



Concrete structures



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Australian Standard[®]

Concrete structures

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PREFACE

This Standard was prepared by Standards Australia Committee BD-002, Concrete Structures, to supersede AS 3600—2009.

This Standard incorporates Amendment No. 1 (November 2018) and Amendment No. 2 (May 2021). The changes required by the Amendment are indicated in the text by a marginal bar and amendment number against the clause, note, table, figure or part thereof affected.

The principal objective of this Standard is to provide users with nationally acceptable unified rules for the design and detailing of concrete structures and members, with or without steel reinforcement or prestressing tendons, based on the principles of structural engineering mechanics. The secondary objective is to provide performance criteria against which the finished structure can be assessed for conformance with the relevant design requirements.

The following list indicates the major differences between this edition and the 2009 edition of AS 3600:

- (a) Addition of the following new sections:
 - (i) Section 14 *Design for Earthquakes Actions* (formerly Appendix C).
 - (ii) Section 15 *Diaphragms*.
 - (iii) Section 16 *Steel Fibre Reinforced Concrete*.
 - (iv) Section 18 *Design for Fatigue*.
 - (v) Appendix C *Residual Tensile Strength Test for SFRC*.
- (b) Revision of the following requirements:
 - (i) Phi factors.
 - (ii) Maximum steel strength.
 - (iii) Shear in deep slabs.
 - (iv) Fire design, including—
 - (A) axis distances for fire design;
 - (B) continuous top reinforcement; and
 - (C) minimum slab thickness.
 - (v) Modification of models and calculations of—
 - (A) shrinkage;
 - (B) creep;
 - (C) deflections; and
 - (D) development lengths for higher strength steels.
 - (vi) Steel shrinkage in areas modelled by strut and tie.
 - (vii) Punching shear.
 - (viii) Ductility for pre-cast concrete connections.
 - (ix) Heating and re-bending bars.
 - (x) Crack control.

Statements expressed in mandatory terms in notes to figures and tables are deemed to be requirements of this Standard.

The terms 'normative' and 'informative' are used in Standards to define the application of the appendices to which they apply. A 'normative' appendix is an integral part of a Standard, whereas an 'informative' appendix is only for information and guidance.

CONTENTS

	<i>Page</i>
SECTION 1 SCOPE AND GENERAL	
1.1 SCOPE AND APPLICATION	8
1.2 NORMATIVE REFERENCES	9
1.3 EXISTING STRUCTURES	9
1.4 DOCUMENTATION	9
1.5 CONSTRUCTION	10
1.6 DEFINITIONS	10
1.7 NOTATION	17
SECTION 2 DESIGN PROCEDURES, ACTIONS AND LOADS	
2.1 DESIGN PROCEDURES	34
2.2 DESIGN FOR STRENGTH	35
2.3 DESIGN FOR SERVICEABILITY	39
2.4 DESIGN FOR FATIGUE	41
2.5 ACTIONS AND COMBINATIONS OF ACTIONS	41
SECTION 3 DESIGN PROPERTIES OF MATERIALS	
3.1 PROPERTIES OF CONCRETE	44
3.2 PROPERTIES OF REINFORCEMENT	51
3.3 PROPERTIES OF TENDONS	52
3.4 LOSS OF PRESTRESS IN TENDONS	54
3.5 MATERIAL PROPERTIES FOR NON-LINEAR STRUCTURAL ANALYSIS	57
SECTION 4 DESIGN FOR DURABILITY	
4.1 GENERAL	58
4.2 METHOD OF DESIGN FOR DURABILITY	58
4.3 EXPOSURE CLASSIFICATION	58
4.4 REQUIREMENTS FOR CONCRETE FOR EXPOSURE CLASSIFICATIONS A1, A2, B1, B2, C1 AND C2	61
4.5 REQUIREMENTS FOR CONCRETE FOR EXPOSURE CLASSIFICATION U	62
4.6 ABRASION	62
4.7 FREEZING AND THAWING	62
4.8 AGGRESSIVE SOILS	63
4.9 RESTRICTIONS ON CHEMICAL CONTENT IN CONCRETE	65
4.10 REQUIREMENTS FOR COVER TO REINFORCING STEEL AND TENDONS	65
SECTION 5 DESIGN FOR FIRE RESISTANCE	
5.1 SCOPE	68
5.2 DEFINITIONS	68
5.3 DESIGN PERFORMANCE CRITERIA	70
5.4 FIRE RESISTANCE PERIODS (FRPs) FOR BEAMS	71
5.5 FIRE RESISTANCE PERIODS (FRPs) FOR SLABS	74
5.6 FIRE RESISTANCE PERIODS (FRPs) FOR COLUMNS	77
5.7 FIRE RESISTANCE PERIODS (FRPs) FOR WALLS	81
5.8 INCREASE OF FIRE RESISTANCE PERIODS (FRPs) BY USE OF INSULATING MATERIALS	83

SECTION 6 METHODS OF STRUCTURAL ANALYSIS

6.1	GENERAL.....	85
6.2	LINEAR ELASTIC ANALYSIS	88
6.3	ELASTIC ANALYSIS OF FRAMES INCORPORATING SECONDARY BENDING MOMENTS.....	90
6.4	LINEAR ELASTIC STRESS ANALYSIS.....	90
6.5	NON-LINEAR FRAME ANALYSIS	91
6.6	NON-LINEAR STRESS ANALYSIS.....	91
6.7	PLASTIC METHODS OF ANALYSIS	92
6.8	ANALYSIS USING STRUT-AND-TIE MODELS	93
6.9	IDEALIZED FRAME METHOD OF ANALYSIS	93
6.10	SIMPLIFIED METHODS OF FLEXURAL ANALYSIS	95

SECTION 7 STRUT-AND-TIE MODELLING

7.1	GENERAL.....	103
7.2	CONCRETE STRUTS.....	103
7.3	TIES	108
7.4	NODES.....	108
7.5	ANALYSIS OF STRUT-AND-TIE MODELS	109
7.6	DESIGN BASED ON STRUT-AND-TIE MODELLING.....	109

SECTION 8 DESIGN OF BEAMS FOR STRENGTH AND SERVICEABILITY

8.1	STRENGTH OF BEAMS IN BENDING.....	110
8.2	STRENGTH OF BEAMS IN SHEAR	113
8.3	GENERAL DETAILS FOR BEAMS.....	123
8.4	LONGITUDINAL SHEAR IN COMPOSITE AND MONOLITHIC BEAMS	127
8.5	DEFLECTION OF BEAMS.....	128
8.6	CRACK CONTROL OF BEAMS.....	131
8.7	VIBRATION OF BEAMS	135
8.8	T-BEAMS AND L-BEAMS	135
8.9	SLENDERNESS LIMITS FOR BEAMS	136

SECTION 9 DESIGN OF SLABS FOR STRENGTH AND SERVICEABILITY

9.1	STRENGTH OF SLABS IN BENDING.....	137
9.2	STRUCTURAL INTEGRITY REINFORCEMENT	140
9.3	STRENGTH OF SLABS IN SHEAR.....	141
9.4	DEFLECTION OF SLABS.....	145
9.5	CRACK CONTROL OF SLABS	147
9.6	VIBRATION OF SLABS	151
9.7	MOMENT RESISTING WIDTH FOR ONE-WAY SLABS SUPPORTING CONCENTRATED LOADS.....	151
9.8	LONGITUDINAL SHEAR IN COMPOSITE SLABS.....	151

SECTION 10 DESIGN OF COLUMNS FOR STRENGTH AND SERVICEABILITY

10.1	GENERAL.....	152
10.2	DESIGN PROCEDURES	152
10.3	DESIGN OF SHORT COLUMNS.....	153
10.4	DESIGN OF SLENDER COLUMNS	154
10.5	SLENDERNESS.....	155
10.6	STRENGTH OF COLUMNS IN COMBINED BENDING AND COMPRESSION	159
10.7	REINFORCEMENT REQUIREMENTS FOR COLUMNS.....	162
10.8	TRANSMISSION OF AXIAL FORCE THROUGH FLOOR SYSTEMS.....	170
10.9	CRACK CONTROL	171

SECTION 11 DESIGN OF WALLS

11.1 GENERAL.....	172
11.2 DESIGN PROCEDURES	172
11.3 BRACED WALLS.....	173
11.4 EFFECTIVE HEIGHT.....	173
11.5 SIMPLIFIED DESIGN METHOD FOR WALLS SUBJECT TO VERTICAL COMPRESSION FORCES	174
11.6 DESIGN OF WALLS FOR IN-PLANE SHEAR FORCES	175
11.7 REINFORCEMENT REQUIREMENTS FOR WALLS	176

SECTION 12 DESIGN OF NON-FLEXURAL MEMBERS, END ZONES AND BEARING SURFACES

12.1 GENERAL.....	179
12.2 STRUT-AND-TIE MODELS FOR THE DESIGN OF NON-FLEXURAL MEMBERS.....	179
12.3 ADDITIONAL REQUIREMENTS FOR CONTINUOUS CONCRETE NIBS AND CORBELS	181
12.4 ADDITIONAL REQUIREMENTS FOR STEPPED JOINTS IN BEAMS AND SLABS	181
12.5 ANCHORAGE ZONES FOR PRESTRESSING ANCHORAGES	181
12.6 BEARING SURFACES	183
12.7 CRACK CONTROL	183

SECTION 13 STRESS DEVELOPMENT OF REINFORCEMENT AND TENDONS

13.1 STRESS DEVELOPMENT IN REINFORCEMENT.....	185
13.2 SPLICING OF REINFORCEMENT.....	192
13.3 STRESS DEVELOPMENT IN TENDONS	195
13.4 COUPLING OF TENDONS	199

SECTION 14 DESIGN FOR EARTHQUAKE ACTIONS

14.1 GENERAL.....	197
14.2 DEFINITIONS.....	197
14.3 STRUCTURAL DUCTILITY FACTOR (μ) AND STRUCTURAL PERFORMANCE FACTOR (S_p).....	199
14.4 GENERAL EARTHQUAKE DESIGN REQUIREMENTS	199
14.5 INTERMEDIATE MOMENT-RESISTING FRAMES (IMRFs)	201
14.6 LIMITED DUCTILE STRUCTURAL WALLS	204
14.7 MODERATELY DUCTILE STRUCTURAL WALLS.....	209

SECTION 15 DIAPHRAGMS

15.1 GENERAL.....	210
15.2 DESIGN ACTIONS.....	210
15.3 CAST IN-PLACE TOPPINGS.....	211
15.4 DIAPHRAGM REINFORCEMENT.....	211

SECTION 16 STEEL FIBRE REINFORCED CONCRETE

16.1 GENERAL.....	213
16.2 DEFINITIONS.....	213
16.3 PROPERTIES OF SFRC	214
16.4 DESIGN OF SFRC MEMBERS CONTAINING REINFORCEMENT OR TENDONS	219
16.5 DURABILITY	224
16.6 FIRE	224

