≥25 000 and <30 000.

2 In Western Australia, for slabs under 25 m in length, 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 SL53 when maximum slab length ≤12 000.
Use SL63 when maximum slab length >12 000 and <18 000.
Use SL62 when maximum slab length ≥18 000 and <25 000.

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

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3.3.3 Reinforced footing

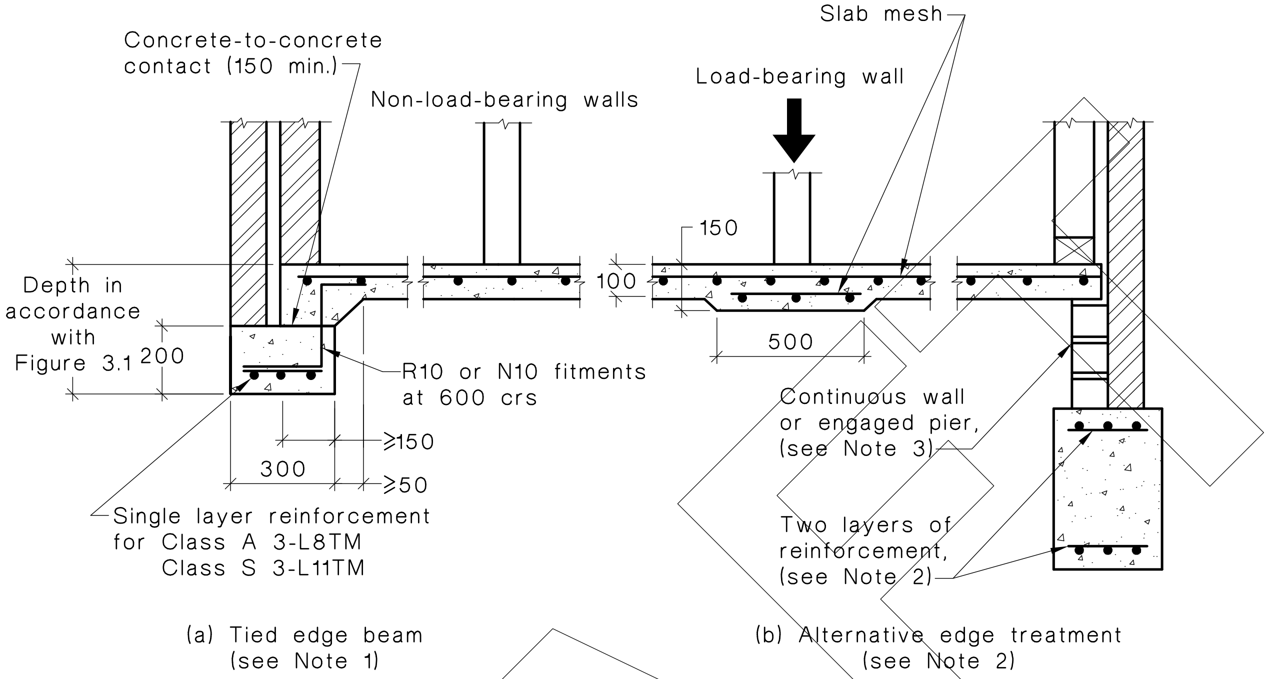

FIGURE 3.3 FOOTING SLAB FOR CLASS A AND FOR CLASS S SITES FOR CLAD FRAME, ARTICULATED MASONRY VENEER, MASONRY VENEER, ARTICULATED FULL MASONRY OR FULL MASONRY

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

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.

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.

Fitments shall be structurally anchored above and below the joint.

3.4 WAFFLE RAFTS

3.4.1 General

Waffle rafts shall be specified in accordance with Figure 3.4. Modifications to the details given in Figure 3.4 shall not be undertaken without engineering design in accordance with Section 4.

85 mm slab thickness may be used in garage areas.

Internal and edge beams are to be arranged to maintain continuity at re-entrant corners in accordance with Clause 5.3.8.

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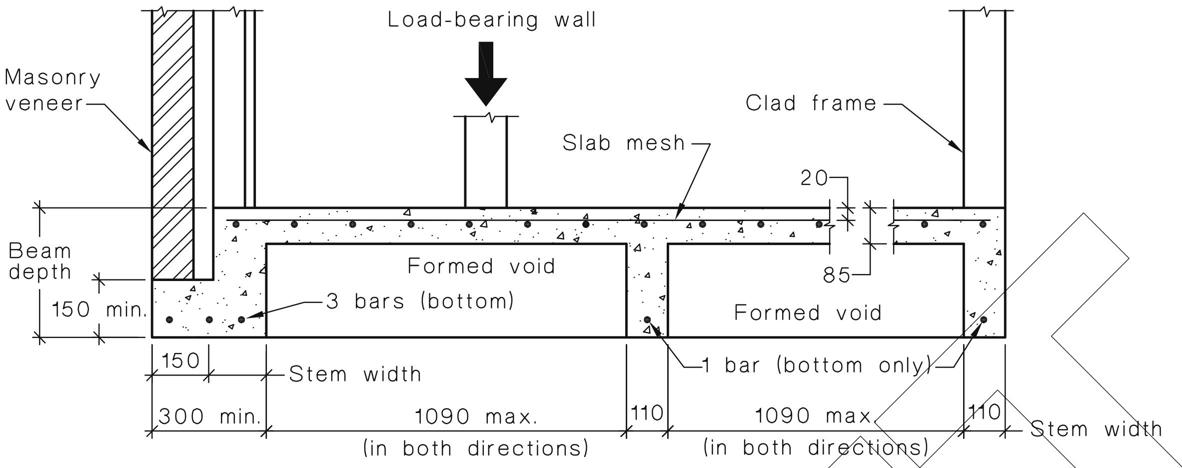

(a) Typical edge rebate

Site class	Type of construction	Beam and rib reinforcement				Slab mesh	
		Depth (D) mm	Edge beam		Rib	Slab length (m)	
			Mesh alternative	Bar alternative		< 20	≥ 20 & < 30
A	Clad frame	260	3-L8TM	3N12	1N12	SL72	SL82
	Articulated masonry veneer	310	3-L8TM	3N12	1N12	SL72	SL82
	Masonry veneer	310	3-L8TM	3N12	1N12	SL72	SL82
	Articulated full masonry (S/S)	310	3-L8TM	3N12	1N12	SL72	SL82
	Full masonry	—	—	—	—	—	—
S	Clad frame	260	3-L8TM	3N12	1N12	SL72	SL82
	Articulated masonry veneer	310	3-L8TM	3N12	1N12	SL72	SL82
	Masonry veneer	310	3-L8TM	3N12	1N12	SL72	SL82
	Articulated full masonry (S/S)	385	3-L8TM	3N16	1N16	SL72	SL82
	Full masonry	—	—	—	—	—	—
M	Clad frame	310	3-L8TM	3N12	1N12	SL72	SL82
	Articulated masonry veneer	310	3-L8TM	3N12	1N12	SL72	SL82
	Masonry veneer	310	3-L8TM	3N12	1N12	SL72	SL82
	Articulated full masonry (S/S)	610	2x3-L11TM	3N16	1N16	SL72	SL82
	Full masonry	—	—	—	—	—	—
M-D	Clad frame	310	3-L8TM	3N12	1N12	SL72	SL92
	Articulated masonry veneer	310	3-L8TM	3N12	1N12	SL72	SL92
	Masonry veneer	385	2x3-L11TM	3N16	1N16	SL72	SL92
	Articulated full masonry (S/S)	610	2x3-L11TM	3N16	1N16	SL72	SL92
	Full masonry	—	—	—	—	—	—
H1	Clad frame	310	3-L11TM	3N12	1N12	SL82	SL92
	Articulated masonry veneer	385	3-L11TM	3N12	1N12	SL82	SL92
	Masonry veneer	460	2x3-L11TM	3N16	1N16	SL82	SL92
	Articulated full masonry (S/S)	610	2x3-L11TM	3N16	1N16	SL82	SL92
	Full masonry	—	—	—	—	—	—
H1-D	Clad frame	310	3-L11TM	3N12	1N12	SL82	SL92
	Articulated masonry veneer	385	3-L11TM	3N12	1N12	SL82	SL92
	Masonry veneer (S/S)	460	2x3-L11TM	3N16	1N16	SL82	SL92
	Articulated full masonry	—	—	—	—	—	—
	Full masonry	—	—	—	—	—	—
H2	Clad frame	310	3-L11TM	3N12	1N12	SL82	SL92
	Articulated masonry veneer	385	2x3-L11TM	3N16	1N16	SL82	SL92
	Masonry veneer	—	—	—	—	—	—
	Articulated full masonry	—	—	—	—	—	—
	Full masonry	—	—	—	—	—	—

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Site class	Type of construction	Beam and rib reinforcement				Slab mesh	
		Depth (D) mm	Edge beam		Rib	Slab length (m)	
			Mesh alternative	Bar alternative		< 20	≥ 20 & < 30
H2-D	Clad frame	385	2x3-L11TM	3N16	1N16	SL82	SL92
	Articulated masonry veneer (S/S)	460	2x3-L11TM	3N16	1N16	SL82	SL92
	Masonry veneer	—	—	—	—	—	—
	Articulated full masonry	—	—	—	—	—	—
	Full masonry	—	—	—	—	—	—

NOTES:

1 This table applies only to waffle rafts with typical edge rebate (a).

2 No solutions have been provided for Class H2.

DIMENSIONS IN MILLIMETRES

FIGURE 3.4 (in part) WAFFLE RAFT

3.4.2 Stem width

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.

3.4.3 Reinforcement

Additional reinforcement shall be provided for all beams where the stem width exceeds 150 mm. The size and specification of top bars shall be the same as bottom bars except as specified in Figure 3.4. The total number of reinforcement bars in beams shall be as follows:

Stem width mm	Top steel (additional to slab mesh)
110 to 150	0
151 to 220	1
221 to 330	2
331 to 440	3

Beam base width mm	Bottom steel
110 to 150	1
151 to 220	2
221 to 330	3
331 to 440	4

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3.4.4 Construction

Construction details are given in Clauses 6.4 and 6.6.

3.4.5 Piers

The waffle raft for a one-storey building for clad frame or masonry veneer on moderately or highly reactive 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 N12 bar at the top shall be provided in the ribs intersecting the piers, but no shear fitments are required.

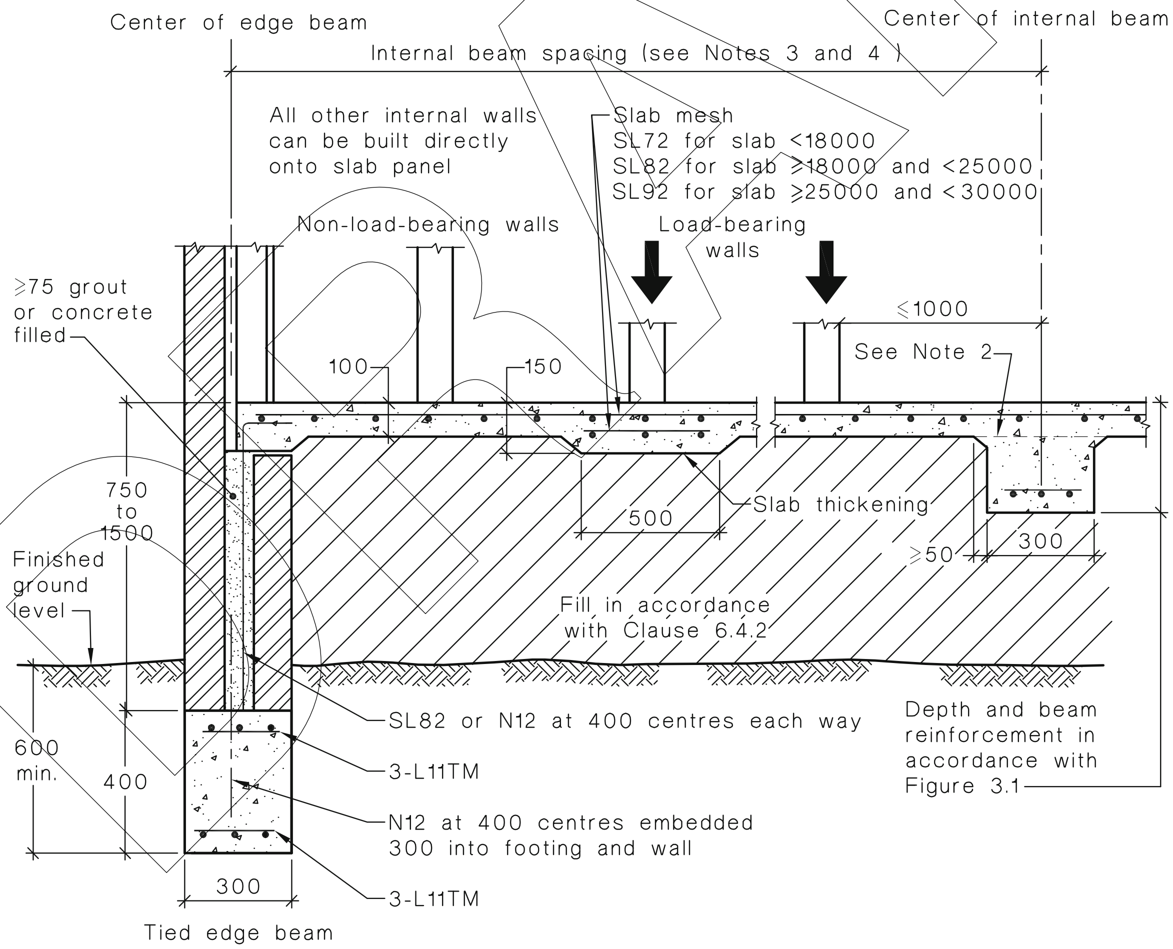
3.5 STIFFENED SLAB WITH DEEP EDGE BEAM

3.5.1 General

A stiffened slab with edge beam may be used on Class M sites for masonry veneer or articulated masonry veneer construction. Details shall be in accordance with Figure 3.5.

3.5.2 Beam spacing

Beam spacing shall not exceed 5.0 m for masonry veneer construction or 6.0 m for articulated masonry veneer construction.



DIMENSIONS IN MILLIMETRES

FIGURE 3.5 STIFFENED SLAB WITH DEEP EDGE BEAM FOR MASONRY VENEER AND ARTICULATED MASONRY VENEER CLASS M SITE

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3.5.3 Reinforcement

The reinforcement of the cavity shall consist of N12 bars at 400 centres in each direction, with the vertical bars 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.

3.5.4 Construction joints

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 transversed by W10 or N10 fitments at 600 mm centres or equivalent reinforcement.

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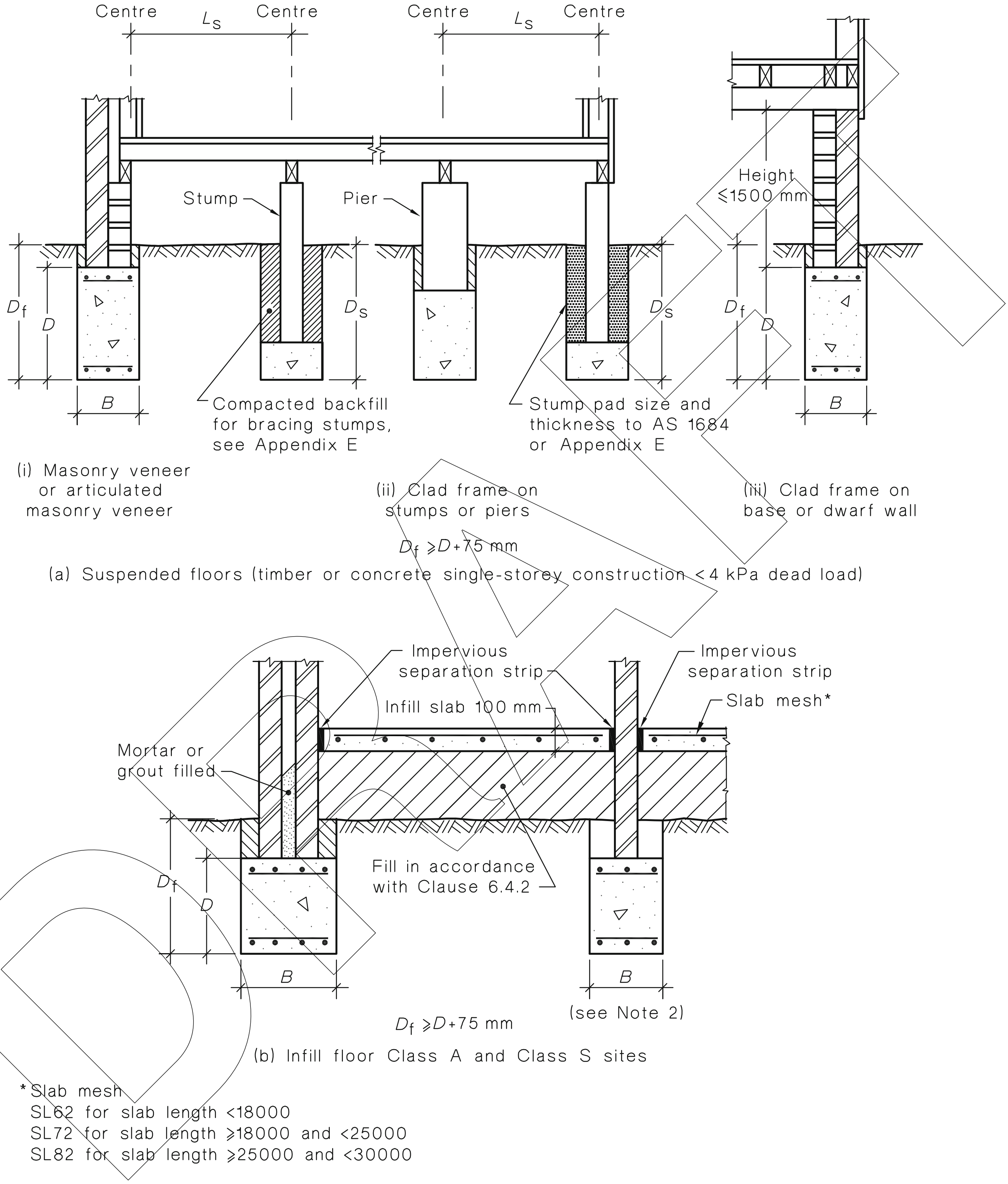
3.6 STRIP FOOTINGS

3.6.1 General



DIMENSIONS IN MILLIMETRES

FIGURE 3.6 (in part) STRIP FOOTING SYSTEMS

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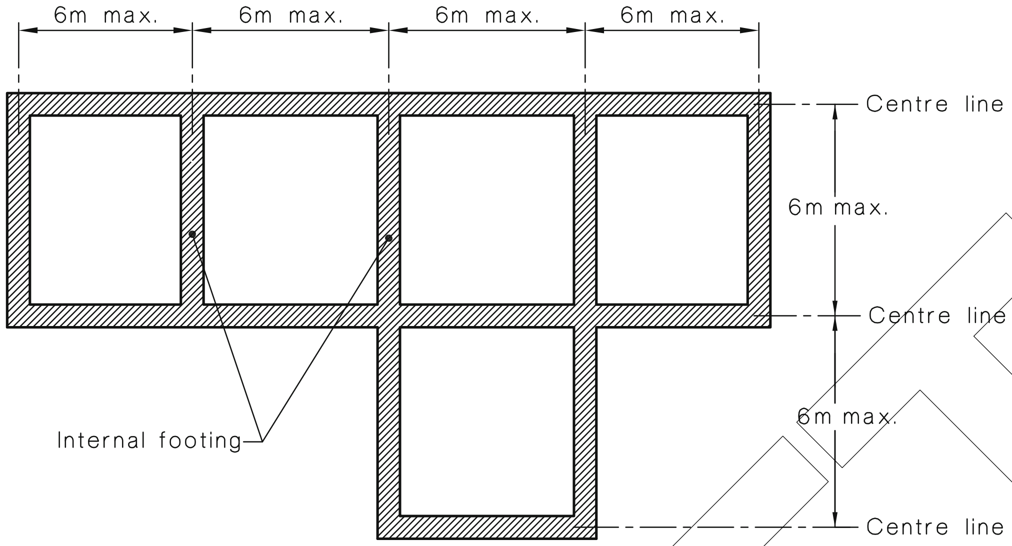

(b) Example of footing system with re-entrant corners

DIMENSIONS IN MILLIMETRES

Site class	Type of construction	*D*	*B*	Reinforcement	D_s	L_s
Class A	Clad frame	300	300	3-L8TM	400	—
	Articulated masonry veneer	300	300	3-L8TM	400	—
	Masonry veneer	300	300	3-L8TM	400	—
	Articulated full masonry	300	400	4-L8TM	400	—
	Full masonry	300	400	4-L8TM	400	—
Class S	Clad frame	400	300	3-L8TM	400	—
	Articulated masonry veneer	400	300	3-L8TM	400	—
	Masonry veneer	400	300	3-L8TM	400	—
	Articulated full masonry	400	400	4-L11TM	400	—
	Full masonry	500	400	4-L11TM	400	—
Class M	Clad frame	400	300	3-L11TM	500	—
	Articulated masonry veneer	450	300	3-L11TM	500	—
	Masonry veneer	500	300	3-L12TM	500	—
	Articulated full masonry	600	400	4-L12TM	500	—
	Full masonry	900 (Note 2)	400	4-L12TM	500	—
Class M-D	Clad frame	500	300	3-L11TM	800	—
	Articulated masonry veneer	550	300	3-L12TM	800	—
	Masonry veneer	700 (Note 2)	300	3-N16	800	—
	Articulated full masonry	1 100 (Note 2)	400	4-N16	800	—
Class H1	Clad frame	500	300	3-L11TM	1 000	≥2 400
	Articulated masonry veneer	600	300	3-L12TM	1 000	≥2 400
	Masonry veneer	850 (Note 2)	300	3-N16	1 000	≥2 400
	Articulated full masonry	1 100 (Note 2)	400	4-N16	1 000	≥2 400

FIGURE 3.6 (in part) STRIP FOOTING SYSTEMS

All masonry walls shall be supported on strip footings.

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3.6.2 Deep beams

For all beams 700 m or deeper, as specified in the table in Figure 3.6, 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.

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.

Bracing forces and uplift forces to stumps may be provided for using the details in Appendix E.

3.6.3 Infill floors

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.

3.6.4 Reinforcement

If strip footings deeper than those required are used, the reinforcement shall be increased to match that specified for the deepened proportions.

Where footings are wider than the specified width, an extra bar of the same bar size is required top and bottom for each 100 mm additional width.

$D_f \geq D + 75$ mm.

3.7 REINFORCEMENT EQUIVALENCES

The bar sizes given in Table 3.3 are deemed to comply with the requirements for trench mesh reinforcement in beams and footings. L11TM and L12TM may be replaced by RL1118 and RL1218 mesh respectively. Two layers of L8TM may be used as a replacement for L11TM. Where a single layer of trench mesh would be too wide for the footing or beam, multiple layers, bundled together, or equivalent reinforcement shall be used.

Alternative arrangements of beam or footing reinforcement may be used, if the flexural strength of the section is unimpaired.

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TABLE 3.3

REINFORCING BAR SIZES DEEMED TO BE EQUIVALENT TO TRENCH MESH REINFORCEMENT

Trench mesh	Area of steel mm^2	Bar alternative	Trench mesh alternative
2-L8TM	91	2-N10 or 1-N12	-
3-L8TM	136	2-N10 or 2-N12	-
4-L8TM	182	2-N12	2-L11TM
5-L8TM	227	2-N12	3-L11TM
2-L11TM	180	1-N16 or 2-N12	2 × 2-L8TM
3-L11TM	270	3-N12	2 × 3-L8TM
4-L11TM	360	2-N16	2 × 4-L8TM
2-L12TM	222	2-N12	3-L11TM
3-L12TM	333	3-N12	4-L11TM
4-L12TM	444	4-N12	5-L11TM

3.8 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 subclauses may be used for design:

(a) Fill used as temporary support need not be controlled or rolled fill, 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 SL72 top and SL72 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.

3.9 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 175 mm, or the dead load per unit area is not greater than 4 kPa;

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

(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 bar 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 mesh placed in the bottom of the thickened section shall be provided.

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3.10 FOOTINGS FOR CONCENTRATED LOADS

3.10.1 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 m^2.

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

On moderately and highly reactive sites separate footings shall not be used unless the construction supported is structurally isolated from the rest of the building.

3.10.2 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, pad footings shall be reinforced top and bottom with SL72 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.

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SECTION 4 DESIGN BY ENGINEERING PRINCIPLES

4.1 GENERAL

To comply with this Standard slabs, or footing systems designed in accordance with engineering principles shall also be designed in accordance with this Section and AS 3600. Where a specific provisions given below is different from that in AS 3600, the provision below shall be used.

This Section may be used to extend the range of validity of, or to modify, the deemed-to-comply designs contained in Section 3 of this Standard.

4.2 DESIGN CRITERIA

Slabs and footings and associated superstructures shall be designed to satisfy the performance criteria set out in Clause 1.3 when subjected to the loads noted therein.

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 the lesser of the two values given in Table 4.1 for the applicable type of construction.

TABLE 4.1

MAXIMUM DESIGN DIFFERENTIAL FOOTING MOVEMENT, Δ, FOR DESIGN OF FOOTINGS AND RAFTS

Type of construction	Maximum differential deflection, as a function of span, (mm)	Maximum differential deflection (mm)
Clad frame	L/300	40
Articulated masonry veneer	L/400	30
Masonry veneer	L/600	20
Articulated full masonry	L/800	15
Full masonry	L/2000	10

4.3 DESIGN OF FOOTING SYSTEMS

Footing systems shall be designed in accordance with one of the following—

(a) stiffened raft footing systems supporting a superstructure that relies entirely on the raft to resist cracking, (see Clause 4.4 or 4.5);

(b) shallow footing systems other than stiffened rafts (see Clause 4.6);

(c) footing systems supporting walls with sufficient strength to span without hogging or cracking (see Clause 4.7); or

(d) piered or piled footing systems (see Clause 4.8).

4.4 STIFFENED RAFT FOOTING SYSTEMS

A stiffened raft footing system that supports a superstructure that relies entirely on the raft stiffness to resist movement and cracking shall be proportioned as follows:

(a) The raft structure shall comprise a grid of approximately orthogonal beams structurally connected to a concrete slab.

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(b) 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.

(c) 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 the lesser of the two values given in Table 4.1 for the applicable type of construction.

(d) Where permanent slab joints are used, the design shall consider the variation in section stiffness at the joint location.

(e) 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 $B_w + 1$ m for an edge beam, and $B_w + 0.2$ L and $B_w + 2$ m for an internal beam.

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

(f) From the soil-structure analysis using the action effects given in Clause 1.4, the design bending moment at a cross-section (M^*) and the required stiffness ($E \times I$) may be determined. The stiffness, $E \times I$, of the slab shall be not less than that required by the analysis. In the determination of $E \times I$ the value of E shall be taken as 15,000 MPa for N20 concrete and I shall be as defined in AS 3600. The structural design for strength of the cross-section shall satisfy the requirement that—

   (i) 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 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. The structural design for strength of the cross-section shall satisfy the requirement that—

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

   where

   M_u is the ultimate strength calculated in accordance with AS 3600

   ϕ 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.

(g) Internal and external beams shall be arranged in accordance with Clauses 5.3.8 and 5.3.9.

(h) Beam spacing shall be adequate to ensure the structural integrity and stiffness of the raft. The maximum beam spacing shall not exceed 1.25 times the maximum values given in Figure 3.1 for the applicable site classification. For Class E sites the beam spacing shall not exceed 5 m.

(i) For ductility the cross-section shall be reinforced so the ultimate strength calculated on the basis of a reinforced section (M_u) is 20% greater than the cracking moment capacity (M_{cr}), where M_{cr} 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.

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(j) Shear reinforcement is required in raft beams only where the calculated shear force exceeds the design strength of the unreinforced section. Side face reinforcement is not required in deep raft beams.

4.5 SIMPLIFIED METHOD FOR RAFT DESIGNS

4.5.1 Application

Stiffened rafts may be designed in accordance with this clause, provided the design parameters are within the following range:

Design parameter	Range
y_s	10 mm to 100 mm
Δ	5 mm to 50 mm
Span	5 m to 30 m
Beam spacing	≤1.25 values in Figure 3.1. Clause 5.3.9 shall apply at external corners of the building. For Class E sites the beam spacing shall not exceed 5 m
Beam depth	250 mm to 1000 mm
Minimum depth of any beam	≥0.8 max. beam depth
Beam width	110 mm to 400 mm
Design distributed load	to 10 kPa
Design edge line load	to 25 kN/m

The slab mesh specified shall be not less than SL72 for slab spans <18 m; SL82 for spans ≥18 m and <25 m; and SL92 for spans ≥25 m and the ductility requirements of Clause 4.4(i) are to be satisfied. It is not 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 y_s/Δ shall be determined where Δ 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 y_s/Δ, 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 = the beam web width in millimetres

D = the overall depth of the beam in millimetres

W = 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.

4.6 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-

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structure interaction of the footing system. Lift-off shall not be considered in strip footings deeper than 0.6 m.

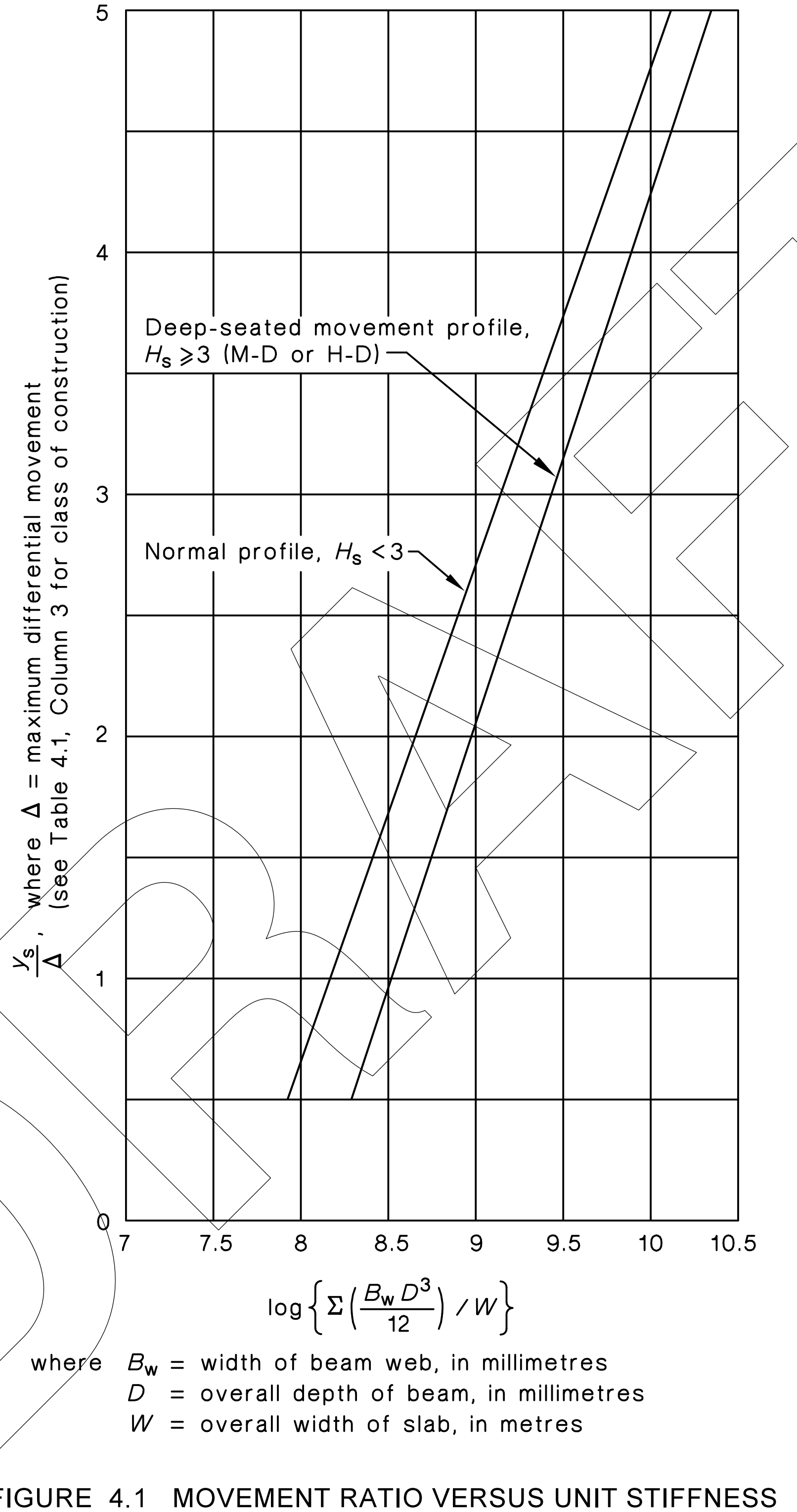

FIGURE 4.1 MOVEMENT RATIO VERSUS UNIT STIFFNESS

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.

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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 the 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 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 that 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 PILED OR PIERED FOOTING SYSTEMS

A pier-and-beam, pier-and-slab or piled footing system shall be designed in accordance with engineering principles and Appendix G.

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SECTION 5 DETAILING REQUIREMENTS

5.1 GENERAL

The detailing of all footing systems shall comply with Clauses 5.2 to 5.5. For highly reactive and extremely reactive sites, detailing shall also comply with Clause 5.67.

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 run-off from storms and local topography.

(b) The effect of excavation or filling.

(c) The possibility of flooding.

(d) The effects of existing and post-construction landscaping.

(e) The level of existing legal point of stormwater discharge.

(f) Plumbing and drainage requirements, for example, the height of the overflow relief gully relative to drainage fittings and ground level (see AS 3500).

(g) Minimum height from finished ground level to the damp proof course level (see AS 3700).

(h) 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. Where filling is placed adjacent to the building, the filling shall be compacted and graded to ensure drainage of water away from the building.

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 on Class 1 buildings

The possibility of surface water entering living areas in Class 1 buildings may be reduced by the following measures. The minimum height of the slab above finished ground, landscaping or paving level shall be 150 mm, except in the following cases:

(a) In sandy, well-drained areas the minimum height shall be 100 mm.

(b) Where adjoining paved areas slope away from the building these heights can be reduced to 50 mm.

(c) These heights may be further reduced locally at entrances that are shielded from the weather.

5.3 REQUIREMENTS FOR RAFTS AND SLABS

5.3.1 Concrete

The grade of concrete shall be not less than N20 grade in accordance with AS 1379, with 20 mm nominal maximum aggregate size, or as provided in Clauses 5.5 and 5.6, or as specified by the designer. Slump shall be selected to suit construction requirements.

