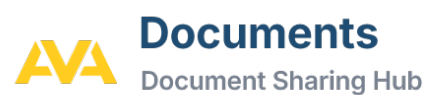




Bridge design

Part 3: Foundation and soil-supporting structures



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 - Bureau of Steel Manufacturers of Australia
 - Cement and Concrete Association of New Zealand
 - Cement Concrete & Aggregates Australia—Cement
 - Concrete Institute of Australia
 - Consult Australia
 - Engineers Australia
 - New Zealand Heavy Engineering Research Association
 - Rail Industry Safety and Standards Board
 - Steel Construction New Zealand
 - Steel Reinforcement Institute of Australia
 - Sydney Trains
-

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Australian Standard[®]

Bridge design

Part 3: Foundation and soil-supporting structures

Originated as HB 77.3—1996.
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PREFACE

This Standard was prepared by the Standards Australia Committee BD-090, Bridge Design, to supersede AS 5100.3—2004.

This Standard is also designated as AUSTROADS publication AP-G51.3-17.

The objective of the AS(AS/NZS) 5100 series is to provide nationally acceptable requirements for—

- (a) the design of road, rail, pedestrian and cyclist-path bridges;
- (b) the specific application of concrete, steel and composite steel/concrete construction, which embody principles that may be applied to other materials in association with relevant Standards; and
- (c) the assessment of the load capacity of existing bridges.

The objective of this Part (AS 5100.3) is to specify the requirements and principles for the design of foundations for bridges and associated soil retaining structures in Australia.

The requirements of the AS(AS/NZS) 5100 series are based on the principles of structural mechanics and knowledge of material properties, for both the conceptual and detailed design, to achieve acceptable probabilities that the bridge or associated structure being designed will not become unfit for use during its design life.

Whereas earlier editions of the *Bridge design* were essentially administered by the infrastructure owners and applied to their own inventory, an increasing number of bridges are being built under the design-construct-operate principle and being handed over to the relevant statutory authority after several years of operation. This Standard includes clauses intended to facilitate the specification to the designer of the functional requirements of the owner, to ensure the long-term performance and serviceability of the bridge and associated structure.

Significant differences between this Standard and its 2004 version, and earlier versions of *Bridge design*, are the following:

- (i) *Definitions and notations* Brought into line with current Standards Australia practice.
- (ii) *Piling clauses* Updated in line with AS 2159—2009, *Piling—Design and installation*.
- (iii) *Anchorage* Testing requirements revised in line with current practice.
- (iv) *Foundation design principles* In recognition that geotechnical engineering design principles differ from structural engineering design principles, the design procedures have been extensively revised. Designers are required to use geotechnical engineering methods appropriate to the foundation problem at hand, together with appropriate characteristic values and factors, when deriving economical and safe solutions. It is further required that designers apply engineering judgement to the application of sound rational design methods outlined in texts, technical literature and other design codes to supplement the design requirements of this Standard.
- (v) *Design procedures* Substructures have been classified as either foundations, where most of the loads on the substructure come from the bridge structure and loads on it, or as soil-supporting structures, where most of the applied loads are from earth pressure. Different design procedures are required for each. The loads and resistances for a soil-supporting structure will largely depend on the soil properties, whereas the loads for a foundation will not be as dependent on the soil properties.

- (vi) *Relevant Standard* The philosophy used for the design of earth-retaining structures in this Standard differs from that used in AS 4678, *Earth-retaining structures*, which was prepared by Standards Australia Committee CE-032. It is considered that for bridges and road-related structures, where soil/structure interaction occurs and the loads are predominantly soil-imposed, the design method adopted is more realistic. However, AS 4678 includes criteria that may be used to supplement the design of structures covered by this Standard.

The term 'shall' has been used in this Standard for mandatory requirements and the term 'should' has been used for desirable (best practice) and/or other measures which, while recommended, are not mandatory.

Statements expressed in mandatory terms in Notes to Tables are deemed to be requirements of this Standard.

The term 'informative' has been used in this Standard to define the application of the appendix to which it applies. An 'informative' appendix is only for information and guidance.