Page

16.7	PRODUCTION OF SFRC	224
SECTION 17 MATERIAL AND CONSTRUCTION REQUIREMENTS		
17.1	MATERIAL AND CONSTRUCTION REQUIREMENTS FOR CONCRETE AND GROUT	228
17.2	MATERIAL AND CONSTRUCTION REQUIREMENTS FOR REINFORCING STEEL	230
17.3	MATERIAL AND CONSTRUCTION REQUIREMENTS FOR PRESTRESSING DUCTS, ANCHORAGES AND TENDONS.....	233
17.4	CONSTRUCTION REQUIREMENTS FOR JOINTS AND EMBEDDED ITEMS	235
17.5	TOLERANCES FOR STRUCTURES AND MEMBERS.....	235
17.6	FORMWORK.....	236
17.7	PREFABRICATED CONCRETE STRUCTURES	239
SECTION 18 DESIGN FOR FATIGUE		
18.1	GENERAL.....	241
18.2	MAXIMUM COMPRESSIVE STRESS IN CONCRETE.....	241
18.3	PLAIN CONCRETE WITH COMPRESSION-TENSION STRESS.....	243
18.4	PLAIN CONCRETE WITH PURE TENSION OR COMBINED TENSION- COMPRESSION STRESS.....	243
18.5	SHEAR LIMITED BY WEB COMPRESSIVE STRESSES	243
18.6	SHEAR IN SLABS	243
18.7	ADJUSTMENT FACTOR FOR BOND BEHAVIOUR IN REINFORCING AND PRESTRESSING STEEL.....	244
18.8	TENSILE STRESS RANGE IN STEEL	245
18.9	CALCULATION OF STRESSES IN REINFORCEMENT AND TENDONS OF FLEXURAL MEMBERS.....	248
SECTION 19 JOINTS, EMBEDDED ITEMS AND FIXINGS		
19.1	JOINTS.....	249
19.2	EMBEDDED ITEMS.....	250
19.3	FIXINGS	250
SECTION 20 PLAIN CONCRETE PEDESTALS AND FOOTINGS		
20.1	GENERAL.....	252
20.2	DURABILITY	252
20.3	PEDESTALS	252
20.4	FOOTINGS.....	252
SECTION 21 SLAB-ON-GROUND FLOORS, PAVEMENTS AND FOOTINGS		
21.1	GENERAL.....	254
21.2	DESIGN CONSIDERATIONS.....	254
21.3	FOOTINGS.....	254
APPENDICES		
A	REFERENCED DOCUMENTS.....	255
B	TESTING OF MEMBERS AND STRUCTURES.....	257
C	RESIDUAL TENSILE STRENGTH TEST FOR SFRC	263
BIBLIOGRAPHY.....		263

STANDARDS AUSTRALIA

Australian Standard

Concrete structures

SECTION 1 SCOPE AND GENERAL

1.1 SCOPE AND APPLICATION**1.1.1 Scope**

This Standard sets out minimum requirements for the design and construction of concrete building structures and members that contain reinforcing steel or tendons, or both. It also sets out minimum requirements for plain concrete pedestals and footings.

NOTES:

- 1 The general principles of concrete design and construction and the criteria embodied in this Standard may be appropriate for concrete structures other than buildings, members not specifically mentioned herein and to materials outside the limits given in Clause 1.1.2.
- 2 It is intended that the design of a structure or member to which this Standard applies be carried out by, or under the supervision of, a suitably experienced and competent person.
- 3 For guidance on the design of maritime structures refer to AS 4997.
- 4 If alternate materials and methods to those prescribed in this Standard are to be used, they would need to be considered as part of the development of a Performance Solution to demonstrate compliance with the relevant Performance Requirements of the National Construction Code (NCC) and be accepted by the relevant building authority.

This Standard is not intended to apply to the design of mass concrete structures.

1.1.2 Application

This Standard applies to structures and members in which the materials conform to the following:

(a) Concrete with—

- (i) characteristic cylinder compressive strength at 28 days (f'_c) in the range of 20 MPa to 120 MPa; and
- (ii) with a saturated surface-dry density in the range 1800 kg/m³ to 2800 kg/m³.

(b) Reinforcing steel of Ductility Class N or E in accordance with AS/NZS 4671.

NOTE: These reinforcing materials may be used, without restriction, in all applications referred to in this Standard. This Standard has been written using Ductility Class N reinforcing steels which are readily available in Australia. Where Ductility Class N is referenced in this Standard, the Earthquake Ductility Class E steels may be substituted but the availability of supply in Australia needs to be checked prior to specification on design drawings.

(c) Reinforcing steel of Ductility Class L in accordance with AS/NZS 4671 may be used as main or secondary reinforcement in the form of welded wire mesh, or as wire, bar and mesh in fitments, provided it is not used in any situation where the reinforcement is required to undergo large plastic deformation under strength limit state conditions.

NOTE: The use of Ductility Class L reinforcement is further limited by other clauses within the Standard.

- (d) Higher reinforcing steel grades >500 MPa to 800 MPa meeting the requirements of Table 3.2.1. For ultimate limit states the strength of the reinforcement in design models shall not be taken as greater than 600 MPa unless noted otherwise.
- (e) Prestressing tendons conforming with AS/NZS 4672.1 and tested in accordance with AS/NZS 4672.2.
- (f) Steel fibres conforming to ISO 13270:2013 and meeting the requirements of Clause 16.3.3.8.

1.1.3 Exclusions

The requirements of this Standard shall not take precedence over design requirements and material specifications set out in other Australian Standards that deal with specific types of structures.

1.2 NORMATIVE REFERENCES

Normative documents referred to in this Standard are listed in Appendix A.

NOTE: Informative documents referred to in this Standard are listed in the Bibliography at the end of this document.

1.3 EXISTING STRUCTURES

The general principles of this Standard shall be applied when evaluating the strength or serviceability of an existing structure.

NOTE: Existing structures are likely to contain materials that do not conform with the material specifications herein and may have been designed to different requirements, but the general principles of this Standard would apply. (See also Appendix B.)

1.4 DOCUMENTATION

The drawings and/or specification for concrete structures and members shall include, when required, the following:

- (a) Reference number and date of issue of applicable design Standards.
- (b) Imposed actions (live loads) used in design.
- (c) The earthquake design category determined from AS 1170.4.
- (d) Any constraint on construction assumed in the design.
- (e) Exposure classification for durability.
- (f) Fire resistance level (FRL), if applicable.
- (g) Class and grade designation of concrete.
- (h) Any required properties of the concrete.
- (i) The curing procedure.
- (j) Grade, Ductility Class and type of reinforcement and grade and type of tendons.
- (k) The size, quantity and location of all reinforcement, tendons and structural fixings and the cover to each.
- (l) The location and details of any splices, mechanical connections and welding of any reinforcement or tendon.
- (m) The maximum jacking force to be applied in each tendon and the order in which tendons are to be stressed.
- (n) The shape and size of each member.

- (o) The finish and method of control for unformed surfaces.
- (p) Class of formwork in accordance with AS 3610 and AS 3610.1 as applicable for the surface finish specified.
- (q) The minimum period of time after placing of concrete before stripping of forms and removal of shores.
- (r) The location and details of planned construction and movement joints, and the method to be used for their protection.

1.5 CONSTRUCTION

All concrete structures, designed in accordance with this Standard, shall be constructed so that all the requirements of the design, as contained in the drawings and specifications, are achieved.

1.6 DEFINITIONS

1.6.1 General

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

1.6.2 Administrative definitions

1.6.2.1 *Building authority or other relevant regulatory authority*

The body having statutory powers to control the design and construction of the structure in the area in which the structure is to be constructed.

1.6.2.2 *Drawings*

The diagrams forming part of the documents setting out the work to be executed.

1.6.2.3 *Specification*

The requirements forming part of the documents setting out the work to be executed.

1.6.3 Technical definitions

1.6.3.1 *Action*

Set of concentrated or distributed forces acting on a structure (direct action), or deformation imposed on a structure or constrained within it (indirect action).

NOTE: The term 'load' is also often used to describe direct actions.

1.6.3.2 *Action effects*

Internal forces, bending moments and torsion due to actions (i.e. the stress resultants).

1.6.3.3 *Anchorage zone*

Region between the face of the member where the prestress is applied and the cross-section at which a linear distribution of stress due to prestress is achieved.

1.6.3.4 *Average ambient temperature*

Average value of the daily maximum and minimum ambient temperatures over the defined period at a site.

1.6.3.5 *Average axis distance*

See Clause 5.2.1.

1.6.3.6 *Axis distance*

Distance from the centre-line axis of a longitudinal bar or tendon to the nearest surface exposed to fire (see Figure 5.2.2).

1.6.3.7 *B-region*

Portion of a member in which the assumption that plane sections remain plane can be applied.

1.6.3.8 *Basic creep coefficient*

Mean value of the ratio of final creep strain to elastic strain for a specimen loaded at 28 days under a constant stress of $0.4f'_c$ (see Clause 3.1.8.2).

1.6.3.9 *Bottle-shaped compression field*

Compression field that is wider at mid-length than at its ends [see Figure 7.2.1(c)].

1.6.3.10 *Braced column*

Column in a structure for which the lateral actions, applied at the ends in the direction under consideration, are resisted by components such as masonry infill panels, shear walls or lateral bracing.

1.6.3.11 *Characteristic strength*

Value of the material strength, as assessed by standard test, that is exceeded by 95% of the material (lower characteristic strength).

1.6.3.12 *Closed fitment*

A unit or multiple units of reinforcement used as an external or internal fitment that form a continuous perimeter around a concrete element with the ends of the fitment anchored into the concrete using a minimum of 135° hooks around a longitudinal bar.

1.6.3.13 *Closed tie*

A unit of reinforcement used as an external or internal fitment having a straight leg and minimum of 135° hooks at each end fixed around a longitudinal bar.

1.6.3.14 *Collector*

An element that takes the distributed lateral action from a diaphragm and delivers it to a vertical element. Also known as a drag bar, strut or distributor. A distributor takes the actions from a vertical element and distributes it into the diaphragm.

1.6.3.15 *Column strip*

See Clause 6.1.4.1.

1.6.3.16 *Composite concrete member*

Member consisting of concrete members constructed separately but structurally connected so the member responds as a unit to applied actions.

1.6.3.17 *Concrete*

Mixture of cement, aggregates and water, with or without the addition of chemical admixtures.

1.6.3.18 *Construction joint*

Joint that is located in a structure or part of a structure for convenience of construction and made so that the load-carrying capacity and serviceability of the structure, or part of the structure, will be unimpaired by the inclusion of the joint.

1.6.3.19 *Cover*

Distance between the outside of the reinforcing steel or tendons and the nearest permanent surface of the member, excluding any applied surface finish.

1.6.3.20 Creep coefficient

Mean value of the ratio of creep strain to elastic strain under conditions of constant stress.

1.6.3.21 Critical opening

Opening through the thickness of a slab where an edge, or part of the edge, of the opening is located at a clear distance of less than $2.5b_o$ from the critical shear perimeter [see Figure 9.3(A)(b)].

1.6.3.22 Critical shear perimeter

Perimeter defined by a line geometrically similar to the boundary of the effective area of a support or concentrated load and located at a distance of $d_{om}/2$ therefrom [see Figure 9.3(A)].

1.6.3.23 Cross tie

An internal fitment with a single reinforcement leg anchored at one end with a 135° (minimum) hook and anchored at the other end with a 90° cog. Both the hook and cog are anchored around a longitudinal bar. See Figure 10.7.4.2.

1.6.3.24 D-region

Portion of a member within a distance equal to the member depth (D), from a discontinuity.

1.6.3.25 Design life

Period for which a structure or a structural member is to remain fit for use for its designed purpose with maintenance.

1.6.3.26 Design strip

See Clause 6.1.4.2.

1.6.3.27 Diaphragm

A horizontal or near horizontal concrete element such as a floor or roof used to transmit horizontal actions into the vertical elements of the force resisting system.

1.6.3.28 Direct loading

Loading on a structure that includes the self-weight of its component members and externally applied loads.