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5.3.2 Reinforcement

Reinforcement in rafts and slabs shall be placed in accordance with the following:

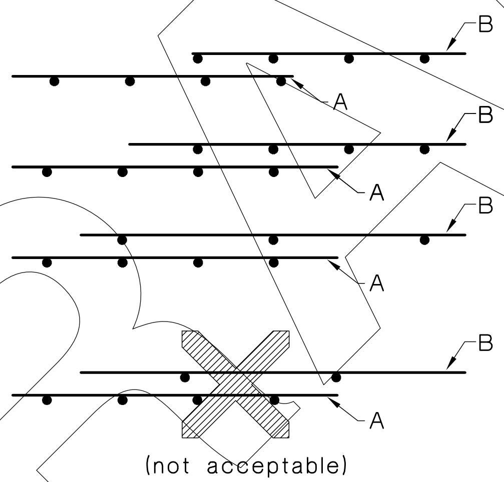
(a) Minimum concrete cover for the reinforcement shall be 40 mm to unprotected ground, 40 mm to external exposure, 30 mm to a membrane in contact with the ground, and 20 mm to an internal surface. The slab mesh shall be placed towards the top of the raft or slab within the zone defined by these limits.

(b) Raft or slab mesh shall be lapped 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 mesh 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 up to a bar diameter of 16 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 are permitted through the middle third of the depth of 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 MESH

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 a damp-proofing membrane where required.

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

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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) Properties 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.

(ii) *Impact resistance*—shall be determined using the falling dart impact test outlined in AS/NZS 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 puncture 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 for continuity at joints shall be not less than 200 mm.

(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).

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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) Where the edge rebate exceeds 150 mm in depth, the minimum horizontal width of the edge beam at the base of the rebate shall not be less than 200 mm, except that if W10 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.

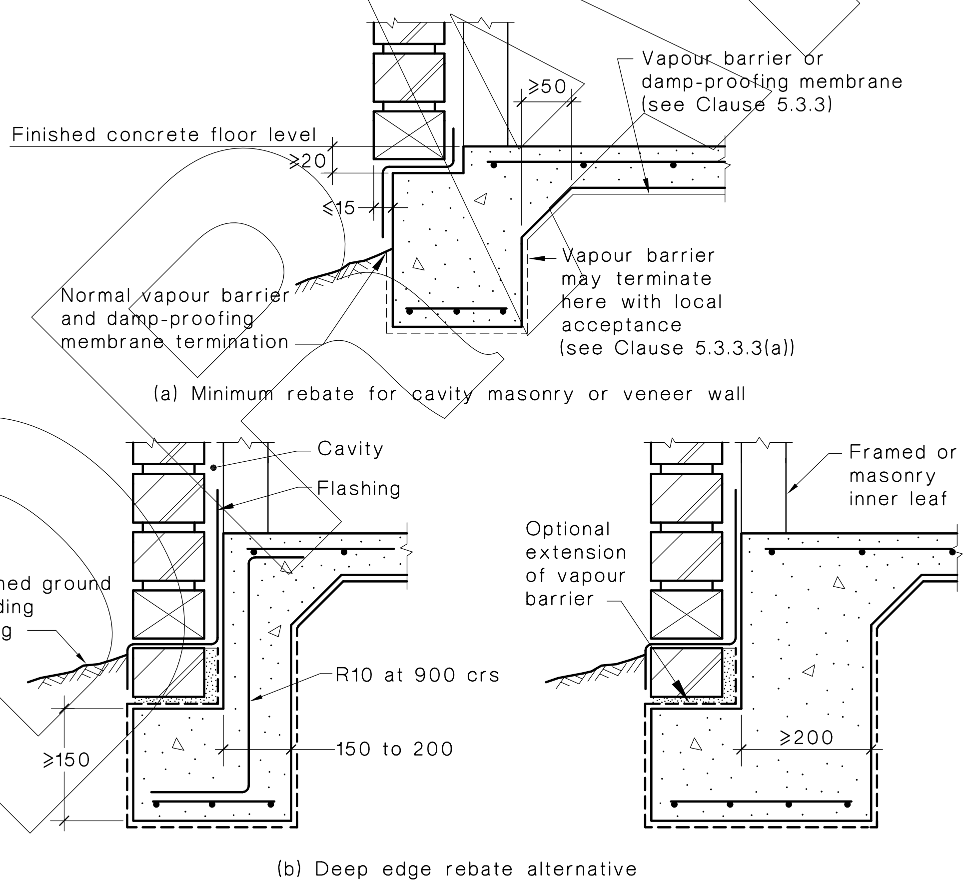
(c) The depth of concrete below the edge rebate shall be not less than 150 mm.

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

(e) 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.

(f) 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 assessed in accordance with engineering principles.

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.



NOTE: The cavity and flashing details shown are diagrammatic only. See AS 3700 and AS 3660.1.

DIMENSIONS IN MILLIMETRES

FIGURE 5.2 EDGE REBATE DETAILS

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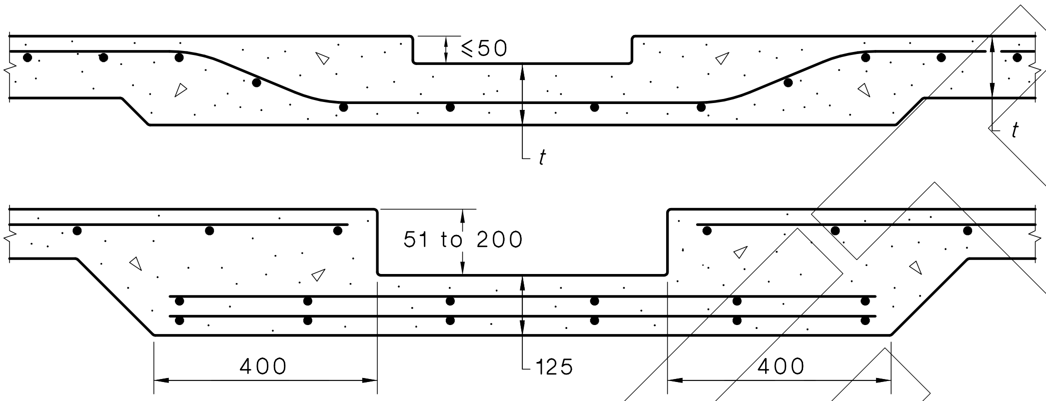
5.3.5 Recesses in slab panels

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.



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 the slab thickness is increased by 25 mm and an increase made in the mesh of one level, for example, SL72 for SL62, SL82 for SL72 and SL92 for SL82. The mesh 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 cracking control

Provision for control of or allowance for shrinkage cracking shall be as follows:

(a) Where brittle floor coverings are to be used over an area greater than 16 m^2, extra measures shall be taken to control shrinkage cracking. Such measures shall include one or more of the following:

   (i) The amount of slab reinforcement shall be not less than SL92 or equivalent throughout the slab panels where brittle finishes are to be used. Alternatively, an additional sheet of slab mesh shall be placed in those areas.

   (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. Appendix B discusses performance criteria and foundation maintenance.

(b) At re-entrant corners, two strips of 3-L8TM, or one strip of 3-L11TM or 3-N12 bars, shall be placed across the direction of potential cracking. All such reinforcement shall have a minimum length of 2 m.

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5.3.8 Beam continuity in rafts

Where the raft design includes internal beams, continuity shall be provided in accordance with the following criteria:

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 detailing is required to provide continuity. The requirements apply to stiffened rafts including waffle rafts. 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, any one of the details specified in Figure 5.4 is deemed to provide continuity of beams.

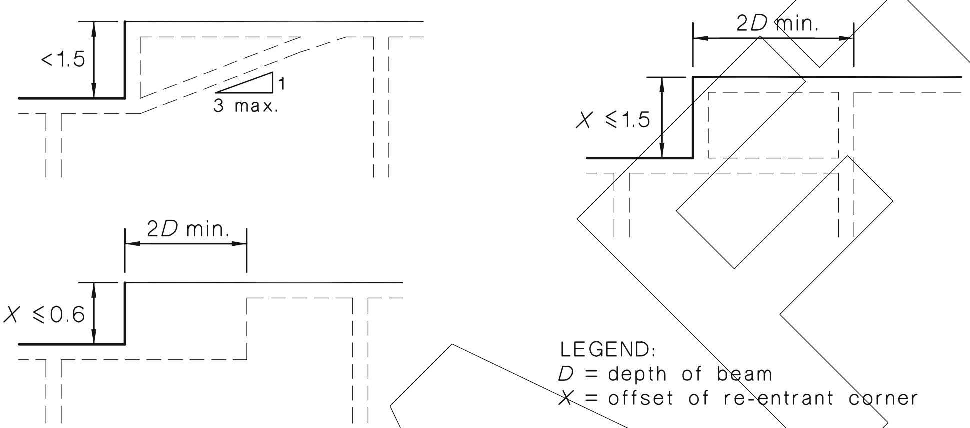
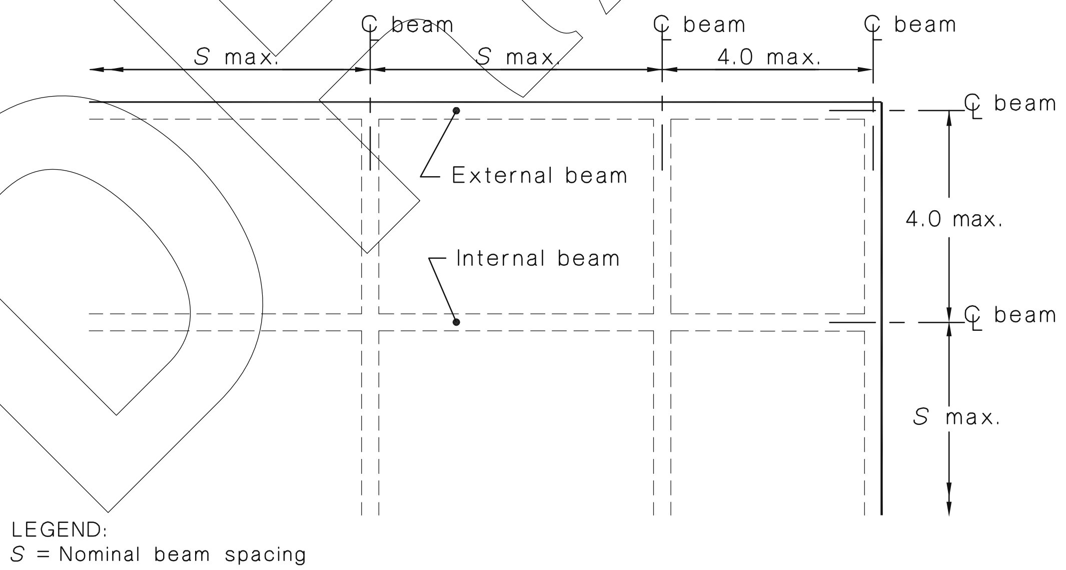


FIGURE 5.4 LAYOUT OF FOOTING BEAMS

5.3.9 Beam layout restrictions

Where the raft design includes internal beams, at all external corners the maximum distance between the corner and the intersection of the first internal beam with the edge beam shall be 4.0 m. See Figure 5.5.



NOTE: S = nominal beam spacing.

FIGURE 5.5 BEAM SPACING AT EXTERNAL CORNERS

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It is essential to maintain the equivalent stiffness characteristics of a raft design model in both directions. In the cases of an irregular (i.e. non rectangular) building footprint, additional beams, or "compound beams" should be provided as shown in Figures 5.6 and 5.7.

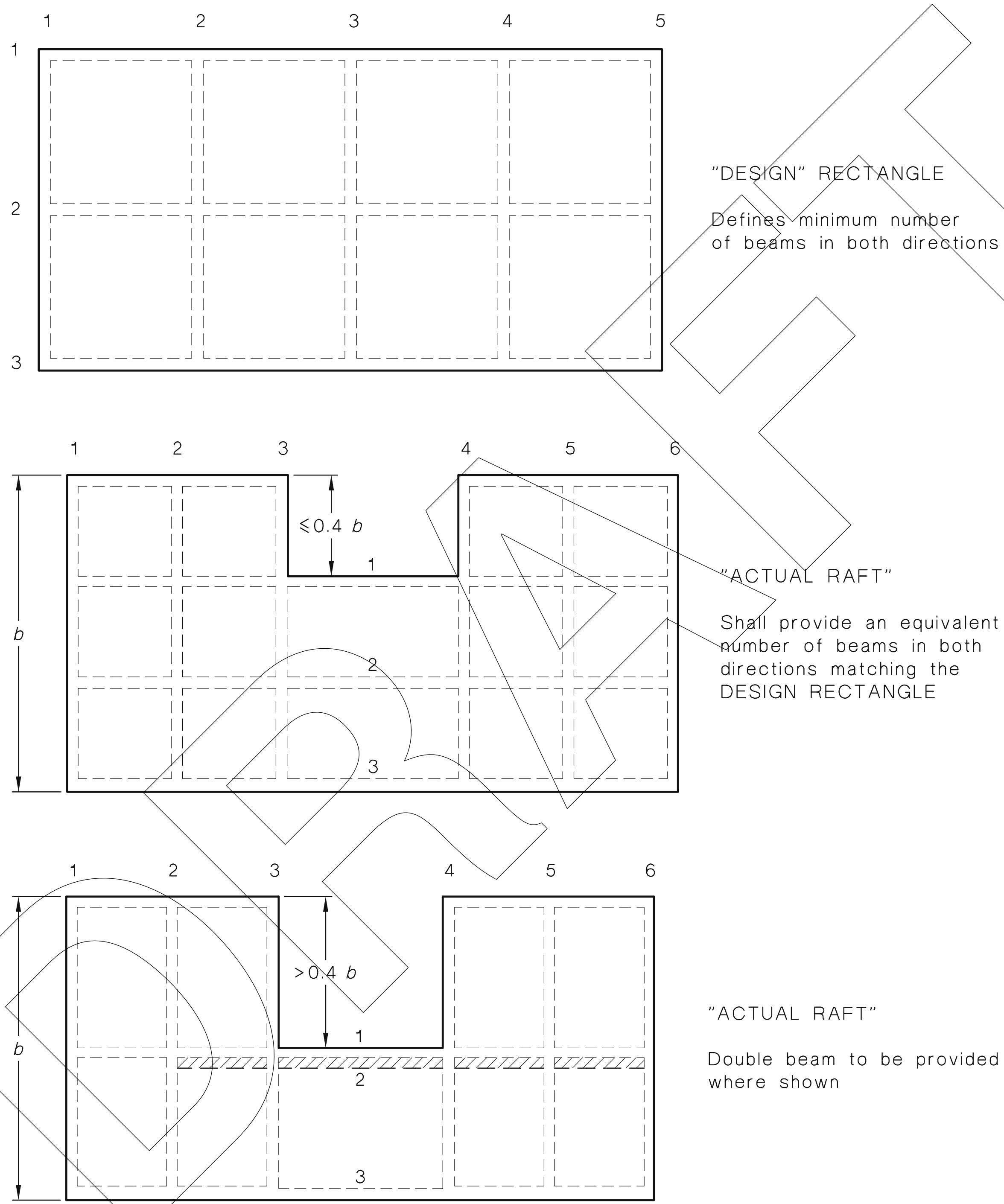

FIGURE 5.6 INTERNAL 'INSET' DESIGN

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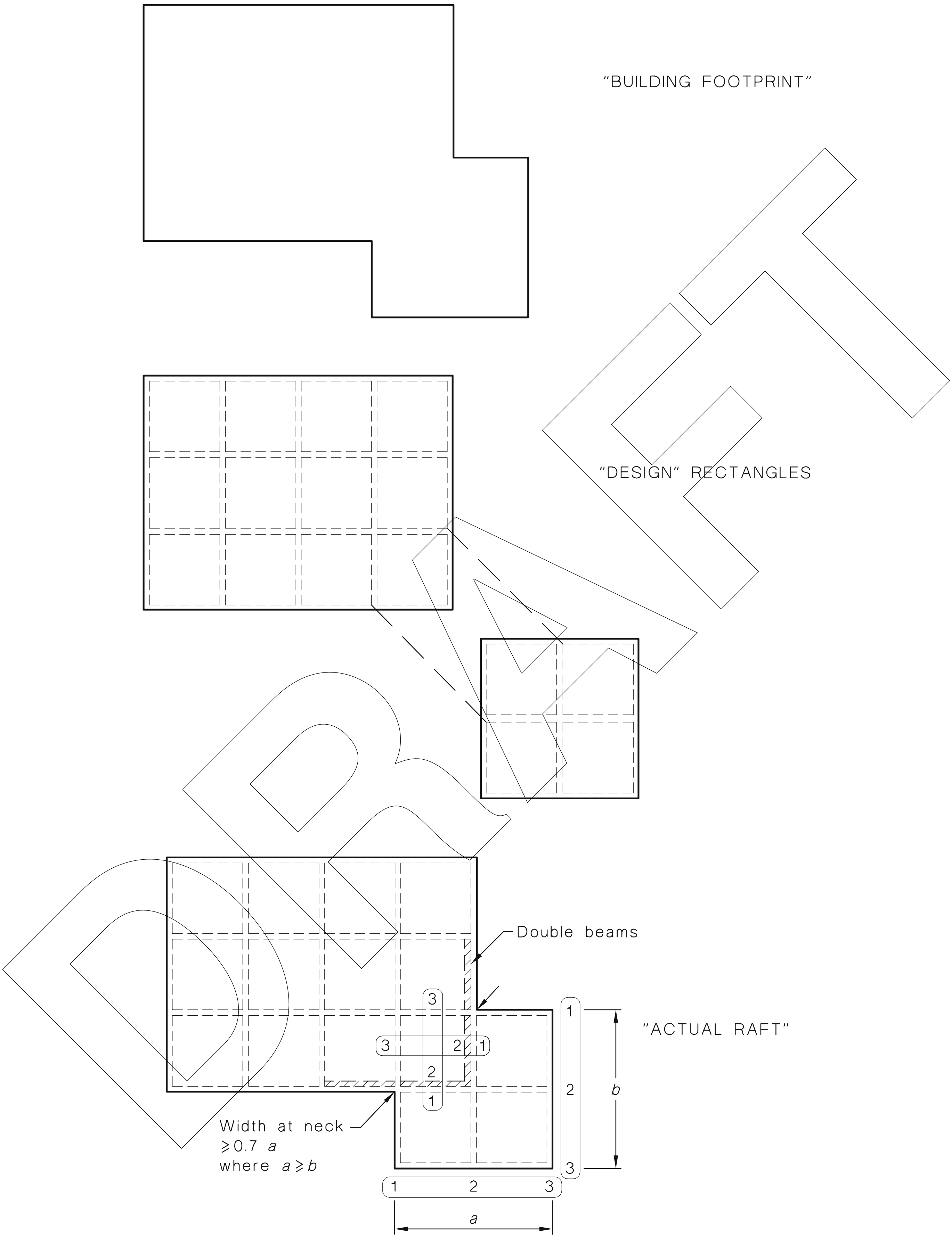

FIGURE 5.7 SUPPLEMENTARY 'GARAGE' DESIGN

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5.4 REQUIREMENTS FOR PAD AND STRIP FOOTINGS

5.4.1 Concrete

The grade of concrete shall be not less than N20 in accordance with AS 1379, with 20 mm nominal maximum aggregate size, or as provided in Clauses 5.5 and 5.6, or as specified by the designed. 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 mesh 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 continue 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 are permitted through the middle third of the depth of the footing. The effect of other footing penetrations shall be taken into account by the provision of extra concrete 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 one vertical in ten horizontal, or the footing shall be stepped in accordance with one of the methods given in Figure 5.6.

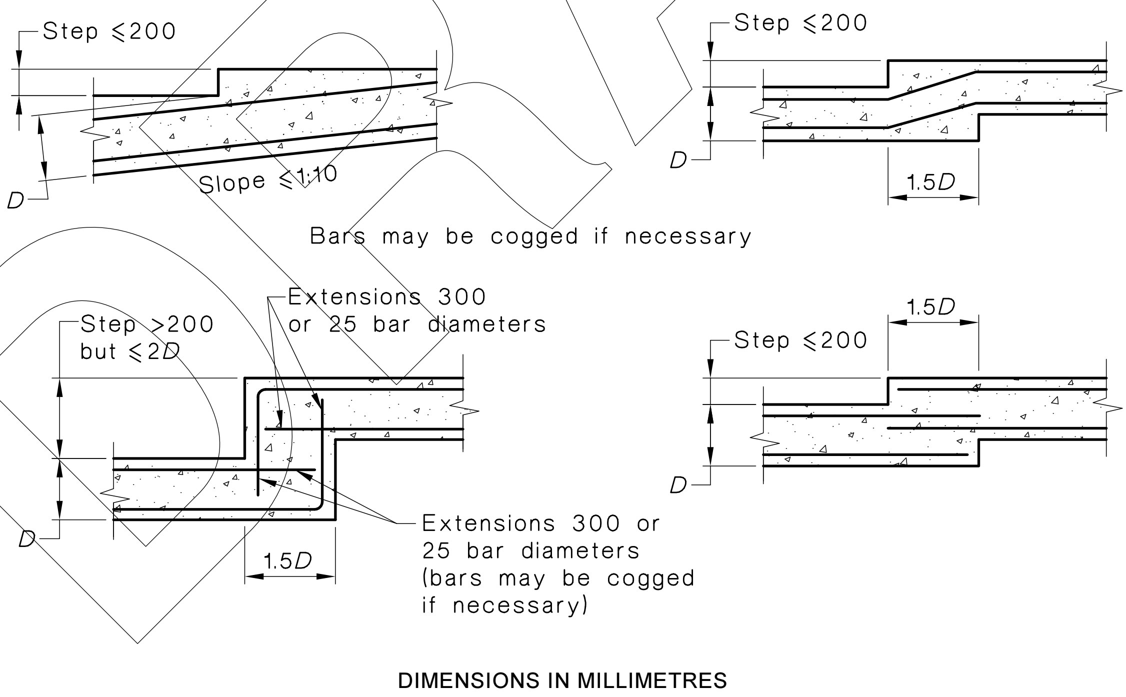

FIGURE 5.8 ACCEPTABLE METHODS OF STEPPING STRIP FOOTINGS

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5.5 REQUIREMENTS IN AGGRESSIVE SOILS

5.5.1 General

In buildings with masonry and concrete exposed to saline soils or where the surface exposure includes exposure to acid sulphate soils or to soils with a magnesium content of less than 1000 ppm, the concrete raft, slab, strip or pad footing shall be protected from the aggressive soil or groundwater by complying with either:

(a) Isolation of the concrete or masonry member from the aggressive soil in accordance with Clause 5.5.2, or

(b) Application of the concrete strength and detailing requirements in Clause 5.5.3.

NOTE: In highly saline areas the likelihood of damage will be reduced if the requirements of both Clauses 5.5.2 and 5.5.3 are implemented. For acid sulfate and sulfate soils, additional recommendations are given in the commentary.

5.5.2 Isolate concrete from the ground

The concrete member shall be isolated from the aggressive soil or groundwater by one of the following:

(a) A damp-proofing membrane in accordance with Clause 5.3.3 and terminated at finished ground or paving level as shown in Figure 5.7.

(b) A damp-proofing membrane in accordance with Clause 5.3.3 terminated at finished ground or paving level and lapped with a suitable 0.5 mm thick damp-proofing material complying with AS/NZS 2904 a minimum of 75 mm vertically or horizontally in accordance with Figure 5.7. The damp-proofing material shall extended up to the finished ground or paving level, and be sealed around all penetrations by pipes or plumbing fittings.

NOTE: A suitable 0.5 mm thick damp-proofing material can be embossed black polythene film of high impact resistance of 0.5 mm thickness prior to embossing and meeting the requirements of Clause 7.6 of AS/NZS 2904.

(c) A damp-proofing membrane in accordance with Clause 5.3.3 terminated below finished ground or paving level and lapped a minimum 75 mm with a suitable damp-proofing coating applied to the face of the concrete. The damp-proofing coating shall extend up to the finished ground or paving level, and be sealed around all penetrations by pipes or plumbing fittings.

Where the damp-proofing membrane is damaged during installation, or the finished ground or paving level is altered, the provisions of either part (b) or (c) shall be complied with.

Where a damp-proofing membrane is installed, a layer of bedding sand shall be provided under the slab panels. Where this layer is deeper than 100 mm, it shall comply with Clause 6.4.2.

5.5.3 Concrete strength and detailing requirements

Concrete strength and detailing requirements shall be as follows:

(a) The exposure classification of the concrete in saline soils shall be in accordance with Table 5.1, where EC_e is the electrical conductivity of a soil water extract.

(b) The exposure classification of the concrete in acid sulfate soils and sulfate soils shall be in accordance with Table 5.2.

(c) The concrete strength and curing requirements shall be as shown in Table 5.3. All concrete, including exposed edges of slabs or edge beams, shall be cured for the minimum period specified.

(d) Curing shall be achieved by the application of water to, or the retention of water in, the freshly cast concrete and shall commence as soon as practicable after finishing of

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any unformed surfaces has been completed. Where the retention of water in the fresh concrete relies on the application to exposed surfaces of sprayed membrane-forming curing compounds, the compounds used shall comply with AS 3799.

(e) A raft, waffle raft or slab shall be provided with a vapour barrier or damp-proofing membrane complying with the requirements of Clause 5.3.3 and installed in accordance with the details shown in Figure 5.7.

(f) All concrete shall be adequately compacted.

(g) The minimum reinforcement cover for concrete members in contact with the ground or protected by a vapour barrier shall be as shown in Table 5.4.

TABLE 5.1

EXPOSURE CLASSIFICATION FOR CONCRETE IN SALINE SOILS

Soil electrical conductivity (EC_e)	Exposure classification		
<4	A1		
4–8	A2		
8–16	B1		
>16	B2		

NOTES:

1 EC_e is the saturated electrical conductivity in deciSiemens per metre.

2 Guidance on concrete in saline environments can be found in CCAA T56.

3 Exposure classifications are from AS 3600.

4 The currently accepted way of determining the salinity level of the soil is by measuring the electrical conductivity (EC) of a soil and water mixture in deciSiemens per metre (dS/m) and using conversion factors that allow for the soil texture, to determine the extract electrical conductivity (EC_e).

5 The division between a non-saline and saline soil is generally regarded as an EC_e value of 4dS/m, therefore no increase in the minimum concrete strength is required.

TABLE 5.2

EXPOSURE CLASSIFICATION FOR CONCRETE IN SULFATE SOILS

Exposure conditions			Exposure classification	
Sulfates (expressed as SO_4)*		pH	Soil conditions A†	Soil conditions B‡
In soil ppm	In groundwater ppm			
<5000	<1000	>5.5	A2	A1
5000–10 000	1000–3000	4.5–5.5	B1	A2
10 000–20 000	3000–10 000	4–4.5	B2	B1
>20 000	>10 000	<4	C2	B2

* Approximately 100 ppm SO_4 = 80 ppm SO_3

† Soil conditions A—high permeability soils (e.g., sands and gravels) which are in groundwater

‡ Soil conditions B—low permeability soils (e.g., silts and clays) or all soils above groundwater

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TABLE 5.3

MINIMUM STRENGTH AND CURING REQUIREMENTS FOR CONCRETE

Exposure classification	Minimum f'_c (Mpa)	Minimum initial curing requirement
A1	20	Cure continuously for at least 3 days
A2	25	
B1	32	Cure continuously for at least 7 days
B2	40	
C1	≥50	
C2	≥50	

TABLE 5.4

MINIMUM REINFORCEMENT COVER FOR CONCRETE

Exposure classification	Minimum cover in saline soils† (mm)	Minimum cover in sulfate soils‡ (mm)
A1	See Clause 5.3.2	40
A2	45	50
B1	50	60
B2	55	65
C1	-	70
C2	-	80

† Where a damp-proofing membrane is installed, the minimum reinforcement cover in saline soils may be reduced to 30 mm.

‡ Where a damp-proofing membrane is installed, the minimum reinforcement cover in sulphate soils may be reduced by 10 mm.

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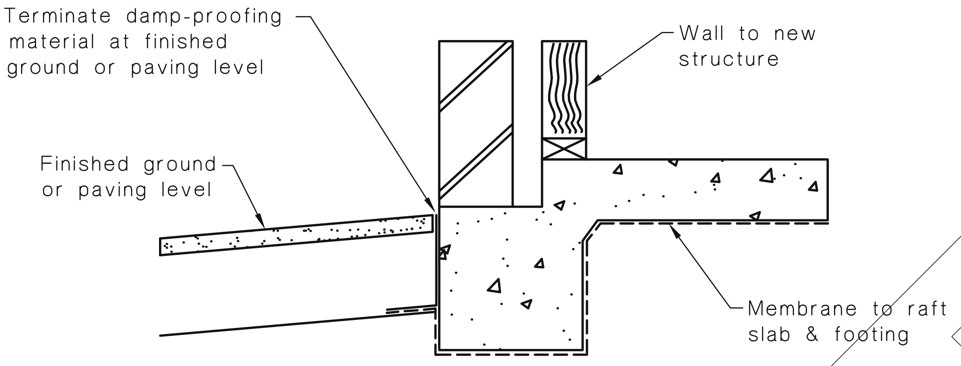
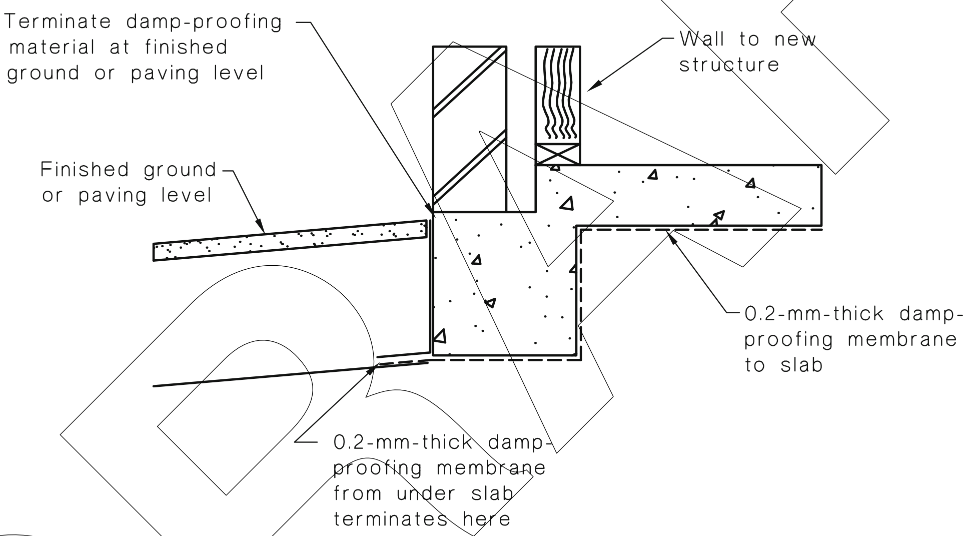


(a) Stiffened raft footing alternative



(b) Waffle raft alternative

FIGURE 5.9 USE OF DAMP-PROOFING MEMBRANE FOR SLAB EDGE PROTECTION

5.5.4 Additional requirements for sulfate soils

Where surface exposure includes exposure to sulfate soils with a magnesium content of not less than 1 000 mg/L the concrete exposure classification shall be as shown in Table 5.2, and the strength and curing requirements shall be as shown in Table 5.2.

All concrete shall be adequately compacted.

5.6 ADDITIONAL REQUIREMENTS FOR CLASS M, H1, H2 AND E SITES

5.6.1 Masonry detailing

The following aspects of masonry detailing shall be used to reduce the effects of movement:

(a) Extensions shall be isolated from the original structure by means of control joints to allow for differential movement.

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

5.6.2 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.

5.6.3 Drainage requirements

Buildings on moderately, highly or extremely reactive sites shall be provided with drainage systems designed in accordance with the following:

(a) Surface drainage shall be considered in the design of the footing system and necessary modification shall be included in the design documentation. Surface drainage of the site shall be controlled from the start of site preparation and construction. The drainage system shall be completed by the finish of construction of the building.

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

(c) Subsurface drains shall not be used within 1.5 m of the building unless designed in accordance with engineering principles.

5.6.4 Plumbing requirements

Buildings on highly or extremely reactive sites shall be provided with a 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 where practicable, but where necessary shall be detailed 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 highly reactive sites and 40 mm thick on extremely reactive sites. Sleeves allowing equivalent movements may be used as an alternative.

(b) For slab or strip footings on highly and extremely reactive sites, joints in drains within 3 m of the building shall incorporate mechanical flexible couplings that can accommodate without leakage differential vertical movement between the building and the adjacent ground equal to the estimated characteristic surface movement of the site. On-site waste water treatment units in particular require careful detailing.

(c) On-site wastewater treatment units and associated land application 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.

(e) Cold water pipes and heated or hot water pipes shall not be installed under a slab, unless the pipes are installed within a conduit so that if the pipe leaks water it will be noticed above the slab or outside the slab and will not leak unnoticed under the slab.

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SECTION 6 CONSTRUCTION REQUIREMENTS

6.1 GENERAL

The construction of footing systems designed in accordance with Sections 3, 4 and 5 shall comply with Clauses 6.2 to 6.5. For moderately, highly and extremely reactive 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

Temporary excavations in the area of the footing shall be carried out only where adequate support for the footing system is maintained. Examples of such temporary excavation include levelling of the building platform and trenching for services.

Where it is expected that future excavation in the area of the footing system may be required for maintenance of underground services provision shall be made for continued support of the footings, for example by provision of piers to beneath the expected excavation level.

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 prior assessment in accordance with engineering principles.

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 H1, H2 and E sites additional requirements are given in Clause 6.6.

The methods given for construction on sloping sites assume that the site is not subject to landslip.

6.4.2 Filling

Filling used for the support of a slab, shall be controlled fill or rolled fill:

(a) Sand fill up to 0.8 m deep that is well compacted by a vibrating plate or vibrating roller in layers not more than 0.3 m thick is deemed to be controlled fill. For sand fill not containing gravel-sized material a blow count of 7 or more per 0.3 m using the penetrometer test described in AS 1289.6.3.3 is deemed to satisfy this requirement.

Non-sand fill up to 0.4 m deep that well compacted by a mechanical roller in layers not more than 0.15 m thick is deemed to be controlled fill. Clay fill shall be moist during compaction.

(b) Rolled fill consists of material compacted in layers by repeated rolling with an excavator or similar equipment. The depth of 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.