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STANDARDS AUSTRALIA

Australian Standard
Bridge design**Part 3: Foundation and soil-supporting structures**

SECTION 1 SCOPE AND GENERAL

1.1 SCOPE

This Standard sets out minimum design requirements and procedures for the design in limit states format of foundations and soil-supporting structures for road, rail and pedestrian bridges, culverts not specifically covered by other Standards, and subways of conventional size and form.

Foundations include shallow footings, piles and anchorages.

Soil-supporting structures include retaining walls, abutments and buried structures.

The provisions of this Standard also cover the design of foundations for road furniture, such as lighting poles and sign-support structures and noise barriers.

The Standard does not cover the design of—

- (a) corrugated steel pipes and arches;
- (b) precast reinforced concrete box culverts;
- (c) underground concrete drainage pipes; and
- (d) reinforced soil structures.

NOTES:

- 1 For reinforced soil structures, refer to relevant authority specifications.
- 2 The structures covered by this Standard are those specified in Clause 1 of AS 5100.1. This Standard is not applicable to situations outside the scope of AS 5100.1.
- 3 The requirements for structural design and detailing of concrete and steel are specified in AS 5100.5 and AS/NZS 5100.6; however, a number of specific structural design provisions that result from soil-structure interaction are covered by this Standard.
- 4 Requirements for corrugated steel pipes and arches are covered by AS/NZS 2041.1.
- 5 Requirements for fibre-reinforced concrete pipes are covered by AS 4139.
- 6 Requirements for underground concrete drainage pipes are covered by AS 3725 and AS 4058.

1.2 APPLICATION

For the design of foundations for overhead wiring structures for electrified rail lines, the requirements of the relevant authority shall apply.

The loads to be applied shall be those specified in AS 5100.2, together with earth pressure loads determined in accordance with this Standard.

The general design procedures to be adopted shall be as specified in this Standard. Unless specified otherwise by the relevant authority, the detailed methods and formulae to be used shall be those specified in the relevant Standard for the geotechnical or structural element. Where no Australian Standard exists covering the design of the geotechnical or structural element, rational design methods outlined in texts or other design Standards and technical literature shall be used, as approved by the relevant authority.

1.3 NORMATIVE REFERENCES

The following are the normative documents referenced in this Standard:

NOTE: Documents for informative purposes are listed in the Bibliography.

AS

1597	Precast reinforced concrete box culverts
1597.2	Part 2: Large culverts (from 1500 mm span and up to and including 4200 mm span and 4200 mm height)
1726	Geotechnical site investigations
2159	Piling—Design and installation
5100	Bridge design
5100.1	Part 1: Scope and general principles
5100.2	Part 2: Design loads
5100.5	Part 5: Concrete

AS/NZS

1554	Structural steel welding
1554.1	Part 1: Welding of steel structures
1554.3	Part 3: Welding of reinforcing steel
5100	Bridge design
5100.6	Part 6: Steel and composite construction

1.4 DEFINITIONS

For the purpose of this Standard, the definitions below apply. Definitions peculiar to a particular clause are also given in that clause.

1.4.1 Characteristic value

In the context of this Standard, the assessed value of a material parameter used in design.

1.4.2 Design values

The values of variables entered into the calculations.

1.4.3 Foundation

A structural member from which loads imposed predominantly from or via the structural members above, or from loads applied to the structure, are transferred to the ground.

1.4.4 Geotechnical engineer

A suitably qualified engineer with relevant geotechnical experience in charge of geotechnical investigation or design, or both.

1.4.5 Reinforced soil walls and structures

Earth retaining structures with face within 20° of vertical, which comprise steel or polymer tensile reinforcement embedded in specified fill, together with facing elements, connections and footings.

1.4.6 Soil supporting structure

Structures whose main function is to support predominantly soil-imposed loads from vertical or steep-faced soil or earth embankments.

1.5 NOTATION

Symbols used in this Standard are listed below.

Unless a contrary intention is given, the following applies:

- (a) Where non-dimensional ratios are involved, both the numerator and denominator are expressed in identical units.
- (b) The dimensional units for length, force and stress in all expressions or equations are to be taken as millimetres (mm), Newtons (N) and megapascals (MPa) respectively, unless specifically noted otherwise.