1.6.3.29 Discontinuity

Abrupt change in geometry or loading, including prestress.

1.6.3.30 Duct

Conduit (plain or corrugated) to accommodate prestressing tendon(s) for post-tensioned installation.

1.6.3.31 Ductility Class

Designation relating to the ductility of reinforcement ('L' designates 'low', 'N' designates 'normal', 'E' designates 'earthquake').

NOTE: For further information refer to AS/NZS 4671.

1.6.3.32 Durability

Ability of a structure and its component members to perform the functions for which they have been designed, over a specified period of time, when exposed to their environment.

1.6.3.33 Effective area of a support or concentrated load for slabs in shear

Area totally enclosing the actual support or load and for which the perimeter is a minimum [see Figure 9.3(A)].

1.6.3.34 *Effective depth*

Distance from the extreme compressive fibre of the concrete to the resultant tensile force in the reinforcing steel and tendons in that zone, which will be tensile at the ultimate strength condition of pure bending.

1.6.3.35 *Embedded items*

Items, other than reinforcement and tendons, that are embedded in a concrete member or structure.

NOTE: Embedded items include pipes and conduits with their associated fittings, sleeves, permanent inserts for fixings and other purposes, prestressed anchorages, holding-down bolts and other supports.

1.6.3.36 *Exposure classification*

Designation indicative of the most severe environment to which a concrete member is to be subjected during its design life (see Table 4.3).

1.6.3.37 *Fan-shaped compression field*

Compression field that has non-parallel straight sides [see Figure 7.2.1(b)].

1.6.3.38 *Fire resistance*

Ability of a structure or part of it to fulfil its required functions (loadbearing and/or separating function) for a specified fire exposure, for a specified time.

1.6.3.39 *Fire resistance level (FRL)*

Fire resistance periods for structural adequacy, integrity and insulation expressed in that order.

NOTE: Fire resistance levels for structures, parts and elements of construction are specified by the relevant authority [e.g. in the Building Code of Australia (BCA)].

1.6.3.40 *Fire resistance period (FRP)*

Time, in minutes, for a member to reach the specified failure criteria (i.e. structural adequacy, integrity and/or insulation) if tested for fire in accordance with the appropriate Standard.

NOTE: For structures that need to conform with the BCA requirements, the appropriate Standard is AS 1530.4.

1.6.3.41 *Fire-separating function*

Ability of a boundary element of a fire compartment (e.g. wall, floor or roof) to prevent fire spread by passage of flames or hot gases (integrity) or ignition beyond the exposed surface (thermal insulation) during a fire.

NOTE: When tested in accordance with AS 1530.4, prototypes of such members are exposed to fire from only one direction at a time and are assumed to be similarly exposed for the purpose of interpreting Section 5.

1.6.3.42 *Fitment*

Unit of reinforcement commonly used to restrain from buckling the longitudinal reinforcing bars in beams, columns and piles; carry shear, torsion and diagonal tension; act as hangers for longitudinal reinforcement; or provide confinement to the core concrete.

NOTE: Also referred to commonly as a stirrup, ligature or helical reinforcement.

1.6.3.43 *Fixing or fastener or anchor or lifter*

Material cast into or installed into concrete after it has cured for the purpose of maintaining in position reinforcement, tendons, ducts, formwork, or inserts, used to lift concrete members, or to transfer load from other elements into concrete lifting of members.

1.6.3.44 Flat plate

Flat slab without drop panels.

1.6.3.45 Flat slab

Continuous two-way solid or ribbed slab, with or without drop-panels, having at least two spans in each direction, supported internally by columns without beams and supported externally by walls or columns with or without spandrel beams, or both.

1.6.3.46 Footing

Part of a structure in direct contact with and transmitting load to the supporting foundation.

1.6.3.47 Foundation

Soil, subsoil or rock, whether built-up or natural, by which a structure is supported.

1.6.3.48 Grout

A mixture of cement and water, with or without the addition of sand, or chemical admixtures, that is proportioned to produce a material that will subsequently harden to achieve the specified compressive strength.

1.6.3.49 Headed reinforcement

Steel bar that achieves anchorage by means of a head or end plate.

1.6.3.50 Helical reinforcement

Unit of reinforcement that is wound in a helical fashion around the main longitudinal reinforcing bars in a column or pile restraining them from buckling and to carry shear, torsion and diagonal tension or around tendons at an anchorage to resist bursting action effects.

1.6.3.51 Hollow-core slab or wall

Slab or wall having mainly a uniform thickness and containing essentially continuous voids.

1.6.3.52 Initial force

Force immediately after transfer, at a stated position in a tendon.

1.6.3.53 Insulation (fire)

The ability of a fire-separating member, such as a wall or floor, to limit the surface temperature on one side of the member when exposed to fire on the other side.

1.6.3.54 Integrity (fire)

Ability of a fire-separating member to resist the passage of flames or hot gases through the member when exposed to fire on one side.

1.6.3.55 Jacking force

Force in a tendon measured at the jack.

1.6.3.56 Ligature (reinforcement)

See 'Fitment'.

1.6.3.57 Lightweight concrete

Concrete having a saturated surface-dry density in the range of 1800 kg/m³ to 2100 kg/m³.

1.6.3.58 Limit state

Limiting condition at which the structure ceases to fulfil its designed function.

1.6.3.59 Loadbearing function

Ability of a structure or member to sustain specified actions during the fire.

1.6.3.60 Loadbearing wall or column

Member designed to support or transmit vertical loads additional to its own weight where the design axial force at mid-height of the member is greater than the lesser of $0.03 f'_c A_g$ or $2 A_g$.

1.6.3.61 Mean strength

Statistical average of a number of test results representative of the strength of a member, prototype or material.

1.6.3.62 Middle strip

See Clause 6.1.4.3.

1.6.3.63 Movement joint

Joint that is made between parts of a structure for the specific purpose of permitting relative movement between the parts of the structure on either side of the joint.

1.6.3.64 Node

Point in a joint in a strut-and-tie model where the axes of the struts, ties and concentrated forces acting on the joint intersect.

1.6.3.65 Nodal zone

Volume of concrete around a node, which is assumed to transfer strut-and-tie forces through the node.

1.6.3.66 One-way slab

Slab characterized by flexural action mainly in one direction.

1.6.3.67 Plain concrete member

Member either unreinforced, containing less than minimum reinforcement or reinforced but assumed to be unreinforced for the purpose of design.

1.6.3.68 Post-tensioning

Tensioning of tendons after the concrete has hardened.

1.6.3.69 Prestressed concrete

Concrete into which internal stresses are induced deliberately by tendons.

NOTE: It includes concrete commonly referred to as 'partially prestressed'.

1.6.3.70 Prestressing steel

See 'Tendon'.

1.6.3.71 Pretensioning

Tensioning of tendons before the concrete is placed.

1.6.3.72 Prismatic compression field

Compression field that is parallel sided [see Figure 7.2.1(a)].

1.6.3.73 Reinforcement

Steel bar, wire or mesh but not tendons.

NOTE: Commonly referred to as reinforcing steel.

1.6.3.74 Ribbed slab

Slab incorporating parallel ribs in one or two directions.

1.6.3.75 Self-compacting concrete

Concrete that is able to flow and consolidate under its own weight, completely fill the formwork or excavation even in the presence of dense reinforcement, whilst maintaining homogeneity and without the need for additional compaction, and which conforms with specified requirements for slump flow, viscosity and passing ability.

1.6.3.76 Shear wall

Wall that is designed to resist lateral forces acting in or parallel to the plane of the wall.

1.6.3.77 Short column

Column in which the additional bending moments due to slenderness can be taken as zero.

1.6.3.78 Slender column

Column that does not satisfy the requirements for a short column.

1.6.3.79 Span support

See Clause 6.1.4.4.

1.6.3.80 Strength grade

Numerical value of the characteristic compressive strength of concrete at 28 days (f'_c), used in design.

1.6.3.81 Structural adequacy (fire)

Ability of a member to maintain its structural function when exposed to fire.

1.6.3.82 Strut-and-tie model

Truss model made up of struts and ties connected at nodes.

1.6.3.83 Tendon

Wire, strand or bar (or any discrete group of such wires, strands or bars) that is designed to be pretensioned or post-tensioned.

1.6.3.84 Tie

Tension member in a strut-and-tie model.

1.6.3.85 Torsion strip

Strip of slab of width a , whose longitudinal axis is perpendicular to the direction of M_v^* [see Figure 9.3(B)].

1.6.3.86 Transfer

Time of initial transfer of prestressing forces from the tendons to the concrete.

1.6.3.87 Transmission length

Length, at transfer, over which the stress in a pretensioned tendon builds up from zero at one end to its full value.

1.6.3.88 Transverse width

See Clause 6.1.4.5.

1.6.3.89 Two-way slab

Slab characterized by flexural action in two directions.

1.6.3.90 Uniform strain

Strain in the reinforcement at maximum stress, corresponding to the onset of necking.

1.6.3.91 Upper characteristic strength

Value of the material strength, as assessed by standard test, which is exceeded by 5% of the material.

1.7 NOTATION

The symbols used in this Standard, including their definitions, are listed below.

Unless a contrary intention appears, the following applies:

- (a) The symbols used in this Standard shall have the meanings ascribed to them below, with respect to the structure, or member, or condition to which a clause is applied.
- (b) Where non-dimensional ratios are involved, both the numerator and denominator shall be expressed in identical units.
- (c) The dimensional units for length, force and stress, in all expressions or equations, shall be taken as millimetres (mm), newtons (N) and megapascals (MPa) respectively, unless noted otherwise.
- (d) An asterisk (*) placed after a symbol as a superscript (e.g. M_y^*) denotes a design action effect due to the design load.

Symbol	Definition
A_b	= cross-sectional area of a reinforcing bar
$A_{b,fit}$	= cross-sectional area of the fitment
A_{bar}	= the cross-sectional area of the bar (see Clause 13.1.4)
A_c	= smallest cross-sectional area of the concrete strut at any point along its length and measured normal to the line of action of the strut (see Table 5.6.4 and Clause 7.2.3); <i>or</i> = cross-sectional area bounded by the centre-line of the outermost fitments (see Clause 10.7.3.3)
$A_{c,eff}$	= the effective area of concrete in tension surrounding the bars with depth $h_{c,ef}$ equal to the lesser of $2.5(D-d)$, $(D-kd)/3$ or $D/2$ (see Clause 8.6.2.3)
A_{cp}	= total area enclosed by outside perimeter of concrete section (see Clause 8.2.1.2)
A_{ctu}	= area of concrete within the tensile zone (mm^2) at ultimate (see Clause 16.4.2)
A_g	= gross cross-sectional area of a member
A_{head}	= the net bearing area of the head (see Clause 13.1.4)
A_m	= an area enclosed by the median lines of the walls of a single cell (see Clause 8.3.3)
A_{oh}	= area enclosed by centre-line of exterior closed transverse torsion reinforcement, including area of holes (if any) (see Clause 8.2.5.6)
A_p	= cross-sectional area of prestressing steel
A_{pt}	= cross-sectional area of the tendons in the zone that will be tensile under ultimate load conditions