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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) Where slab panels, edge beams, internal beams and load support thickenings are to be supported on natural soil, the allowable bearing pressure of the soil shall be not less than 50 kPa.

(ii) Slab panels, internal beams and load support thickenings may be founded on controlled or rolled fill.

(iii) Edge beams may be founded on controlled fill. 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 one vertical to two horizontal. Edge beams shall not be founded on rolled fill.

(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 bases of edge beams and footings may be stepped or sloped not more than one vertical to ten horizontal.

(e) Except for sites with saline soils as detailed in Clause 5.5.2, 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 building by at least 1 m and shall be retained or battered beyond this point by a slope protected from erosion and not steeper than one vertical to two horizontal. 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 (a) or (b) above and with Figure 6.1(c) to reduce the extent of excavation or fill. At a change in elevation, the step shall comply with the following:

(i) The ground behind the step shall be drained to prevent moisture build up and the face of the slab step against the soil shall be waterproofed.

(ii) The edge rebate requirements of Clause 5.3.4 shall be incorporated in the construction.

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

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(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.

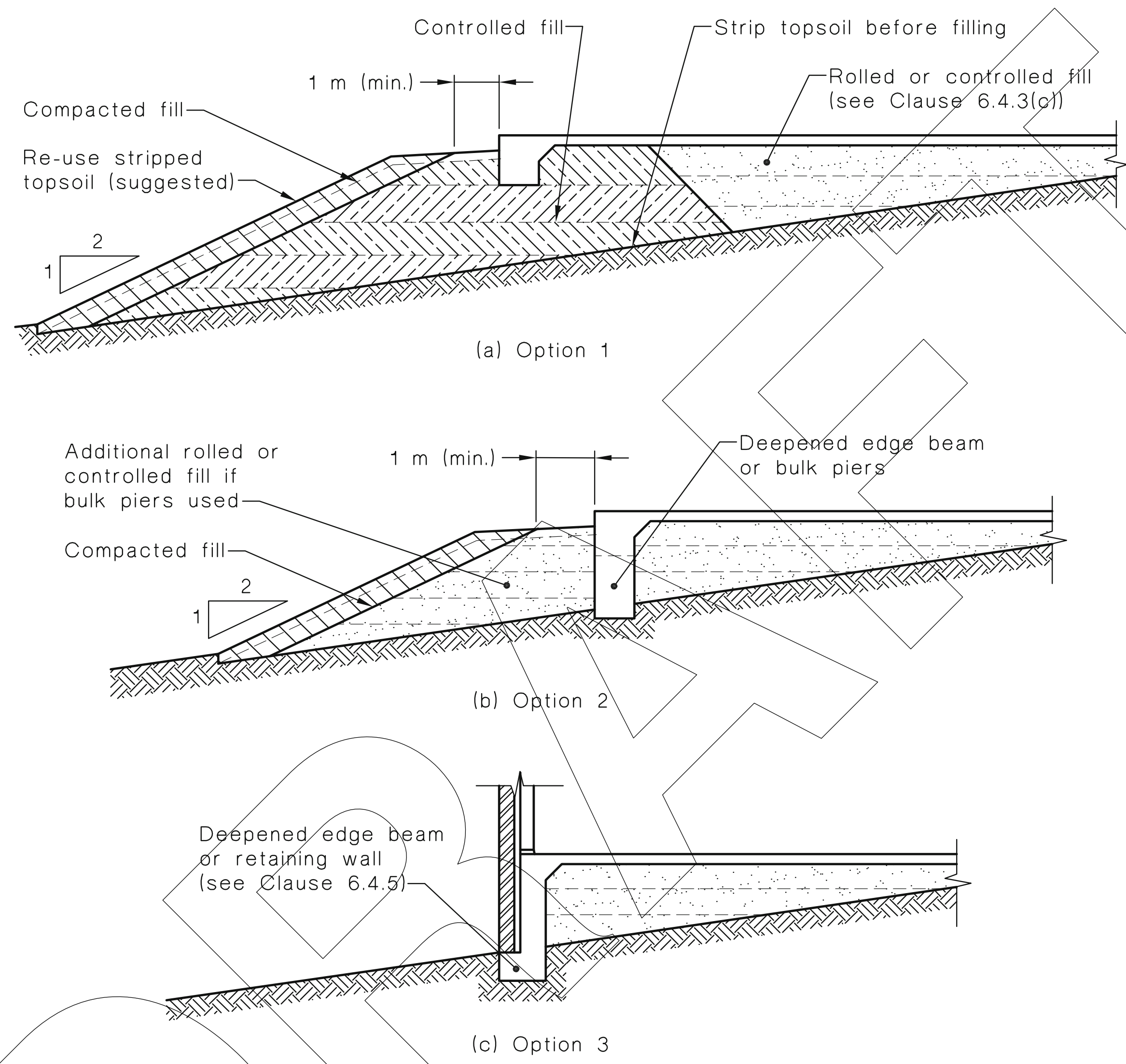

FIGURE 6.1 FILL AND SLAB EDGE OPTIONS FOR LOW SIDE OF SLOPED SITES

(d) 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 sites with steep slopes, benching and consideration of slope stability may be required.

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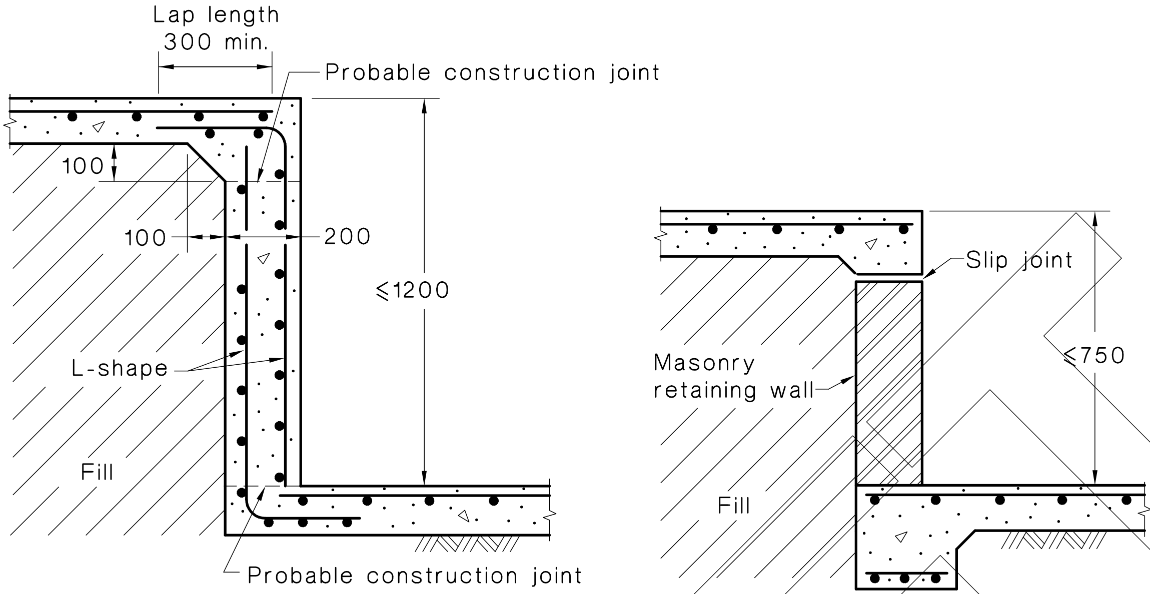

NOTE: Drainage provision should be made.

DIMENSIONS IN MILLIMETRES

FIGURE 6.2 SLAB STEP OPTIONS ON CLASS A OR S SITES

6.4.5 Retention of fill under slabs for ClassA, 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:

(a) The fill up to a height of 750 mm shall be retained by a deepened edge beam structurally continuous 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 in depth, vertical reinforcement of centrally placed SL82 mesh 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 N12 bars at 400 mm centres.

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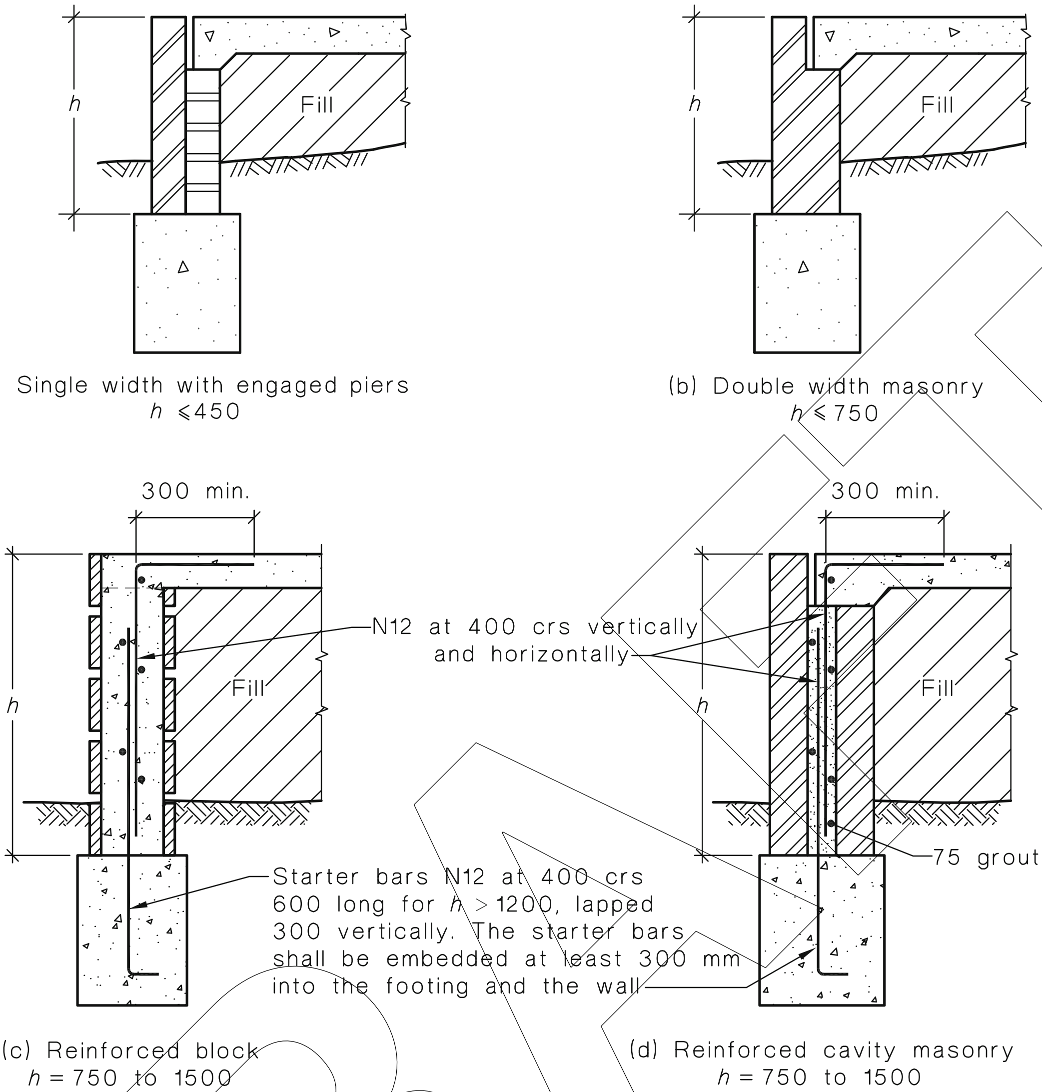

Wall height (h)	Wall construction
h < 450	Single width masonry with engaged piers at 1200 mm centres
h ≤ 750	Double width masonry wall 230 mm thick. Solid or filled concrete block wall 200 mm nominal thickness
h ≤ 1 500	Double width masonry with a 75 mm filled cavity or a 200 mm filled block wall reinforced with tied N12 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 > 1 500	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

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6.4.6 Fixing of reinforcement and void formers

Reinforcement and void formers 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.

6.5 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 H1, H2 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 have minimum design 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 of the underside of the footing shall be 300 mm.

(d) Trenches shall be dewatered and cleaned prior to concrete placement such that no significant softened or loosened material remains.

6.6 ADDITIONAL REQUIREMENTS FOR MODERATELY, HIGHLY AND EXTREMELY REACTIVE SITES

For stiffened rafts, waffle rafts, or strip footings on moderately, highly and extremely reactive sites, the following requirements apply to the building services and footing system in addition to Clauses 6.4 and 6.5:

(a) Where the design of the footing system relies on particular detailing of masonry construction to minimize any damage caused by foundation movement, that detailing shall be included on the drawings.

(b) Penetrations of the edge beam and footing by drain pipes shall be sleeved using closed-cell polyethylene lagging or similar.

(c) Water run-off shall be collected and channelled away from the building 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.

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For slab or strip footings on highly and extremely reactive sites, the following requirements apply:

(i) Joints in drains within 3 m of the building shall incorporate movement joints that can accommodate without leakage differential vertical movement between the building and the adjacent ground equal to the estimated characteristic surface movement of the site. On-site waste water treatment units in particular require careful detailing.

(ii) Concrete in beams shall be mechanically vibrated.

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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. When the design consists of the selection of a design given in Section 3 for a Class A, S or M site, the designer should be experienced in residential building design or construction. For Class P, H or E sites, the designer should be a qualified engineer experienced in the design of footing systems for buildings.

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 the person or organization responsible for the maintenance of the building and the site.

NOTE: The owner should be familiar with the performance and maintenance requirements set out in Appendix B.

Qualified engineer Professional civil engineer specializing in either geotechnical or structural engineering and experienced in the design of footing systems for buildings or similar structures.

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APPENDIX B

FOUNDATION PERFORMANCE AND MAINTENANCE

(Informative)

B1 GENERAL

The designs and design methods given in this Standard are based on the performance criteria in Clause 1.3. Importantly, significant damage may 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 buildings, 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) H1 and H2 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, H1, H2 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.

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B2.3 Class M, H1, H2 and E sites

Sites classified as M, H1, H2, 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 building. The ground immediately adjacent to the building should be graded to a uniform fall of 50 mm minimum away from the building over the first metre. The subfloor space for buildings 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 building should be avoided. Care should be taken to avoid overwatering of gardens close to the building footings.

(c) *Restrictions on trees and shrubs* Planting of trees should be avoided near the foundation of a building or neighbouring building 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) 1½ × mature height for Class E sites.

(ii) 1 × mature height for Class H1 and H2 sites.

(iii) ¾ × 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 buildings and masonry veneer buildings. For frame buildings clad with timber or sheeting, lesser precautions may be appropriate.

B3 PERFORMANCE OF WALLS

It is acknowledged that minor foundation movements occur on nearly all sites and that it is impracticable to design a footing system that will protect the building 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 buildings. 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.

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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 buildings 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 may 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 will involve the wall remaining free of cracks and articulation joint movements, and remaining within the limits for the particular jointing system.

B4 PERFORMANCE OF CONCRETE FLOORS

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 movement causing the 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 occurred 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.

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APPENDIX C

CLASSIFICATION OF DAMAGE DUE TO FOUNDATION MOVEMENTS

(Normative)

TABLE C1

CLASSIFICATION OF DAMAGE WITH REFERENCE TO WALLS

Description of typical damage and required repair	Approximate crack width limit (see Note 3)	Damage category
Hairline cracks	< 0.1 mm	0 Negligible
Fine cracks that do not need repair	< 1 mm	1 Very slight
Cracks noticeable but easily filled. Doors and windows stick slightly	< 5 mm	2 Slight
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	5 mm to 15 mm (or a number of cracks 3 mm or more in one group)	3 Moderate
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	15 mm to 25 mm but also depends on number of cracks	4 Severe

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.

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.

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.

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.

Account should be taken of the past history of damage in order to assess whether it is stable or likely to increase.

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.

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TABLE C2

CLASSIFICATION OF DAMAGE WITH REFERENCE TO CONCRETE FLOORS

Description of typical damage	Approx. crack width limit in floor	Change in offset from a 3 m straight edge centred over defect (see Note 6)	Damage category
Hairline cracks, insignificant movement of slab from level	< 0.3 mm	< 8 mm	0 Negligible
Fine but noticeable cracks. Slab reasonably level	< 1.0 mm	< 10 mm	1 Very slight
Distinct cracks. Slab noticeably curved or changed in level	< 2.0 mm	< 15 mm	2 Slight
Wide cracks. Obvious curvature or change in level	2 mm to 4 mm	15 mm to 25 mm	3 Moderate
Gaps in slab. Disturbing curvature or change in level	4 mm to 10 mm	> 25 mm	4 Severe

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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 and D4 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 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.

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TABLE D1

CLASSIFICATION BASED ON TYPICAL PROFILES—VICTORIA

Soil profiles	Climatic zone			
	1	2	3	4–5
Group (1) soils				
Clays derived from Limestones, Marls, and other Calcium-rich sediments. Including alluvial clays and calcareous earths derived from these deposits.				
≤0.6 m depth of clay	M	M	M	M
>0.6 m ≤1 m depth of clay	H1 to H2	H1 to H2	H1 to H2	H1-D to H2-D
>1.0 m depth of clay	H2	H2	H2 to E	E-D
Group (2) soils				
Clays derived from alkaline volcanics (e.g. Basalts, Dolerites, Greenstones) or sedimentary rocks with interbedded alkaline volcanics or pyroclastics.				
Including alluvial clays derived from any of these deposits.				
≤0.6 m depth of clay	M	M	M	M-D
>0.6 m ≤1.5 m depth of clay	M	M to H1	M to H1	M-D to H2-D
>1.5 m depth of clay	M to H1	H1 to H2	H2 to E	H2-D to E-D
Deep lateritic, gravely or coarse sandy clay profiles (see Note 2)	M	M	M to H1	H1-D to H2-D
Group (3) soils				
Non-basaltic and non-calcareous residual clays derived from sedimentary, metamorphic, granitic or other acid volcanic rocks.				
≤1.0 m depth of clay	M	M	M	M-D
>1.0 ≤1.8 m depth of clay	M	M	M to H1	M-D to H1-D
>1.8 m depth of clay	M	M to H1	M to H1	H1-D to H2-D
Group (4) soils				
Alluvial, glacial and estuarine soils silts, sands or gravels which overlie deep clays. The sand cover may be aeolian (wind-blown). The classification is highly dependent on clay type, total thickness and its proximity to the surface.				
≤0.6 m silts or sands overlying clays	S to M	M	M to H1	M-D to E-D
>0.6 ≤1 m silts or sands overlying clays	A to S	S to M	M	M-D to H1-D
>1 m silts or sands overlying clays	A	A to S	S	S to M-D
Group (5) soils				
Interbedded silts, sands, and clay mixtures. (The classification is highly dependent on clay type, depth, thickness and its proximity to the surface)				
Total clay depth <30% of H depth	A to S	S	S	M-D
Total clay depth >30% <50% of H_s depth	S	M	M	M-D to H1-D
Total clay depth >50% of H_s depth	M	M to H1	H1 to H2	H2-D to E-D

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NOTES TO TABLE D1

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

2 Where the sites are to be excavated for levelling purposes the worst case soil profile is to be used for classification.

3 The above classifications may not apply in sites that have organic or peaty soils, collapsing soils, unstable or creeping slopes, mining works and conditions that have or may cause abnormal foundation soil moisture.

4 Where a range of classifications is provided the classifier should make a judgement within this range based on site conditions, type of structure and local experience or y_s calculated by using the I_{pt} for each soil stratum.

5 The above table should only be used by practitioners with local geological knowledge and experience derived from many years of successful investigations.

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

7 For further information refer to AS 2870 Supplement 1, Atlas of Australian resources, Department of National Development and Australian Soil Resource and local Geological maps.

TABLE D2

CLASSIFICATION OF ALL SYDNEY CLAY SOILS

Depth of clay in profile m	Classification
<0.6	S
≤0.6 ≤1.8	M
>1.8	H1 to H2

NOTE: The H1 to H2 classification arises from the possibility of moisture changes at depths in excess of 1.8 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 either 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.

TABLE D3

SITE CLASSIFICATION BASED ON LOCATION AND TYPICAL PROFILE—PERTH

Examples	Range
Clays derived from weathered dolerite in Darling Range or along foothills	M to H2
Clay material of Guildford formation	S to H2

NOTES:

1 Actual classification of clay material of Guildford formation depends on depth of sand cover and clay type.

2 Refer to 1:50,000 Scale Environmental Geology Map Series, published by the Department of Minerals and Energy, Western Australia.

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TABLE D4

SITE CLASSIFICATION BASED ON LOCATION AND TYPICAL PROFILE—ADELAIDE

Soil group	Typical soil types	Classification
Silts sands and gravels	Sand A1, DS EMS	A to S
Shallow clays (over rock)	SR	S
Silty and sandy clays (less reactive)	Clayey A1, RZ, TR, P4, SW	M
Podsolic and solodic soil	P1, P2, P3 and S	S to H2
Red brown soils		
Profiles with shallow layers of less reactive clay	RB2, RB4, RB6, RB7, RB9	M to H2
Profiles with deeper layers of more reactive clay	RB1, RB3, RB5, RB8	H2 to E
Hindmarsh or Keswick clay underlying any soil (except black earth)		
Depth to clay > 2 m		H2 to E
Depth to clay from 1 m to 2 m		E
Black earth	BE	E

NOTE: Typical soil type profiles are illustrated in 'The Soils and Geology of the Adelaide Area', Taylor J.K., Thomson, B.P. and Shepherd R.G., Bulletin 46, Department of Mines, Geological Survey of SA, 1974.

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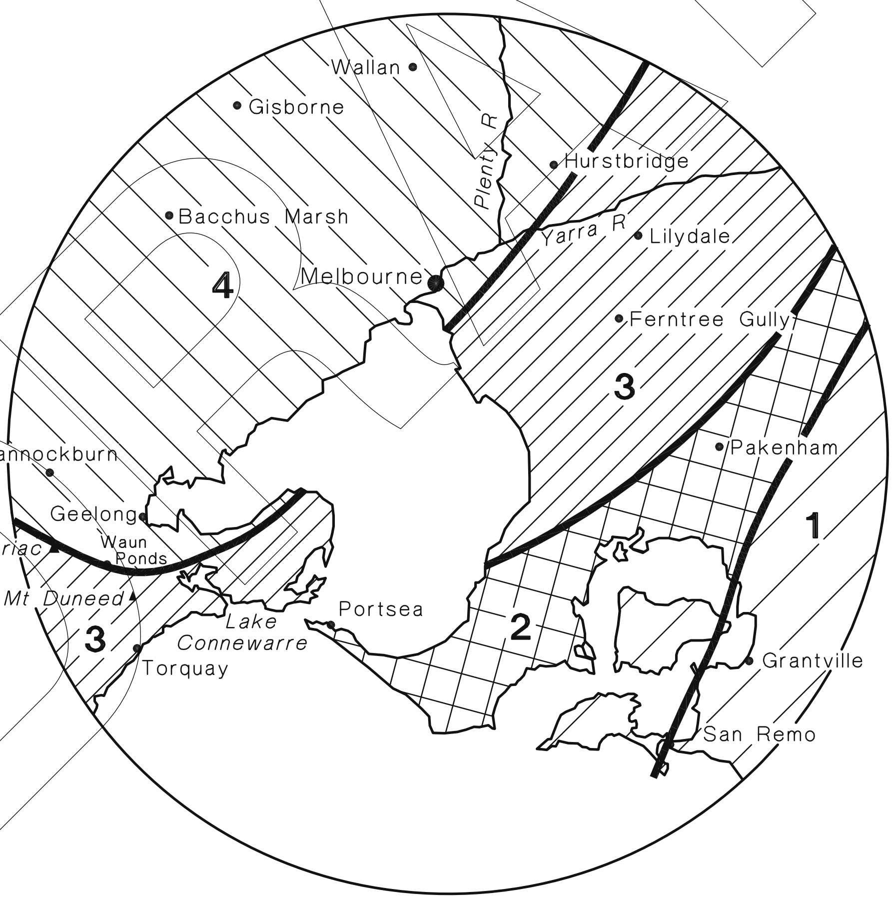

FIGURE D1 MELBOURNE AND ENVIRONS CLIMATIC ZONES
(Outside Melbourne inset area—refer Figure D2)

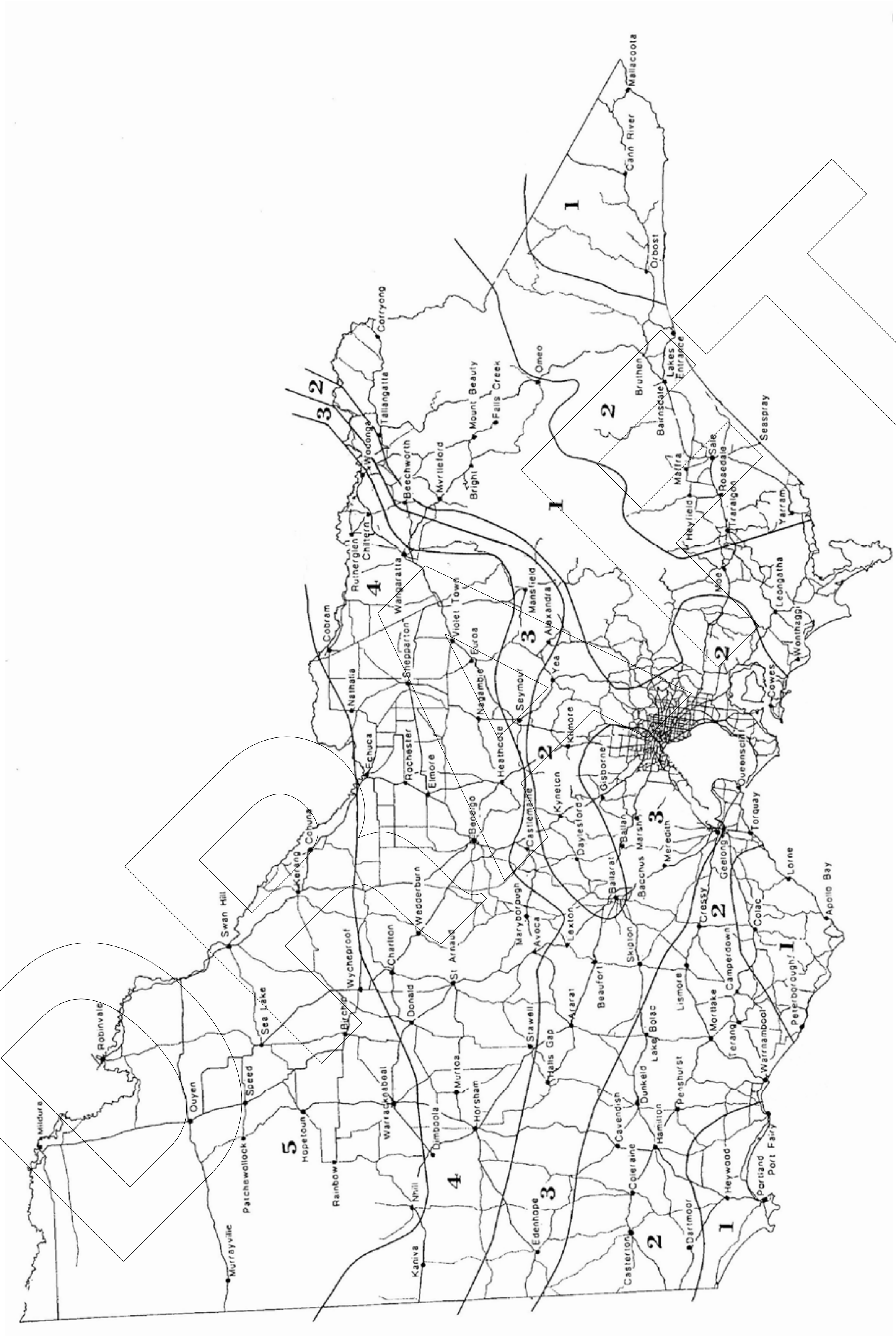

FIGURE D2 VICTORIAN CLIMATIC ZONES

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APPENDIX E

STUMP PAD SIZES, BRACED STUMP UPLIFT 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. No allowance needs to 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:

$$\frac{U^*}{U} < 1.0 \text{ and } \frac{H^*}{H} < 1.0 \text{ for Class A and S sites}$$

$$< 0.9 \qquad < 1.0 \text{ for Class M site}$$

$$< 0.7 \qquad < 0.8 \text{ for Class H and M-D sites}$$

and for combined uplift and horizontal load,

$$\frac{U^*}{U} + \frac{H^*}{H} < 1.0 \text{ for Class A and S sites}$$

$$< 0.9 \text{ for Class M sites}$$

$$< 0.7 \text{ for Class M-D and H1 sites}$$

where

U* = uplift load on stump

H* = design uplift capacity on stump

U = $\phi\, U_{\mathrm{ULT}}$, geotechnical design strength of stump in uplift, from Figure E2

H = $\phi\, H_{\mathrm{ULT}}$, geotechnical design strength of stump for horizontal load, from Figure E2

U_{ULT}, H_{ULT} = ultimate strength in uplift, horizontal loads and strength reduction factor respectively

The lower ends of diagonal members are to be attached to stumps not more than 150 mm above ground level.

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

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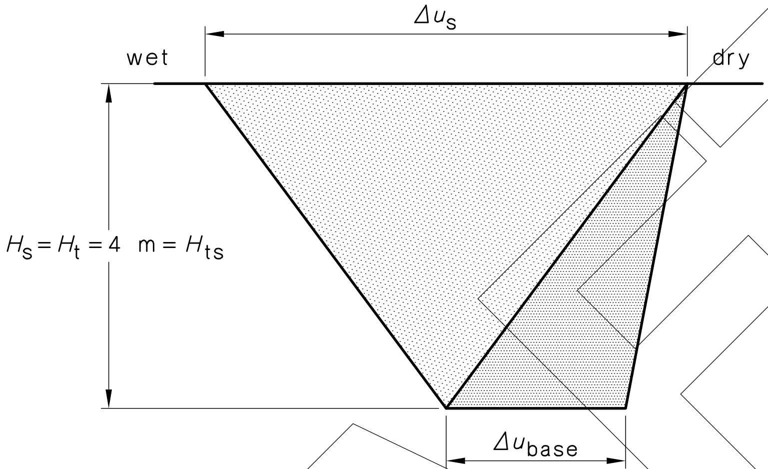
Stump horizontal capacity (see Table E2) is for compacted soil backfill suitable for 100 kPa bearing. For soil with less than 100 kPa lateral allowable bearing pressure the horizontal capacity from Table E2 shall be reduced by multiplying by $\left(\frac{\text{allowable bearing pressure}}{100}\right)$.

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:

Effective supported area m^2	Width of square pad mm	Diameter of circular pad mm	Thickness (t) mm
10	400	500	200
20	500	600	200
40	600	750	250

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

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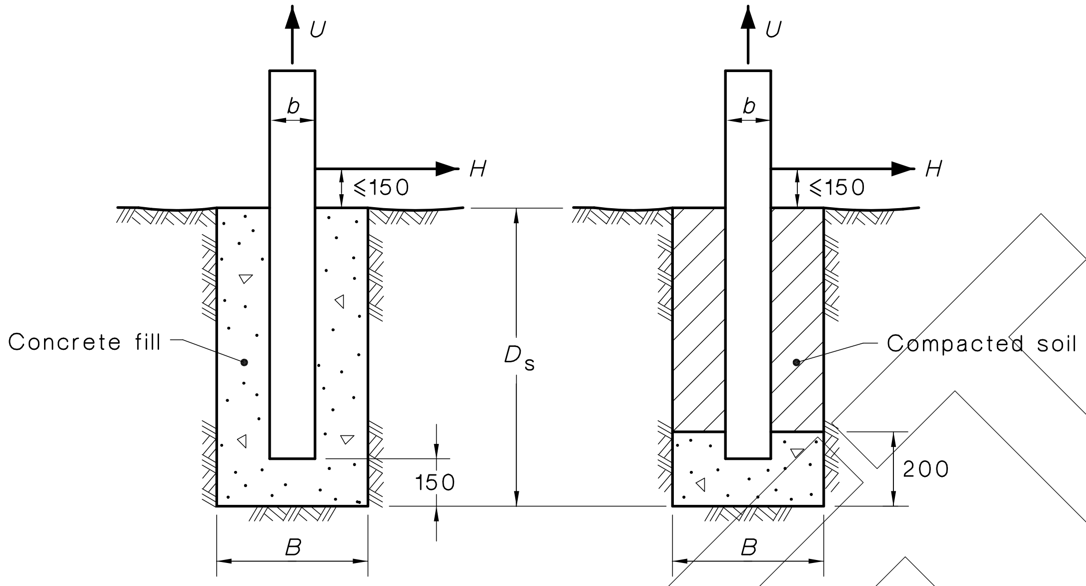

DIMENSIONS IN MILLIMETRES

FIGURE E2 BRACED STUMPS

TABLE E1

SOIL BACKFILL BRACED STUMPS— UPLIFT CAPACITY kN

Stump depth D_s mm	Footing diameter B				
	250	**300**	**350**	**400**	**450**
400	0.8	1.1	1.3	1.5	1.6
600	2.0	2.4	2.7	3.1	3.6
800	3.8	4.4	5.0	5.6	6.2
1 000	6.5	7.3	8.1	9.0	9.9

TABLE E2

SOIL BACKFILL BRACED STUMPS— HORIZONTAL LOAD CAPACITY kN

Stump depth D_s mm	Stump thickness B, mm			
	100	**125**	**150**	**200**
400	2.2	2.7	3.3	4.4
600	3.6	4.5	5.4	7.2
800	5.1	6.3	7.6	10.1
1 000	6.6	8.2	9.8	13.0

NOTE: Loose sand is not suitable for soil backfilled braced stumps; concrete backfill may be used for braced stumps.

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TABLE E3

CONCRETE BACKFILL BRACED STUMPS— UPLIFT CAPACITY kN

Stump depth D_s mm	Footing diameter *B*, mm				
	250	**300**	**350**	**400**	**450**
400	1.0	1.2	1.5	1.8	2.2
600	2.2	2.6	3.1	3.6	4.2
800	4.1	4.7	5.4	6.2	7.1
1 000	6.8	7.7	8.7	9.8	10.9

TABLE E4

CONCRETE BACKFILL BRACED STUMPS— HORIZONTAL LOAD CAPACITY kN

Stump depth D_s mm	Footing diameter *B*, mm				
	250	**300**	**350**	**400**	**450**
400	4.0	4.8	5.6	6.4	7.2
600	6.8	8.2	9.5	10.9	12.3
800	9.8	11.7	13.7	15.6	17.6
1 000	12.8	15.3	17.9	20.4	23.0

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APPENDIX F

SOIL STRUCTURE INTERACTION ANALYSIS FOR STIFFENED RAFTS

(Informative)

F1 DESIGN PROCEDURES FOR STIFFENED RAFTS

Design parameters can be determined by an analysis that allows for interaction of the structure with the foundation over a design range of soil moisture conditions. 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 commonly 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 should 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.