Symbol	Definition
E_d	design action effect
E_e	design action effects imposed by the soil
E_{pr}	ultimate passive resistance of the soil in front of the footing
F_{em}	bending moments, shear forces or axial loads in the foundation induced by lateral soil movements
F_{es}	compressive and tensile loads in the foundation, structure or its element caused by vertical soil movement
F_{nf}	negative friction loads on the foundation caused by consolidation of surrounding soil
H_{ug}	ultimate shear resistance at the base of the footing
k	concrete placement factor
R_a	anchorage resistance
R_{ak}	characteristic anchorage strength
R_{am}	measured anchorage capacity
$R_{d,g}$	design geotechnical strength
$R_{d,s}$	design structural strength
R_u	ultimate strength
$R_{u,g}$	ultimate geotechnical strength
$R_{u,s}$	ultimate structural strength
Δh	depth of soil below nominal ground level in front of retaining wall over which passive earth pressure is to be ignored
ϕ	strength reduction factor
ϕ_c	conversion factor
ϕ_g	geotechnical strength reduction factor
ϕ_n	importance category reduction factor
ϕ_s	structural strength reduction factor

1.6 SITE INVESTIGATION

1.6.1 General

A site investigation shall be carried out for all structures, to provide the necessary geotechnical information required for the design and construction of foundations and soil-supporting structures.

The investigation shall be carried out under the supervision of a geotechnical engineer, unless specified otherwise by the relevant authority.

The site investigations shall be carried out in accordance with AS 1726.

Investigations shall be one of the following:

- (a) *Preliminary investigation* An investigation conducted at the feasibility stage in order to assess alternative sites or routes, to prepare conceptual designs, to determine preliminary costings and to define constraints for the design.

The extent and coverage of the preliminary investigation shall be as required by the relevant authority. The preliminary investigation may include—

- (i) field reconnaissance;
- (ii) topography;
- (iii) hydrology;
- (iv) geomorphology;
- (v) hydrogeology;
- (vi) examination of neighbouring structures and excavations;
- (vii) geological and geotechnical maps and records;
- (viii) previous site investigations and construction experience in the vicinity;
- (ix) aerial photographs;
- (x) maps;
- (xi) regional seismicity; or
- (xii) any other relevant information.

- (b) *Design investigation* Design investigation shall provide sufficient geotechnical information for the design and construction of the project.

The extent and coverage of the design investigation shall include but not be limited to the following:

- (i) Nature and size of the structure and its elements, including any special requirements.
- (ii) Conditions with regard to the surroundings of the structure, such as neighbouring structures, traffic, utilities, services, hazardous chemicals and similar conditions.
- (iii) Ground conditions with particular regard to geological complexity.
- (iv) Groundwater conditions.
- (v) Regional seismicity.
- (vi) Influence of the environment on the structure, such as hydrology, surface water, subsidence and the like.
- (vii) Aggressivity of soil and groundwater with respect to materials used in the structure (e.g., acid sulfate soils).
- (viii) Scour effects.
- (ix) Working in the vicinity of electrified rail lines.
- (x) Other relevant factors.

1.6.2 Ground investigations

The number of boreholes or other in situ tests, or both, depends on the proposed structure and the inferred uniformity of the subsoil conditions.

Unless specified otherwise by the relevant authority, the minimum number of boreholes shall be as follows:

- (a) *For bridge foundations* Minimum of one per abutment or pier for bridges with bridge width less than 10 m, with an additional borehole for each 10 m of bridge width or part thereof.
- (b) *For other structures* Investigation as appropriate to the structure and its importance.

NOTES:

- 1 This minimum level of investigation would only be satisfactory for sites with relatively uniform subsoil strata and easily defined foundation conditions.
- 2 Additional boreholes or test locations would be required where bridge approaches involve cuttings or embankments, in order to check that these earthworks would not cause vertical or lateral ground movements, or slope instability, which could adversely affect the bridge or associated structures.