A2

Symbol	Definition
A_s	= cross-sectional area of reinforcement (see Clauses 3.4.3.2 and 13.2.2); <i>or</i> = cross-sectional area of a single anchored bar of diameter d_b (see Clause 13.1.2.3)
A_{sc}	= cross-sectional area of compressive reinforcement
A_{sf}	= area of fully anchored reinforcement crossing the interface
A_{si}	= cross-sectional area of steel bar (tendon, wire) (see Clause 5.2.1) = area of reinforcement in the i th direction crossing a strut (see Clause 7.2.4)
A_{st}	= cross-sectional area of longitudinal tensile reinforcement; <i>or</i> = cross-sectional area of reinforcement in the zone that would be in tension under the design loads if the effects of prestress and axial loads are ignored
A_{sv}	= cross-sectional area of shear reinforcement
$A_{sv.min}$	= cross-sectional area of minimum shear reinforcement
A_{sw}	= cross-sectional area of the bar forming a closed fitment
A_{tr}	= cross-sectional area of a transverse bar along a development or lap length (see Clause 13.1.2.3)
$A_{tr.min}$	= cross-sectional area of the minimum transverse reinforcement along the development length (see Clause 13.1.2.3)
A_o	= a reference area taken as $A_o = 15\,600\text{ mm}^2$ (see Clause 16.4.2) = area enclosed by shear flow path, including any area of holes therein (see Clause 8.2.1.2)
A_1	= a bearing area (see Clause 12.6)
A_2	= largest area of the supporting surface that is geometrically similar to and concentric with A_1 (see Clause 12.6)
a	= a distance; <i>or</i> = shear span, equal to the distance between the centroids of an applied load and a support reaction in a structure (see Clause 7.2.4); <i>or</i> = perpendicular distance from the nearer support to the section under consideration (see Clause 9.6); <i>or</i> = dimension of the critical shear perimeter measured parallel to the direction of M_v^* [see Figure 9.3(B)]
a_i	= axis distance of steel bar (tendon, wire) 'i' from the nearest exposed surface (see Clause 5.2.1)
a_m	= average axis distance (see Clause 5.2.1)
a_s	= axis distance (see Clause 5.2.2)
a_{sup}	= length of a support in the direction of the span (see Clause 6.1.4.4)

Symbol	Definition
b	= width of a rectangular cross-section or member; <i>or</i> = width of beam at the centroid of the bottom reinforcement (see Clause 5.4.1); <i>or</i> = width of ribs [see Table 5.5.2(C) and Table 5.5.2(D)]; <i>or</i>
A2 b_c	= smaller column cross-sectional dimension if rectangular, or the column diameter if circular (see Table 5.6.3, Table 5.6.4 and Clause 10.7.4.3)
b_{ef}	= effective width of a compression face or flange of a member
b_f	= width of the shear plane (see Clause 8.4.3)
b_l	= size of rectangular, or equivalent rectangular column, capital, or bracket, measured in the direction of the span for which moments are being determined (see Clause 14.5.3.2)
b_o	= dimension of an opening (see Clause 9.3.1.2 and 9.3.1.5)
b_t	= size of rectangular, or equivalent rectangular column, capital, or bracket, measured transverse to the direction of the span for which moments are being determined (see Clause 14.5.3.2)
A2 b_v	= effective width of a web for shear (see Clause 8.2.1.5)
b_w	= a width of the web; <i>or</i> = minimum thickness of the wall of a hollow section (see Clause 8.3.3)
c (c_l)	= cover to reinforcing steel or tendons
c_d	= a dimension (in millimetres) corresponding to the smaller of the concrete cover to a bar developing stress and half the clear distance to the next parallel bar developing stress, as shown in Figure 13.1.2.2
A2 CMOD	= crack mouth opening displacement (see Clause 16.2.1)
COD	= crack opening displacement (see Clause 16.2.2)
D	= overall depth of a cross-section in the plane of bending; <i>or</i> = depth or breadth of the symmetrical prism as appropriate (see Clause 12.5.6)
D_{Ed}	= fatigue damage factor
D_b	= overall depth of a spandrel beam
A2 [Text deleted]	
D_s	= overall depth of a slab or drop panel; <i>or</i> = the member depth at the theoretical cut-off point or debonding point (see Clause 8.1.11.1)
d	= effective depth of a cross-section in the plane of bending
d_b	= nominal diameter of a bar, wire or tendon
d_c	= depth of the idealized strut (see Clause 7.2.4); <i>or</i> = core dimension measured between the centre-lines of the outermost fitments measured through the depth of the section (see Clause 10.7.3.3)

Symbol	Definition
d_d	= diameter of a prestressing duct (see Clause 8.2.6)
d_f	= diameter of the bar forming the fitment (see Clause 14.5.2.2)
d_g	= maximum nominal aggregate size (see Clause 8.2.4.2)
d_i	= mandrel pin diameter for bending reinforcement
d_o	= distance from the extreme compressive fibre of the concrete to the centroid of the outermost layer of tensile reinforcement or tendons (not less than $0.8D$ for prestressed concrete members)
d_{om}	= mean value of d_o , averaged around the critical shear perimeter
d_p	= distance from the extreme compressive fibre of the concrete to the centroid of the tendons in that zone, which will be tensile under ultimate strength conditions
d_s	= overall dimension measured between centre-lines of the outermost fitments (see Clause 10.7.3.3)
d_{sc}	= distance from the extreme compressive fibre of the concrete to the centroid of compressive reinforcement (see Clause 8.1.7)
d_v	= the effective shear depth of the member calculated in accordance with Clause 8.2.1.9
EC_e	= electrical conductivity (see Clause 4.8.2)
E_c	= mean value of the modulus of elasticity of concrete at 28 days
E_{cj}	= mean value of the modulus of elasticity of concrete at the appropriate age, determined in accordance with Clause 3.1.2
E_d	= design action effect (see Clauses 2.2.2 to 2.2.6)
E_p	= modulus of elasticity of tendons, determined in accordance with Clause 3.3.2
E_s	= modulus of elasticity of reinforcement, determined in accordance with Clause 3.2.2
e	= eccentricity of prestressing force or load; <i>or</i> = the base of Napierian logarithms
e_a	= an additional eccentricity (see Clause 11.5.1)
F	= total vertical component of the external load carried through the shear span (see Clause 12.2.1)
F_d	= uniformly distributed design load, factored for strength or serviceability, as appropriate
$F_{d,ef}$	= effective design service load per unit length or area, used in serviceability design
F_{Rj}	= load recorded at CMOD _j (see Figure 16.3.3.8)
$f'_{0.5}$	= characteristic residual tensile strength of concrete (at 28 days) at a Crack Opening Displacement (COD) of 0.5 mm
$f'_{1.5}$	= characteristic residual tensile strength of a concrete (at 28 days) at a Crack Opening Displacement (COD) of 1.5 mm

Symbol	Definition
$f_{0.5m}$	= mean values of the tensile strength at Crack Opening Displacement (COD) of 0.5 mm
$f_{1.5m}$	= mean values of the tensile strength at Crack Opening Displacement (COD) of 1.5 mm
$f_{c,fat}$	= compressive strength for fatigue effects
f_{cm}	= mean value of cylinder strength (see Clause 3.1.1.2)
f_{cmi}	= mean value of the in situ compressive strength of concrete at the relevant age (see Clause 3.1.1.2 and Table 3.1.2)
f_{ct}	= uniaxial tensile strength of concrete (see Clause 3.1.1.3)
$f_{ct,f}$	= measured flexural tensile strength of concrete (see Clause 3.1.1.3)
$f_{ct,sp}$	= measured splitting tensile strength of concrete (see Clause 3.1.1.3)
f_{cv}	= concrete shear strength (see Clause 9.2.4)
f_{pb}	= characteristic minimum breaking strength (see Clause 3.3.1)
f_{po}	= the stress in prestressing tendons when strain in the surrounding concrete is zero (see Clause 8.2.4.2.1)
f_{py}	= yield strength of tendons determined in accordance with Clause 3.3.1
f_r	= average confining pressure on the core cross-section taken at the level of the fitments (see Clause 10.7.3.3)
$f_{r,eff}$	= effective confining pressure applied to the core of a column (see Clause 10.7.3.3)
f_{si}	= stress in reinforcement in the i th direction crossing a strut
f_{sy}	= characteristic yield strength of reinforcement (referred to as R_e in AS/NZS 4671), determined in accordance with Clause 3.2.1
$f_{sy,f}$	= characteristic yield strength of reinforcement used as fitments
f_{Lm}	= mean flexural tensile strength corresponding to the limit of proportionality, determined in accordance with Clause 16.3.3.8 with $F_{R,j}$ substituted by F_L
$f_{R,1m}$	= mean residual flexural tensile strength corresponding to a CMOD of 0.5 mm, determined in accordance with Clause 16.3.3.7
A2 $f_{R,2m}$	= mean residual flexural tensile strength corresponding to a CMOD of 1.5 mm, determined in accordance with Clause 16.3.3.7
$f_{R,3m}$	= mean residual flexural tensile strength corresponding to a CMOD of 2.5 mm, determined in accordance with Clause 16.3.3.7
A2 $f_{R,4m}$	= mean residual flexural tensile strength corresponding to a CMOD of 3.5 mm, determined in accordance with Clause 16.3.3.7
f'_c	= characteristic compressive (cylinder) strength of concrete at 28 days
f'_{cc}	= characteristic compressive strength of the concrete in the column (see Clause 10.8)
f'_{ce}	= effective compressive strength of the concrete in the joint (see Clause 10.8)
A2 f'_{cp}	= characteristic compressive cylinder strength of concrete at transfer

	Symbol	Definition
	f'_{cs}	= characteristic compressive strength of the concrete in the slab or beams (see Clause 10.8)
	f'_{ct}	= characteristic uniaxial tensile strength of concrete (see Clause 3.1.1.3)
	$f'_{ct,f}$	= characteristic flexural tensile strength of concrete at 28 days (see Clause 3.1.1.3)
A2	f'_w	= characteristic residual tensile strength of SFRC corresponding to a COD w
	G	= permanent action (dead load)
	g	= dead load, per unit length or area
	g_p	= permanent distributed load normal to the shear interface per unit length, newtons per millimetre (N/mm) (see Clause 8.4.3)
A2	H	= overall height of a wall measured from the boundary at its base to the soffit or connection at its top, continuing through any intermediate slabs or walls
	H_w	= floor-to-floor unsupported height of a wall
	H_{we}	= effective height of a wall
	h	= overall depth of a joint (see Clause 10.8)
	h_s	= flange thickness of a ribbed slab
	h_{sp}	= distance between tip of the notch and top of cross section in millimetres (see Clause 16.3.7)
	I	= second moment of area of the uncracked concrete cross-section about the centroidal axis
	I_c	= second moment of area of a column
	I_{cr}	= second moment of area of a cracked section with the reinforcement transformed to an equivalent area of concrete
	I_{ef}	= an effective second moment of area (see Clause 8.5.3 and Clause 16.4.7.3.2)
	$I_{ef,max}$	= maximum effective second moment of area (see Clause 8.5.3)
	I_f	= second moment of area of a flexural member
	J_t	= a torsional modulus
	j	= time after prestressing, in days (see Clause 3.3.4.3)
	K	= a factor that accounts for the weighted average effectiveness of transverse reinforcement in controlling potential splitting cracks along a development or lap splice length (see Clause 13.1.2.3)
	k	= a coefficient, ratio or factor used with and without numerical subscripts
	k_1	= a coefficient that accounts for the bond properties of the bonded reinforcement (see Clause 8.6.2.3)
	k_2	= a coefficient that accounts for the longitudinal strain distribution (see Clause 8.6.2.3)
	k_{3Dt}	= the three-dimensional orientation factor (see Clause C2)