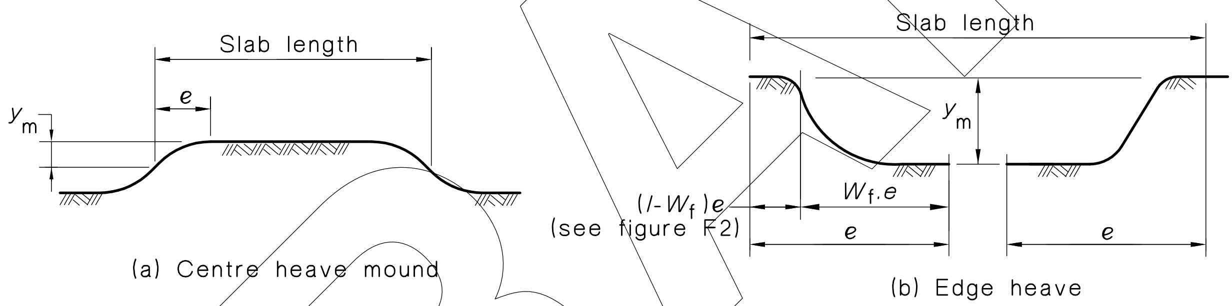

FIGURE F1 IDEALIZED MOUND SHAPES TO REPRESENT DESIGN GROUND MOVEMENT (WALSH METHOD)

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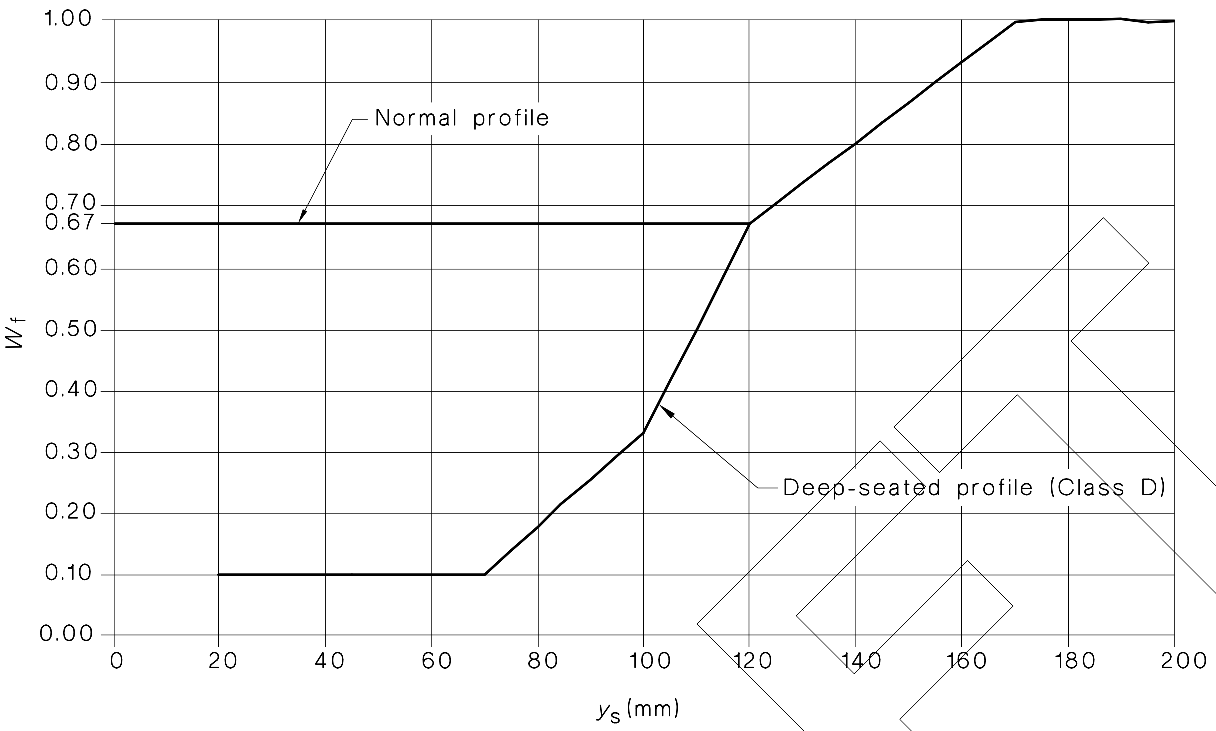

FIGURE F2 W_f FACTOR FOR WALSH MOUND SHAPE

F2 ANALYSIS PARAMETERS FOR STIFFENED RAFTS

The general procedures for the analysis 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:

		Walsh method	Mitchell method
(i)	Centre heave	$0.7y_s$	$0.7y_s$
(ii)	Edge heave on initially dry site	$0.5y_s$	$0.7y_s$

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 $2e$, the value of y_m may be reduced linearly with (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.

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

(i) For centre heave, in metres:

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

(ii) For edge heave, in metres:

$e = 0.2L \leq (0.6 + y_m/25)$, where y_m is in millimetres . . . F4(2)

For the Mitchell method:

Mound exponent (m) = $1.5L/(D_{cr} - D_e)$ . . . F4(3)

where

$$D_{cr} = \frac{H_s}{7} + \frac{y_m}{25}, \text{ where } y_m \text{ is in millimetres and } H_s \text{ is in metres}$$

D_e = 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 kPa/m to k = 1500 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.

F3 REFERENCES

1 WALSH, P.F., WALSH, S.F. *Structure/reactive clay model for a microcomputer* CSIRO Australia, DBR report R 86/9 1986.

2 MITCHELL, P.W. *The Structural Analysis of Footings on Expansive Soils*. 5th International Conference on Expansive Soils, Adelaide 1984.

3 HOLLAND, J.E. *The Design, Performance and Repair of Housing Foundations*, Swinburne Institute of Technology 1981.

4 POULOS, H.G. *The Analysis of Strip Footings on expansive Soils*. Research Report No R456, University of Sydney, School of Civil and Mining Engineering 1983.

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APPENDIX G

DEEP FOOTINGS

(Informative)

G1 DESIGN PROCEDURES FOR DEEP FOOTINGS

Deep footings may be driven or jacked timber, concrete or steel piles, excavated or bored piers and steel screw piles. The design of deep footings should be by engineering principles using this Appendix and AS 2159 when appropriate. The structural strength of deep footings should be designed using AS 1720, AS 4100 or AS 3600 as appropriate.

G2 LOADS

The loads from the residential building to be supported by deep footings should be determined using engineering principles and the dead, live, earthquake and wind loads defined in AS 1170.

The permanent and imposed actions in Clause 1.4.2 of this Standard should not be used in the design of deep footings.

G3 GEOTECHNICAL SITE INVESTIGATIONS

A geotechnical site investigation for the design of deep footings should be taken to a depth not less than 1.5 m beyond the founding depth of the footings, and not less than 1.5 times Hs for the site.

The geotechnical strength of the foundation should be determined by appropriate field and laboratory testing of the ground at depths relevant to the design. The information required from the site investigation as defined in AS 2159 should also apply to this Standard for deep footings.

G4 DRIVEN PILE FOOTINGS

G4.1 General

Driven piles to this Standard generally support imposed live and dead loads that are of a similar magnitude to loads caused by shrinking or swelling of the soil foundations.

Driven piles generally used in residential construction have a mass of less than the pile driving hammer.

The following requirements give consideration to the above conditions normal in residential scale construction.

G4.2 Loads

The design action on the piles should include imposed loads from the residential structure plus actions from swelling or shrinking foundations.

For natural foundations the uplift action due to soil swelling on a driven pile may be assumed to act on the pile for a depth from 0.25 H_s to 1.0 H_s. Unless determined by other methods the uplift stress on the surface area of the pile may be taken to be 25z kPa, where z is the depth measured from ground surface. A load factor of 1.5 should be used to calculate the uplift design action on the pile.

For a shrinking natural foundation no action effect needs to be considered.

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G4.3 Load capacity of driven piles in natural ground

Driven piles in natural ground should satisfy the following requirements:

(a) For unspliced piles driven by drop hammer, the design geotechnical strength may be calculated in accordance with—

$$R_{ug} = (R_{ug})_2 - (R_{ug})_1 \qquad \text{. . .G4.3(1)}$$

where

R_{ug} = geotechnical strength of the pile

$(R_{ug})_1$= geotechnical strength of the pile determined at a depth equal to 0.75 H_s

$(R_{ug})_2$= geotechnical strength of the pile determined at the final depth of installation of the pile.

$$(R_{ug})_1 \text{ and } (R_{ug})_2 = 0.4\frac{W_h \times h_h}{S} \qquad \text{. . .G4.3(2)}$$

where

W_h = hammer weight in kilonewtons

h_h = drop height of the hammer in metres

S = pile set in metres, average for five blows

The design geotechnical strength of the pile should be taken as—

$\varphi_g R_{ug}$

where

R_{ug} is from equation G4.3(1)

and

φ_g = 0.45 for compressive load and 0.35 for tension load.

The design geotechnical strength of the pile should be equal to or greater than the design action effect S^* due to all imposed loads.

$$S^* \leq \varphi_g R_{ug} \qquad \text{. . .G4.3(3)}$$

For deep filled sites pile design should use AS 2159.

(b) For piles driven by methods other than drop hammer or where the pile hammer weight is less than the pile weight, the design strength of the pile should be determined by engineering principles using AS 2159.

(c) The structural strength of piles should be determined using engineering principles using AS 1720, AS 4100 or AS 3600 as appropriate.

G5 DESIGN OF BORED AND EXCAVATED PIERS

G5.1 Pile system

Bored and excavated piers should be designed in accordance with this Appendix and the appropriate Section of AS 2159. Bored and excavated piers may be used in piled footing systems to support all types of residential construction.

G5.2 Loads

The design of bored and excavated piers should consider all imposed loads from the residential construction plus loads caused by swelling or shrinking foundations determined by engineering principles.

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G5.3 Load capacity of bored and excavated piers

For piers the geotechnical design strength should be based on base resistance plus side friction or adhesion where effective. No side adhesion or friction should be assumed to exist to a depth of 0.75 H_s for down loads. For uplift load due to soil swelling side friction or adhesion should be assumed to be effective.

G6 DESIGN OF STEEL SCREW PILES

G6.1 Pile system

Screw piles should be designed in accordance with this Appendix and the appropriate Section of AS 2159. Screw piles may be used in piled footing systems to support all types of residential construction.

G6.2 Loads

Screw piles should be designed for all imposed loads from the supported residential construction plus load due to swelling or shrinking of the foundation. For sites with deep fill the effect of negative skin friction should be considered.

G6.3 Minimum depth

The installed depth of screw piles in reactive foundations should not be less than 1.25 H_s, where H_s is given in Table 2.4, where screw piles are used to support footing systems adjacent to deep service trenches, the depth of pile should not be less than the depth of the trench. The effect of lateral earth loading on the pile shaft should be considered when trench opening can occur after the construction of the piles. Where part of the footing system is piled, as may occur adjacent to deep service trenches, the effect of differential movement should be considered.

G6.4 Design geotechnical strength of screw piles

Screw piles should satisfy the following requirements:

(a) The design geotechnical strength of a screw pile should not be less than the design action effect—

$$\varphi_g R_{ug} \geq S^* \quad \text{. . .G6.4(1)}$$

(b) For screw pile installation with measurement of installation torque, the design geotechnical strength may be calculated for axial actions in accordance with—

$$\varphi_g R_{ug} = 10\ T_i \text{ For compression loads}$$

and . . G6.4(2)

$$\varphi_g R_{ug} = 7.5\ T_i \text{ For tension loads}$$

where

φ = the geotechnical strength reduction factor equal to 0.45 when used in equation G6.4(2)

R_{ug} = ultimate geotechnical strength kN

T_i = installation torque kNm for a screw pile at a minimum depth of 1.25 H_s

(c) Where vertical screw piles are used to resist horizontal actions, the piles should have adequate strength and stiffness. When determining the structural and geotechnical strength, a loss of ground support due to soil shrinkage in reactive soils should be considered. Loss of ground support over a depth of 0.3, 0.4, 0.5 and 0.75 times H_s for Class S, M, H and E may be used.

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(d) The design structural strength of a screw pile should be determined by engineering principles and AS 4100 and should not be less than the design action effects. Allowance should be made for loss of section due to corrosion when determining the pile structural strength, unless determined otherwise the corrosion allowance should be not less than 1.5 mm from both inside and outside of the shaft. For grout filled piles, the shaft corrosion on the inside surface may be assumed to be zero.

(e) The thickness of helix plate should not be less than 12 mm plate. The maximum helix outstand measured from the outside of the shaft should be 10 times the helix plate thickness.

(f) The shaft of the screw pile should be proportioned to have a torsional strength of 1.2 times T_i from equation G6.4(1), with no allowance for corrosion. When piles have to be installed through hard ground, a torsion capacity higher than 1.2 T_i may be required.

(g) In reactive sites Class M, H or E the screw pile shaft should not contain splices or thickenings larger than the outside diameter of the shaft. Shaft splicing if required should use butt welding.

In stiff ground pre-boring may be used to install screw piles with the diameter of the pre-bore hole not larger than 90% of the shaft diameter. Over sized pre-boring should be avoided as it allows ingress of water into the foundation.

(h) The shaft of screw piles should be designed for eccentricity of loads as defined in AS 2159. If the screw pile is to resist bending actions then the shaft should be embedded into the pile cap or footing sufficient to generate the required resistance.

G7 PRE-BORING FOR PILES IN REACTIVE SITES

The use of pre-boring to allow pile installation in hard or dense ground conditions may be used. It is critical for future performance of the piles that the pre-boring does not create an oversized hole that allows surface water ingress into the foundation. The maximum pre-bore diameter that should be used is 90% of the minimum pile diameter.

The installation of piles should not create voids or permeable paths that could allow water ingress to reactive clay foundations.

G8 SWELL PRESSURE ON PILE SUPPORTED FOOTING OR BEAM

The swell pressure that may be generated against pile supported beams or slabs can be high and difficult to resist in residential scale construction. Design to avoid uplift on pile support structures is recommended if possible.

Where the foundation can swell against piled beams the pressure can be estimated using the following methods:

$$p_s = \frac{y_s k}{1000} \qquad \text{. . .G8}$$

where

p_s = swell pressure under footing kPa, unfactored. For strength design use a load factor of at least 1.5

y_s = characteristic ground surface movement mm

k = swelling soil stiffness kPa/m

For beams or strip footings the swell pressure should be assumed to act over the footing or beam width plus 300 mm. The swell stiffness, k, should be assumed to be 1500 kPa/m as a minimum value.

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APPENDIX H

GUIDE TO DESIGN OF FOOTINGS FOR TREES

(Informative)

H1 LIMITATIONS

The method given in this Appendix is essentially the one that has been used with apparent success since July 1990 in South Australia. This method does not separately assess all characteristics that affect a tree's ability to draw moisture. However, when combined with engineering judgement, this method has been found to be sufficient to encompass the tree impact on foundation performance in the South Australian context.

This approach to the design of footing systems in the presence of tree effects will not necessarily result in a footing system that achieves the performance requirements of this standard. The risks of underperformance arise from factors that include the inherent variability and unpredictability of living, growing trees and their interaction with the environment, as well as imperfections in the method of modelling the effect of trees. A reason for the success of this approach to design for trees in South Australia is that the increased risk of underperformance is understood by designers and the existence of the increased risk and the potential effects of the underperformance are effectively communicated to owners.

It is recognised that in different climate zones the recommended depth of tree drying effect and the design suction changes attributed to trees may vary from that which has been adopted in South Australia. The modified parameters for more temperate climates are given in Table H1. The modified values have been based on consideration of limited data from South-East Queensland juxtaposed with the South Australian experience.

H2 DEFINITIONS

H2.1 Design height of single tree, *HT*

The overall height of tree from ground level to the top of the crown. Depending on circumstances, the height of tree may be taken to be the existing height, an estimate of the mature height of the tree or an estimate of the height that it will attain within the design life of the building.

H2.2 Design height of a group of trees, HT_g

Should be taken to be 0.9 times the height of the tallest tree in the group.

H2.3 Distance of tree to the building, *Dt*

The shortest horizontal distance, *Dt*, between a tree trunk and the nearest building wall, post or column.

H2.4 Group of trees

Either a group or row of trees in which three or more adjacent trees are spaced on a centre to centre distance, *s*, such that *s* is less than 1.0 times the average height of the trees under consideration and the minimum distance from the building to any tree under consideration, *Dt*, is respectively less than 1.5 *HT*, or 2.0 *HT* for a row of 4 or more trees.

H2.5 Maximum design drying depth, *H*t

The design depth below ground level of soil drying attributable to the effect of a single tree or group of trees.

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H2.6 Influence distance, *Di*

Is the maximum lateral reach of the drying influence of the tree under consideration. For a single tree *Di* should be taken as 1.0 times *HT* and for a group of trees, *Di* should be 1.5 times HT_g.For a group of 4 or more trees in a row, *Di* should be 2.0 times HT_g.

H3 MAXIMUM DESIGN DRYING DEPTH, H_t

For the greater South Australian climate, the design depth of tree drying for a single tree or tree group may be taken as 4 m and 4.5 m, respectively. For other climate zones and associated design depths of suction change, H_s, recommendations on depth of drying by trees are provided in Table H1.

H4 DESIGN PROCEDURE

The design procedure should include the following steps:

(a) Determine design site characteristic movement, y_s, according to AS 2870 (neglecting tree influence).

(b) In the absence of advice on mature tree heights, the ratio *Dt*/*HT* may be taken to be 0.5. In the absence of advice on mature heights, single trees with *Dt* greater than 25 m and groups of trees with *Dt* greater than 50 m may be ignored.

(c) Find the maximum extra suction change caused by the vegetation, Δu_{base} at the maximum design drying depth, H_t, (refer Figure H1 and Table H1).

(d) Determine the maximum potential tree movement, $y_{t\,max}$ for the tree induced suction change that is in addition to the normal design suction profile. The ground movement caused by the added suction change may be calculated in accordance with the principles outlined in estimating y_s as given in Clause 2.3.1.

(e) Calculate the design tree effect as a surface movement y_t as follows:

(i) For single trees, or groups of trees, with *Dt*/*HT* less than 0.5, y_t should be taken as $y_{t\,max}$. For *Dt*/*HT* greater than 0.5, y_t should be determined from Equation H4 and should not be less than zero.

$$y_t = 1 - \left[\frac{\frac{D_t}{HT} - 0.5}{\frac{D_i}{HT} - 0.5}\right] y_{t\,max} \qquad \text{. . .H4}$$

(ii) For design of the footing system, adopt a double sided mound design together with the same mound shape parameters as used in design without a tree effect.

(iii) Design the footing system for a tree-affected differential, centre heave, mound height, y_m trees, equal to $(0.7y_s + y_t)$.

(iv) Where footings are designed for tree drying effects, M_u for the centre heave case should not be less than 1.5 M_{cr}, and additionally, reinforcement should be provided so that the centre sagging moment resistance should not be less than the centre heave moment resistance.

(v) Where footings are designed for the effects of tree removal, M_u should not be less than 1.5 M_{cr} for both edge and centre heave.

(vi) The height of tree and the number and location of trees assumed in the design should be stated and communicated to the owner as important parameters and limitations of the design.

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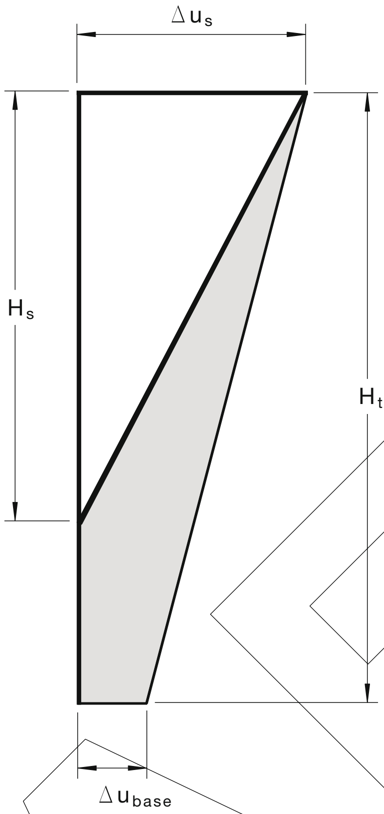

H_s (m)	Single tree		Tree group	
	Δ_{ubase} (pFP)	H_t (m)	Δ_{ubase} (pFP)	H_t (m)
1.5	0.30	2.4	0.40	3.1
1.8	0.33	2.8	0.43	3.4
2.3	0.36	3.2	0.46	3.8
3	0.40	3.6	0.49	4.1
4	0.44	4	0.52	4.5

NOTE: Some further information on the drying effects of trees can be found in Cameron, D.A. (2001), *The extent of soil desiccation near trees in a semi-arid environment* (Int. J. Geotechnical and Geological Engineering, Kluwer Academic Publishers, v19, no. 3 and 4, pp 357-370) and Beal, N. and Cameron, D. A. (2007), A method for evaluating the influence of trees on expansive soil movement in light of case studies from SE Queensland (Proc. 10th ANZ Conference on Geomechanics, Common Ground, Brisbane, Oct 2007, V2, pp 200-205).

FIGURE H1 DESIGN SUCTION CHANGE DISTRIBUTION WITH DEPTH FOR TREE DRYING EFFECTS FOR DIFFERENT CLIMATE ZONES

H5 ALTERNATIVE DESIGN METHODS

Alternative design methods for the impact of trees on foundations are available.

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APPENDIX I

BIBLIOGRAPHY

(Informative)

AS
1684 Residential timber-framed construction

1720 Timber structures

2159 Piling—Design and installation

3500 Plumbing and drainage
3500.2 Part 2: Sanitary plumbing and sanitary drainage

4100 Steel structures

AS/NZS
4680 Hot-dipped galvanized (zinc) coatings on fabricated ferrous articles

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COMMENTARY

to

AS 2870—20XX

Residential slabs and footings

PREFACE

The layout of this Commentary follows that of the Standard. The numbering differs only in that its clauses, figures and tables are prefixed by the letter 'C', e.g. Clause C3.2.1 of this Commentary refers to Clause 3.2.1 of the Standard. Where there is no commentary to a Clause of the Standard it does not appear, therefore the Clause numbers in this Commentary are not consecutive. References to various publications and papers are listed as the last item of the Section or Appendix in which they occur. Section C7 provides recommendations not given in the Standard.

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INTRODUCTION

PURPOSE

This Standard provides for simple standard methods for the design of residential footings based on current structural and geotechnical principles. It applies to a variety of footing systems for most foundation conditions including reactive soils. Reactive soils are common in many parts of Australia and the Standard is strongly focussed on providing appropriate design solutions for footings and slabs on such soils. The Standard is in mandatory form for use in building control.

DESIGN REQUIREMENTS

In order to provide more background to footing design, a brief discussion follows on the aspects that are taken into account in the Standard—

- *Design for swelling and shrinkage movements* The primary cause of foundation failure of domestic structures is associated with the movement of reactive clay soils. A soil is said to be reactive or expansive when it undergoes appreciable volume change with changes in moisture content. The reactivity of a soil depends upon the size of clay particles, their mineral composition and the proportion of clay in the soil. Laboratory tests of soil reactivity on a single or a small number of samples may not accurately characterise the overall reactivity of a clay profile. In particular, the usual engineering index properties (e.g. liquid and plastic limits and linear shrinkage), when assessed on their own may not be reliable.

Soil movement that might occur on a site depends not only on the reactivity of the clay but also on the depth and distribution of the clay in the soil profile and on changes in moisture content. Moisture changes usually occur slowly in clays and produce swelling upon wetting and shrinkage upon drying. These moisture changes often result from a combination of causes, and include the following:

- Seasonal and long term climate changes, including dry summers, floods and droughts.
- Influence of the building, covering the garden and drainage; particularly trees, which may cause severe drying.
- Long term effects of the whole urban infrastructure, including paving and drainage.
- Initial moisture conditions at the site relative to the long term design conditions, including special conditions such as demolition of an existing house, removal of large trees and similar.

The actual pattern of the movement of a reactive clay foundation depends on the moisture and clay variation and may be quite complex. Building distortions may often include asymmetric and warping components. Nonetheless, for the purpose of design, the pattern of differential movement can generally be represented by one of the forms given in Figure C1.

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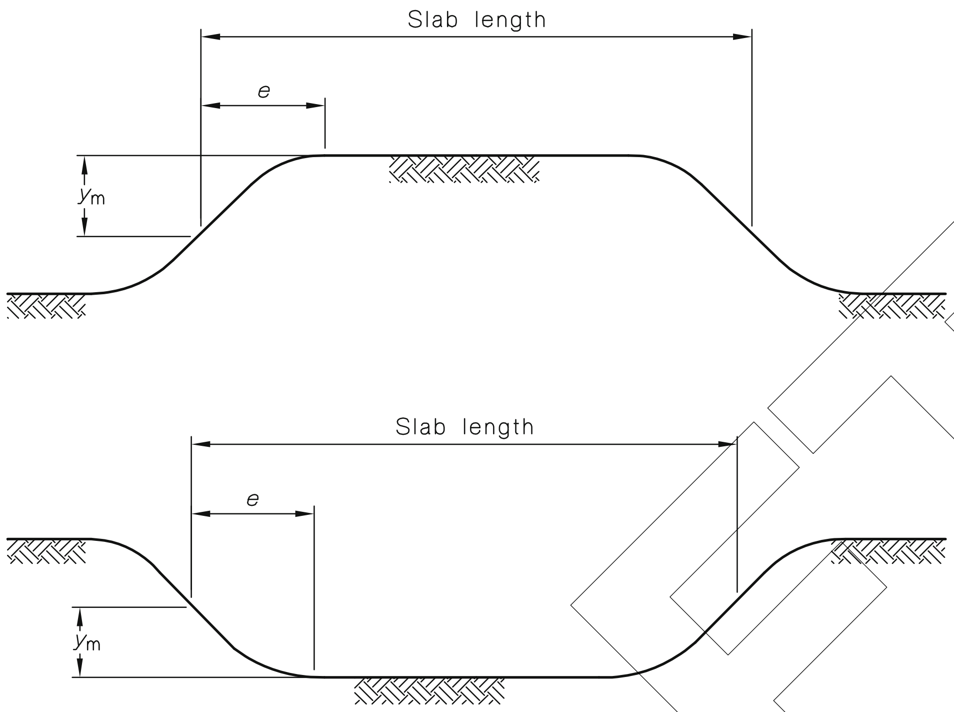

FIGURE C1 IDEALIZED GROUND MOVEMENT PATTERNS FOR FOOTINGS AND SLABS ON CLAYS (Walsh shapes)

The design of a slab to accommodate ground movements requires the provision of sufficient overall strength and stiffness. Whereas a very flexible slab could deform in the same way as the foundation, the stiffness of a properly designed slab limits the differential movement as a result of interaction of the foundation and structure. This interaction utilizes the mass of the slab and structure and its flexural stiffness and strength. Some contribution may be made by tensile membrane action of the slab. The stiffness of the slab not only reduces the deformations, but also transfers load to the relatively high areas of the foundation, and thereby tends to suppress heave at those locations.

Protection of the clay from extreme moisture changes is also important. Although some measures such as perimeter paths can be incorporated in the design, generally the owner has the immediate responsibility for protection of the foundation from severe moisture changes after completion of a building.

Strip footings undergo similar ground movement patterns and are designed on the same general basis as raft slabs, that is, strength and stiffness. However, although strip footings may be founded at depths where moisture changes should be less, in some cases (particularly where failures can occur by soil swelling) deep strip footings may trap moisture, increasing the soil swell. Generally, strip footings are more vulnerable to sideways and twisting movements and such movements can cause damage. Therefore, for highly reactive sites the alternative of an integral stiffened raft footing system is preferred.

An alternative design philosophy requires the removal and replacement of a reactive clay or the covering of it with a suitable non-reactive material. In such a case, consideration should be given to the effects that such replacement will have on the soil moisture regime particularly when, as is likely, the replacement soil is more porous and permeable than the natural material. The resulting infiltration and impoundment of water in the reservoir formed by the excavation in the natural clay may lead to deep and severe moisture changes in the underlying natural clay.

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- *Design for settlement of compressible soils or fill* Uneven settlement may occur on filled or soft alluvial sites. A solution for filled or soft sites could involve compaction of the soft or loose soil and fill, stiffening of the footing or slab to resist the differential movements or the provision of piers or deep beams taken down to found on firmer strata in some circumstances. A stable foundation may be provided by properly compacted fill material not containing deleterious material.

For slabs on non-reactive soils, distribution of imposed loads to the foundation is generally not a significant problem. Around the edge of the slab, either a thickened beam or a separate strip footing may be used to support the usually more heavily loaded external walls. These distribute the load along the beam as well as laterally to reduce foundation pressures. Under internal walls, in most cases the slab panel itself is sufficient to support the load from the wall and roof. Nonetheless, to allow for some unevenness in the loading and the foundation, additional support is appropriate for some of the loads that occur in two-storey construction.

For strip footings, distribution of imposed loads to the foundation requires that the footing possesses adequate strength to transfer the load laterally and longitudinally. The required flexural strength is usually moderate and may be determined by the assumption of uniform support. Alternatively, a more refined analysis may be carried out using an elastic representation of the foundation.

For reactive soils, the distribution of loads to the foundation requires consideration of soil behaviour and soil-structure interaction as discussed previously.

- *Design for sensitivity of superstructure* Whether a building can tolerate movement without damage depends upon the type of construction and the various design details such as whether or not the walling is articulated.

RESPONSIBILITIES

Footing design and construction involves a number of steps: site classification, selection of the footing system, structural design, construction in accordance with the required design details and construction methods, and proper maintenance. In addition to the builder, this process may involve an engineer, the Building Authority, the owner, and all parties who share responsibility for any failure. In particular, the owner has a responsibility to ensure the site is properly maintained and the Standard attempts to guide owners in this area.

The functions of the various parties likely to be involved in the overall building process are set out in Appendix A of the Standard.

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SECTION C1 SCOPE AND GENERAL

C1.1 SCOPE

The Standard applies to site classification and footing system design for houses and the like, extensions and outbuildings.

The recommendations in the Standard were developed from research and experience in the design and performance of house footings and slabs, but there is no reason why they cannot be applied to other similar structures. The similarities should be in the size, the loading and the type of construction.

Different building practices, such as the use of control joints in concrete slabs, are used in large non-residential structures but the Standard makes no design provision for these. As well, it is unlikely the Standard will be appropriate for industrial floors, except for the lightest applications.

The Standard has been based on methods of construction that are generally well accepted throughout Australia. Nonetheless, footing design is a developing field and it is possible that new or locally effective footing systems may not be included. The Standard should not be used to inhibit the development of such systems provided they comply with the design and performance considerations set out in Clauses 1.3 and 1.4.

C1.2 APPLICATION

The application Clause outlines the procedures to be followed in using the Standard. Where conflict with AS 3600 arises with regard to footing system design and construction, the provisions of AS 2870 prevail.

C1.3 PERFORMANCE OF FOOTING SYSTEMS

The current costs of building failure are modest compared with the costs of overly conservative design. Moreover, if the designs in the Standard are followed, failures should be very rare. The performance of footing systems on reactive sites depend in part upon the adopted routine of post-construction maintenance. If the homeowner's maintenance role is to be diminished, or higher expectations of performance are demanded, then the footing system should be designed according to engineering principles. Furthermore, the performance criteria adopted in the Standard may not be adequate for party walls, which have special architectural performance requirements.

Performance is based largely on the size and frequency of cracking in walls and concrete floors. All building materials move, e.g. clay bricks expand, timber and plasterboard shrink. Consequently some cracking in buildings is inevitable and is independent of foundation movement. On reactive and soft or non-uniform soils, foundation movement adds to this tendency to crack. A large number of buildings in Australia are constructed on clays that move with changes of soil moisture conditions that arise in part from effects of covering the ground with the building. Generally the movements will be moderate and the prescribed designs in the Standard will cope with the movement. If extreme moisture conditions, that may have been avoided had a reasonable level of site maintenance been achieved occur, then significant damage will be more likely and probably more severe. To attempt to design for such conditions on every clay site would add significantly to the cost of housing throughout Australia.

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To avoid extreme moisture conditions, it is essential that owners become aware of their responsibility to care for and adequately maintain a reactive clay site. Guidance to the owner is given in Clause 1.4 and a CSIRO Information Sheet, entitled 'Guide to Home Owners on Foundation Maintenance and Footing Performance', is available for distribution to homeowner's. This pamphlet may be obtained from CSIRO Publishing. At the time of publishing the pamphlet is available from http://www.publish.csiro.au/pid/3612.htm. It is suggested that a copy be given to the new home owner by the builder. The problem of subsequent owners is not simple and it is suggested that the owner should pass on the information sheet. In reactive clay areas, it is expected that the Building Authority will be interested in ensuring that the Information Sheet is disseminated. Site maintenance after occupation becomes part of an owner's accepted responsibilities.

C1.4 DESIGN CONDITIONS

C1.4.1 General

Design of footings in accordance with AS 2870 takes into account those environmental conditions arising from a normal site, maintained in accordance with Appendix B and CSIRO Note 10-91. These conditions are expected to cover most situations encountered in a normally maintained building site and the designs do include some provision for conditions slightly divergent from ideal. However, abnormal sites may arise as a consequence of either previous land use, inadequate site maintenance or the presence, growth or removal of trees. Special engineering consideration is needed for such sites, and these sites are usually classified as Class P.

The effect of trees on a reactive clay site will depend on matters such as climate, tree species, tree size, soil type and profile, watering and the interaction between the tree and the site development. These matters are not fully understood.

As a first step, informative guidance is now provided for the design for tree effects in Appendix H of the Standard.

Zero lot line developments make observance of some of the provisions of the maintenance more problematic but the technical requirements still apply.

C1.4.2 Design action effects

The design (factored) action for both strength (safety against yield) and serviceability (deflection and crack control) is the same. Moreover the strength design action is significantly less than the value given in AS 3600. Mostly, the low value arises from the relatively low cost of failure as explained in Walsh (Ref. 1). These design actions are also consistent with the performance requirements given in Clause 1.3.1.