Boreholes, pits or other in situ tests, as required, shall extend through any strata that may influence strength, stability or serviceability, of the foundations or soil-supporting structures during or after construction.

The presence of groundwater and its effects shall be investigated.

NOTE: Specific groundwater effects may include—

- (a) the level and fluctuations of the permanent water table;
- (b) the inflow rates into excavations;
- (c) effects of dewatering on the water table and on adjacent structures;
- (d) the presence of, and the pressures associated with, artesian and sub-artesian conditions; and
- (e) the potential aggressiveness of the groundwater to buried concrete, steel and other materials likely to be affected.

The results of a geotechnical investigation shall be compiled in a geotechnical report verified by a geotechnical engineer.

1.7 MATTERS FOR RESOLUTION BEFORE DESIGN

The matters for resolution listed below shall be confirmed as accepted by the relevant authority or owner of a bridge or associated structure before commencing the design process.

- 1 Design requirements for foundations for overhead wiring structures (see Clause 1.2).
- 2 Detailed method and formulae to be used for the design of geotechnical or structural elements (see Clause 1.2).
- 3 Supervision of site investigation (see Clause 1.6).
- 4 Extent and coverage of preliminary and design investigation (see Clause 1.6).
- 5 Minimum number of boreholes (see Clause 1.6.2).
- 6 Selection of the geotechnical strength reduction factors (see Clause 2.3.5).
- 7 Testing requirements if design by prototype testing (see Clause 2.6).
- 8 Requirement for consideration of future development (see Clause 2.8).
- 9 Other durability criteria (see Clause 4.1).
- 10 Use of treated and untreated timber (see Clause 4.2).

- 11 Requirements for prevention of corrosion of reinforcement (see Clause 4.3).
- 12 Acceptance of rates of corrosion for steel surface (see Clause 4.4).
- 13 Requirements to minimize corrosion effects on stray currents (see Clause 4.4).
- 14 Durability requirements of other materials (see Clause 4.5).
- 15 Design requirements for durability of materials used in shallow foundations (see Clause 5.3.6).
- 16 Requirements for structural design and detailing for shallow footings (see Clause 5.4).
- 17 Requirements for materials and construction for shallow foundations (see Clause 5.5).
- 18 Bridges essential for post-disaster recovery (see Clause 6.3.2).
- 19 Use of timber piles (see Clause 6.3.2).
- 20 Requirements for durability of materials used (see Clause 6.3.4).
- 21 Requirements for structural design and detailing for construction of piles (see Clause 6.4).
- 22 Requirements for materials and construction for piles (see Clause 6.5.1).
- 23 Requirements for testing of piles (see Clause 6.6).
- 24 Design requirements for durability of anchorages and anchorage components (see Clause 7.3.6).
- 25 Requirements for materials and construction for anchorages (see Clause 7.4).
- 26 Requirements for method of installation and on-site assessment tests for anchorages (see Clause 7.6.1).
- 27 Proof load test for anchors (see Clause 7.6.2).
- 28 Requirements for anchorage suitability tests (see Clause 7.6.3).
- 29 Requirements for anchorage acceptance tests (see Clause 7.6.4).
- 30 Requirements for the design of retaining walls and abutments (see Clause 8.1).
- 31 Acceptance of geotechnical strength reduction factor for retaining walls and abutments (see Clause 8.3.1).
- 32 Design requirements for durability of retaining walls and abutments (see Clause 8.3.5).
- 33 Requirements for structural design and detailing for retaining walls and abutments (see Clause 8.4).
- 34 Requirements for materials and construction for retaining walls and abutments (see Clause 8.5).
- 35 Approval of drainage system for retaining walls and abutments (see Clause 8.6).
- 36 Requirements for the design of buried structures (see Clause 9.1).
- 37 Design requirements for the durability of materials (see Clause 9.3.3).
- 38 Requirements for structural design and detailing for buried structures (see Clause 9.4).
- 39 Requirements for materials and construction for buried structures (see Clause 9.5).