Symbol	Definition
k_{3Dtb}	= three-dimensional orientation factor (see Clause 16.3.3.4)
k_{co}	= cohesion coefficient (see Clause 8.4.3)
k_{cs}	= factor used in serviceability design to take account of the long-term effects of creep and shrinkage
kd	= the depth of the neutral axis on the cracked section (see Clause 8.6.2.3)
k_d	= a factor to reduce the allowable fatigue stress range in reinforcement at the location of a bend radius $d_i/2.k_d = 0.35 + 0.026 (d_i/d_b) \leq 1.0$ (see Clause 18.8)
k_e	= effectiveness factor accounting for the arrangement of the fitments
k_g	= member size factor determined by Equation 16.4.2, where area of concrete within the tensile zone (mm^2) at ultimate is calculated as $A_{ctu} = b_v d_v \cot \theta_v$ (see Clause 16.4.4.2.1)
k_i	= the instantaneous curvature calculated as the slope of the strain diagram in Figure 16.4.7.3.2(b)
k_m	= coefficient calculated in accordance with Clause 10.4.2
k_r	= ratio of the depth, or breadth, of an anchorage bearing plate to the corresponding depth, or breadth, of the symmetrical prism (see Clause 12.5.4)
A2 k_s	= fibre orientation casting bias factor and is taken as 0.64 (see Clause 16.4.4.2.1)
k_u	= neutral axis parameter being the ratio, at ultimate strength under any combination of bending and compression, of the depth to the neutral axis from the extreme compressive fibre to d
k_{uo}	= ratio, at ultimate strength, without axial force of the depth to the neutral axis from the extreme compressive fibre to d_o
L	= centre-to-centre distance between the supports of a flexural member
L_e	= effective length of a column
L_{ef}	= effective span of a member, taken as the lesser of $(L_n + D)$ and L for a beam or slab; <i>or</i> = $L_n + D/2$ for a cantilever
L_l	= distance between centres of lateral restraints or from a lateral restraint to the free edge
L_n	= length of clear span in the direction in which moments are being determined, measured face-to-face of supporting beams, columns or walls, or for a cantilever, the clear projection
L_o	= L minus 0.7 times the sum of the values of a_{sup} at each end of the span (see Clause 6.10.4.2)
L'_o	= smaller value of L_o for adjoining spans (see Clause 6.10.4.5)
L_p	= development length of tendons
L_{pa}	= length of the tendon from the jacking end to a point at a distance 'a' from that end (see Clause 3.4.2.4)
L_{pt}	= transmission length for pretensioned tendons

Symbol	Definition
L_s	= span between formwork supports (see Clause 17.6.2.4)
L_{sc}	= development length of a bar for a compressive stress less than the yield stress
L_{st}	= development length of a bar for a tensile stress less than the yield stress
$L_{sy.c}$	= development length in compression, being the length of embedment required to develop the yield strength of a deformed bar in compression (see Clause 13.1.5.1)
$L_{sy.cb}$	= basic development length of a deformed bar in compression (see Clause 13.1.5.2)
$L_{sy.t}$	= development length in tension, to develop the characteristic yield strength of a deformed bar in tension (see Clause 13.1.2 and Figure 13.1.2.3)
$L_{sy.t.lap}$	= the tensile lap length for either contact or non-contact splices (see Clause 13.2.2)
$L_{sy.tb}$	= basic development length of a deformed bar in tension (see Clause 13.1.2.2)
L_t	= width of a design strip [see Figure 6.1.4(A)]
L_u	= unsupported length of a column, taken as the clear distance between the faces of members capable of providing lateral support to the column. Where column capitals or haunches are present, L_u is measured to the lowest extremity of the capital or haunch
L_w	= overall length of a wall
L_x	= shorter effective span of a slab supported on four sides
L_y	= longer effective span of a slab supported on four sides
l_b	= length of the bursting zone (see Clause 7.2.4)
l_f	= length of the steel fibre (see Clause C2)
l_x	= shorter span of a two-way slab [see Table 5.5.2(A)]
l_y	= longer span of a two-way slab [see Table 5.5.2(A)]
A2 $l_{o.fi}$	= effective length of a column under fire conditions (see Clause 5.6.3)
M^*	= design bending moment at a cross-section
M_f^*	= design moment in the fire situation (see Table 5.6.4)
M_s^*	= maximum bending moment at the section based on the short-term serviceability load or construction load (see Clause 8.5.3.1)
$M_{s.1}^*$	= design bending moment at the serviceability limit state, calculated with $\psi_s = 1.0$ (see Clauses 8.6.1 and 9.4.1)
M_v^*	= design bending moment to be transferred from a slab to a support
M_x^*, M_y^*	= design bending moment in a column about the major and minor axes respectively; <i>or</i>

Symbol	Definition
	= positive design bending moment, at midspan in a slab, in the x and y direction respectively
M_1^*, M_2^*	= smaller and larger design bending moment respectively at the ends of a column
M_c	= moment used in the calculation of the buckling load (N_c) (see Clause 10.4.4)
$M_{cr,t}$	= bending moment at time t causing cracking of the section with due consideration to prestress, restrained shrinkage and temperature stresses
M_{nb}	= sum of nominal flexural strengths of the beams framing into the joint (see Clause 14.5.6)
M_{nc}	= sum of the nominal flexural strengths of columns framing into the joint (see Clause 14.5.6)
M_o	= total static moment in a span (see Clause 6.10.4.2); <i>or</i>
M_u	= ultimate strength in bending at a cross-section of an eccentrically loaded compressive member
M_{ub}	= particular ultimate strength in bending when $k_{uo} = 0.003/(0.003 + f_{sy}/E_s)$
M_{uo}	= ultimate strength in bending, without axial force, at a cross-section
$(M_{uo})_{min}$	= minimum required strength in bending at a critical cross-section (see Clause 8.1.6.1)
M_{ux}, M_{uy}	= ultimate strength in bending about the major and minor axes respectively of a column under the design axial force N^*
m	= number of fitments legs crossing the confinement plane (see Clause 10.7.3.3)
	= number of intervals with constant amplitude
N	= number of resisting stress cycles, to be calculated from the fatigue strength
N^*	= axial compressive or tensile force on a cross-section
N_{Rsk}	= number of cycles for resistance of constant amplitude stress $\Delta\sigma R_{sk}$
N_f^*	= design axial load in the fire situation (see Clause 5.6.3)
N_c	= buckling load used in column design
N_i	= ultimate number of constant amplitude cycles in interval 'i' that can be carried before failure
N_u	= ultimate strength in compression, or tension, at a cross-section of an eccentrically loaded compression or tension member respectively
	= ultimate strength per unit length of wall (see Clause 11.5.1)
N_{ub}	= particular ultimate strength in compression of a cross-section when $k_{uo} = 0.003/(0.003 + f_{sy}/E_s)$
N_{uo}	= ultimate strength in compression, without bending, of an axially loaded cross-section
N_{uot}	= ultimate strength in tension, without bending, of an axially loaded cross-section

Symbol	Definition
n	= number of bars uniformly spaced around helical reinforcement (see Clause 13.2.4); <i>or</i> = number of laterally restrained longitudinal bars (see Clauses 10.7.3.3 and 10.7.3.4)
n_{bs}	= number of longitudinal bars being developed or spliced at which a potential splitting crack can develop (see Table 13.1.2.3)
n_e	= the effective modular ratio $(1 + \phi_{cc})E_s/E_c$ (see Clause 8.6.2.3)
n_f	= number of fitment bars within longitudinal spacing or pitch s that a potential splitting crack has to cross (see Table 13.1.2.3)
n_i	= foreseen number of constant amplitude cycles in interval 'i'
n_{sc}	= foreseen number of stress cycles during the required design service life (see Clause 18.1)
P	= force in the tendons; <i>or</i> = maximum force occurring at the anchorage during jacking (see Clause 12.5.4); <i>or</i> = applied loads (see Clause 12.2)
P_e	= total effective prestress force allowing for all losses of prestress
P_v	= vertical component of the prestressing force
p	= a reinforcement ratio
p_{cw}	= web reinforcement ratio for compressive reinforcement (see Clause 8.5.3.1)
$p_{p,eff}$	= the reinforcement ratio given by $A_{st}/A_{c,eff}$ (see Clause 8.6.2.3)
p_w	= a reinforcement ratio in a wall; <i>or</i> = web reinforcement ratio for tensile reinforcement (see Clause 8.5.3.1)
Q	= imposed action (live load) including impact, if any
Q_{fat}	= the cyclic load for fatigue design
q	= imposed action (live load) per unit length or area
R	= design relaxation of a tendon, determined in accordance with Clause 3.3.4.3
R_b	= basic relaxation of a tendon, determined in accordance with Clause 3.3.4.2
R_d	= design capacity of a member or structure (equal to ϕR_u or $\phi_{sys} R_{u,sys}$)
R_u	= ultimate strength of a member (see Clause 2.2)
$R_{u,sys}$	= mean capacity of the structure (see Clause 2.2.5)
r	= radius of gyration of a cross-section
$S_{cd,max}$	= maximum compressive stress level
$S_{cd,min}$	= minimum compressive stress level
S_p	= structural performance factor (see Clause 14.3)

Symbol	Definition
s	= centre-to-centre spacing of fitments including shear, torsional or confining reinforcement, measured parallel to the longitudinal axis of a member; <i>or</i> = standard deviation; <i>or</i> = maximum spacing of transverse reinforcement within $L_{sy,c}$, or spacing of fitments, or spacing of successive turns of helical reinforcement, all measured centre-to-centre, in millimetres (see Clause 13.2.4); <i>or</i> = spacing of anchored shear reinforcement crossing interface (see Clause 8.4.3); <i>or</i> = factor related to type of cement
s_b	= clear distance between bars of the non-contact lapped splice (see Figure 13.2.2)
s_m	= spacing of bars being developed, in millimetres
s_{max}	= maximum centre-to-centre spacing of the shear reinforcement (see Clause 8.4.4)
$s_{r,max}$	= the maximum crack spacing (see Clause 8.6.2.3)
T	= a temperature; <i>or</i> = force resultant of transverse tensile stresses (see Clause 12.5.4)
T^*	= torsional moment at a cross-section
T_b^*	= bursting force calculated at the ultimate limit state (see Clause 7.2.4)
$T_{b,s}^*$	= bursting force calculated at the serviceability state (see Clause 7.2.4)
$T_{b,cr}$	= bursting (or splitting) force across a strut caused at the time of cracking of the strut (see Clause 7.2.4)
T_{cd}	= the net tension force caused by flexure shear and axial force on the flexural compressive side of a cross-section (see Clause 8.2.8.2)
T_{cr}	= torsional cracking moment (see Clause 8.2.1.2)
T_{td}	= the net tension force caused by flexure shear and axial force on the flexural tensile side of a cross-section (see Clause 8.2.8.2)
T_u	= ultimate torsional strength
$T_{u,max}$	= ultimate torsional strength of a beam limited by web crushing failure (see Clause 8.3.3)
T_{us}	= torsional resistance (see Clause 8.2.5.6)
T_w	= vertical component of the force carried by the secondary struts (see Clause 12.2)
t	= time
t_d	= difference between the actual effective thickness of the slab and the effective thickness specified in Table 5.5.1, for the required FRP (see Clause 5.8.2)
t_f	= thickness of topping or flange anchored by shear reinforcement (see Clause 8.4.4)