C1.4.3 Other design considerations

(No Commentary)

C1.5 DEEMED-TO-COMPLY STANDARD DESIGNS

(No commentary)

C1.6 ARTICULATION REQUIREMENTS

(No commentary)

C1.7 NORMATIVE REFERENCES

(No commentary)

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C1.8 DEFINITIONS

There are no universally accepted sets of definitions for footing and building types so some definitions may differ from local custom. In the interests of a national Standard, certain terms have been chosen and defined for use in this Standard. Where possible, the definitions are consistent with building regulations and other Standards. Attention is drawn to the definitions of silt, sand and load-bearing walls, that are different from the usual engineering definitions. The definition of reinforced singleleaf masonry is different to the definition used in AS 3700.

A distinction has been made between the various forms of slabs, for example a slab-on-ground, a stiffened raft or a footing slab. In addition, various specific terms for masonry construction have been defined. Clad frame construction is defined, the definition being illustrated in Figure C1.1 of this Commentary.

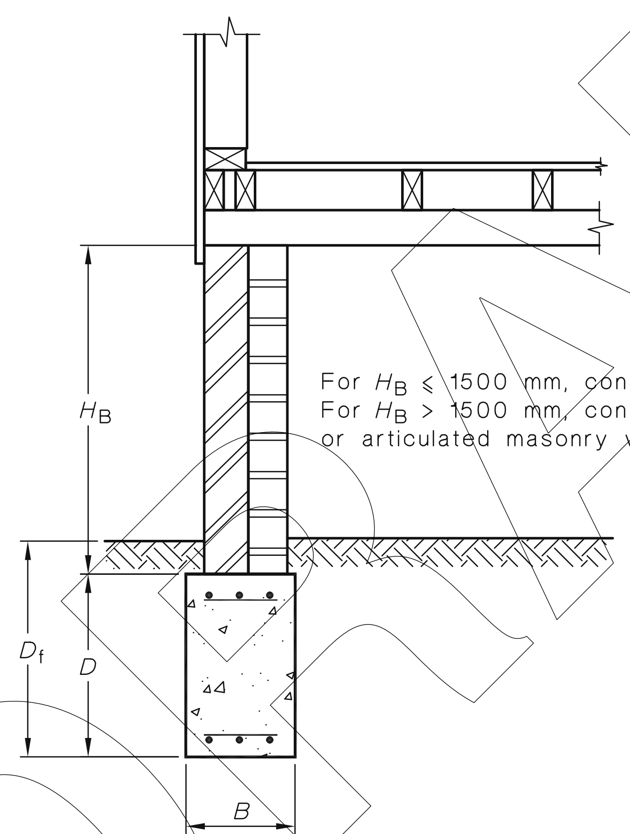

FIGURE C1.1 STRIP FOOTING SYSTEMS, CLAD FRAME

C1.9 NOTATION

(No commentary)

C1.10 REINFORCEMENT DESIGNATION

There has been some debate about ductility levels for reinforced concrete building components as a consequence of the availability of reinforcing steel products with higher characteristic yield strengths.

AS/NZS 4671—Steel Reinforcing for Concrete – has introduced various ductility grades and measures for reinforcing steel. For instance these distinctions have particular relevance in the design of suspended concrete beams and slabs and lesser relevance for footing systems.

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None the less, appropriate ductility (the ability of a structure to undergo large deformations without rupture) is a common and desirable feature in structural systems and has been taken into account in the process of selection of the Standard Designs.

In general, both deformed bars (D500N) and round and deformed mesh (D500L) are now distributed nationally and form the basis of design for the Standard.

REFERENCES

1 WALSH (1985) *Load Factors and Design Criteria for Stiffened Rafts on Expansive Clays*. Civ. Eng. Trans. Vol. CE 27 No. 1 February, Inst of Eng. Australia.

2 WALSH (1995) *Buildings Foundations and Movements with Particular Reference to the Effect of Trees.* ACSE Seminar - Building movements, Sydney, August.

C1.11 INFORMATION IN DOCUMENTS

(No Commentary)

DRAFT

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SECTION C2 SITE CLASSIFICATION

C2.1 GENERAL

C2.1.1 Classification

(No commentary)

C2.1.2 Site classification based on soil reactivity

All sites are required to be classified. The footing system must be suitable for the site and the only method of achieving this is to assess the site and to classify it.

The main soil types of are sands and clays, with silts as an intermediate type.

The various types of soil are distinguished in an engineering assessment by the size of the particles that constitute the soil such as—

- *sands*—which comprise material down to 0.075 mm;
- *silts*—which include the range 0.075 mm to 0.002 mm; and
- *clays*—which consist of very fine particles smaller than 0.002 mm.

For the purposes of this Standard the terms 'sand', 'silt' and 'clay' have been broadened. When soils contain mixed types, the finer particles usually control behaviour. For example, clayey sand behaves more like a clay than a sand. For the purposes of the Standard, sand is defined as soil with less than 15% clay and silt fines, and silt is redefined as a fine-grained but non-plastic and non-cohesive soil. It is important to realize these simplified classifications are different from conventional geotechnical engineering classifications.

A general summary of the properties of these common soil types is given in Table C2.1 below. More detailed methods of site classification are given in the Standard. A guide to site classification based on site reactivity is given in the Standard at Table 2.1. Class P sites have been excluded from this Table. Abnormal site environment factors lead to a classification of Class P. Class P also includes sites subject to landslip and mine subsidence. Common types of sites that are deemed to be Class P are described in Clause 2.1.3 of the Standards.

The Standard does not provide specific designs for Class P sites. A classification of P, by itself, will not usually provide sufficient information to enable an appropriate footing system design to be prepared. Additional information will usually be required, according to the nature of the factors leading to the P classification.

Allowable bearing capacity or soil strength and stiffness may affect the classification of soft clay or silt, or loose sand. In most cases, the strength of a soil may be estimated from penetrometer tests or from the simple field rules given in Table C2.1. Foundation strength is rarely a cause of failure and simple rules or past experience provide adequate guidance. For these reasons engineering tests to assess allowable bearing capacity should not be required. On natural sites, the reactivity of a site is usually the most important aspect of the classification and is discussed below. More specific discussion for each State is to be found in the subsequent Sections.

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TABLE C2.1

SIMPLE FIELD RULES FOR IDENTIFICATION OF MATERIALS

Foundation soil type	Physical characteristics
Rock	Rock is a strong material and includes shaley material and strongly cemented sand or gravel that does not soften in water. Material that cannot be excavated by a backhoe may be taken to be rock. NOTE: Foundation partly on rock and partly on soil should receive special attention.
Sand and gravel	Medium dense sand or gravel is granular material into which a 50 mm survey peg can be driven with difficulty. Loose sand (including silty sand) should be checked to determine if the soil is subject to collapse. Collapsing soils experience a sudden settlement or show a decrease in volume on watering and loading, or excavation and backfilling. Collapsing soil is Class P.
Silts and clays	Very soft clay or silt soil can be penetrated by the fist and is unsuitable as a foundation. Soft clay or silt is stronger than 'very soft' but not as strong as the firm material described below. The classification can be based on local experience or on an engineering assessment. Firm clay can only be mounded in its natural moist state by strong pressure in the fingers and can be penetrated 50 mm by the thumb with moderate effort.

Generally the first source of information about site conditions should be the Building Authority. In some areas, where there has been no history of trouble with reactive clay, advice might be given that the area is not reactive and a special investigation is not needed. The selection of sand or clay classification should be fairly obvious from local knowledge or from a simple site investigation. On the other hand, the Building Authority may suggest that reactive clays could be expected and care will be needed with the classification. Unless local knowledge is available, a qualified engineer or engineering geologist should be consulted. In areas subjected to deep climate-induced moisture changes, classification by a qualified engineer or engineering geologist is recommended.

Class A sites include sands and rock for which moisture-induced movement is not expected. Class S sites include silts and some clays for which only slight movements are expected. For a reactive clay site the classification is M, H1, H2 or E. Although numerical measures for surface movement are attached to these classes in Clause 2.2, the significance of these values should not be over-emphasized. Of equal importance, although less definite, is classification by existing building performance or by soil profile identification.

The site classification process requires a secondary classification based on the regional climate and, accordingly, the expected depth of soil moisture change or depth of movement, H_s. Experience has shown that slightly stiffer footing systems are required in semi-arid areas than in more temperate regions for sites of the same level of classification. This experience suggests that it is not only the magnitude of the movement which dictates the design of the footing; the shape of the distorted ground, as represented by the design parameters of edge distance or mound exponent, also plays an important part in the design. It is proposed that the shape is dependent on the depth of movement, with the most severe distortions occurring in semi-arid areas. This dependency has been expounded in Appendix F of the Standard. Figure C2.1 illustrates the effect of depth of movement on mound shape.

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Secondary classification requires a '-D' to be attached to the primary classification to indicate that H_s is greater than three metres. The absence of '-D' would indicate that movements are relatively shallow. So in Melbourne or Sydney a site having a y_s of 35 mm would be classified as M, but a site with the same movement in either Adelaide or Mildura would be classified as Class M-D.

The local presence of shallow bedrock does not alter H_s. However, a proven local permanent water Table level may change the secondary classification, since H_s is reduced.

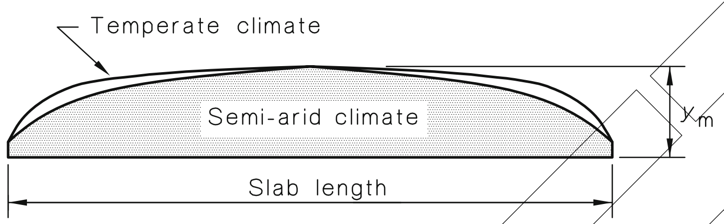

FIGURE C2.1 THE EFFECT OF CLIMATE ON MOUND SHAPE

The classification of a site on which controlled fill has been placed depends on—

- the nature of the fill (e.g. clay or sand);
- the depth of fill; and
- the nature of the underlying natural ground.

Thus controlled fill sites can be of any classification ranging from Class A for sand-fill on a sand site to Class P for fill over very soft compressible clay. Clay fills on clay are usually reactive and may be Class S, M, H1, H2 or E.

Where slab-on-ground construction incorporates underslab termiticide irrigation systems, the potential for these systems to cause extra foundation movement may need to be considered.

It is desirable that building owners and operators of the systems should be aware of the potential for such systems to cause foundation movement on reactive clay sites. Improper installation, operation or damage to the irrigation system may increase the potential for it to cause differential movement.

The Committee consider that the data and experience with the systems are not sufficient to allow specific guidance to be incorporated in the Standard.

Australian Standard AS 3660.1 – Termite Management was published in 2000, together with accompanying documents AS 3660.2 and AS 3660.3.

Physical termite barrier systems have now, in large part, supplanted chemical termite barriers throughout mainland Australia. Consequently, the likelihood of damage previously associated with the impact of water based termiticides on reactive clay soils has been reduced.

C2.1.3 Classification of other sites

Sites with unusual foundation problems such as mine subsidence, uncontrolled fill, landslip conditions or soft soil are classified as problem sites and will require a footing design by a qualified engineer. It is important for the problem sites to be correctly identified as in some cases they can appear to be similar to stable sites. For example, collapsing soils have a high bearing capacity when dry, but a much lower bearing pressure when wet, and hence need to be classified as a soft foundation.

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Uncontrolled fill is a common site problem. Where the building site is an infill site in an older area, uncontrolled fill should, in particular, be considered more likely than normal. Fill is often difficult and sometimes impossible to recognize. Often the layout of the subdivision will indicate areas likely to have been filled, such as previous gullies and similar. Rubbish buried in the soil profile is a clear indication of fill. Another indicator is the appearance of a top soil layer or a normal soil profile typical of the immediate vicinity, in the area under the fill. A useful method is to test the soil for consistent resistance to a penetrometer. Loose or soft fill can be located by probing the site with a length of reinforcing rod.

Classification of mine subsidence sites is usually provided by Mine Subsidence Authorities. Their requirements apply not only to mined areas but also to future leases. Where underground mining does occur in the area and there is no statutory control of mine subsidence, the Classifier should take necessary precautions.

In Item (e) severe moisture changes need only be considered when such conditions are known at the time of classification, for example, an existing large tree is to be removed, or a request is made to design footings for close tree plantings on a reactive site.

A classification of P, of itself, will not usually provide sufficient information for the preparation of a footing design. Depending on the cause for the P classification, supplementary geotechnical information will normally be required to allow a design to proceed.

C2.2 METHODS FOR SITE CLASSIFICATION

Accurate identification of the reactivity of a clay site by means of tests on samples throughout the soil profile is complex and expensive and may not be justified routinely on individual building sites.

Other methods are available and the Standard provides three procedures as follows:

- Prior performance.
- Profile identification.
- Movement estimates.

The simplest method based on the history of performance should not be underrated. Classification by history of performance is based on the fact that highly and extremely reactive clay sites cause clearly visible cracking of older masonry buildings on light strip footings. An inspection of the neighbourhood should indicate whether such a category is appropriate for the area. Such an inspection would only be meaningful if some knowledge of the soil conditions were available. Thus, either a soil or geological map should be consulted to ensure the neighbourhood has a similar soil profile to that of the proposed building site. It is also necessary to have some idea of the type of footings common in the area. If strengthened footings for reactive clays have been used for most of the buildings, this method is not applicable. Strengthened footings could be expected for the past 40 years or more in Adelaide but only for 20 years in Melbourne. In New South Wales, stiffened footings were generally introduced in the mid-1980s.

The method relies on an assessment of damage (cracking) of buildings of masonry (either veneer or full) construction, or the level of maximum differential movement of clad frame houses. Preferably, the appraisal should be based on buildings with similar wall construction to that which is intended to be built and which are at least 10 years old. If light footings have been used satisfactorily in the past, the classification of a site in that area should be Class S or at the worst Class M.

The degree of clay movement depends on the nature of the clay, depth of the clay, change in moisture content, and the ease with which water can soak into the clay. The extent of the moisture changes the clay will undergo is largely a function of the prevailing climate.

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No single test can identify all these parameters. The Standard describes the properties of the foundation by one parameter, the expected free surface movement, y_s. This is the vertical movement range expected during the life of the building from a reasonable estimate of dry conditions to a similar estimate of wet conditions and does not take into account the moderating effect of the footing system. The Standard nominates 50 years as the 'life' of the building and 'reasonable' as the level that could be expected for 19 buildings out of every 20. This does not mean that the building is not expected to last more than 50 years nor that 1 in 20 buildings could fail. It is, however, more reliable than using average conditions or an undefinable 'extreme' concept.

The effects of trees, poor site drainage, leaking plumbing and exceptional moisture-induced movements as outlined in Clause 1.3.3 are not taken into account in the calculation of y_s.

With the following definitions certain classifications are made—

S	=	Slightly reactive		y_s	≤ 20 mm
M	=	Moderately reactive	20 mm	$< y_s$	≤ 40 mm
H1	=	Highly reactive	40 mm	$< y_s$	≤ 60 mm
H2	=	Highly reactive	60 mm	$< y_s$	≤ 75 mm
E	=	Extremely reactive		y_s	>75 mm

In this assessment, y_s should be interpreted as the characteristic value that has a 5% chance of being exceeded in the life of the building, which may be taken as 50 years. Calculation of y_s shall assume the site maintenance complies with Appendix B.

To classify the site from estimates of soil movement requires geotechnical testing for, or assessment of, instability indices of the clay soils throughout the depth of soil affected by moisture change. In combination with a design moisture change profile (expressed as suction), this gives a good estimate of the likely movement.

Linear shrinkage, plastic index and similar tests are not recommended for guesstimating movement unless sufficient data has been accumulated for soils of particular geological origin and type to correlate these simple tests with instability index values and hence allow the surface movement to be estimated.

Some areas such as Sydney and Melbourne may be classified without tests by identifying soil profiles, the behaviour of which are well known in the region. Such methods may be more accurate than movement estimates based on soil tests and recommended suction changes. The Tables in Appendix D of the Standard provide a ready guide to the expected level of site classification. These methods of soil profile identification are as follows:

- *Classification of Victorian clay sites*

In Melbourne and the surrounding district, it is recommended that the classification be based on both the prevailing climate (refer Figures D1 and D2 in Appendix D) and the soil profile, i.e. the texture, feel and colour of the layers of soil if a hole is dug with a spade, backhoe or simple auger. Some guidance can be found in geological maps, which can be purchased from the Department of Mines. The 1:63 360 series is recommended. The accuracy of these maps near geological boundaries may not be sufficient to forecast soil types in areas on the scale of residential allotments. In such cases, the most reactive soil profile in the vicinity of the allotment should be assumed, unless proven otherwise.

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Classification is generally simple. For all clays in the Melbourne area, the theoretical depth of movement varies between 1.5 and 2.3 metres, depending upon the climatic zone. Therefore the ground movements are relatively shallow-seated and the subclassification, -D, does not apply. Generally speaking, the highest classification level will be Class H, which may be applied to the Tertiary basaltic clays near Berwick and Flinders, together with the extensive area of Quaternary basaltic clays to the north and west, depending upon the thickness of the clay layer at the site. The Class E category is unusual for a Melbourne basaltic clay as is Class H for other residual clays.

- *Classification of South Australian clay sites*

For the Adelaide region, reference may be made to publications and maps published by the Department of Mines and Energy, South Australia and in particular, References 1, 2 and 3. Soil profile identification is only one part of the classification process in Adelaide, due to both soil variability and high levels of site reactivity. Soil cores are retrieved and a visual-tactile examination for reactivity is conducted by an experienced geotechnical engineer. From this assessment, the maximum site movement is estimated and the site is accordingly classified. Soil testing is not normally required, but it is recommended for unusual soils or as a periodic check on the competence of the classifier. As Adelaide experiences a distinctly semi-arid climate, with a design depth of movement of four metres, the sub-classification '-D' applies to all site classifications.

- *Classification of New South Wales clay sites*

Reactive soils are common throughout New South Wales.

In rural areas (particularly the semi-arid and subhumid interior) well known examples of reactive soils include black, grey and brown clays. Many of these are found in north-western NSW and, to a lesser extent, mid- and south-western NSW.

Due to wide climatic variations, these soils have high movement potential in both the horizontal and vertical planes.

Gilgai formation, evident as surface humps and hollows formed by massive shrinking and swelling of the soils, are not uncommon.

Most of the soils in the western suburbs of Sydney and along most of the north shore ridge are clay soils weathered from shales (termed the Wianamatta Group). Some soils still cover the rock from which they were formed (residual soils) and others have been washed downhill (slopewash soils). For this group, the classification is generally Class M. For those areas where it can be shown by simple site excavation that the depth of clay on the site is less than 0.6 m, the classification may reduce to Class S. Some sites in this group should be classified as Class H, where unusually severe moisture changes may be expected, e.g. where the natural drainage is altered in a major way or in fringe areas of landslides where major water content changes may occur. Many of these sites are also prone to landslip and therefore must be classified as Class P.

In other areas of Sydney, the clays have not merely been washed downhill, but have been transported by rivers and streams to form deep alluvial deposits. These forms of alluvium are clearly identified on the soil maps as Mulgoa, Elderslie and Nepean. These may have clay deposits of various thicknesses and the classification varies accordingly. Deep clay layers may potentially be affected by changing groundwater regimes arising from either extreme drought or by urbanisation. Therefore, where clay depths exceed 2.5 m, a Class H classification may be more appropriate. If test data are used to check the classification, the theoretical depth of suction change must be increased to two metres or the depth to weathered rock, whichever is less.

Generally the site classification for most of the clay soils in Sydney will be Class M.

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Some sites around Sydney are in sandstone or sand areas and may therefore be classed as S, or even A, if a site specific geotechnical assessment has been carried out.

- *Classification of Western Australian clay sites*

Although many sites in the Perth area comprise stable sand soils, care must be exercised as reactive clay, loose sand and peat may give problems. Low density deposits of sand, particularly of calcareous composition, are prone to long term settlement. Drainage of surface water or ground water at shallow depth overlying or within clay may also be required. Guidance in terms of soil conditions in particular areas may be obtained by reference to the 1:50 000 scale Environmental Geology Series maps of the Perth Metropolitan area published by the Department of Minerals and Energy, Geological Survey of W.A.

Soil conditions in many coastal towns vary with proximity to the foreshore and river courses. For example, in some coastal towns, sites may be located on reactive clay, or problem categories, whereas in other coastal towns stable sand sites predominate.

Many inland country towns for example, Kalgoorlie, Northam, York, Dalwallinu, Ravensthorpe, Manjimup and Kununurra have reactive clay soils. In other areas (low density), sandy soils may show collapse on wetting. Examples include clayey sand in the Pilbara Region and sand which is in a loose condition, associated with limestone pinnacles in coastal areas. Local building knowledge, behaviour of surrounding buildings and site inspection are required to ascertain if testing for unstable soils is necessary.

- *Classification of Queensland clay sites*

In Queensland a wide variety of soils and climates can be encountered. Soil mapping for site classification purposes has not been developed extensively for Queensland areas. Such mapping is problematic in areas of Brisbane due to hilly terrain and consequent complexity of distribution and variation soil and soil types. Localised basalt flows and the intrinsically highly reactive soils that are weathered from them can result in sharp local variation in profile reactivity and hence site classification. Nevertheless, mapping could well be of assistance in other areas of the state where there is more consistency of soil over broad areas.

Generally on clay sites, it will be necessary to engage a qualified engineer to classify the site. There are areas of 'black earths', which consist of intrinsically highly reactive clays. These occur in broad areas of the Darling Downs, which includes Toowoomba but also in smaller areas surrounding Brisbane and Ipswich and more generally in the Lockyer valley. Such clays are well known for their large movement and would warrant Class H or E classification depending on location and climate zone. Since climate changes with distance from the coastline, careful consideration must be given to the selection of the depth of seasonal movement Hs. For example, this depth increases from 1.5 to 2.3 metres across Brisbane and Ipswich. Fox (2000 and 2002) (Refs. 8 and 9) provides guidance on climate zones and depth of seasonal influence throughout Queensland.

The classification should be based on engineering principles if, as is usual, soil testing is to be used. Shrinkage index tests on an 'undisturbed' core sample are recommended rather than the conventional plastic index and linear shrinkage tests unless a reliable correlation of these tests with ground movements in the region is available.

In summary, unless there is well-established local knowledge about the behaviour of the clay sites, the site classification will require some engineering input.

- *Classification of Tasmanian and Northern Territory clay sites*

No general information is available about the reactivity of Tasmanian and Northern Territory clays, but considerable local expertise is available from the building and

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consulting engineering profession. Information in Table D1 may be considered to supplement local expertise.

C2.3 ESTIMATION OF THE CHARACTERISTIC SURFACE MOVEMENT

Estimation of the characteristic surface movement, y_s, for classification requires the soil suction model proposed by Aitchison (Ref. 5). In this model, soil suctions and instability indices are required to predict movement. These two parameters and the suction model are discussed in the following:

- *Soil suction* Soil suction is a measure of the internal stress caused by moisture in unsaturated clays. It is also a measure of the affinity that unsaturated soil has for water and can be expressed in terms of the energy required to extract a unit of water from the soil. The gradient of suction determines the direction of moisture diffusion in the soil. Suction is useful in the assessment of reactive site movement because it is a measure that is independent of soil type. It is further useful because it is more readily related to the effect of climate on soil moisture state than is the case for other measures of soil moisture. (For example, soil moisture content varies depending on soil type as well as climate.)

Total soil suction consists of two components, namely matrix and solute suction. The matrix suction refers to the soil's affinity for water at the same salinity level. Solute suction is related to the salinity of the pore water. Changes in either form of suction may cause soil volume changes. Large changes in the solute suction and consequent movements are usually associated with leaking plumbing services.

For convenience, suction is expressed as follows—

$$u = \text{suction, in pF units} = \log_{10}(\text{suction in kPa}) + 1.01$$

Suctions may be measured by a commercially available psychrometer or thermistors (total suction) or by filter paper techniques (matrix and total suction). Both techniques require considerable care. An Australian Standard test method is available for soil suction determination using a psychrometer to measure the dew point temperature (AS 1289.2.2.1). Whilst the methods of ground movement estimation set out in the Standard are based around soil suction, they do not necessarily require the measurement of the suction of soil samples in their implementation.

The design suction profiles for the estimation of y_s should be related to local experimental data for the characteristic wet and dry profiles. It needs to be emphasized that such data must be relevant to the definition of y_s. The suction data should reflect the characteristic wet and dry condition in the soil profile. The wet condition should reflect the effect of development, which particularly in arid areas, may be wetter than the ordinary open field seasonal wet condition. Data from an open field site subjected to seasonal moisture changes may underestimate the suction change. Experimental suction profile data influenced by anomalies such as trees or other leaking pipes will also be invalid.

The characteristic value is defined as the value that has a 95% chance of occurring in the life of the building. Thus it is not necessary to consider the extremes of drying or wetting of the profile. The Standard provides recommended design suction change profiles and conveniently expresses the suction change as decreasing linearly with depth. However it should be recognized that this simplification of the profile may lead to overestimates of movement if the depth of suction change is estimated as the extreme value for suction change.

- *Instability index* The instability index (I_{pt}) may be estimated from the shrinkage index (I_{ps}), which is determined from shrink-swell, loaded shrinkage or core shrinkage tests (AS 1289.7.1.1, 7.1.2 and 7.1.3). A description of these tests is given in Cameron (Ref. 6).

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Guidance on estimation of the instability index from the shrinkage index is given in Clause 2.3.1 of the Standard.

- *Design movement* The design surface movement, y_s, for site classification is the integral of movement over the depth of suction change as follows:

$$y_s = \frac{1}{100}\int_0^{H_e} I_{pt}\,\Delta u\,dh \qquad \text{. . .C2.2.3}$$

where

y_s = characteristic surface movement (in mm)

α = Lateral restraint factor, see Clause 2.3.2

I_{ps} = shrinkage index, see Clause 2.3.2

Δu = soil suction change at depth (z) from the surface, expressed in pF units

h = Depth to the point under consideration, in metres

Having determined the surface characteristic movement, the reported value for site classification should be to the nearest 5 mm. Information on the accuracy of estimates using the suction model is given in the study conducted by Cameron (Ref. 6).

C2.4 SITE INVESTIGATION REQUIREMENTS

C2.4.1 General

The physical requirements for site investigation relating to the frequency and depth of subsoil exploration locations are given in this clause.

C2.4.2 Purpose

(No commentary)

C2.4.3 Depth of investigation

(No commentary)

C2.4.4 Minimum number of exploration requirements

The number of boreholes per site is dependent upon the variability of the soil deposit, as well as the size of the planned building. Less boreholes are required for small extensions and outbuildings. Soil variability over a site is likely if either uncontrolled filling or gilgais are present. Gilgais are undulating surface structures (see Clause 1.8.29), which are indicative of highly expansive soils, and which give rise to variability of soil layering over relatively short distances. Where gilgais are recognized, more boreholes will be required per site to adequately determine the site classification. Gilgai structures are well known in suburban Adelaide.

C2.4.5 Assessment of allowable bearing pressure

For natural soils, the most convenient expression of the load carrying capacity of the soil without the risk of failure or excessive settlement is the allowable bearing pressure. Most natural soils should be able to sustain the required pressures of 50 kPa or 100 kPa. Simple methods for assessing allowable bearing pressure are given below, but these should never be used to override an engineering assessment. Even the use of a pocket penetrometer for clays is preferred to 'rules of thumb'.

Conventional engineering techniques may be used to assess the allowable bearing pressure of soils. For example, in sand the Perth penetrometer may be used as a field test for safe bearing capacity. In general, the allowable bearing pressure takes into consideration both the strength and settlement characteristics of the soil. In particular, where the soil includes deposits of soft silt or clay, or loose sand, then settlement may govern and further

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investigation would be required. The following simple rules for safe bearing capacity may be used in conjunction with local knowledge:

- Loose sand means deposits into which a sharp pointed wooden post 50 mm square can easily be driven by a 5 kg hammer. (Loose sand shall not be used as foundation without an engineering investigation, except that a stiffened slab may be used on loose sand where there is well established local knowledge of satisfactory performance.)

Sand deposits into which a sharp pointed wooden post 50 mm square can be driven with difficulty by a 5 kg hammer may be taken as having acceptable bearing pressure.

- Soft silt or clay means a fine-grained soil which can easily be penetrated 25 mm in its natural condition by the thumb. Soft silt or clay shall not be used as a foundation without an engineering investigation.

Silt or clay that can be penetrated to a depth of 25 mm or less by the thumb with a moderate effort may be taken as having adequate pressure.

NOTES:

1 Tests on silts and clays should be made at moisture contents typical of wet conditions by testing fresh samples at suitable depths or by avoiding tests during dry periods.

2 Tests for allowable bearing pressure should be made at a depth immediately beneath the foundation level. The soil at deeper levels should be checked to confirm that no weaker strata exist.

3 If collapsing soils are suspected, then their presence may be further confirmed by the response of the soil to heavy watering or by excavation and backfilling (a lower volume after backfilling indicates a collapsing soil).

4 The above guidelines are approximate and should not be used to limit allowable bearing pressures assessed by more accurate methods.

5 The above methods do not apply to fill material.

C2.5 ADDITIONAL CONSIDERATIONS FOR SITE CLASSIFICATION

C2.5.1 Sites consisting predominantly of sand or rock

(No commentary)

C2.5.2 Effect of site works on classification

In Clause 2.4.5, the Standard sets limits to the amount of cut or fill that can be made to a site before reclassification is necessary. Some examples of the effect of cut or fill on classification are—

- increase in reactive movements by removal of part or all of a protective non-reactive soil layer (cuts up to half a metre deep are assumed not to affect the classification);
- reactive movements worsened by the addition of clay fill; and
- settlements caused by the weight of fill where weaker material underlies the site.

C2.5.3 Effect of fill on classification

The specification of compacted fill that is deemed to be controlled, without formal testing, is given in Section 6. Maximum thicknesses are also given. Where mechanical compaction is used, the depth of compacted fill which is allowed is up to 800 mm of sand (using a vibrating roller or plate) or 400 mm of material other than sand (using a mechanical roller).

Consideration needs to be given to the combined effects of the existing soil profile and the superimposed compacted fill. Where controlled fill has been used and has been subject to an engineering investigation of the fill and the underlying soil, it may be reasonable to assign a classification of Class A, S, M, H1, H2 or E to the site. In assigning such a classification, the classifier must assume all shrinkage cracks are effectively closed, which

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means lateral swelling of the soil is constrained and thus all soil volume change is expressed as vertical movement. The placement and compaction of fill is likely to diminish any existing cracking in the underlying natural ground due to closure of the cracks by the compactive effort and also by infilling of the cracks by the fill material.

A site classification can be improved by removal of clay and replacement with fill or by covering the clay with permanent fill. The depth of the fill should be based on an assessment of the effect of the fill on the movement in accordance with engineering principles but normally a depth of at least 1 m would be needed. Where the clay is replaced, the fill should be carefully chosen and compacted to protect the underlying clay from moisture changes. Fill materials should be selected to limit moisture changes in underlying reactive clay. Sealing and drainage of both the fill and the underlying clay may be required, particularly where excavation of the site may lead to entrapment of water. Where the site is covered with selected fill, the main effect of such fill is the establishment of uniform stable moisture conditions. To achieve this the fill should be placed well before construction begins, e.g. two to five years.

Non-sand fill should be placed at a moisture content close to the optimum moisture content (OMC) for standard compactive effort. Compaction with heavy equipment at a lower moisture content may provide an initially strong and dense soil fill. However, in the long term, moisture will be re-distributed throughout the covered fill, leading to a wetting up of the soil towards the value of the OMC. Density and strength will be lost as the soil subsequently swells.

Reclassification of filled sites—Long term equilibrium moisture conditions may be taken as marginally wet of optimum moisture condition (standard compactive effort) in the eastern coastal area or marginally dry of optimum moisture condition (standard compactive effort) in arid areas. Equilibrium moisture conditions may be estimated by reference to similar clays that have stabilized near the centre of large sealed surfaces. Allowance should be made for variation of moisture conditions in the foundation due to construction of the fill.

Alternatively, the movement may be estimated by reference to established knowledge of the behaviour of similar fills in a similar area. The alternative site classification shall not be less severe than the site classification of the natural ground unless the controlled fill consists of non-reactive material and is deeper than one metre or 0.5 H_s, whichever is greater.

REFERENCES

1 TAYLOR, J.K., THOMASON, B.P. AND SHEPHERD R.G. *The Soils and Geology of the Adelaide Area*. Department of Mines and Energy, S.A., 1974, Bulletin No 46.

2 TAYLOR,J.K. *Soils of the Southern Adelaide Region*, 1976.

3 SELBY, J. AND LINDSAY, J.M. *Engineering Geology of the Adelaide City Area*. Department of Mines and Energy, S.A., 1982.

4 New South Wales BUILDERS LICENSING BOARD. *Classification of New South Wales Soils for Housing*, Sydney, 1985.

5 AITCHISON, G.D. *The Quantitative Description of the Stress-Deformation Behaviour of Expansive Soils*. Proc., 3rd Int. Conf. on Expansive Soils, Israel 1973, 79–82.

6 CAMERON, D.A. *Tests for Reactivity and Prediction of Ground Movement*. Civ. Engg. Trans., I.E.Aust., Vol. CE31, No.3, December 1989, pp 121–132.

7 CAMERON, D.A. *Site Classification to AS 2870 Public Comment Draft.* Australian Geomech. News, June 1995, pp 41–47.

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8 FOX, E.A. *A Climate-based design depth of moisture change map of Queensland and the use of such maps to classify sites under AS2870-1996* Australian Geomechanics Journal. Vol 35 No 4, Dec 2000, pp 53–60.

9 FOX, E.A. *Development of a map of Thornthwaite Moisture Index isopleths for Queensland* Australian Geomechanics Journal. Vol 37 No 3, June 2002, pp 51–55.

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SECTION C3 STANDARD DESIGNS

C3.1 SELECTION OF FOOTING SYSTEMS

C3.1.1 Selection procedure

The choice of an appropriate footing systems is most commonly made between a concrete slab and a suspended timber floor. The selection is made to suit site conditions, and the preferences of the builder and owner.

The standard designs assume generally adopted building practices, and unusual or extreme forms of construction involving heavily loaded structural columns, suspended concrete floors or highly brittle features are not included.

The background to the design of slabs and footings involves the following:

- *Design details and construction*

All footing systems designed pursuant to Clause 3.1 must comply with Sections 5 and 6, which provide design details and construction requirements.