SECTION 2 GENERAL DESIGN REQUIREMENTS

2.1 AIM

The aim of the design of structures covered by this Standard is to provide a foundation or soil-supporting structure that is durable, stable and has adequate strength while serving its intended function and that also satisfies other relevant requirements, such as robustness, ease of construction, minimum disruption of normal operations during construction and minimal effects on adjacent existing structures accounting for effects of future works.

Foundation behaviour shall be compatible with the superstructure so that both remain serviceable and can perform their intended functions.

2.2 DESIGN

The design of foundations or soil-supporting structures shall take into account, as appropriate, strength, stability, serviceability, durability and other relevant design requirements in accordance with this Standard.

2.3 DESIGN FOR STRENGTH

2.3.1 General

Foundations and soil-supporting structures shall be designed for both structural and geotechnical strength as follows:

- (a) For foundations where the loads are imposed predominantly from or via the structure or loads applied to the structure (e.g., shallow footings, piles and anchorages), the strength shall be determined in accordance with Clause 2.3.2.
- (b) For soil-supporting structures where the loads are predominantly soil-imposed loads (e.g., abutments and buried structures), the strength shall be determined in accordance with Clause 2.3.3.

Where structures act as both foundations and soil-supporting structures (e.g., diaphragm walls supporting bridge abutments), such structures shall be designed to satisfy the requirements of both foundations and soil-supporting structures.

2.3.2 Foundations

Foundations shall be designed as follows:

- (a) The appropriate loads and other actions shall be determined in accordance with Clause 3.2.
- (b) The loads and action effects shall be factored and combined in accordance with Clause 3.3.2, to determine the design action loads (E_d) for strength for the foundation and its components for each appropriate load combination.

The design geotechnical strength ($R_{d,g}$) shall be obtained by multiplying the appropriate geotechnical strength reduction factor (ϕ_g), selected in accordance with Clause 2.3.5, and the ultimate geotechnical strength ($R_{u,g}$), determined in accordance with Sections 5, 6 and 7 as appropriate, using unfactored characteristic values of material parameters, that is—

$$R_{d,g} = \phi_g R_{u,g} \quad \dots 2.3.2(1)$$

The foundation components shall be proportioned so that

$$R_{d,g} = \phi_g R_{u,g} \geq E_d \quad \dots 2.3.2(2)$$

- (c) The design structural strength ($R_{d,s}$) shall be obtained by multiplying the appropriate structural strength reduction factor (ϕ_s) and the ultimate structural strength ($R_{u,s}$) for each structural component, determined in accordance with AS 5100.5 or AS/NZS 5100.6, as appropriate, that is—

$$R_{d,s} = \phi_s R_{u,s} \quad \dots 2.3.2(3)$$

The structural components of the foundation shall be proportioned so that—

$$R_{d,s} = \phi_s R_{u,s} \geq E_d \quad \dots 2.3.2(4)$$

where

$$E_d = \text{design action effect}$$

2.3.3 Soil-supporting structures

Soil-supporting structures shall be designed as follows:

- (a) The appropriate loads and other actions shall be determined in accordance with Clause 3.2.
- (b) The loads and action effects shall be combined in accordance with Clause 3.3.3, to determine the design loads for strength and stability.
- (c) An appropriate engineering analysis shall be carried out with all loads and load combinations unfactored to determine the design action effects imposed by the soil (E_e) for—
 - (i) the soil-supporting structure as a whole for geotechnical strength design (e.g., active pressure on a retaining wall, or earth pressure on a buried structure); and
 - (ii) each component of the structure for structural strength design (e.g., bending moments or shear forces).

NOTE: As an example, for geotechnical strength design of a retaining wall, the action effects would include the earth pressure arising from dead loading, surcharge loading, pressures arising from compaction, earthquake loading and water pressure. For geotechnical strength design of a buried structure, the action effects would include both vertical and lateral earth pressures arising from the above sources.