Symbol	Definition
t_h	= hypothetical thickness of a member used in determining creep and shrinkage, taken as $2A_g/u_e$
t_{nom}	= nominal thickness of topping applied (see Clause 5.8.2)
t_w	= thickness of a wall
u	= length of the critical shear perimeter (see Clause 9.3.1.5)
u_c	= the length of the outside perimeter of concrete cross-section (see Clause 8.2.1.2)
u_e	= exposed perimeter of a member cross-section plus half the perimeter of any closed voids contained therein, used to calculate t_h
u_h	= perimeter of the centre-line of the closed transverse torsion reinforcement (see Clause 8.2.1.2)
V^*	= design shear force at a cross-section
V_{eq}^*	= the equivalent factored shear force (see Clause 8.2.1.2)
V_{min}^*	= minimum design shear action calculated for all load combinations (see Clause 2.5.2.2)
V_o	= shear force which would occur at a section when the bending moment at that section was equal to the decompression moment M_o
V_u	= ultimate shear strength
$V_{u,max}$	= ultimate shear strength limited by web crushing failure
V_{uc}	= ultimate shear strength excluding shear reinforcement (see Clause 8.2.3)
V_{uo}	= ultimate shear strength of a slab with no moment transfer (see Clause 9.3.3)
V_{us}	= contribution by shear reinforcement to the ultimate shear strength of a beam or wall (see Clauses 8.2.3 and 11.6.4)
w	= average clear spacing between adjacent tied longitudinal bars (see Clause 10.7.3.3); <i>or</i> = width of loaded area (see Figure 12.2.1) or node [see Figure 7.2.4(A)] = Crack Opening Width (COD) in relation to Steel Fibre Reinforced Concrete (SFRC)
w'_{max}	= characteristic maximum crack width (see Clause 8.6.1) = calculated maximum crack width in a reinforced concrete member at any time after cracking (see Clause 9.5.1)
X	= a dimension [see Figure 9.3(A)]
x	= shorter overall dimension of a rectangular part of a cross-section
Y	= a dimension [see Figure 9.3(A)]
y	= larger overall dimension of a rectangular part of a cross-section
y_1	= larger overall dimension of a closed fitment (see Clause 9.3.1.5)
Z	= section modulus of the uncracked cross-section, referred to the extreme fibre at which flexural cracking occurs (see Clause 8.1.6.1)

Symbol	Definition
z	= projection of the inclined compressive strut normal to the shear span (see Clause 7.2.4); <i>or</i> = internal moment lever arm between the centroids of the flexural compression force and the flexural tension force acting on the section (see Clause 8.2.8.2)
α	= coefficient; <i>or</i> = angle of divergence between bottled shape compression fields and idealized parallel sided strut (see Clause 7.2.4)
α_b	= coefficient for beams (see Clause 8.1.6.1)
α_c	= coefficient (see Clause 10.3.1)
α_n	= coefficient (see Clause 10.6.4)
α_s	= correlation factor (see Clause 10.4.3)
α_{tot}	= sum in radians of the absolute values of successive angular deviations of the prestressing tendon over the length (L_{pa}) (see Clause 3.4.2.4)
α_v	= angle between the inclined shear reinforcement and the longitudinal tensile reinforcement (see Clause 8.2.3.3)
α_x, α_y	= short and long span bending moment coefficients respectively, for slabs supported on four sides (see Clause 6.10.3.2)
β	= an effective compression strength factor (see Clause 2.2.3); <i>or</i> = fixity factor (see Clause 10.5.4); <i>or</i> = a ratio (see Clauses 8.4.2 and 8.5.3.1); <i>or</i> = a factor with or without alphanumeric subscripts (see Clause 8.2.7)
β_{cc}	= factor for strength gain in concrete with time
β_d	= a factor (see Clause 10.4.3)
β_h	= a ratio (see Clause 9.3.1.5)
β_n	= factor to account for the effect of the anchorage of ties on the effective compressive strength of a nodal zone (see Clause 7.4.2)
β_p	= an estimate, in radians per metre (rad/m), of the angular deviation due to wobble effects (see Clause 3.4.2.4)
β_s	= strut efficiency factor (see Clause 7.2.2)
β_x, β_y	= short and long span bending moment coefficients respectively, for slabs supported on four sides (see Clause 6.10.3.2)
γ	= the ratio, under design bending or design combined bending and compression, of the depth of the assumed rectangular compressive stress block to $k_u d$
γ_1, γ_2	= column end restraint coefficients, determined in accordance with Clause 10.5.3
γ_i	= angle between the axis of a strut and the bars in the i th direction of reinforcement crossing that strut (see Clause 7.2.4)
γ_F	= load factor for fatigue load combinations (see Clause 2.5.2.3)
γ_P	= factor for prestress for fatigue load combinations (see Clause 2.5.2.3); <i>or</i>

Symbol	Definition
A2	= load factor for vertical component of prestress (see Clause 8.2)
Δ	= a deflection
$\Delta\sigma_p$	= change in the stress due to the change in length of the prestressed tie (see Clause 7.3.2)
$\Delta\sigma_{Rsk}(n_{sc})$	= resisting stress range relevant to n_{sc} cycles obtained from a characteristic fatigue strength function
$\Delta\sigma_s$	= maximum nominal steel stress range under the acting load combination for steel
$\delta, \delta_b, \delta_s$	= moment magnifiers for slenderness effects (see Clause 10.4)
ε	= a strain
ε_{cc}	= strain due to concrete creep (see Clauses 3.1.8.1 and 3.4.3.3)
ε_{cm}	= the mean strain in the concrete between the cracks (see Clause 8.6.2.3)
ε_{cs}	= design shrinkage strain, determined in accordance with Clause 3.1.7.1
ε_{cs}^*	= final design shrinkage strain of concrete
ε_{csd}	= drying shrinkage strain, determined in accordance with Clause 3.1.7.2
ε_{cse}	= autogenous shrinkage strain, determined in accordance with Clause 3.1.7.2
ε_{cse}^*	= final autogenous shrinkage strain, determined in accordance with Clause 3.1.7.2
$\varepsilon_{csd,b}$	= basic drying shrinkage strain, determined in accordance with Clause 3.1.7.2
$\varepsilon_{csd,b}^*$	= final drying basic shrinkage strain, determined in accordance with Clause 3.1.7.2
ε_{pu}	= strain at maximum stress of a prestressing tendon
ε_{sm}	= the mean strain in the reinforcement at the design loads for the serviceability limit states, including the effects of tension stiffening and any imposed deformations (see Clause 8.6.2.3)
ε_{su}	= uniform strain at maximum stress, corresponding to the onset of necking
ε_x	= longitudinal strain in the concrete at the mid-depth of the section (see Clause 8.2.4.2.2)
η_c	= factor for stress gradient for concrete in the compression zone of a cracked section
η_s	= factor which increases the stress in the reinforcing steel due to differences in bond behaviour between prestressing and reinforcing steel
θ	= angle measured between the axis of the strut and the axis of a tie passing through a common node (see Clauses 7.2.2 and 12.2); <i>or</i> = angle between tie leg and confinement plane (see Clause 10.7.3.3)
θ_v	= angle between the axis of the concrete compression strut and the longitudinal axis of the member (see Clause 8.2.3.3)
λ_1	= a factor being 1.0 for normal concrete and 0.75 for lightweight concrete

Symbol	Definition
λ_{uc}	= a ratio of loads (see Clause 10.4.3)
μ	= friction curvature coefficient (see Clause 3.4.2.4); <i>or</i> = coefficient of friction (see Clause 8.4.3); <i>or</i> = structural ductility factor (see Section 14)
μ_{fi}	= load level for structural adequacy for a column (see Clause 5.6.3)
ν	= Poisson's ratio for concrete, determined in accordance with Clause 3.1.5
ζ	= ratio of bond strength (see Clause 18.7)
ρ	= density of concrete, in kilograms per cubic metre (kg/m ³), determined in accordance with Clause 3.1.3
ρ_p	= transverse compressive pressure, in megapascals, at the ultimate limit state along the development length perpendicular to the plane of splitting (see Clause 13.1.2.3)
ρ_s	= volumetric ratio of the fitments relative to the volume of the core (see Clause 10.7.3.3)
ρ_{wh}	= horizontal reinforcement ratio (see Clause 14.6.7)
ρ_{wv}	= vertical reinforcement ratio (see Clause 14.6.7)
σ	= stress in the context of ultimate and serviceability limit states of steel fibre reinforced concrete (SFRC) (see Clause 16.1)
$\sigma_{c,1}$	= minimum compressive stress within a distance of 300 mm from the surface under the relevant load combination of actions
$\sigma_{c,2}$	= maximum compressive stress within a distance of 300 mm from the surface under the same load combination as that for which $\sigma_{c,1}$ was determined
$\sigma_{c,300}$	= compressive stress at a depth of 300 mm from the extreme compressive fibre for same load case as $\sigma_{c,max}$, but not less than zero (compression is positive) (see Clause 18.2)
$\sigma_{c,max}$	= maximum compressive stress at the extreme fibre under consideration, compression measured positive, $\gamma_F [G, P, Q_{fat}]$
$\sigma_{c,min}$	= minimum compressive stress at the extreme fibre under consideration, taken as zero if tensile, $\gamma_F [\{G, P, \psi_s Q\}, Q_{fat}]$
σ_{ci}	= sustained stress in the concrete at the level of the centroid of the tendons, calculated using the initial prestressing force prior to any time-dependent losses and the sustained portions of all the service loads (see Clause 3.4.3.3)
σ_{cp}	= average intensity of effective prestress in concrete
σ_{cs}	= maximum shrinkage-induced tensile stress on the uncracked section at the extreme fibre at which cracking occurs (see Clause 8.5.3.1)
$\sigma_{ct,min}, \sigma_{ct,max}$	= minimum and maximum tensile stress
$\sigma_{max}, \sigma_{min}$	= the maximum and minimum concrete design compressive stress (see Clause 2.5.2.3)
σ_o	= a constant sustained stress (see Clause 3.1.8.1)

Symbol	Definition
σ_{pa}	= stress in the tendon at a distance 'a', measured from the jacking end (see Clause 3.4.2.4)
$\sigma_{p,ef}$	= effective stress in the tendon after allowing for all losses (see Clause 8.1.8)
σ_{pi}	= stress in the tendon immediately after transfer
σ_{pj}	= stress in the tendon at the jacking end (see Clause 3.4.2.4)
σ_{pu}	= maximum stress that would be reached in a tendon at ultimate strength of a flexural member
σ_s	= maximum nominal steel stress range under the acting load combination (see Clause 18.8)
σ_{sc}	= a compressive stress being developed in a bar in compression (see Clause 13.1.5.4)
σ_{scr}	= tensile steel stress at the serviceability limit state for a beam in flexure or in tension (see Clause 8.6.1) or for a slab in flexure (see Clause 9.4.1)
$\sigma_{scr,1}$	= tensile stress in reinforcement at a cracked section, due to the short-term load combination for the serviceability limit states, calculated with $\psi_s = 1.0$, when direct loads are applied (see Clause 8.6.1)
σ_{st}	= tensile stress in reinforcement (see Clause 13.1.2.4)
$\Sigma(I/L)_c$	= sum of the stiffness in the plane of bending of all the columns meeting at and rigidly connected to the end of the column under consideration (see Clause 10.5.4)
$\Sigma(\beta I/L)_b$	= sum of the stiffness in the plane of bending of all the beams or slabs, or both, meeting at and rigidly connected to the same end of the column under consideration (see Clause 10.5.4)
τ	= age of concrete at the time of loading, in days
τ^*	= design shear stress acting on the interface (see Clause 8.4.2)
τ_u	= unit shear strength (see Clause 8.4.3)
ϕ	= capacity reduction factor for design using linear elastic analysis (see Clause 2.2.2)
ϕ_s	= stress reduction factor for design using linear stress analysis (see Clause 2.2.3)
$\phi_{c,fat}$	= fatigue strength capacity reduction factor for concrete
$\phi_{s,fat}$	= fatigue strength capacity reduction factor for steel
ϕ_{st}	= strength reduction factor for design using strut-and-tie analysis (see Clause 2.2.4)
ϕ_{sys}	= system strength reduction factor for design using non-linear methods of analysis (see Clauses 2.2.5 and 2.2.6)
φ	= sum of the shear associated with development of nominal moment strengths (see Clause 14.5.2.2)
φ_{cc}	= design creep coefficient at any time t (see Clause 3.1.8.3 and Clause 16.4.7.3.3)