- *Slab systems*

For a concrete slab a choice is needed between two main types of slab, namely the slab-on-ground with integral edge beams and the footing slab with separately poured edge footings. The footing slab requires more material and requires two pours to construct but it has a number of advantages, for instance, it adapts to sloping sites better than a slab-on-ground, and it does not require complex formwork and the trenches are open for less time. The integral slab-on-ground is stronger and is often more economical with materials. The choice will often be related to local experience, e.g. footing slabs are dominant in Western Australia, slab-on-ground in South Australia, Victoria and Tasmania and New South Wales. Two-pour footing slabs were previously dominant in Queensland but now practice has moved towards slab-on-ground.

- *Structural proportions of slabs*

A considerable part of the design process for slabs on Class A and Class S sites is largely based on past satisfactory performance of similar slabs, rather than any theoretical justification.

Most of the structural strength of slabs for Class A and Class S sites is provided by the concrete. The reinforcement is included to control shrinkage and to provide some flexural strength in the case of cracking due to foundation movement. For the 300 mm deep edge beams, the flexural reinforcement L8TM is just above the minimum required to ensure that the reinforced flexural strength is greater than the cracking strength by 20%.

The width of the edge beam and footings reflects the load applied to the footing. For the slab-on-ground it is assumed that a significant part of the load will be supported by the adjacent slab panels, consequently the minimum width of 300 mm is adopted, assuming an allowable bearing pressure of only 50 kPa is required. For the edge footing of a footing slab, the contribution by the adjoining slab panels is only available for the tied form of construction. Under footing slabs with separate strip footings, 100 kPa is the allowable bearing pressure and that the width is to be as specified for individual strip footings.

- *Slab thickness*

For slab on ground construction (other than waffle rafts) slabs are generally required to be 100 mm thick. This is regarded as the practical minimum thickness for normal building construction, unless the construction is supervised by a qualified engineer, in which case, the minimum slab thickness may be 85 mm.

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For two-storey construction, under-walls supporting the upper floor or under any masonry walls, the slab should be thickened to 150 mm over a width of 500 mm and provided with an extra strip of mesh as shown in the Standard. Otherwise the loads are within the capacity of the slab and there is no need to thicken the slab. Thus, in single storey construction thickening is not needed under either masonry or load-bearing framed walls.

- *Slab reinforcement*

The reinforcement for slabs-on-ground is specified as SL72. For footing slabs without tied beams the required reinforcement is reduced to SL62 where the slab length is less than 18 000 mm, SL72 where the slab length is between 18 000 and 25 000 mm and SL82 where the slab length is between 25 000 and 30 000 mm, due to the slab being freer to shrink without restraint. Nonetheless, these levels of reinforcement are very low—SL72 represents 0.2% and SL62 represents 0.16%. For slabs longer than 18 m the cracking problems are potentially greater and mesh sizes SL82 and SL72 are required. Additional or heavier reinforcement or other measures may also be required where brittle floor coverings are used (see Clause 5.3.7). The slab mesh also acts as negative reinforcement for the edge beams. This avoids the need to locate bar reinforcement near the edge rebate. See Figure C3.1.

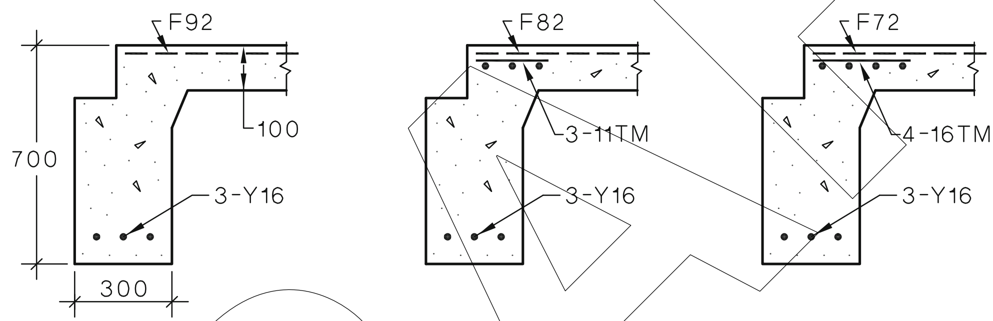

FIGURE C3.1 REINFORCEMENT OPTIONS

- *Stiffened rafts*

A variety of systems are available for placing a concrete floor on a reactive clay. The general form of construction of a stiffened raft is shown in Figure C3.2.

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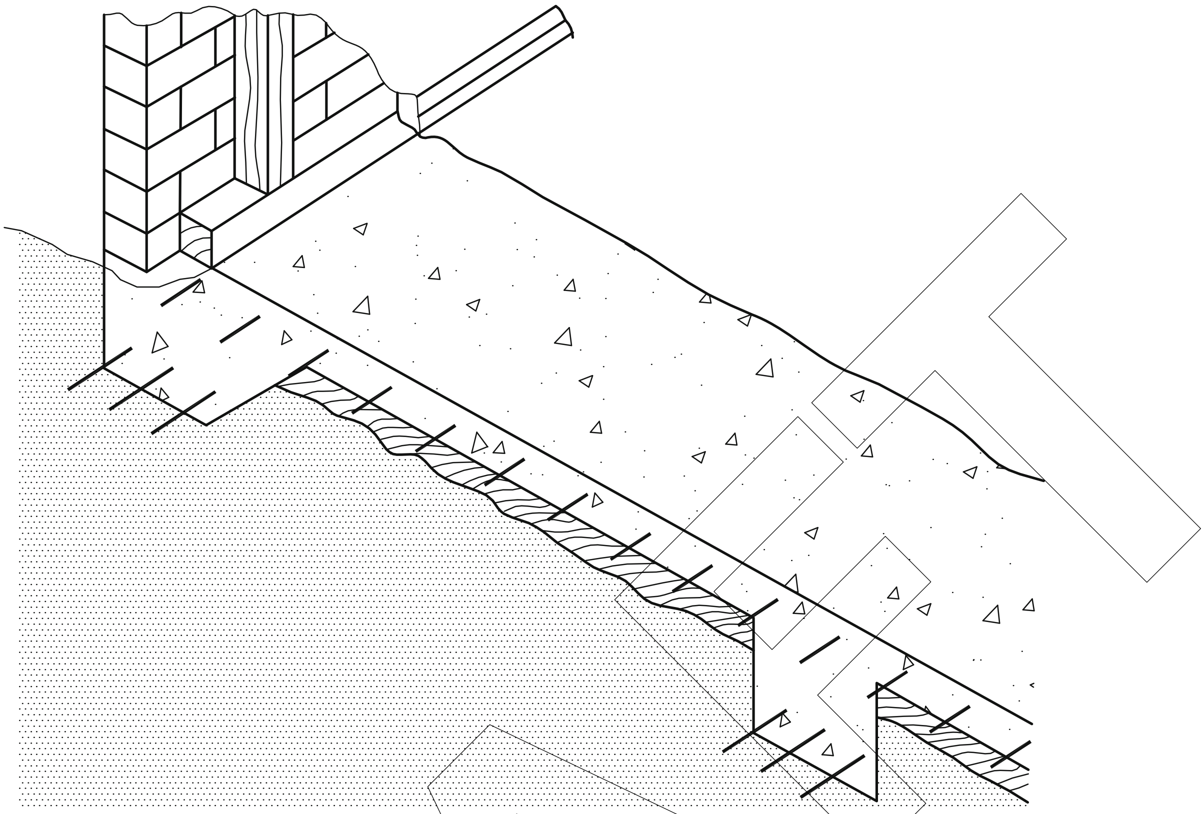

FIGURE C3.2 STIFFENED RAFT CONSTRUCTION

Stiffened rafts are constructed in Queensland and northern New South Wales with construction joints in the beams. The system relies on a structural connection between the edge footing and the stiffened slab by a reasonable concrete bond and by steel ties. This is not always easy to achieve and construction methods need to be carefully planned and controlled. This form of construction is now less common in Queensland, having been replaced by single pour raft construction.

The designs prescribed in the Standard were developed in part from an assessment of the performance of actual footing systems. This evaluation relied heavily on experience in Melbourne, with Sydney and Brisbane conditions also taken into account. Adelaide soil and climate were found to be quite different and separate designs were developed.

The most reliable data were for one-storey brick veneer buildings on moderately and highly reactive sites in Melbourne. This information was used to check the accuracy of the model based on engineering principles (Ref. 3). This model was then used to obtain designs for other conditions by extrapolation.

In a stiffened raft, the beams provide the double function of load support and stiffness against foundation movement. In order to provide the latter function, the beams must be arranged in a grillage. Particular care needs to be taken to ensure that irregularities in the perimeter plan shape of the building are supported by the stiffening beam grillage. When designing the stiffening beam layout, the designer needs to keep in mind that under centre heave or edge settlement conditions, the perimeter stiffening beam may loose ground support and depend largely on internal stiffening beams for support. Salient parts of the footing system plan such as may be required for a brittle portico structure need careful consideration if they are to be effectively integrated with the stiffened footing system for the building.

The layout of the beams should not be dictated by the layout of walls over the slab but rather should be arranged to provide a rational stiffening grillage for the whole slab.

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If a beam is within 1000 mm centre-to-centre of a wall over the slab, the slab is considered strong enough to transfer the load to the beam. This may not be adequate in two-storey solid masonry construction with a concrete floor at the first floor level. In such cases the slab should be specially designed.

For clad frame and masonry veneer, only light beams are required and this reflects the movement tolerance of the framed construction relative to the differential movement expected. The beam spacing of 6 m to 7 m is permitted and this should only require relatively few beams. If the spacing in the one orthogonal direction is reduced, the spacing in the other direction may be increased. The top reinforcement to the beams is provided by the mesh used in the slabs.

For full and articulated masonry, the designs are much stiffer and stronger. This reflects experience in Adelaide regarding vulnerability of such wall construction to cracking, and the sizes needed to achieve satisfactory performance.

For the highly reactive sites, much stronger designs are given. The 'standard case' of masonry veneer has edge beams 300 mm × 500 mm with 3 wires of L12TM. This is stronger than the intermediate slab which prior to the advent of the 1986 version of this Standard has often been successfully used in Melbourne on such sites. The stronger design was adopted to allow for the wider variety of sites that may be covered by this category of highly reactive sites (H1 and H2).

The beam sizes of Figure 3.1 provide adequate stiffness to ensure that non-structural wall systems placed on the slab are not subjected to excessive deflection. However, Clause 3.2.5 permits a reduction in these beam sizes to 300 mm × 300 mm with 3-L11TM reinforcement, if reinforced hollow concrete blockwork walls are structurally connected to the beams and act with them to resist movement.

In this case the walls must be 190 mm single leaf hollow concrete blockwork, reinforced with at least N12 bars at not more than 2.0 m centres, tied into the footings with starter bars and incorporate a continuous bond beam with at least two N12 bars around the top of the wall. (See Figure C3.3.) The walls should be adequately waterproofed.

This construction behaves as a 'stiff box'. Articulation of the bond beams should not be included since it destroys the continuity. When using this detail, care must be taken to ensure the adequacy and continuity of internal beams, particularly at re-entrant corners where internal beams are deeper than the external beams. Figure C3.4 shows a typical section and detail at re-entrant corners. This system is further considered in Clause 4.7

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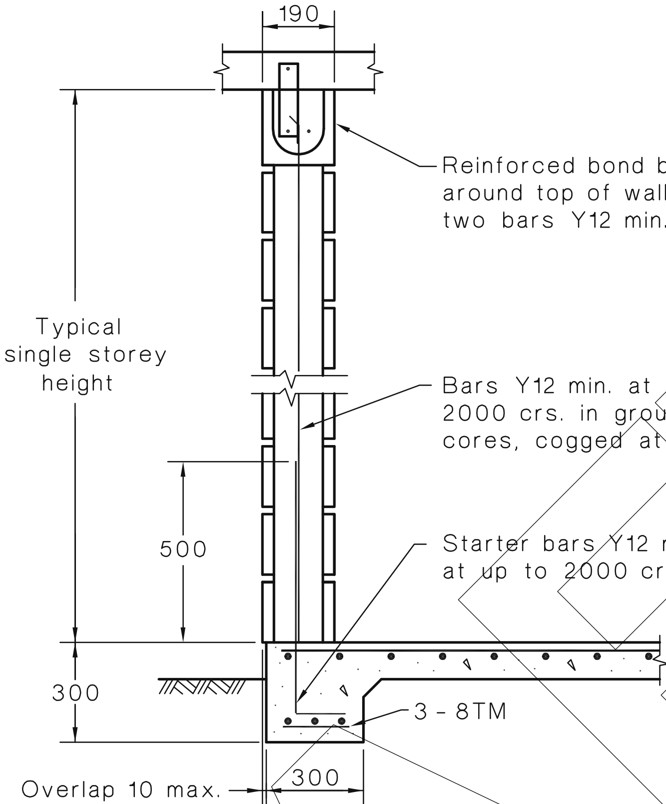

NOTE: Waterproofing is required to exterior face walls constructed and reinforced in accordance with AS 3700. Footings are suitable for openings up to 1800 mm. For wider openings use established concrete and reinforced concrete masonry analysis methods to determine the required footing sizes.

FIGURE C3.3 TYPICAL DETAILING FOR FOOTING AND SINGLE-LEAF REINFORCED MASONRY WALL COMBINATIONS

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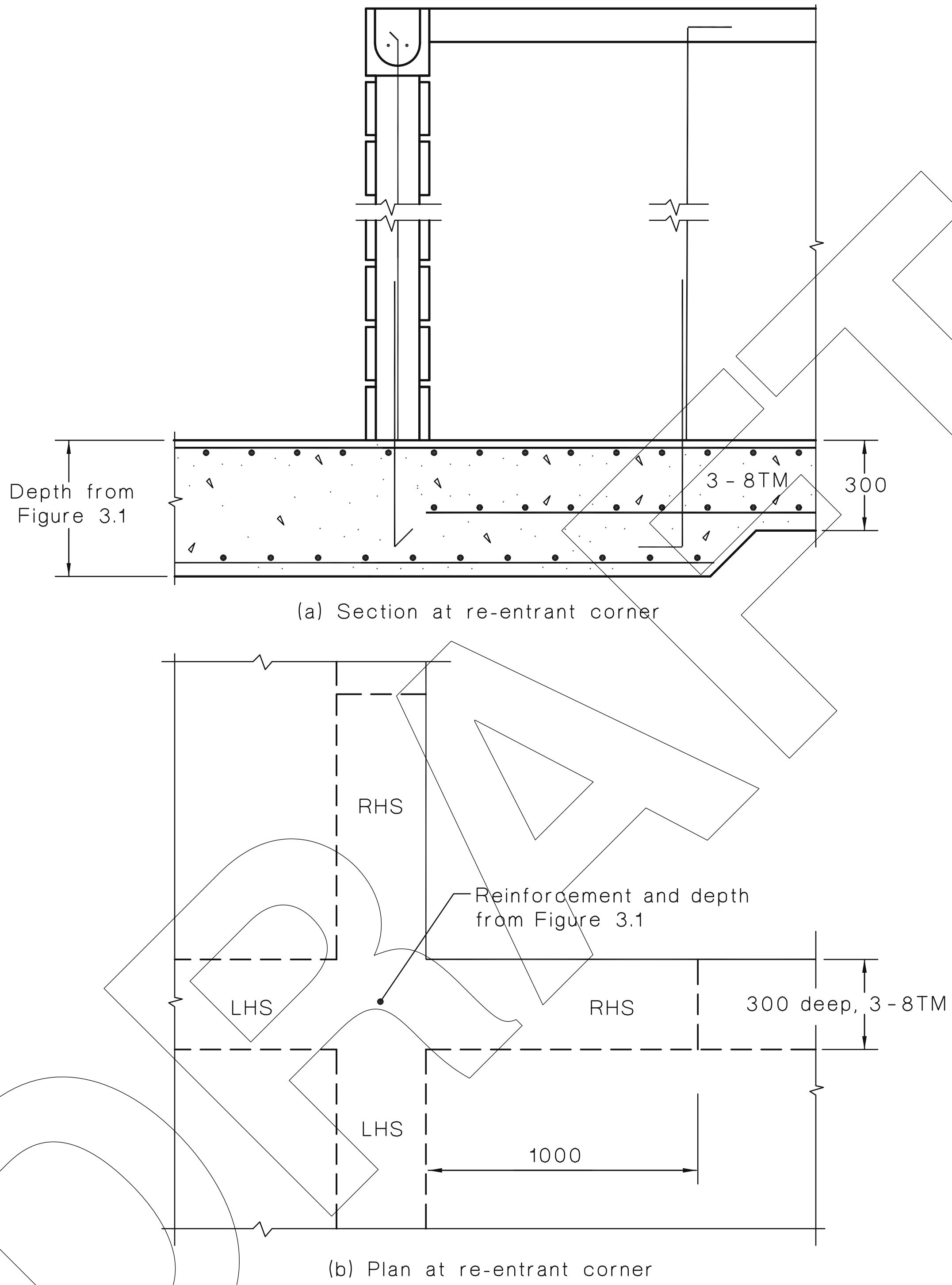

FIGURE C3.4 TYPICAL RE-ENTRANT CORNER DETAILS

- *Waffle rafts*

Waffle rafts are a particular form of raft slab where the raft, including ribs, is constructed on a prepared flat ground surface. The regular grid of ribs is formed using void formers. The structural design method in Appendix F is also suitable for waffle rafts. Although the bearing area provided by the narrow ribs is less than that of a conventional raft, an allowable bearing pressure of 50 kPa under the ribs is adequate.

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The designs provided in the Section on waffle rafts are based on engineering analysis using the same principles as for stiffened rafts. The construction is completely on-ground rather than in-ground and this has several features:

- The shrinkage behaviour is improved due to the lower restraint compared with a raft with embedded beams.
- The structural performance is enhanced as there is no concern about down drag of embedded beams due to clay shrinkage.
- The proportions of the cross-section may be achieved reliably without excess concrete being needed due to over excavation.
- There is a greater propensity for ingress of moisture under the slab.

Bored piers (if required) should be designed in accordance with engineering principles and Appendix G5 of the Standard.

Both down load and uplift conditions should be considered and the design of bored and excavated piers should be determined by engineering principles.

- *Stiffened slab with deep edge beams, SSD (Class M)*

This form of slab, illustrated in Figure 3.5 in the Standard, is restricted to Class M sites and the more flexible internal construction of clad frame or masonry veneer. This form of construction relies on deep strong edge beams to provide stiffness. Internal beams at re-entrant corners in T- and L-shaped buildings would have a significant effect but they are not always required (see Figure 3.5, Note 4). The edge beams may include reinforced masonry.

- *Strip footing proportions*

A strip footing is a footing of rectangular cross-section used to support the external or internal walls of a building. For clad frame construction a strip footing is only required if a masonry dwarf wall is used. For masonry veneer the external wall is supported by a strip footing and the internal frame is usually supported on pad footings with stumps or piers, although internal strip footings are possible. For solid masonry, strip footings will be required under both internal and external walls.

The proportions of a strip footing are controlled by several factors including the allowable bearing pressure, the need for strength and stiffness to cope with some minor movements, practical limits on size and a suitable foundation depth.

The typical applied bearing pressures are given in Table C3.1 for the footing widths in the Standard and, except for two-storey masonry construction, are usually quite moderate. To allow for uneven loading and eccentricity, the minimum required allowable bearing pressure is set at 100 kPa.

TABLE C3.1

TYPICAL APPLIED PRESSURE UNDER STRIP FOOTINGS (kPa)

Type of construction	Single storey	Double storey
Clad frame	33	50
Masonry veneer	50	65
Solid masonry	65	80

Although theoretically this Table suggests the sizes could be even smaller for the lightly loaded footings, there are practical difficulties in constructing footings narrower than 300 mm and problems with possible eccentricity of the load may occur with very narrow

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footings. For simplicity, the Standard has adopted the same sizes for both one and two-storey construction.

Strip footings are able to withstand some foundation movement. For example, the masonry veneer footing could withstand loss of support over a length of up to 3 m within its length, reducing to approximately 1.2 m at the corner.

- *Pad footings*

Pad footings are used to support stumps or piers which in turn support a framed structure. Considerable differences exist between State practices in this area.

The loading on a stump may be determined from Appendix E and AS 1684, depending on the bearer spacing and similar. For larger loads an appropriate pad size is specified depending on the area supported. The design of pad footings on reactive clays should take into account the expected depth of moisture change. However, it will frequently be uneconomical to found footings at completely stable depths. Shallower footings with the consequent possible need for minor maintenance, such as repacking, may be more economical.

- *Strip and pad footings on reactive sites*

Standard designs for strip and pad footing systems on reactive sites have been extended to cover class M-D sites and some full masonry applications. This reflects the findings of recent surveys in the Melbourne area which indicate good performance from such systems when correctly specified.

The plastic membrane around the strip footings, where specified, is intended to limit down drag where clay soil shrinks. The internal support may be on deep stumps or gridded internal strip footings. A combination of the two types of internal support is possible, but is not recommended due to the potential for differential movement.

In some cases, to minimize the damage likely to be caused by differential movements, a minimum spacing is specified from the outside footing to the first row of internal stumps. This is intended to ensure that any differential movement between the internal and external footings is only expressed over a reasonable length of structure thus limiting the rotations and deflection ratio.

The cross-section proportions are chosen to give high contact pressure, strength and stiffness to both suppress and resist ground movement. Settlement of stumped or piered footings under the internal area of buildings is common but fairly simple to repair by packing. Such settlement occurs because the clay under the building dries to equilibrium within the ventilated subfloor space. This subfloor space is very dry in comparison with the clay and can cause clay drying to significant depths with associated 'settlement' movements. The founding depths specified in the Standard may not always be sufficient to avoid settlement of internal footings but have been chosen for economic reasons.

A variety of materials may be used as infill floors to strip footing systems. When selecting floor and wall finishing systems, designers should take account of the potential for differential movement between the floor and the wall.

- *Reactive designs on stable sites*

In some circumstances it may be economical to use a reactive clay design (e.g. a waffle raft) on a Class A or S site.

Selection procedure—Limitations on application

The Standard provides standard designs for a number of different styles of footing. In selecting from the standard designs, it is important to remember that the solutions are intended to cover a range of the systems most commonly used Australia-wide.

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There are distinct limitations on the 'deemed-to-comply' application of these standard solutions and these are listed in the Standard. Some particular points are noted below.

- *Slab size*

Factors that normally are not critical may become so when slabs are longer than 30 m in their longest dimension. Examples are concrete shrinkage and raft action. A more subtle limitation relates to the interaction of slab distortion and stiff roof structures that span the full width of the building, such as trussed a roof. The deemed-to-comply designs tacitly assume that trusses will be arranged to span across the lesser width of the building, which dimension will normally be much smaller than the overall length of the building. The truss span will typically be less than 10 m. If for any reason the trusses are arranged to span the length of the building or if the building is more nearly square in plan, then the standard footing system designs for a given maximum length may not be adequate to limit damaging interactions between the trussed roof and other parts of the building. This circumstance is more likely to arise in buildings of a character other than detached domestic residences.

- *Joints*

The standard slabs systems rely on composite action between the footing and slab components. If the structural integrity of the slab is interrupted by a permanent joint the strength and stiffness of the full section will be less than adequate in most cases.

- *Concentrated loads*

The restrictions relating to wall heights, columns and the like are to ensure that the load limits implicit in the standard designs are not exceeded.

- *Unreinforced masonry arches*

Unreinforced masonry arches are specifically excluded as they are not only physically crack sensitive but they also usually represent an architectural feature and owners have a lower than usual tolerance for cracks in such features.

C3.1.2 Design for single-leaf masonry, mixed construction and earth masonry

Some concessions are permitted in this Clause to allow for the greater strength and improved crack control of reinforced masonry. This Clause is generally expected to apply to the masonry construction typical of the cyclonic areas of Queensland.

C3.1.3 Construction with framed party walls

(No commentary)

C3.1.4 Design for masonry feature walls

Masonry veneer or strip footing buildings may include isolated masonry walls such as feature walls and walls for garages. This Clause permits the use of the masonry veneer slab or footing system with minor local modifications under the wall concerned. If an additional tie beam is required it should be integral with the main footing system to reduce the risk of differential movement.

C3.1.5 Design for outbuildings and extensions to dwellings

The Clause requires articulation at the junction of the extension and the existing building. Articulation may be provided by a full height door or window.

A minor concession is offered in this Clause for clad framed outbuildings and extensions. Design can be used for one class less severe than that required by that site classification. Thus Class M design may be used on a Class H1 or H2 site. For the purpose of this Clause an outbuilding should be limited to 9 m length.

This Clause also permits the use of footings of the same proportions as the main building.

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C3.1.6 Design for rock outcrops

Additional reinforcement can be used instead of expensive excavation of isolated rock outcrops. This provision is also relevant to floaters or isolated detached rocks within the soil profile.

C3.1.7 Design for partial rock foundation

Where a cut and fill or similar condition results in part of a building being on rock and part on natural soil (or controlled fill), then the possibility of minor differential movement exists. To accommodate such movement articulation or strengthening is required.

Where the building is supported over a large area by rock with the balance on reactive clay, there is a potential for severe differential movement and appropriate design changes by a professional engineer will be needed.

C3.1.8 Design for complete rock foundation

(No commentary)

C3.2 STIFFENED RAFT

(No commentary)

C3.3 FOOTING SLAB

(No commentary)

C3.4 WAFFLE RAFTS

(No commentary)

C3.5 STIFFENED SLAB WITH DEEP EDGE BEAM

(No commentary)

C3.6 FOOTINGS FOR CONCENTRATED LOADS

On a reactive clay site it is important that separate footings are not used for concentrated loads because of the possibility of differential movements. Such movements can be tolerated if the structure giving rise to the loads is fully isolated from the rest of the house.

REFERENCES

1 WALSH P.F. *To Beam or not to Beam*. Building Surveyor, 1978. Vol. 2 p.24/26

2 CAMERON D.A. AND WALSH P.F. *Footing Systems and Floors for Houses; Opinions, Experiences and Trends*. CSIRO Division of Building Research Report,1984.

3 WALSH P.F. *The Analysis of Stiffened Rafts on Expansive Clays*. CSIRO—Division of Building Research, Technical Paper No 3, 1978.

4 JUNIPER P.M. AND YTTRUP P.J. *Footing systems for small scale buildings—A new era*. Queensland Master Builders Association, Housing and Construction in the Age of Technology International Conference 1988, Gold Coast, Queensland.

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SECTION C4 DESIGN BY ENGINEERING PRINCIPLES

C4.1 GENERAL

The Standard allows the modification by engineering principles of the standard designs given in Section 3. Footing system design by engineering principles is permitted as a complete alternative to adoption of the designs given in Section 3 of the Standard. With adequate justification, a slightly or completely different footing system could be designed, but this option should not be used unless there are good grounds for changing the standard designs.

The Standard also allows for the design of slabs or footings in accordance with AS 3600. This alternative should only be adopted by engineers who have considerable knowledge of the concepts of soil/structure interaction and of the related structural design procedures.

It is also possible for an engineer to select a standard design without modification. In such case the engineer may judge that some of the limitations in Clause 3.1.1 may not apply. If a footing system is designed by a qualified engineer, that design need not follow any of the structural proportions set out for the standard designs. It is also possible to use engineering principles to extend the applicability of the standard designs or to modify them for special purposes.

The following points relate to the engineering principles involved in the development and modification of the standard designs:

(a) *Stiffened rafts*

The design for stiffened rafts requires the provision of strength and stiffness to control the effects of ground movements so the relative deformations of the raft are within the tolerance limits for the building. A suitable method of design is given in Section 4, although design can also be based on a history of past satisfactory performance. As with strip footings, very deep beams should be avoided, otherwise account should be taken in the design of the factors referred to in Clause 3.5.

The stiffness of the raft relies on the full depth of the beam and slab. Permanent joints in the slab, e.g. control joints for contraction and expansion, reduce the concrete section at the joint location and should not be used unless the raft design makes special provision for the reduction in the effective section.

(b) *Strip footing design*

In addition to the normal requirements of load distribution and limitation of the bearing pressure, the design of a strip footing on reactive clay should take into account—

(i) expected ground movements;

(ii) adhesion on the sides of the footing; and

(iii) differential moisture conditions created by the intrusion of the footing into the soil.

In the absence of more accurate information, the effect of adhesion may be taken into account by considering the loading on the uplifting member calculated according to soil mechanics principles. It is also possible to reduce adhesive soil loads using plastic sheeting.

It has been found that deeper strip footings are not always effective due to Items (ii) and (iii) above and that shallow more heavily reinforced footings may be more appropriate.

The design methods in Section 4 may be useful for strip footings although more often, past satisfactory experience is appropriate.

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(c) *Concentrated loads*

Normally the method of support for concentrated loads will be directly on a beam or footing for moderate loads or on a strengthened beam or footing for heavier loads. The amount of strengthening required for the beam can only be clearly assessed using the beam-on-mound analysis in a design by engineering principles. As a rough guide, loads near the corners should be provided with sufficient support assuming a cantilevered corner over say 2 m. Internal beams may need to be strengthened to provide load transfer to intersecting beams at each end.

(d) *Pier-and-beam, pier-and-slab or pile footing systems*

In addition to the structural design requirements of AS 3600, the design of a pier-and-beam or pier-and-slab footing system should take into account:

- depth of piers to natural or stable soil including allowance for anchorage; and
- provision against uplift in design or isolation of the footing system or superstructure.

Pier-and-beam and pier-and-slab design generally require attention to pier anchorage and isolation of the slab and beams from swelling soil. Piers should be founded in soil at a level unaffected by moisture variation. Piers can have under-reamed bases within stable soil or alternately they may be lengthened in the stable soil to ensure adequate anchoring by skin friction. In either case, the tensile capacity of the pier section has to be carefully considered. The design anchorage requirements may be reduced by requiring piers to be sleeved within part or all of the swelling soil zone.

Isolation of the beams and slabs is difficult to achieve economically. Void formers that rely on degradation of organic products should not be used unless it can be ensured that the material will rot away rapidly. Alternatively, it may be feasible to tie down beams. Where void formers are used, it is essential that the space created does not become a water trap that contributes to soil swelling.

Experiments in Melbourne (Ref. 1) have shown that piles can be very effective in resisting reactive clay movements. Piles can be used as point supports or in combination with beams. The comments on pier-and-beam and pier-and-slab are also relevant to piled systems.

C4.2 DESIGN CRITERIA

The deflection of a footing system should be measured from a straight line joining the ends. This removes the rotational deformation from the determination of differential deflections, see Figure C4.4 a, b and c.

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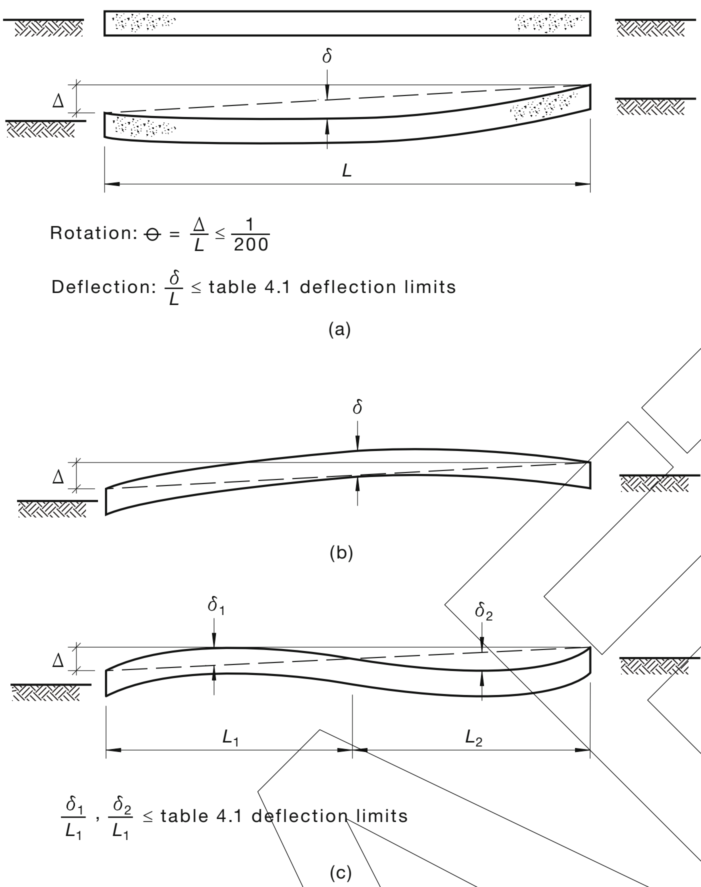

FIGURE C4.2 Measurement of deflection

C4.3 DESIGN OF FOOTING SYSTEMS

(No commentary)

C4.4 RAFT FOOTING SYSTEMS

Table 4.1 provides guidelines for maximum design differential movements for different types of construction. The value selected from this Table should not be used out of context, or have inordinate importance placed on them. Various limitations on these values are—

- The values are for use in footing system design. They do not necessarily refer to a measurement that can be applied to an existing structure.
- The differential movements referred to in this Table are between elements contained within the structure, as measurements of distortion of the frame. A complete footing system may move as a unit, without causing structural distress or serviceability problems.
- While movements stated as a function of span are useful design parameters, their applicability in assessing existing structures is limited. For example, it is very difficult to determine the actual span that is applicable for the formula.

C4.5 SIMPLIFIED METHOD FOR RAFT DESIGNS

C4.5.1 Application

The lines given in Figure 4.1 are derived from the standard stiffened raft footings of Section 3. They can be considered to represent the 'families' of footings for shallow and deep clay profiles. It follows that alternative footing systems that fall on the respective line will perform in a similar manner to the Section 3 footings.

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The inclusion of Figure 4.1 in the Standard is to provide an intermediate tier of analysis, allowing the engineer to interpolate between the Section 3 systems. This procedure is expected to be of value in allowing a rational determination of different beam depth and spacing, of footing needs for different types of superstructure or of sites of particular y_s, without the need for full engineering analysis.

C4.5.2 Modification procedure

Note that the calculation of the stiffness parameter is based on the rectangular beam section, that is, neglecting the flange. This does not cause a loss in accuracy, as the lines are derived from the rectangular sections only of the standard designs.

C4.6 DESIGN OF FOOTING SYSTEMS OTHER THAN STIFFENED RAFTS

(No commentary)

C4.7 FOOTING SYSTEMS FOR REINFORCED SINGLE LEAF MASONRY WALLS

(No commentary)

C4.8 DESIGN FOR PILED OR PIERED FOOTING SYSTEMS

(No commentary)

REFERENCES

1 CAMERON D.A. AND WALSH P.F. *The Pile Experiment*. CSIRO—Division of Building Research Report, 1983.

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SECTION C5 DETAILING REQUIREMENTS

C5.1 GENERAL

(No commentary)

C5.2 DRAINAGE REQUIREMENTS

C5.2.1 General requirements

Defective surface drainage is a common causal factor in reactive clay foundation movement problems. The selection of appropriate site falls and floor levels should be part of the planning and setting out process.