- (d) The design geotechnical strength ($R_{d,g}$) (e.g., passive resistance on a retaining wall) shall be obtained by multiplying the appropriate geotechnical strength reduction factor (ϕ_g), selected in accordance with Clause 2.3.5, and the ultimate geotechnical strength ($R_{u,g}$), determined in accordance with Sections 8 and 9, as appropriate, using unfactored characteristic values of material parameters, that is—

$$R_{d,g} = \phi_g R_{u,g} \quad \dots 2.3.3(1)$$

The structure shall be proportioned so that—

$$R_{d,g} = \phi_g R_{u,g} \geq E_d \quad \dots 2.3.3(2)$$

where E_d is the design action effect, which shall be equal to $1.0E_e$ for geotechnical strength design.

NOTE: ϕ_g for soil-supporting structures takes into account the load factors being 1.0.

- (e) The design structural strength ($R_{d,s}$) shall be obtained by multiplying the appropriate structural strength reduction factor (ϕ_s) and the design structural strength ($R_{u,s}$) for each structural component, determined in accordance with AS 5100.5 or AS/NZS 5100.6, that is—

$$R_{d,s} = \phi_s R_{u,s} \quad \dots 2.3.3(3)$$

Each of the structural components shall be proportioned so that—

$$\phi_s R_{u,s} \geq E_d \quad \dots 2.3.3(4)$$

where E_d is the design action effect, which shall be equal to $1.5E_e$ for structural strength design, unless specified otherwise.

2.3.4 Characteristic values

Characteristic values of the soil and rock parameters shall be selected based on the following considerations:

- (a) Geological and geotechnical background information.
- (b) The possible modes of failure.
- (c) Results of laboratory and field measurements, taking into account the accuracy of the test method used.
- (d) A careful assessment of the range of values that may be encountered in the field.
- (e) The ranges of in situ and imposed stresses that may be encountered in the field.
- (f) The potential variability of the parameter values and the sensitivity of the design to these variabilities.
- (g) The extent of the zone of influence governing the soil behaviour, for the limit state being considered.
- (h) The influence of workmanship on artificially placed or improved soils.
- (i) The effects of construction activities on the properties of the in situ soil.

NOTES:

- 1 In general, the characteristic value of geotechnical parameter should be a conservatively assessed value of that parameter. Engineering judgement needs to be exercised in making such an assessment, with geotechnical engineering advice being obtained as required.
- 2 Many soil parameters are not constants, but depend on factors such as the level of stress or strain, the mode of deformation, drainage conditions, moisture contents and their variations over time.
- 3 It should be recognized that a low characteristic value of a geotechnical parameter is not always necessarily a conservative value. For example, in cases involving dynamic or earthquake loads, conservatism may require the selection of a high value of a particular parameter. The sensitivity of the calculated result to the relevant parameter should be taken into consideration.
- 4 Bending moments in buried structures are sensitive to the relative stiffness of the structure and the surrounding soil. The design should consider variation in the stiffness parameters of both the soil and the structure.
- 5 Except where specifically noted, the term soil includes soil and rock. In many cases, weak weathered rock can be analysed as for soil; however, special techniques may be required for the analysis of strong rock.

2.3.5 Geotechnical strength reduction factors (ϕ_g)

The geotechnical strength reduction factors specified in this Standard shall be used taking into account the following:

- (a) Methods used to assess the geotechnical strength.
- (b) Variations in the soil conditions.
- (c) Imperfections in construction.
- (d) Nature of the structure and the mode of failure.
- (e) Importance of the structure and consequences of failure.
- (f) Standards of workmanship and supervision of the construction.
- (g) Load variations and cyclic effects.

NOTE: Values of ϕ_g for specific cases are set out in Sections 5, 6, 7, 8 and 9.

The geotechnical strength reduction factors selected shall be confirmed and accepted by the relevant authority.

2.4 DESIGN FOR STABILITY

The structure as a whole and each of its elements, including the foundations, shall be designed to prevent instability due to overturning, uplift or sliding, as follows:

- (a) Loads determined in accordance with Clause 3.2 shall be subdivided into components tending to cause instability and components tending to resist instability.
- (b) The design action effects (E_d) shall be calculated from the components of the load tending to cause instability, using the load combinations specified in Clause 3.3.
- (c) The ultimate resistance shall be calculated as set out in Sections 5, 6, 7, 8 and 9. The design resistance shall be computed by multiplying the ultimate resistance by the appropriate strength reduction factor.
- (d) The whole or part of the structure shall be proportioned so that the design action effects are less than or equal to the design resistance.