Symbol	Definition
ϕ_{cc}^*	= final design creep coefficient (see Clause 3.1.8.3)
$\phi_{cc.b}$	= basic creep coefficient of concrete, determined in accordance with Clause 3.1.8.2
ψ_a	= factor for reduction of imposed (live) floor loads due to area (refer to AS/NZS 1170.1)
ψ_c	= combination imposed action (live load) factor used in assessing the design load for strength (refer to AS/NZS 1170.0)
ψ_s	= short-term imposed action (live load) factor used in assessing the design load for serviceability (refer to AS/NZS 1170.0)
ψ_l	= long-term imposed action (live load) factor used in assessing the design load for serviceability (refer to AS/NZS 1170.0)
Ω	= dimension of node [see Figure 7.2.4(A)]

SECTION 2 DESIGN PROCEDURES, ACTIONS AND LOADS

2.1 DESIGN PROCEDURES

2.1.1 Design for strength and serviceability

Concrete structures shall be designed for ultimate strength and serviceability limit states in accordance with the general principles and procedures for design as set out in AS/NZS 1170.0 and the specific requirements of Clauses 2.2 and 2.3.

Notwithstanding the requirements of Clauses 2.2 and 2.3, it shall be permissible to carry out design checks for strength and serviceability by testing a structure or a component member in accordance with Appendix B.

2.1.2 Design for earthquake actions

A2 | Where structures are required by AS 1170.4 to be designed for earthquake actions they shall conform with that Standard, this Standard and the provisions of Section 14 of this Standard. Reinforcement shall be detailed to provide the structure with the assumed ductility.

2.1.3 Design for robustness and structural integrity

Concrete structures shall be designed to be robust in accordance with Section 6 of AS/NZS 1170.0 and BCA Clause BV2, whichever is applicable.

In the detailing of reinforcement and connections for structural integrity, members of a structure shall be effectively tied together to improve integrity of the overall structure. For cast in place concrete, see Sections 8, 9, 10 and 11 for specific requirements. For specific requirements for prefabricated concrete structures, see Section 17.

2.1.4 Design for durability and fire resistance

Concrete structures shall be designed to be—

- (a) durable in accordance with the procedures and criteria given in Section 4; and
- (b) fire resistant in accordance with the procedures and criteria given in Section 5.

2.1.5 Design for fatigue

Fatigue shall be considered in the design of structures and structural elements subject to regular cyclic loads such as vibrating machines, crane-rails, heavy traffic areas, but need not be considered where the foreseen number of stress cycles n_{sc} is less than 10 000.

Design actions for use in fatigue analysis shall be determined in accordance with the methods specified in Clause 6.1.3, except that the moment redistribution for elastic method of Clause 6.2.7 and plastic method of Clause 6.7 are not permitted. Non-linear analysis is permitted; however, sections shall not undergo large plastic deformations under fatigue load combinations.

NOTE: Linear elastic models should generally be used, and reinforced concrete in tension is considered to be cracked. The ratio of moduli of elasticity for steel and concrete should be taken as $E_s/E_c = 10$.

2.1.6 Material properties

The properties of materials used in the design shall be in accordance with Section 3.

When evaluating the behaviour of a concrete structure, member or cross-section, the values of concrete properties used in the calculation shall take into consideration the age of the concrete, rate of loading and expected variations of material properties.

2.2 DESIGN FOR STRENGTH

2.2.1 General

Strength checks for concrete structures and their component members shall be carried out using the procedures specified in Clauses 2.2.2 to 2.2.6, and methods of structural analysis specified in Section 6, as applicable to the strength check procedures being used.

It shall be permissible to use different strength check procedures for different members in a structure, and for the structure as a whole, provided it can be shown that all external actions and forces and calculated internal stress resultants are consistent with the requirements of equilibrium and compatibility for the entire structure.

2.2.2 Strength check procedure for use with linear elastic methods of analysis, with simplified analysis methods and for statically determinate structures

The strength check procedure for use in conjunction with—

- (a) linear elastic methods of analysis of indeterminate structures and members;
- (b) simplified methods of analysis of indeterminate structures and members; and
- (c) static analysis of determinate structures,

shall be carried out as follows:

- (i) It shall be confirmed that the design capacity is equal to or greater than the design action effect, for all critical cross-sections and regions—

$$R_d \geq E_d \quad \dots 2.2.2$$

where

R_d = design capacity (equal to ϕR_u)

E_d = design action effect

- (ii) The design capacity, $R_d = \phi R_u$, shall be obtained using the applicable capacity reduction factor (ϕ), given in Table 2.2.2, and the ultimate strength (R_u), determined in accordance with the relevant sections of this Standard using characteristic values for the material strengths.
- (iii) The design action effect (E_d), shall be determined for the critical combination of factored actions specified in AS/NZS 1170.0 and Clause 2.5 by one of the following methods of analysis:
 - (A) Linear elastic analysis in accordance with Clause 6.2.
 - (B) Linear elastic analysis incorporating secondary bending moments due to lateral joint displacement in accordance with Clause 6.3.
 - (C) One of the simplified methods of analysis in accordance with Clauses 6.9 and 6.10.
 - (D) Equilibrium analysis of a statically determinate structure.

TABLE 2.2.2
CAPACITY REDUCTION FACTORS (ϕ)

Type of action effect	Capacity reduction factor (ϕ)
(a) Axial force without bending:	
(i) Tension	
(A) members with Class N reinforcement and/or tendons	0.85
(B) members with Class L reinforcement	0.65
(ii) Compression	0.65
(b) Bending without axial tension or compression—	
(i) for members with Class N reinforcement and/or tendons	$0.65 \leq (1.24 - 13k_{uo}/12) \leq 0.85$
(ii) for members with Class L reinforcement	0.65
(c) Bending with axial tension—	
(i) for members with Class N reinforcement and/or tendons	$\phi + [(0.85 - \phi) (N_u/N_{uot})]$ and ϕ is obtained from Item (b)(i)
(ii) for members with Class L reinforcement	0.65
(d) Bending with axial compression, where—	
(i) $N_u \geq N_{ub}$	$0.65k_\phi$
(ii) $N_u < N_{ub}$	$0.65k_\phi + [(\phi - 0.65k_\phi) (1 - N_u/N_{ub})]$ and ϕ is obtained from Item (b)
	Short columns with $Q/G \geq 0.25$, $k_\phi = 1.0$, otherwise, $k_\phi = 12/13$
(e) Shear and Torsion	
(i) for members where Class N fitments are provided meeting the requirements of Clause 8.2.1.7, other than for shear strength limited by web crushing	0.75
(ii) otherwise	0.7
(f) Bearing	0.6
(g) Bending, shear and compression in plain concrete	0.6
(h) Bending, shear and tension in fixings	0.6
(i) Bending, shear and axial force in singly reinforced walls forming part of a primary lateral load resisting system	0.65

NOTES:

- 1 In members where Class L reinforcement together with Class N reinforcement and/or tendons are used as longitudinal tensile reinforcement in the design for strength in bending, with or without axial force, the maximum value of ϕ for calculating the member design strength should be taken as 0.65.
- 2 For prestressed beams at transfer $\phi = 0.6$ (see Clause 8.1.6.2).

2.2.3 Strength check procedure for use with linear elastic stress analysis

The strength check procedure for use with a linear elastic stress analysis of a structure or member shall be made as follows:

- (a) The structure or member shall be analysed for the critical combination of factored actions, as specified in AS/NZS 1170.0 and Clause 2.5, by linear stress analysis, in

accordance with Clause 6.4, assuming the concrete to be uncracked, and using accepted principles of mechanics.

- (b) The calculated principal compressive stresses shall not exceed the following value:

$$\phi_s \beta 0.9 f'_c \quad \dots 2.2.3$$

where

ϕ_s = stress reduction factor with values taken from Table 2.2.3

β = an effective compressive strength factor, to be evaluated as follows:

- (i) In regions not containing effective confining reinforcement—

$$\beta = 1.0 \text{ when the principal tensile stress does not exceed } f'_{ct}, \text{ otherwise} \\ \beta = 0.6$$

- (ii) In regions where effective confining reinforcement is provided, β shall be evaluated by rational calculation taking account of the amount of confining steel and the details used, but shall not exceed two.

- (c) Reinforcement and/or tendons shall be provided to carry all of the internal tensile forces, with stresses not exceeding $\phi_s f_{sy}$ and $\phi_s f_{py}$ respectively, where values for the stress reduction factor (ϕ_s) are in accordance with Table 2.2.3.
- (d) In determining the areas of steel reinforcement, it shall be permissible to reduce the peak stresses by averaging the stresses over an area appropriate to the size of the member.
- (e) The stress development of the reinforcement and tendons shall be determined in accordance with Clauses 13.1 and 13.3 respectively.

TABLE 2.2.3
STRESS REDUCTION FACTORS (ϕ_s)

Material	Stress reduction factor (ϕ_s)
Concrete in compression	0.65
Steel in tension	
Class N	0.85
Class L	0.65
Tendons	0.85

2.2.4 Strength check procedure for use with strut-and-tie analysis

The strength check procedure for use with strut-and-tie analysis shall be carried out as follows:

- (a) The strut-and-tie model shall satisfy the requirements of Section 7.
- (b) The forces acting on all struts and ties and nodes shall be determined for the critical combination of factored actions as specified in AS/NZS 1170.0 and Clause 2.4 by an analysis of the strut-and-tie model in accordance with Section 7.
- (c) The compressive force in any concrete strut shall not exceed the design strength of that strut determined in accordance with Clause 7.2.3. The strength reduction factor (ϕ_{st}) to be used in determining the design strength shall be in accordance with Table 2.2.4.
- (d) The tensile force in any tie shall not exceed the design strength of the tie determined in accordance with Clause 7.3.2 where the strength reduction factor (ϕ_{st}) is given in Table 2.2.4.

- (e) The reinforcement and/or tendons in the ties shall be anchored in accordance with Clause 7.3.3.
- (f) The design strength of nodes shall be calculated in accordance with Clause 7.4.2 and shall not be exceeded. The strength reduction factor (ϕ_{st}) shall be in accordance with Table 2.2.4.
- (g) Tie reinforcement shall be provided by Class N reinforcement or tendons.