The effective drainage of the site is a prerequisite for satisfactory performance of the footing system, particularly on reactive clay sites. Problems can arise where the landscaping and other finishing earthworks are not part of the builder's contract, even though drainage requirements have been stipulated as part of the footing design.

In such cases, the owner may be directly or indirectly responsible for the completion of the site works. This highlights the need for the owner to be advised of the general requirement for drainage and any particular requirements attached to the footing design.

The selection of slab levels and slab edge details should take account of the subsequent earthworks that may be required to achieve satisfactory drainage of the site. Intractable foundation problems can be created where the floor level is set too low on flat reactive clay terrain.

The finished ground surface must fall away from the perimeter footing. Where this is achieved by filling, the nature and permeability of the filling should be considered in relation to the underlying soil. Figure C5.1 illustrates an unsatisfactory situation that can result where surface falls are achieved by placing sand over less permeable clay. The permeable filling in combination with the back fall in the underlying clay can trap water and allow it to infiltrate into the foundation soils.

The drainage of zero lot line sites may pose special problems. The Committee considered that there is not sufficient experience with zero lot line construction to enable specific requirements to be included in the Standard. It is also recognised that zero lot line construction on reactive clay sites has the potential to create problems that involve a complex mix of technical and legal aspects.

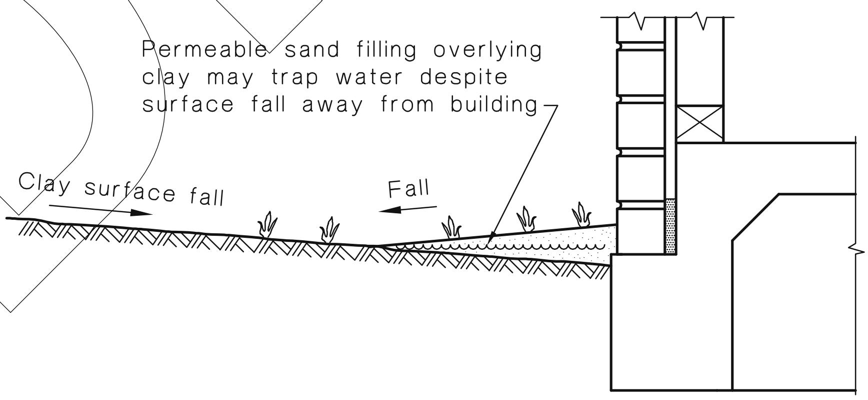

FIGURE C5.1 UNSATISFACTORY METHOD OF ACHIEVING SURFACE FALL AWAY FROM BUILDING

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C5.2.2 Specific requirements for slabs on Class 1 buildings

The freeboard of the slab or height of the slab surface above finished ground is often over-emphasized because drainage of the ground around the slab is far more important, particularly on sloping sites. On low-lying level sites freeboard may be of concern and will certainly be of concern in flood prone areas.

The relative heights of the overflow relief gully, slab and finished ground are intended to stop sewage flooding the building if a blockage occurs, and to prevent rainfall runoff flowing into the sewer. However, this requirement only restricts the freeboard locally. The actual dimensions depend on local plumbing regulations and AS 3500.2, *National Plumbing and Drainage Code*, Part 2: *Sanitary plumbing and sanitary drainage*. There may also be building regulations controlling this aspect.

C5.3 REQUIREMENTS FOR RAFTS AND SLABS

C5.3.1 Concrete

Concrete quality is specified generally in accordance with AS 3600. A concession based on past satisfactory performance is offered for exposed concrete at the edge of the slab and for concrete in external patios in that only N20 grade concrete is required.

The recent recognition of the presence of saline areas, and the need to design for more aggressive soil environments in some locations, impacts on the selection of appropriate concrete grades. (See C5.6.)

C5.3.2 Reinforcement

In the Standard, mesh for slab and beam reinforcement is specified, mainly as a result of experience in most States. Generally, trench mesh is simple to use, can be placed fairly reliably with adequate laps and is easily supported in place. Fitments may be used to hold reinforcement in place but are not required by the Standard.

The builder and Building Authority should be cautious about substituting new forms of reinforcement for conventional steel reinforcement. It should be appreciated that the slab mesh acts not only as shrinkage control but also as structural reinforcement and cannot be replaced by alternative methods on the grounds of equivalent shrinkage control alone. In particular, the claims for polypropylene at the low rates used in Australia were treated with caution by the Committee, and substitution should only be made when adequate provision is made to ensure shrinkage control and structural performance.

Trench mesh overlapping, splicing and minimum cover requirements described in Clause 5.3.2(c) are shown in Figure C5.3.

Clause 5.3.2(d) refers to the lapping of bars in beams at T- and L-intersections. Where the edge and internal beams are not at the same level it is necessary to provide sufficient load transfer across the construction joint. A detail such as that shown in Figure C5.4 would be helpful in avoiding possible weakness of the joint.

C5.3.3 Vapour barrier and damp-proofing membranes

The vapour barrier is a barrier against vapour rising through the air in the soil and otherwise condensing in the slab or being trapped under impermeable floor coverings. It is an important part of construction but the need for it should not be exaggerated. Direct water transmission is best dealt with by effective site drainage, adequate freeboards and good quality concrete, well compacted as it is placed. As the barrier is against vapour, not water, minor punctures are not important. Similarly joints need only to be lapped, not taped. However, intermittent taping is recommended to help to keep the vapour barrier in place.

The BCA now incorporates specific requirements for vapour barriers and damp-proofing membranes. In particular, reference should be made to the NSW and SA variations.

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Experience in Australia has indicated that the vapour barrier may be terminated on the inside of edge beams and at the faces of internal beams. This is permitted by the Standard, where supported by local practice. This concession was intended mainly for two-stage stiffened footing slab construction with very deep (600 mm) beams. For normal slabs and lightly stiffened rafts the vapour barrier should completely underlay the slab, including all beams. It may be terminated at the bottom outside face of the edge beam. Indeed, unless a multiple brick rebate is used and the membrane is not exposed, it seems more satisfactory to terminate the vapour barrier below ground.

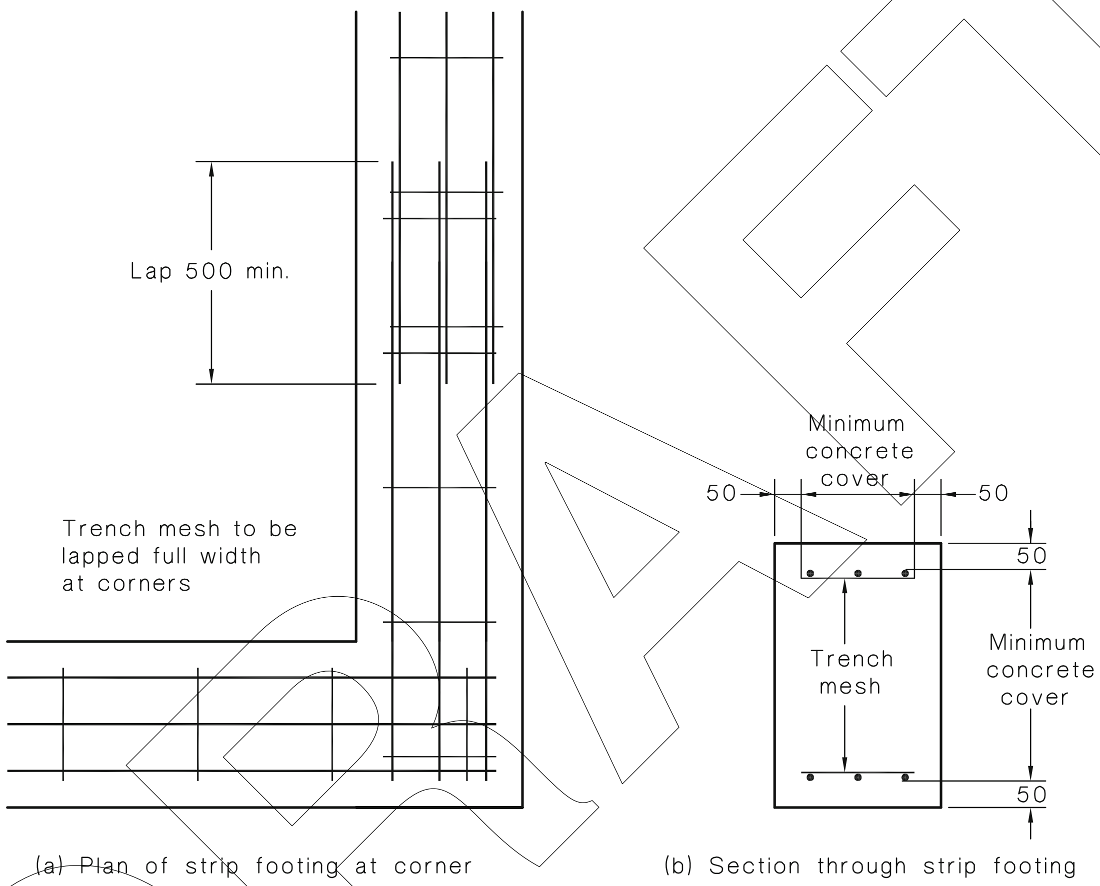

FIGURE C5.3 TRENCH MESH DETAILS

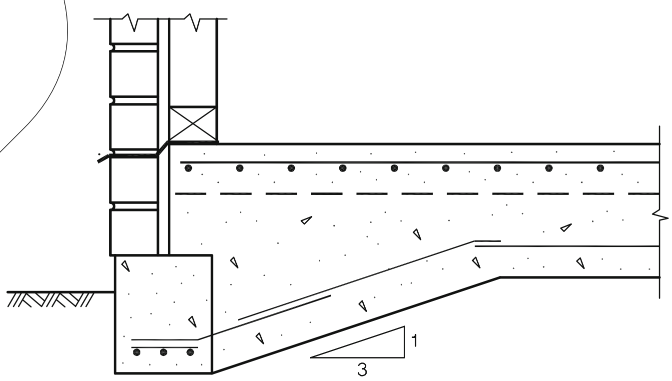

FIGURE C5.4 JUNCTION WHERE EDGE AND INTERNAL BEAMS ARE AT DIFFERENT LEVELS

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Vapour barriers should consist of polyethylene sheet of 0.2 mm minimum thickness. An acceptable level of impact resistance has also been specified for practical construction purposes. Barriers with less impact resistance are likely to be excessively damaged during placement of the reinforcement and concrete.

The answer to most concerns about dampness is proper site drainage and appropriately selected slab levels and good quality concreting practices. In areas such as South Australia that are subject to extreme wetting and drying cycles and where high levels of salts are present (in the soil and building materials) moisture can also migrate by capillary action into the concrete slab and deposit salts at the surface during evaporation.

Continual salt deposits may cause 'salt damp' damage such as powdering and fretting of the concrete or masonry, together with deterioration of floor coverings due to damp and mould. The damp may also cause rotting of timber framing and corrosion of steel framing. The installation of a damp-proof membrane rather than a moisture vapour barrier under concrete slabs will provide a more effective barrier to moisture in these situations.

Where a damp-proof membrane is required it must form a continuous barrier under and around the whole slab and any damage occurring to the membrane during installation must be repaired by taping.

C5.3.4 Edge rebates

The purpose of the rebate is to allow drainage of the cavity and prevent water ingress into the building. Shallow rebates may be trowelled while deeper rebates should be formed.

C5.3.5 Recesses in slab panels

A deepening of the slab soffit is required at recesses to maintain the strength of the slab. The details shown in the Standard (Figure 5.3) apply to slabs with recesses located away from beams.

Recesses may be provided across beams, as long as the beam depth is increased and the beam reinforcement details are amended to maintain equivalent strength and stiffness.

C5.3.6 Heating cable and pipes

(No commentary)

C5.3.7 Shrinkage control

The limitation of shrinkage cracks is a difficult problem in slabs particularly when brittle floor coverings are to be used or if the slab is to act as a termite barrier. In most other cases, shrinkage cracking is not of concern.

The minimum requirements of AS 3600 are just satisfied by the standard meshes specified in Sections 3 and 4, but this level of reinforcement only provides nominal control of cracking. Such control is offered by the tying force exerted across the crack by the reinforcement which keeps the sections of the slab on either side of the crack together and thereby stretches the uncracked section due to elastic and creep extension. Concrete can be expected to shrink by 600 to 800 microstrain for laboratory specimens. After allowing for time and shape effects, for a rectangular house 20 m long this implies a shortening of 12 mm to 16 mm. If the slab was fully restrained and unreinforced the most likely result would be two cracks at 6 m to 7 m spacing, and of 6 mm to 8 mm width, which would be unacceptable. This situation does not occur because the actual slab shrinkage will be less than laboratory values and shrinkage forces actually shorten the overall slab length and stretch the slab panels between cracks.

Even so, cracks up to 1 mm wide may be expected. To reduce the crack widths to negligible proportions would require around 0.6% reinforcement (or more than F81) and would add several hundred dollars or so to the construction cost, hence some cracking is accepted as part of normal slab performance.

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Where crack-sensitive floor coverings are planned, two options are available: use heavier and more expensive reinforcement or delay the installation of floor covering for three to six months until most of the shrinkage has occurred. The use of flexible tile adhesives is very beneficial in increasing the tolerance of tiles to cracking in the underlying slab. Some evidence exists that increasing the mesh in critical areas is beneficial and this practice is encouraged in the Standard. The mesh operates more efficiently to control cracking if it is placed near the top surface and this location is also preferred in the Standard.

The Clause sets out some rules that will moderate, but not eliminate shrinkage cracks.

C5.3.8 Beam continuity in rafts

An important aspect of the structural design of rafts is the arrangement of the internal beams. The following points should be observed:

- Beams should generally be arranged in an orthogonal grid.
- The beams should be continuous in a straight line from edge to edge of the slab. This is more important than putting beams under walls. When beams cannot be placed in a straight line, a maximum deviation of 1 in 3 is allowed.
- For L- and T-shaped buildings the beams should be located to continue the edge beams at the internal corners. Considerable flexibility is allowed in the spacing of the beams. The Standard specifies the maximum spacing for beams and allows an increase in spacing when there are extra beams in the transverse direction. (See Figure C5.5.)
- The beam layout provisions for re-entrant corners do not apply to minor changes in plan such as doorways and protrusions of less than 1.5 m. Special details may be required to maintain beam continuity in these cases. Examples of appropriate details are provided in Figure 5.4.
- When a raft is subjected to foundation movement, the ends and corners are particularly vulnerable areas of the raft structure. This vulnerability should be taken into account when laying out the stiffening beams of a raft. In the absence of engineering design, the spacing between the edge beam and first internal beam should not exceed 4.0 m. (See Figure C5.5.)
- Projecting elements of the house plan such as may occur with portico structures require careful consideration to ensure that they are adequately supported by the raft structure.
- Where stiffening beams are at different levels such as may occur in the provision of beams to support portico columns, or at a step in a raft slab, appropriate provision of reinforcement must be made to provide for full continuity of strength and stiffness through the change in level.

It may also be necessary to take the location of plumbing into account when selecting the beam positions.

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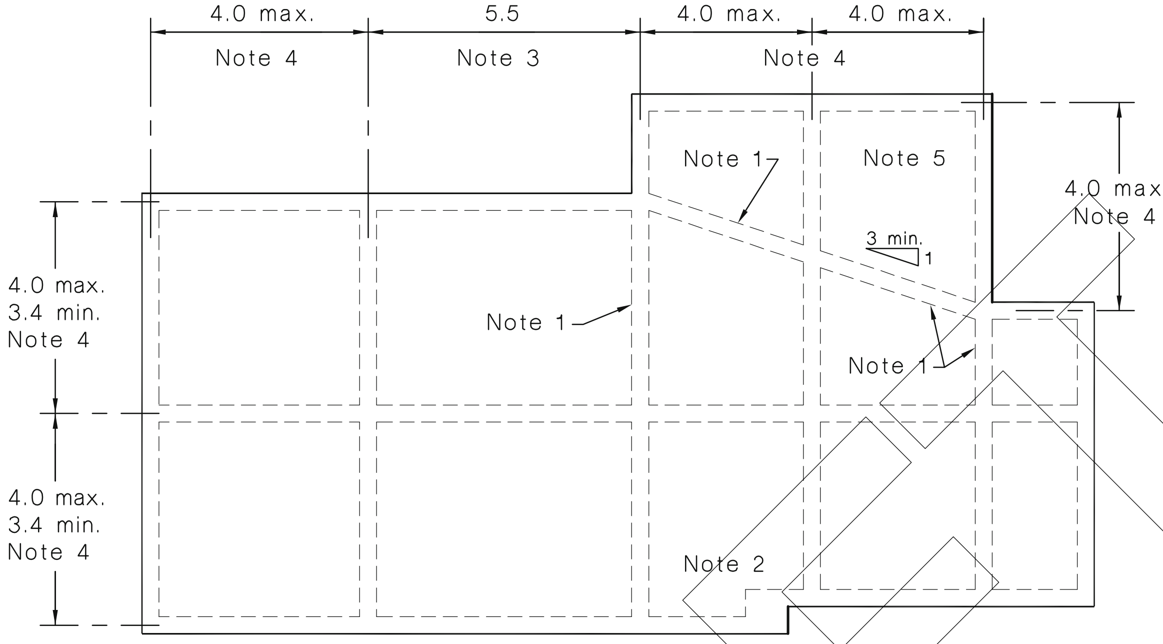

FIGURE C5.5 ARRANGEMENT OF STIFFENING BEAMS

This example is based on a nominal 5.0 m beam spacing.

NOTES:

1 The re-entrant corner has both sides greater than 1.5 m long, and the internal beams are arranged to provide full continuity at the intersection.

2 The re-entrant corner is less than 1.5 m on one side, and continuity has been provided using one of the techniques from Clause 5.3.8.

3 The nominal beam spacing of 5.0 m has been increased by 10%, as the beam spacing in the opposite direction is more than 20% below 5.0 m.

4 The spacing between the beam and the edge beams and the first internal beam should not exceed 4.0 m.

5 The internal beam has been deflected to provide continuity at the re-entrant corners. The deflection is not greater than 1 in 3.

Two-pour raft construction techniques may require special reinforcement details at construction joints. A variant of the two-pour raft construction technique was in common use in Queensland. In this variant, the perimeter edge beams are cast first and then the slab and internal beams are cast in a second pour.

This construction method creates particular difficulties in relation to beam continuity at re-entrant corners such as occurs in ‘T’ and ‘L’ shaped building plans. Special reinforcement details and attention during construction are required at these intersections to ensure that full structural continuity of the beams is achieved. Attention may also be required at ordinary intersections between internal beams and edge beams, particularly where beams of deeper cross-section are used. Figure C5.3 illustrates these issues and shows one of many possible reinforcement detailing solutions.

A related issue in the Queensland two-pour method is that, for various reasons, edge beams may be deeper than the internal stiffening beams. In re-entrant corners this results in the situation where the beam depth changes at the continuation from edge beam to internal beam. Large and abrupt changes in stiffening beam strength and stiffness along the length of a beam are undesirable. In such cases, design modifications to lessen or transition the change in beam cross section should be considered. See Figure C5.6 for an example of this situation.

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C5.3.9 Beam layout restrictions

(No commentary)

C5.4 REQUIREMENTS FOR PAD AND STRIP FOOTINGS

(No commentary)

C5.5 REQUIREMENTS IN AGGRESSIVE SOILS

This Clause is new to the standard.

Exposure to saline soils

Salts exist not only in coastal regions, but are present throughout the landscape, including the drier inland areas of Australia. Sources of salinity include naturally occurring salts from marine sediments, salts released from the process of soil/rock weathering, salts transported from the ocean and deposited by rainfall, or use of recycled 'grey' water containing salts.

Problems with salinity are generally linked to the groundwater system, as water both dissolves and transports the salts through the soil. Saline groundwater can reach the footing system through rising groundwater table levels or by capillary suction of the soil, which may raise water by up to 2 m depending on the soil type (mainly clays).

Salinity can be measured in two ways. The saturated extract electrical conductivity, EC_e, involves saturating the soil with water and then measuring the electrical conductivity. This procedure takes into account the soil texture as the sample is not broken down by mixing with water. Extract electrical conductivity, EC (1:5), is where the soil is mixed with water in the ratio of 1 part soil to 5 parts water and the electrical conductivity is measured. As the soil texture affects the conductivity, conversion factors are then used to estimate the saturated extract electrical conductivity, EC_e, of the actual soil. The latter is a quicker test as the soil is mixed with water and time is not spent waiting for the soil sample to become saturated.

While salinity levels are generally low enough not to have any affect on the concrete, some increase in strength and cover are required for more aggressive soils if the concrete is not protected by a damp-proofing membrane. As noted in Clause 5.5.1, for highly saline soils, it is recommended that both isolation of the concrete from the soil and increased strength and cover requirements be adopted to reduce the risk of damage.

Further information on concrete exposed to saline soils can be found in Guide to Residential Slabs and Footings in Saline Environments published by Cement Concrete and Aggregates Australia.

Exposure to sulphate soils

Naturally occurring sulfates of sodium, potassium, calcium or magnesium may also be found in the soil or dissolved in the groundwater.

The measure of sulfates used in Table 5.2 (expressed as SO_4) is a simplistic and sometimes conservative approach to the definition of aggressivity. It is common to find more than one chemical in the service environment and the effect of these chemicals may be modified in the presence of others. For example, sulfate ions become aggressive at levels of 600 to 1000 ppm when combined with magnesium or ammonium ions. In the presence of chloride ions, however, attack by sulfate ions generally exhibits little disruptive expansion with the exception of conditions of wetting and extreme drying where crystallization can cause surface fretting of concrete.

The chemical concentrations (in ppm) relate only to the proportion of chemical present that is water–soluble.

Where exposure classifications B1, B2, C1 or C2 are indicated in Table 5.2, it is recommended that the cement be Type SR.

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Where exposure classifications B2, C1 or C2 are indicated in acid sulphate soil conditions, it is recommended that a protective coating is used on the concrete surface. If the pH level is below 3.5, specialist advice regarding suitable coatings and other protective measures should be obtained. If a protective coating is used for these exposure classifications, it may be possible to reduce the minimum required reinforcement cover to 50 mm.

Acidic ground conditions may be caused by dissolved ‘aggressive’ carbon dioxide, pure and very soft waters, organic and mineral acids and bacterial activity. Care is required in assessment of pH under ground structure and lifetime conditions since pH can change over the lifetime of the member. Therefore, the pH should not be assessed only on the basis of a present-day test result, rather the ground chemistry should be considered over the design life of the ground structure. Testing for pH should be carried out either in situ or immediately after sampling as there is otherwise a risk of oxidation with time, leading to apparent acidity, which does not correctly represent in situ conditions.

pH alone may be a misleading measure of aggressivity without a full analysis of causes (e.g., still versus running water).

Contamination by the tipping of mineral and domestic wastes or by spillage from mining, processing or manufacturing industries presents special durability risks due to the presence of certain aggressive acids, salts and solvents, which can either chemically attack concrete or lead to a corrosion risk. Certain ground conditions cannot be properly addressed by reference only to Table 4.8.1. These conditions include, for example, areas where acid-sulfate soils exist, contamination by industrial and domestic waste, or spillage from mining, processing or manufacturing industries. In the absence of site-specific chemical information, the exposure condition should be assessed as ‘exposure classification B2’ for domestic refuse and ‘exposure classification C2’ for industrial/mining waste tips. Chemical analysis of the latter may, however, allow a lower risk classification.

Further information on concrete exposed to sulfate soils can be found in Commentary to AS 3600.

FIGURE C5.4 FIGURE PENDING

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C5.6 ADDITIONAL REQUIREMENTS FOR CLASS M, H1, H2 AND E SITES

C5.6.1 Masonry detailing

Considerable care is required on the more reactive sites to minimize the risk of damage, through both careful detailing of the design of the building and thoughtful construction procedures. In particular, masonry should be articulated and susceptible masonry structures avoided. For example, masonry over doors and windows, and in wing-walls and arches should either be avoided or detailed in accordance with TN61. Alternatively, masonry may be reinforced to control cracking.

C5.6.2 Variations in foundation material

Isolated outcrops of rock may be simply removed. Alternatively, the footing depth may be reduced and the footing stiffness maintained, despite a resulting reduction in section, by the use of substantially more reinforcement.

C5.6.3 Drainage requirements

Trenches for service piping may introduce water into the subsoil beneath a building. Backfills are usually highly permeable relative to the surrounding clay soils.

Therefore the surface of the backfill within the vicinity of the building should be 'sealed' to reduce moisture ingress. Additionally, the base of the trench should be sloped away from the building, to drain any water away.

Subsurface drains should be avoided near the footings, where practical, as they can introduce water to the foundation if the drains become blocked. However it is recognized that such drains may be essential behind steps in slabs or for the relief of subsurface water flow. The base of the subsurface trench should be capable of providing some drainage away from the footings in the event of the main drain becoming blocked.

C5.6.4 Plumbing requirements

Drains that pass through footings are required to be wrapped with closed cell foam so as to allow movement between the pipe and the footing. Particular care and vigilance is required to ensure that the lagging is arranged to ensure that concrete, as it is poured, cannot creep around the ends of the lagged section and thereby form a close fitting collar around the pipe, which defeats the purpose of the lagging.

Plumbing and drainage under the slab should be avoided where possible.

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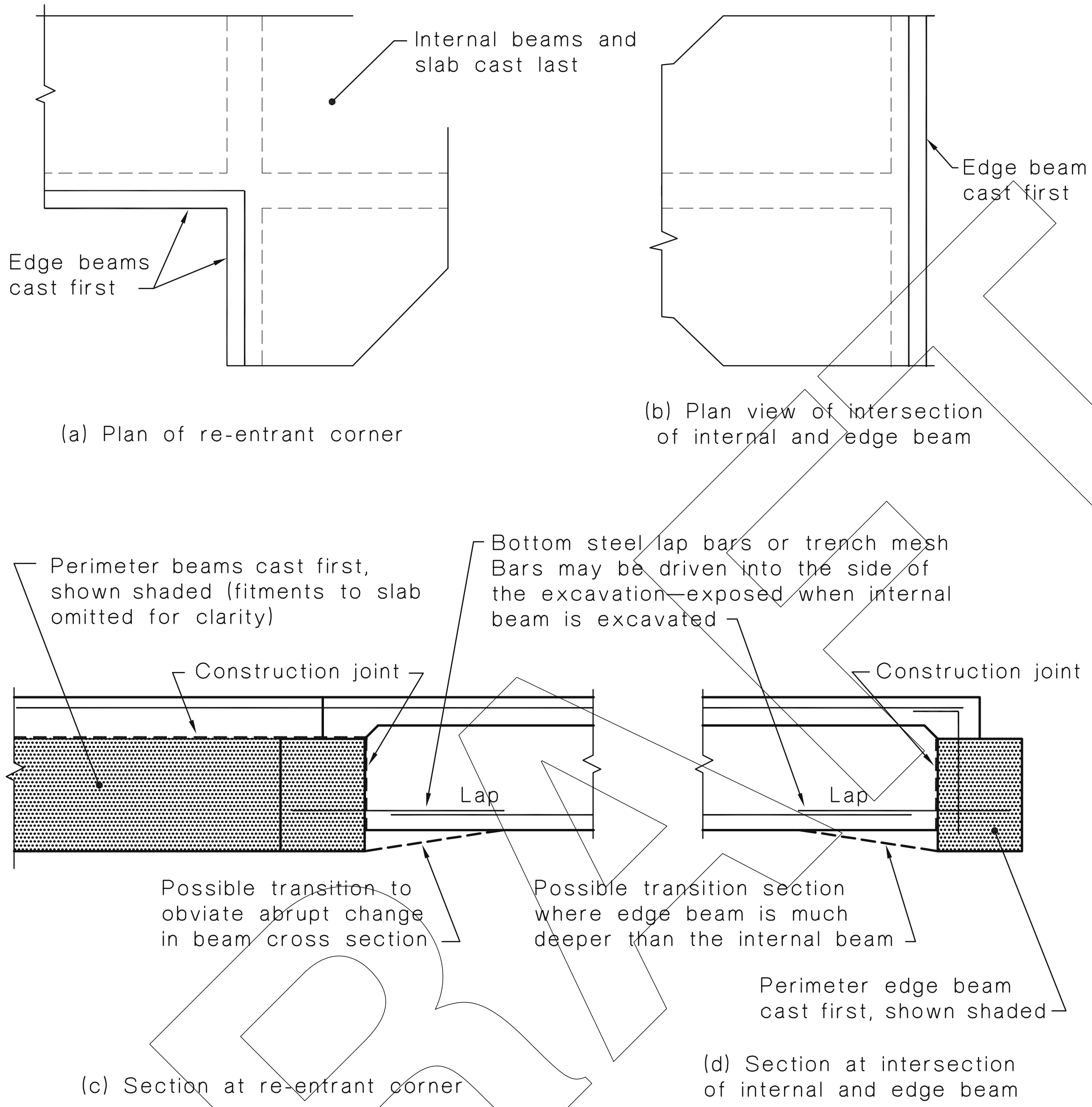

FIGURE C5.6 EXAMPLE OF INTERSECTION OF INTERNAL AND EDGE BEAM

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SECTION C6 CONSTRUCTION REQUIREMENTS

C6.1 GENERAL

The construction requirements are set out in Clauses 6.2 to 6.5 with some extra requirements for Class M, H1, H2 and E sites stated in Clause 6.6.

For durability AS 3600, *Concrete Structures Code*, requires 3 days initial moist curing. The Committee for slabs and footings carefully considered curing and decided that the only durability condition that would definitely require curing was moisture penetration from the edge of the slab. This seems to be a problem mainly encountered in Adelaide where some of the soils are high in salt. Under such circumstances curing is required by Clause 6.4.7. Otherwise normal building practice is expected.

Table 5.3 sets out the minimum strength and curing requirements for concrete for a range of exposure classifications.

Compaction by a vibrator is recommended for Class H1, H2 and E sites.

Temporary service excavations can remove support from footings. This lack of support can result in settlement or rotation of the footing.

Excavation location and depth should be such that the excavation is not deeper than the critical depth line shown in Figure C6.1. The critical depth line can be lowered, if required by lowering the founding level of the footing.

When trenches are to be excavated below the critical depth line, the critical backfill area should be backfilled with material of adequate strength and low permeability to minimize water migration and settlement. Concrete, mortar or (preferably) cement stabilized soil can be used.

Propping may be required to the sides of excavations to ensure safe working conditions and to maintain the integrity of the foundations.

C6.2 PERMANENT EXCAVATIONS

(No commentary)

C6.3 TEMPORARY EXCAVATION

(No commentary)

C6.4 CONSTRUCTION OF SLABS

C6.4.1 General

For Class H1, H2 and E sites the recommendations in Clause 6.6 are essential to ensure the satisfactory performance of the building and footing system and should not be overlooked.

No specific provisions are made about the placement of services beneath the slab, but experience and good practice have shown that—

- services should be bedded on, and backfilled with, properly compacted material which is compatible with the natural material on site;
- services running parallel with edge or internal beams should not be positioned beneath these beams;
- beams through which services pass may need to be locally deepened and may require additional reinforcement (see also Clauses 5.3.2(e) and 5.4.2(e)). The pipe or conduit should be wrapped with void-forming material; and

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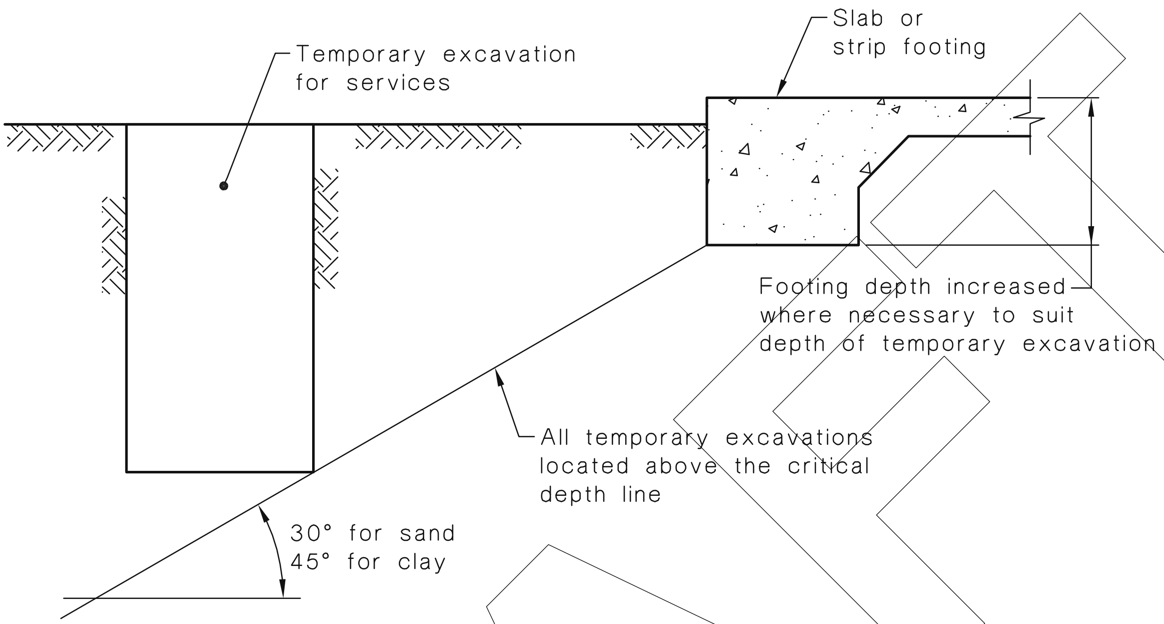
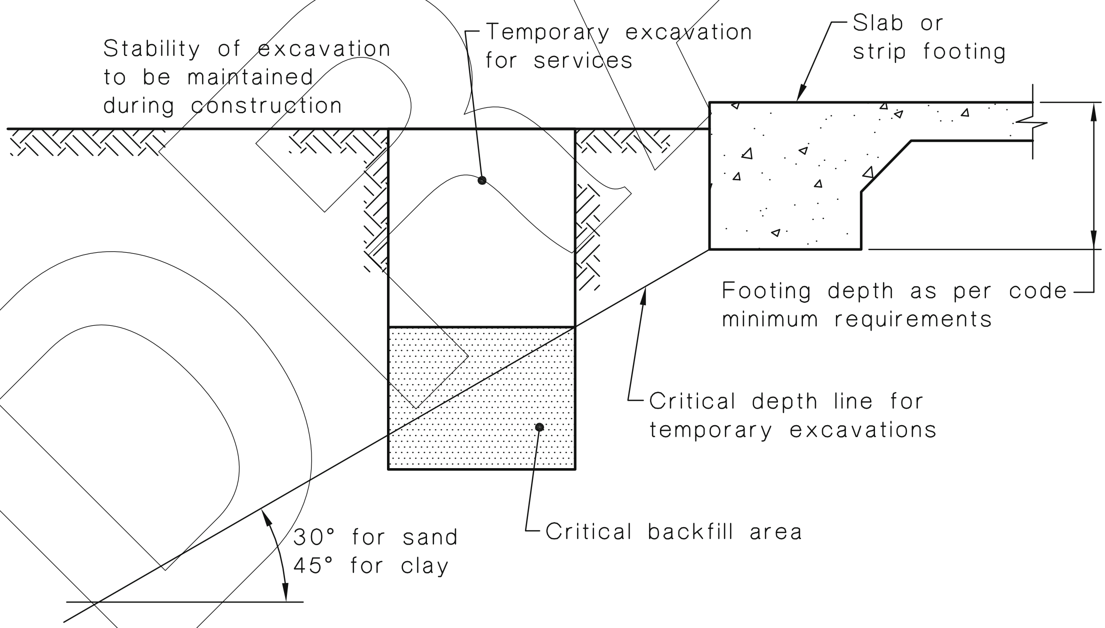
- services should not rise vertically through beams. If such risers are unavoidable, beams may need to be locally widened and may require additional reinforcement. The riser should be wrapped with void-forming material.