2.5 DESIGN FOR SERVICEABILITY

Foundations and soil-supporting structures shall be designed for serviceability by controlling or limiting settlement, horizontal displacement and cracking.

Under the load combinations for serviceability design specified in Clause 3.4, deflections and horizontal displacements shall be limited to ensure that the foundations and the structure remain serviceable over their design lives.

2.6 DESIGN FOR STRENGTH, STABILITY AND SERVICEABILITY BY LOAD TESTING A PROTOTYPE

Notwithstanding the requirements of Clauses 2.3, 2.4 and 2.5, foundations or soil-supporting structures may be designed for strength, stability or serviceability by load testing using appropriate test loads as approved by the relevant authority. If this alternative procedure is adopted, the requirements for durability (see Section 4) and other relevant design requirements (see Clause 2.8) shall apply.

2.7 DESIGN FOR DURABILITY

Foundations and soil-supporting structures shall be designed for durability in accordance with Section 4.

2.8 DESIGN FOR OTHER RELEVANT DESIGN REQUIREMENTS

Any special design criteria, such as scour, fatigue, flood or collision loading, cyclic loading or liquefaction arising from seismic actions shall be considered. Where relevant, these design criteria shall be taken into account in the design of the foundation or the structure in accordance with the principles of the Standard.

When designing new foundations close to existing structures, the effect of the new structure on existing work, during construction and subsequently, shall be considered. The effect of possible future developments on the proposed work after it is completed shall also be considered if required by the relevant authority.

NOTE: Some of the circumstances specified in this Clause may lead to additional loadings (in the case of floods and collisions), a reduction in the depth of soil-resisting loadings (in the case of scour), or to a reduction in soil strength and stiffness (in the case of scour, flood, fatigue, cyclic loading and liquefaction), or a combination of these effects. In the case of collision loading, the rapid rate of load application may provide a basis to adopt increases in the design strength and stiffness of the soil, but such increases are generally ignored for the purposes of design.

SECTION 3 LOADS AND LOAD COMBINATIONS

3.1 GENERAL

The loads and load combinations for strength, stability and serviceability design shall be as specified in Clauses 3.2, 3.3 and 3.4.

3.2 LOADS

3.2.1 General

The design for ultimate and serviceability limit states shall take into account the appropriate action effects arising from the following:

- (a) All loads and other actions specified in AS 5100.2.
- (b) Soil movement resulting from slip, reactive soils, consolidation, heaving and other vertical and lateral earth movements.
- (c) Loads from surcharges.
- (d) Distribution of wheel loads through fill.
- (e) Water pressure loads and seepage forces.
- (f) Increase in loads on buried structures because of differential soil movements.
- (g) Compaction pressures.
- (h) Displacement pressures from piling.
- (i) Any additional loads and actions that may be applied.

3.2.2 Loads induced by soil movement

Allowance shall be made for loads induced by soil movement as follows:

- (a) Where foundations are situated in soil undergoing settlement, allowance shall be made for loads resulting from negative friction on the foundation (F_{nf}).
- (b) Where foundations are situated in expansive soils, such as reactive clays or those subject to frost action, allowance shall be made for the compressive and tensile loads (F_{es}) which may develop in the foundation, structure or its elements.
- (c) Where foundations are subject to lateral soil movements, allowance shall be made for bending moments, shear forces and axial loads (F_{em}) induced by such movements.
- (d) Where heave may arise because of unloading of the ground as a result of excavation, allowance shall be made for the bending moments, shear forces and axial loads (F_{em}) induced by the resulting ground movements.

NOTE: Consideration should be given to each of the following conditions when earth pressure loads on retaining structures are being determined:

- (a) Configuration, nature and drainage properties of the backfill material.
- (b) Displacement characteristics of the wall.
- (c) Interface conditions between the wall and the backfill.
- (d) Method of compaction of the backfill material.
- (e) Sequences of excavation and placement of anchorages and struts.