(a) Excavation above critical depth line



(b) Excavation below critical depth line

FIGURE C6.1 TEMPORARY EXCAVATIONS

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C6.4.2 Filling

The method of compacting fill depends on the depth and type of fill.

Sandfill, up to a compacted depth of 600 mm, may be compacted by repeated rolling with the wheeled or tracked excavator being used on site. Such fill is termed rolled fill. This depth may be increased to 800 mm if the compaction is achieved by means of a vibrating plate or vibrating roller, and provided that the material is placed in layers having a depth of not more than 300 mm. The fill is then designated as controlled fill. For compacted depths greater than 800 mm, the sandfill should be subject to control and testing. Large depths of controlled sand, gravel and rocky fill have been used beneath buildings without problems.

Clean sands may be compacted by flooding but this method is rarely reliable and the final result should be checked by compaction tests. Moreover, swelling problems could be caused on reactive clay sites by the introduction of water to the foundation. On clay sites this method of compaction is not recommended.

Generally clay fill should be avoided unless great care is taken. The permitted depths for clay fill are less and the moisture content should be checked to ensure the clay fill is placed and compacted in a moist condition.

C6.4.3 Foundation for slabs

The preparation of a foundation for a slab involves attention to a variety of matters including the following:

- *Top soil* The usual statement for top soil 'containing significant organic matter' is made more specific by reference to grass roots. If the site includes shrubs and small trees, the soil containing their surface roots should be removed. On the other hand, it is not necessary to remove soil containing small amounts of root material.
- *Erosion* Erosion is generally only a problem for sandy soils and can be a serious design consideration near beachfronts or on filled sloping sites. On sites subject to erosion by wind or surface water, edge beams should be protected by one or more of the following methods:
    - Grading the ground surface to limit the catchment area adjacent to a building to less than 100 square metres.
    - Providing a drainage system that prevents run-off adjacent to the building.
    - Providing a 600 mm wide concrete path around the building.
    - Founding the edge beams at least 300 mm below the finished ground level.
- *Allowable bearing pressure* An allowable bearing pressure of only 50 kPa is required under slab panels and beams, with the exception of separate footings of footing slabs where the requirement is 100 kPa. Virtually all natural soils should be able to provide 50 kPa.

It is also permissible to found the internal panels and beams of slabs on fill in accordance with Clause 6.4.3(c)(ii). It is not necessary to excavate through the fill to support the internal beams. Where controlled fill is used, even the edge beams may be founded on fill in accordance with Clause 6.4.3(c)(iii). However, with shallow depths of fill it will be more often convenient to found the beams in natural soil.

- *Base slope of beams* The base of edge beams and footings may be sloped or stepped. The slope is restricted to 1 in 10 although lateral stability will often be provided by slab membrane action and beams across the slope.
- *Bedding sand* The layer of bedding sand is not a requirement but a construction convenience. On rough ground it does help to protect the membrane and on most sites it reduces wastage of concrete due to over-excavation. Bedding sand is required for

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aggressive soils to protect the membrane from puncturing (refer to Clauses 5.5.2. and 6.4.3(e)). It is not recommended under edge beams on reactive sites.

C6.4.4 Treatment of sloping sites

Most sites include some slope and although it is convenient to illustrate the prescribed designs for flat sites, often modifications for sloping sites will be needed.

For moderate slopes the edge beam can generally be deepened and a very deep edge rebate can be used. For steeper slopes controlled fill past the edge of the slab may be useful. Footing slabs are particularly relevant for sloping sites, and with an appropriate retaining wall can accommodate significant differences in level. The compaction of the fill behind the wall needs to be carefully carried out or the wall may be damaged. Since a 100 mm thick slab can span up to a distance of 1 m, moderate compaction may be accepted for only the first metre inside the perimeter wall for a depth of fill up to 1 m. For depths of fill over 1 m, complete compaction is required and temporary propping of the wall during compaction may be necessary unless proved otherwise by engineering design.

For very steep sites the slab may need steps to accommodate changes in level.

Many of the details such as steps and edge retaining walls have an influence on stiffened raft performance, and care should be taken on reactive sites. For example, the beams must be structurally continuous through the step and where retaining walls are introduced, the slab and footing should be tied together.

For steep slopes, the effect of cut and fill on the possibility of landslip should be considered.

C6.4.5 Retention of fill under slabs for Class A, S and M sites

Some simple prescribed systems are given, but other engineered designs are feasible.

C6.4.6 Fixing of reinforcement and void formers

(No commentary)

C6.4.7 Placing, compaction and curing of concrete

(No commentary)

C6.5 CONSTRUCTION OF STRIP AND PAD FOOTINGS

Many of the details given above for construction of rafts and slabs are also applicable to the construction of strip and pad footings.

C6.6 ADDITIONAL REQUIREMENTS FOR MODERATELY, HIGHLY AND EXTREMELY REACTIVE SITES

(No commentary)

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APPENDIX CA

FUNCTIONS OF VARIOUS PARTIES

(No commentary)

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APPENDIX CB

FOUNDATION PERFORMANCE AND MAINTENANCE

(No commentary)

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APPENDIX CC

CLASSIFICATION OF DAMAGE DUE TO FOUNDATION MOVEMENTS

Appendix C describes a system of damage classification that is used in Clauses 1.3 and 2.2. The Appendix is also intended for use in the description of damaged buildings.

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APPENDIX CD

SITE CLASSIFICATION BY SOIL PROFILE IDENTIFICATION—VICTORIA

The maps in Figures D1 and D2, Melbourne and environs and Victoria respectively, show the depth categories of design suction change, Hs, based on general climatic zones.

Where Table D1 gives a classification choice and the site to be classified is within 1 km (in the Melbourne map) of a more severe depth category, consideration should be given to using the higher classification choice. The higher classifications are generally associated with the more arid regions to the west of Melbourne.

Clay profiles derived from limestones, marls or highly calcareous sediments cause greater ground movements than indicated by the plasticity values. There are indications that in these profiles the 'reactive depth' (H_s) is deeper than that stated in Table D1. This may be due to their open fabric causing a deeper water penetration and evaporation. Although the classifications in Table D1 are an attempt to consider this effect, it is advised that local knowledge and expert professional advice be sought.

The classification of the quaternary alluvials and tertiary sediments profile (Table D2) depends on the depth of silts or sands covering the clay and the type of clay. Where the covering depth exceeds of the depth, H_s, for that climatic zone an 'S' classification may be used.

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APPENDIX CE

STUMP PAD SIZES, BRACED STUMP UPLIFT HORIZONTAL LOAD CAPACITY

(No commentary)

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APPENDIX CF

SOIL STRUCTURE INTERACTION ANALYSIS FOR STIFFENED RAFTS

Edge heave is usually a transitory phase that may occur before centre heave becomes established. The depth of moisture change leading to edge heave is likely to be similar to the depth of seasonal movement rather than the design depth of suction change H_s. The latter depth is usually greater than the depth of seasonal movement, particularly in semiarid regions.

In recognition of these differences, the formulae for edge distance, *e*, and mound exponent, *m*, depend on both *Y*m and *H*s for the case of centre heave, but only on *Y*m in the case of edge heave.

Thus, in the case of centre heave, the form of the mound shape depends on climate, whereas in edge heave, the mound shape is only dependent on *Y*m.

Therefore, while the shape (given by either *e* or *m*) of the centre heave mound has been related to H_s and Y_m, the shape of the edge heave mound has been assumed to be independent of H_s, and therefore, the prevailing climate.

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APPENDIX CG

DEEP FOOTINGS

(No commentary)

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APPENDIX CH

GUIDE TO DESIGN OF FOOTINGS FOR TREES

CH1 LIMITATIONS

(No commentary)

CH2 DEFINITIONS

(No commentary)

CH3 MAXIMUM DESIGN DRYING DEPTH

(No commentary)

CH4 THE PROPOSED DESIGN PROCEDURE

INTRODUCTION

This Appendix is concerned with the design of new buildings for the potential drying effects of existing or proposed trees planted in the vicinity of the dwelling, concurrent with, or after the construction of the dwelling.

As such, trees are expected to exacerbate centre heave deformations by contributing to soil drying (and hence shrinkage settlement) below the edges of buildings, but are not expected to impact adversely on edge heave deformations. Therefore only centre heave design needs to be modified to take account of 'new trees'.

Nevertheless, designers must be aware that trees removed prior to construction will provide an initially extreme soil moisture condition, outside the scope of AS 2870. As moisture is slowly regained beneath the new construction, swelling movements may be exacerbated in the vicinity of the removed trees, which depending on the locations of the trees, could impact adversely on either or both centre and edge heave. To counteract this extra swelling, deep soaking may be conducted in boreholes across the site, prior to construction. Surface soaking is unlikely to provide significant benefit, except on very shallow soil profiles. Soaking may be required over a period of six to twelve months and so may not be practical on many sites. Ground movements and soil moisture (or suction) profiles must be monitored to verify effectiveness of soaking for any benefit to apply in the footing design.

When a building is sited near large mature trees, the possibility of death of any of the trees should be considered and the subsequent rebound of the soil in the vicinity of the trees be taken into account in the design of the footing.

If trees exist on a site, which cannot be regarded as forming a group, then the influence of each tree should be designed for and due regard be given to the locations of the trees with respect to the plan of the building and the potential movement patterns across the whole site.

DESIGN OF BUILDINGS FOR TREE DRYING OF THE SOIL

The Standard provides one approach to design of footings, which has proved to be effective in South Australia. The method is a botanically naive method, relating the potential for movement simply to the distance away from the trees, relative to the height of the tree. The height of a tree may be the height at the time of site investigation, unless a written statement is received from the client suggesting the expected tree heights.

The species of tree, leaf area, and site environment are all important factors which may impact upon the potential for soil shrinkage settlement due to an active root system. Although these complexities have not been considered in the design method, the method has been successfully applied over the last 15 years in South Australia.

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The assumption that the extent of roots is only related to tree height is a simplification. The extent of the root zone may be influenced by climate, because greater water availability in wetter climates should better satisfy tree water demands and reduce the extent of root distribution.

The wilting point suction concept is useful in realizing where trees roots must extend to in order to find water in the soil profile. Seasonably dry soil will often be too dry in the top metre or so to release any water to the vegetation throughout a year. Therefore the roots must feed more deeply to survive, especially in a semi-arid or arid climate. Although the restriction of drying imposed by the concept of a wilting point is followed, a simplified approach has been adopted, which does not extend the depth of movement past four metres and assumes that trees can affect design suction changes from the surface downwards. A more accurate reflection of tree drying effects would be afforded by the suction change distributions illustrated in Figure CH4.1. Further information on the method of assessment of tree induced movement can be found in Cameron (2001) and Cameron and Beal (2007) (Refs 1 and 2)

A further simplifying assumption is that mound shapes are only affected by an increase of the differential mound height, γ_m. Accordingly, the edge distance is increased but not to the degree that might be expected. Offsetting this simple approach, tree influence is considered to occur on both sides of the building, whether or not trees exist on both sides.

FOOTING SYSTEMS

Stiffened raft systems have been used successfully with this design approach. However, well-designed deep piling floor systems, with piling founded well below the depth of drying, can be extremely effective against soil shrinkage, although generally, these systems are a costly alternative when based on construction costs alone.

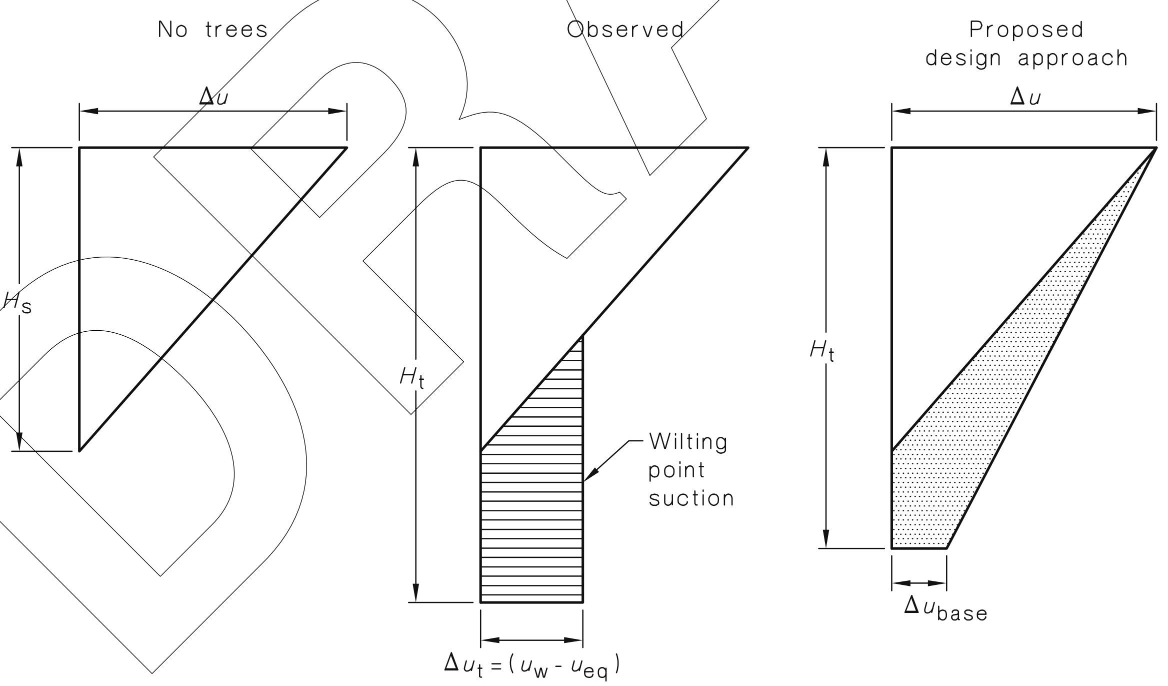

FIGURE CH4.1 DESIGN SUCTION CHANGE DISTRIBUTION WITH DEPTH FOR TREE DRYING EFFECTS INCORPORATING THE WILTING POINT CONCEPT

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DESIGN EXAMPLES

The following examples assume a deep soil profile with uniform reactivity to moisture change and only concern design for trees for centre heave deformation (or edge drying).

Example CH4.1:

Site classification *H–D*, y_s = 65 mm

$\therefore\ y_m$ = 45.5 mm (centre heave) and 32.5 mm (edge heave)

Single tree, *D*/HT = 0.64

$y_{t\ max}$. = 22.8 mm

D_i/HT = 1.0

$\therefore$ from Equation H4, y_t = $(1-(0.64 - 0.5)/((1.0/1.0) - 0.5))\ y_{t\ max} = 0.72 y_{t\ max}$.

$\therefore\ y_t$ = 16.4 mm

$y_{m\ tree}$ = $(0.7\ y\ + y_{\ t})$

= 45.5 + 16.4

= 61.9 mm

Design footing for:

$y_{m\ tree}$ = 61.9 mm (centre heave) and 32.5 mm (edge heave)

Example CH4.2*:*

Site classification M–D, γ_s = 35 mm

$\therefore\ y_m$ = 24.5 mm (centre heave) and 17.5 mm (edge heave)

Group of trees, D_t/HT = 0.7

$y_{t\ max}$. = 21.9 mm

D_i/HT = 1.5

$\therefore$ from Equation E1, γ_T = $(1 - ((0.7)-0.5) / (1.5/1.0)-0.5)\ y_{t\ max}. = 0.8 y_{t\ max}$.

$\therefore\ y_t$ = 17.5 mm

$y_{m\ tree}$ = $(0.7 y_s + y_t)$

= 24.5 + 17.5

= 42.0 mm

Design footing for:

$y_{m\ tree}$ = 42.0 mm (centre heave) and 17.5 mm (edge heave)

These examples do not consider the case of tree removal. With removal of a tree, depending on the location and circumstance, the effect of the tree y_t may be additive to either the centre heave or edge heave design cases.

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The impacts on design of the raft slab footings in these two selected cases using the Walsh method of analysis and assuming typical articulated masonry veneer construction are compared in Table CH4.1. Both internal and external beams are assumed to have the same depth, D and the beam spacing is kept consistent between the analyses.

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TABLE CH4.1
COMPARISON OF DESIGN REQUIREMENTS

Example	Bam depth mm	Slab mesh	Top reinforcement	Bottom reinforcement
CH1 No tree	475	SL72	3N12	3N12
CH1 With tree	600	SL72	2N16	3N16
CH2 No tree	300	SL72	1N12	3N12
CH2 With group of trees	500	SL72	3N12	3N12

REFERENCES

1 CAMERON, D.A. (2001) *The extent of soil desiccation near trees in a semi-arid environment* Int. J. Geotechnical and Geological Engineering. Vol 19 No.'s 3 and 4, pp 357-370, Kluwer Academic Publishers,

2 CAMERON, D. A. and BEAL, N. S. (2007) *A method for evaluating the influence of trees on expansive soil movement in light of case studies from SE Queensland* Proc. 10th ANZ Conference on Geomechanics, Common Ground, Brisbane, Oct 2007. Vol 2, pp 200-205.

CH5 ALTERNATIVE DESIGN METHODS

FOUNDATION AND FOOTINGS SOCIETY OF AUSTRALIA METHOD

Impact of trees on footings

An investigation of the effects of the activity of tree roots with respect to footing performance requires a multi-disciplinary approach involving Geotechnical and Structural Engineers and Arboriculturists. This Practice Note has been written in consultation with senior members of the arboricultural (ISAA) and housing geotechnical industry (FFSA) and provides guidance to reduce the risk of foundation movement and better footing designs in the proximity of trees.

The investigation method outlined here is loosely based on a method of distinguishing the 'aggressiveness' of trees in Clay profiles advanced by P. G. Biddle in the U.K. (Tree Root Damage to Buildings Volume 1 and 2). There are a number of variations from 'Biddle's' methods however, which include a greater number of tree factors to calculate the 'Tree Effect' distance. The reduction of the founding depth, as the distance from the tree increases is similar to that of 'Biddle', but is more conservative to allow for Australian soil, climate and more aggressive native trees. The method presented here is based on many years of combined observations and soil profile and testing of distressed buildings by some of the most experienced Engineers, Geologists and Arboriculturits in the housing industry. The growth of tree roots and their effects on infrastructure is difficult to quantify, therefore it is advised the method outlined below is used with care and should be supported by an inspection by an experienced arboriculturist specialising in tree root growth.

In Figure 1 the distances TD1 and TD2 are equal. The sum of these distances is referred-to as the Tree Effect Distance (TED) and is measured from the edge of the tree canopy nearest to the building site in question. Clayey profiles that are within the TED may experience 'Abnormal Moisture Condition' (AMC) as defined in AS2870 during the life of the tree(s).

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Arboriculturists have found that the water up-take by trees is mainly related to:

- Tree species.
- Tree Health of the tree(s).
- Growth stage of the tree(s).
- Total leaf area.
- Height of the tree(s)
- Root and trunk mass.
- Soil type.
- Climate.

In their advanced growing stage trees require more water to construct their 'frame' than they do in maintaining their frame after maturity.

Structural roots are concentrated nearer the trunk of trees, whereas 'feeder' roots extend well beyond the drip-line (edge of the canopy) and follow the moisture gradient in soil or continuous water paths such as leaky drains or aquifers. The fine, fibrous, feeder roots draw most of the soil moisture and also store it together with the root and trunk mass. Reactive soils extend this moisture gradient well beyond the extremity of the roots by the action of soil suction, causing the ground to dry and shrink well beyond the end of the root system.

Calculation method for 'tree effect distance' (TED)

Introduction

The calculation method presented is mainly directed at determining the area of land around tree(s) that is affected by the tree drying effect and possible 'rebound' if the tree(s) are removed. Some recommendations are made for possible 'ys' and appropriate footing systems within the TED but no advice is given for building within the canopy of tree(s) since this is considered the most difficult prediction area. Where tree(s) have been recently removed, the problem of soil surface 'rebound' should be considered by the designing engineer (even when the trees are not on the subject land).

Tree characteristics

Canopy and water uptake

The total leaf area is an important factor in the amount of water up-take of trees. Trees with a large total leaf surface are high water usage trees. The larger the total leaf area the greater the water requirement and transpiration. In Table 2 the effect of the total leaf area is considered by the tree score in 'Canopy Density and 'Tree Height'. The canopy density is assessed as follows:

- A canopy that shows very little background light is classed as DENSE.
- A canopy that shows a majority of background light is classed as SPARSE.
- The in-between (≈50% light) canopy is classed as MED-DENSE

There are many varieties of tree height within each species and in different soil types and climates. The shape of the leaves also need to be considered in assessing the total leaf surface area. Pinus Radiata have numerous needle-like leaves, Cypress Pines have dense scaly needles, Melaleucas have varying leaf shapes but all these trees have a dense canopy.

There are many trees that have a small foliage area relative to their height and vice versa. Hence, their water need is not necessarily proportional to their height. However the taller trees develop a higher root suction to draw moisture to the top of their crown and therefore have a greater water up-take capacity. Some trees have seasonal dormant periods (e.g. deciduous) during which time they require less water. Others are capable of reducing their

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water need during long dry periods (e.g. eucalypts) and some are capable of storing water during the wet season (e.g. Boab) while others (e.g. Melaleuca) steadily draw moisture from the soil in all seasons.

Exceptions

Some trees have a very large leaf area but not a dense canopy (e.g. Norfolk Island Pines, Moreton Bay Figs and London Plane). These and similar trees should be given the highest canopy and height score (3 + 3) since their total leaf area is large. Trees such as Pencil Pines and Chilean Willows have dense, tall but narrow canopies therefore the canopy and height score is 2 + 2. Plants such as Palms can draw a considerable amount of water and although they generally grow in sandy soils they can also flourish in open-structured and low plasticity clays. Their root system is very dense but rarely grows beyond the edge of their canopy. Where the root ball of the larger species grows very close to shallow footings they have the capacity to lift light structures purely by increasing the soil and root ball volume.

Tree height

Tree height alone is not a good guide to the drying effect of trees in clay profiles. However, taller and more massive trees require more water to maintain their trunk and branches, hence some trees with a large structure but sparse canopy may require as much water as trees with a smaller structure but denser and larger canopy. In the tree score, the height of tree(s) is considered but does not dominate the calculation of the TED. It is difficult to predict the mature height of trees hence a conservative approach and/or an expert arboriculturist is required.

Stage of growth

This section scores trees with respect to their root growth. The rate of root growth is dependent on the life stage of the tree, its health, water need and availability of oxygen and nutrients. A healthy young tree will develop its roots much faster during its early growth than after maturity. Any large species at an immature stage of growth should be given a score of 2 for this section.

Drought tolerant trees

Trees that have evolved in dry continents developed higher suction potentials, which allow them to continue to draw moisture even from relatively dry soils. Some trees have a type of dormancy during droughts allowing them to survive when there is very little water available. These trees are more likely to cause clay shrinkage than other trees even during droughts and their tree score in this section is 2. Many of these trees are well known for their drought resistance, however when in doubt, an expert arboriculturist should be consulted.

Ground and site conditions

Deep fill

Trees growing in filled ground often grow their roots preferentially along the soil layer interfaces therefore they spread their roots at a greater lateral distance than in most natural profiles. The soil interfaces have more oxygen and water and allow the roots to grow more easily. In these conditions the score is 2 for this section.

Adverse conditions

Adverse conditions encourage root growth preferentially towards buildings or greater lateral root growth than normal e.g.:

- Pavements or other covers between the tree and the building.
- A wet garden or leaky services near the building footings.

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- Highly expansive clay over shallow rock.
- Disturbed ground or excavations near building footings.
- Vertical and lateral clay shrinking due to a moisture gradient from the foundation soil to the tree.

Other 'Adverse Conditions' may also be identified and advice sought.

Soil profile effect

Clayey soils have more constant water content than sandy soils. In dry conditions tree roots will grow through the sand in search of a more constant water reservoir. In dense and highly reactive soils roots grow in the fractures where there is more oxygen and water vapour. The high suction in the dry clay nearer the tree draws moisture well beyond the limit of the roots and creates moisture transference towards the tree. This often causes lateral and rotational movements of paths and non-integrated footings as well as settlement. In the clays with a higher reactivity a larger area of moisture gradient is created. Soils with a more open structure, such as top soils, layered clay fill or calcareous clays allow easier root growth than dense uncracked clays. In multi-layered soils the roots will grow preferentially along the top of the most impervious layers where water flows or collects, e.g. where fill overlies a more impervious layer, where sand overlies clay or where clay overlies rock. Soft and highly fractured rock also encourages deep root growth but with very little foundation effect.

Climate effect

The availability of water has a major effect on the extent of tree root growth. Clayey soils have a 'reservoir' of water that can help trees to survive during dry periods, however in very dry arid climates some of this soil moisture is locked in the clay by the action of soil suction. At suction values of 4.2 – 4.5 pF (i.e. 'Tree Wilting Point') clays can have up to 10%-15% water content which is not available to trees.

In wet climates more soil water is available therefore trees rarely need to extend their roots to any great distance from the trunk other than for their stability.

In temperate climates there is sufficient water available other than in droughts. During drought times they can cause considerable damage by extending their roots into new territory and particularly if closer to structures, services and watered garden beds close to buildings.

In dry climates, trees struggle unless close to a permanent water source. Those that survive usually extend their roots to greater depths rather than greater distances. Clayey soils in dry climates are often highly fractured allowing tree roots to grow preferentially downwards along the fractures to soil that is more moist and has a lower suction value.

In arid climates trees are scrubby and survive on very little water, either from scarce storms, mist or from water that condenses on the ground and around surface roots overnight.

Climate Zones 4 and 5 are considered similar to Zone 3 since the root growth is more likely to be downwards rather than outwards hence the engineer should consider a higher 'ys' nearer the tree than stated in Fig. 1.

Pipe leaks and garden watering effects

Garden watering patterns or development of leaks will have a considerable effect on the behaviour of trees. The designing engineer must consider these effects and discuss them with his client.

The establishment of a garden in dry, 'virgin', clayey allotments will change the soil moisture patterns and attract the root growth of trees. If building in clayey sites is carried

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out in drought conditions subsequent foundation heave is more likely. The soil areas around leaky drains or roof gutters will attract roots because of the availability of water, oxygen and disturbed soil for easier root growth.

Neglect of garden watering or water restrictions (which often coincide with droughts) will cause trees to extend their roots into new areas and particularly near well-watered gardens or infrastructure. The disturbed ground near deep continuous footings and drains is particularly attractive for root growth.

Engineering considerations

No design guidance is given for footings under the tree canopy (Area 1). The engineer should use engineering principles for designs in this area and in some cases may consider cantilevered floors.

The footings suggested for soil area 2 are suspended systems supported by drilled concrete piers or timber or steel screw piles founded at minimum depth of 1.5 H_s or rock at P1 and H_s or rock at P2. Excavated piers or deep continuous footings are not recommended in these areas. The engineer may also design a concrete slab footing in area 2 by calculating a design 'y_{st}'. For simplicity TD1and TD2 distances are considered equal.

In soil area 3 the range of 'y_s' for design purpose is 1.5 – 1.0 y_s.

The design engineer should determine any suitable treatments at the change of footing systems. Wall articulation joints are recommended at these points.

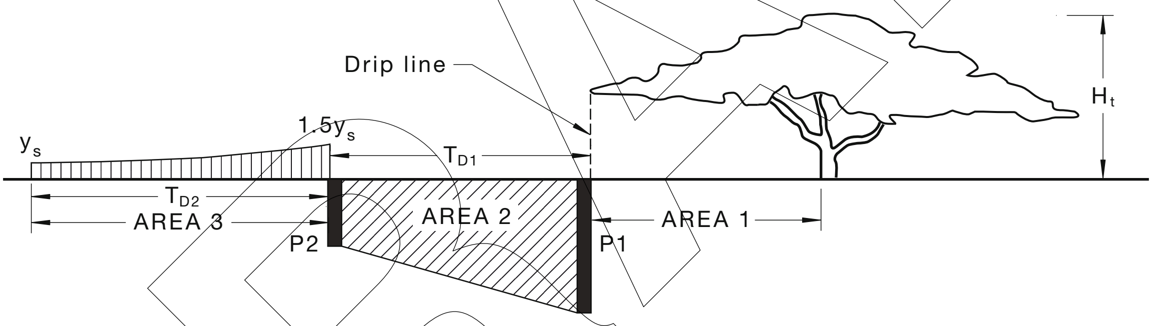

FIGURE CH5.1 TREE HEIGHTS AND SOIL SUCTION CHANGES

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TABLE CH5.1

TREE EFFECT SCORE—SINGLE TREE

	Characteristic	Option	Option Score	Characteristic Score
Tree Characteristics	Canopy	Dense	3	
		Med Dense	2	
		Sparse	1	
	Height	Tall = >15 m	3	
		Med = 8 – 15 m	2	
		Small = <8m	1	
	Stage of Growth	Growing	2	
		Mature	1	
	Drought Resistance	Resistant	2	
		Not resistant	0	
Ground and Site Conditions	Depth of fill	≥1m	2	
		<1m	0	
	Adverse conditions	Yes	1-2	
		No	0	
	Soil Profile Reactivity	High/Extreme reactivity	2	
		Moderate reactivity	1	
Total tree effect score (sum characteristic scores above)				

TABLE CH5.2

TD1 AND TD2 VALUES FOR TREE EFFECT SCORES BY CLIMATE ZONE

Tree Effect Score	Tree Effect	Climate zones		
		1	2	3/4/5
		Distances (m) (TD1 or TD2)		
<6	Low	1	2	3
6-9	Moderate	3	4	5
9-12	High	5	6	7
12-15	Very High	7	8	9
≥15	Extreme	9	10	11

NOTES:

1 P1 = Minimum pile/pier depth = 1.5 Hs or rock, whichever is shallower.
P2 = Minimum pile/pier depth = Hs or rock, whichever is shallower.

2 TD1 = TD2.

3 Table 2 only applies to predominantly clay sites.

4 For tree groups distances TD1 and TD2 should be increased by up to 50%.

5 Pier/pile footings in soil area 2 may be extended to soil area 3 at P2 depths. Alternatively, this part of the footing should be designed to an increased y_s.

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TABLE CH5.3

COMMON TREE NAMES, MATURE HEIGHTS AND CANOPY SIZE

Table CH5.3 shows mature heights and canopy diameters for some common Australian trees that can damage drains, structures and roads. Where the trees are not identified, an arboriculturist's report is recommended or the worst case values used.

Common name	Mature Height (m)	Mature Canopy Φ (m)
Norfolk Island Pine	30-60	15-30
Moreton Bay Fig	20-30	25-40
River/Swamp Sheoak	10-30	10-12
Drooping Sheoak	5-20	5-10
Silky Oak (Grevillea Robusta)	15-30	6-10
False Acacia, Black Locust	9-15	-
Willow/Ovens Wattle	6-10	3-5
Silver/Black Wattle	12-20	4-7
Cedars	Variable	-
Cypress/Radiata Pines	Variable	-
Red Ironbark	10-20	5.10
Lemon-Scented Gum	Up to 15	Up to 8
Sugar Gum	15-30	8-15
Tasmanian Blue Gum	30-60	8-20
Spotted Gum	15-30	8-15
Manna Gum	9-60	6-20
Red-flowered Yellow Gum	5-8	5-8
River Red Gum	20-40	10-25
Yates	5-18	4-12
Karri	Up to 60	-
Lilly Pilly	10-20	5-15
Willow-Myrtle	8-15	5-15
Smooth Barked Apple Myrtle	10-30	6-15
Paperbark (including varieties)	4-8	3-8
Palm (including varieties)	Variable	Variable
Poplar (including varieties)	9-24	3-8
English Oak	Up to 20	10-20
Weeping Willow	9-15	6-12
Chilean Willow	9-15	2-6
Pepper Tree	6-15	-
English Elm	Up to 30	10-15
Strawberry Tree	≈10	-
Flame Tree	10-40	10-15
White Kurrajong	10-30	5-15

(continued)

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TABLE CH5.3 (*continued*)

Common name	Mature Height (m)	Mature Canopy Φ (m)
Kurrajong	6-20	3-6
Golden/Manna Ash	≈12	6-8
Hakea	3-8	3-6
Fruiting Figs	10-20	10-20
Prunus (inc. fruiting varieties)	3-9	2-6
Liquidambar(inc. varieties)	7-10	7-10
Pittosporums (inc. varieties)	4-14	2-8
Brush Box	≈18	-
Desert Ash	≈15	-
Claret Ash	15-20	8-10
Pyramid Tree	8-12	3-6
Plane Tree (inc. London variety)	12-24	8-20
English Elm (inc. golden variety)	Up to 30	12-16

REFERENCES

1 *Urban Tree Risk Management–A community guide to a program design implementation*–1992.

2 *Key guide to Australian Trees* – L. Croninn – 1988.

3 *Gardening Guide to Australian Plants*–G. Elliot-1985.

4 *Damage to buildings on clay soils*–Bulletin 5.1 National Trust Australia–D.A.Cameron, P.F. Walsh-1984.

5 *Tree root intrusion into sewers–Engineering and Water supply* Dept. S.A.-1978.

6 *Shrubs and trees for Australian gardens*–E.E. Lord–1970.

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