TABLE 2.2.4

**STRENGTH REDUCTION FACTORS (ϕ_{st})
FOR DESIGN USING STRUT-AND-TIE ANALYSIS**

Material	Strength reduction factor (ϕ_{st})
Concrete in compression	0.65
Steel in tension	0.85
Fibres in tension	0.7

2.2.5 Strength check procedure for use with non-linear analysis of framed structures

The strength check procedure for use with non-linear analysis of framed structures at collapse shall be carried out as follows:

- (a) It shall be confirmed that the design capacity of the structure is equal to or greater than the design action effect—

$$R_d \geq E_d \quad \dots 2.2.5$$

where

R_d = design capacity of the structure

E_d = design action effect

- (b) The design action effect (E_d) is the critical combination of factored actions as specified in AS/NZS 1170.0 and Clause 2.5.
- (c) The design capacity of the structure ($R_d = \phi_{sys} R_{u,sys}$) shall be obtained using the appropriate system strength reduction factor (ϕ_{sys}), given in Table 2.2.5, and the mean capacity of the structure ($R_{u,sys}$) determined for the same combination of actions adopted in Item (b) to evaluate E_d , by using non-linear frame analysis as specified in Clause 6.5, with mean values of material properties.

TABLE 2.2.5

**SYSTEM STRENGTH REDUCTION FACTORS (ϕ_{sys})
(For application with Clauses 2.2.5 and 2.2.6)**

Type of failure	System strength reduction factor (ϕ_{sys})
For structural systems in which the deflections and local deformations at high overload are an order of magnitude greater than those for service conditions; and yielding of the reinforcement and/or the tendon occurs well before the peak load is reached	0.7
In all other cases	0.5 (see Note)

A2 | NOTE: Values larger than 0.5 may be used if it can be shown that, at high overload, adequate warning is given of impending collapse.

2.2.6 Strength check procedure for use with non-linear stress analysis

The strength check procedure for use with non-linear stress analysis at collapse shall be carried out as follows:

- (a) It shall be confirmed that the design capacity of the structure or the component member is equal to or greater than the design action effect—

$$R_d \geq E_d \quad \dots 2.2.6$$

where

R_d = design capacity of the structure or component

E_d = design action effect on the structure or the design action effects for a component

- (b) The design action effect (E_d) shall be the critical combination of factored actions (or action effects) as specified in AS/NZS 1170.0 and Clause 2.5.
- (c) The design capacity of the structure (or component) ($R_d = \phi_{\text{sys}} R_{\text{u,sys}}$) shall be obtained using the appropriate system strength reduction factor (ϕ_{sys}) given in Table 2.2.5, and the mean capacity of the structure (or component) ($R_{\text{u,sys}}$) which shall be determined for the same combination of actions adopted for E_d , by non-linear stress analysis as specified in Clause 6.6, with mean values of material properties.

2.3 DESIGN FOR SERVICEABILITY

2.3.1 General

Design checks shall be carried out for all relevant service conditions to ensure the structure will perform to its designed function and purpose.

NOTE: Design limits given or implied in Clauses 2.3.2 and 2.3.3 are based on previous design experience, and reflect requirements for normal structures. In special situations other limits may require further guidance. For further guidance refer to Appendix C of AS/NZS 1170.0.

2.3.2 Deflection

The deflection of beams and slabs under service conditions shall be controlled as follows:

- (a) A limit for the calculated deflection of the member shall be chosen and shall be relevant to the structure and its designed use. The chosen value shall be not greater than the value calculated from the appropriate deflection-to-span ratio given in Table 2.3.2.
- (b) The member shall be designed so that, under the design load for serviceability, the deflections, determined either by calculation or controlled by limiting the span-to-depth ratios in accordance with Clause 8.5 for beams and Clause 9.3 for slabs, do not exceed the deflection limit.

For unbraced frames and multistorey buildings subject to lateral loading, a limit for the inter-storey lateral drift shall be chosen, which does not exceed 1/500 of the storey height. The structure shall be designed so that, under the design lateral load for serviceability, the calculated inter-storey lateral drift does not exceed the chosen value.

TABLE 2.3.2
LIMITS FOR CALCULATED VERTICAL DEFLECTIONS
OF BEAMS AND SLABS

Type of member	Deflection to be considered	Deflection limitation (Δ/L_{ef}) for spans (Notes 1 and 2)	Deflection limitation (Δ/L_{ef}) for cantilevers (Note 4)
All members	The total deflection	1/250	1/125
Members supporting masonry partitions	The deflection that occurs after the addition or attachment of the partitions	1/500 where provision is made to minimize the effect of movement, otherwise 1/1000	1/250 where provision is made to minimize the effect of movement, otherwise 1/500
Members supporting other brittle finishes	The deflection that occurs after the addition or attachment of the finish	Manufacturer's specification but not more than 1/500	Manufacturer's specification but not more than 1/250
Members subjected to vehicular or pedestrian traffic	The imposed action (live load and dynamic impact) deflection	1/800	1/400
Transfer members	Total deflection	1/500 where provision is made to minimize the effect of deflection of the transfer member on the supported structure, otherwise 1/1000	1/250

NOTES:

- 1 In general, deflection limits should be applied to all spanning directions. This includes, but is not limited to, each individual member and the diagonal spans across each design panel. For flat slabs with uniform loadings, only the column strip deflections in each direction need be checked.
- 2 If the location of masonry partitions or other brittle finishes is known and fixed, these deflection limits need only be applied to the length of the member supporting them. Otherwise, the more general requirements of Note 1 should be followed.
- 3 Deflection limits given may not safeguard against ponding.
- 4 For cantilevers, the values of Δ/L_{ef} given in this table apply only if the rotation at the support is included in the calculation of Δ .
- 5 Consideration should be given by the designer to the cumulative effect of deflections, and this should be taken into account when selecting a deflection limit.
- 6 When checking the deflections of transfer members and structures, allowance should be made in the design of the supported members and structure for the deflection of the supporting members. This will normally involve allowance for settling supports and may require continuous bottom reinforcement at settling columns.

2.3.3 Cracking

2.3.3.1 General

Cracking in concrete structures shall be controlled so that structural performance, durability and appearance of the structure are not compromised.

2.3.3.2 Control of cracking

The requirements for cracking set out in Clause 2.3.3.1 shall be deemed to be satisfied by designing the structure and members to conform to the following requirements:

- (a) Flexural cracking in concrete beams and slabs under service conditions shall be controlled in accordance with Clauses 8.6.1, 8.6.2, 8.6.3, 8.6.4, 8.6.5, 9.5.1, 9.5.2, 9.5.4, 9.5.5 or 16.4.7.4, where required.
- (b) Cracking caused by shrinkage and temperature in concrete slabs shall be controlled in accordance with Clause 9.5.3.

- (c) Cracking in concrete walls under service conditions shall be controlled in accordance with Clause 11.7.2.
- (d) Cracking in D-regions under service conditions shall be controlled in accordance with Clause 12.7.
- (e) Cracking at openings and discontinuities and in the vicinity of restraints under service conditions shall be controlled in accordance with Clauses 8.6.1, 9.5.4, or 9.5.5, where required.
- (f) Pre-hardening cracking shall be controlled by specification and construction measures so that the durability, serviceability and/or the behaviour of the structure or member is not adversely affected.

2.3.4 Vibration

Vibration in concrete structures and members shall be controlled so that the serviceability and structural performance are not adversely affected.

2.4 DESIGN FOR FATIGUE

Design for fatigue shall be carried out in accordance with Section 18 using the strength reduction factors in Table 2.4.

TABLE 2.4
STRENGTH REDUCTION FACTORS
FOR FATIGUE

Material	Strength reduction factor
Concrete ($\phi_{c,fat}$)	0.65
Steel ($\phi_{s,fat}$)	0.85

A1

2.5 ACTIONS AND COMBINATIONS OF ACTIONS

2.5.1 Actions and loads

The minimum actions and loads used in the design shall be those set out in AS/NZS 1170.0.

2.5.2 Combinations of actions and loads

2.5.2.1 General

The combinations of actions, loads and forces used in the design shall be in accordance with AS/NZS 1170.0. Additional combinations for prestressed concrete and for fatigue are given in Clauses 2.5.2.2 and 2.5.2.3, respectively.

2.5.2.2 Additional combinations for prestressed members

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Except where otherwise stated in the Standard, stress resultants from the effects of prestressing shall be included with a load factor of unity in load combinations for both ultimate and service design.

For the case of permanent action plus prestressing force at transfer, the more severe of the following shall be used:

- (a) $1.15G + 1.15P$; or
- (b) $0.9G + 1.15P$.

NOTE: See also Clauses 6.2.6 and 8.2.1.3.

A2 | 2.5.2.3 Actions and load combinations for fatigue

The combinations of actions, loads and forces used for fatigue design shall be in accordance with Table 2.5.2.3(A), where ψ_s is the short-term combination factor given in AS 1170.0.

TABLE 2.5.2.3(A)
FATIGUE LOAD COMBINATIONS

The maximum design stress range in the steel $\Delta\sigma$	$E_d = \gamma_F [Q_{fat}]$
The maximum and minimum concrete design compressive stress $\sigma_{max}, \sigma_{min}$	$E_d = \gamma_F [\{G, \gamma_P P, \psi_s Q\}, Q_{fat}]$
The maximum design tensile stress in plain concrete σ_{max}	$E_d = \gamma_F [\{G, \gamma_P P, \psi_s Q\}, Q_{fat}]$

The combinations in the brackets $\{G, \gamma_P P, \psi_s Q\}$ represent the most adverse combination of permanent and non-cyclic service level actions acting with the fatigue design action Q_{fat} . The fatigue design action Q_{fat} to be used shall be the load level determined for the design situation.

A2 | The representative value factor for prestress γ_P for the fatigue load combinations shall be determined in accordance with Table 2.5.2.3(B).

TABLE 2.5.2.3(B)
REPRESENTATIVE VALUE FACTOR FOR PRESTRESS (γ_P)

Tendon description	Increases safety	Decreases safety
Pre-tensioning or unbonded tendons	0.95	1.05
Post-tensioning with bonded tendons	0.90	1.10
When measures are taken (e.g. direct measurements of pre-tensioning)	1.0	1.0

The load factor γ_F for the fatigue load combinations shall be taken as 1.1. If the stress analysis is accurate or conservative, and can be verified by in situ observations, γ_F may be reduced to $\gamma_F = 1.0$.

2.5.3 Construction effects

In determining the critical design conditions for strength and serviceability, account shall be taken of the conditions during construction, and in particular—

- (a) the construction sequence;
- (b) the influence of the schedule for stripping of formwork; and
- (c) the method of back-propping, and its effect on the loads applied during construction.

2.5.4 Arrangements of vertical loads on continuous beams, frames and floor systems

When design checks are carried out for continuous beams and continuous floor systems, for two-dimensional framed structures and for three-dimensional framed structures and floor systems, alternative arrangements of the vertical loads shall be considered in order to determine the critical load combinations. Variations in the load intensity on individual spans shall be considered, including partial loading as specified in AS/NZS 1170.1, together with variations in the loading patterns, whereby some spans are loaded and others unloaded.

The loading arrangements to be considered shall include at least the following:

- (a) The factored permanent action (dead load), without variations in pattern.

- (b) For factored imposed action (live load), where the pattern of loaded and unloaded spans is fixed, the full factored imposed action (live load) applied in the specified pattern.
- (c) For imposed action (live load), where the pattern of loaded and unloaded spans is variable, as follows:
 - (i) For continuous beams and two-dimensional frames and floor systems—
 - (A) the factored imposed action (live load) on alternate spans;
 - (B) the factored imposed action (live load) on any two adjacent spans; and
 - (C) the factored imposed action (live load) on all spans.
 - (ii) For three-dimensional framed structures and floor systems, patterned variations of the factored imposed action (live load) shall be applied in chequerboard arrangements, including the principles of Items (A), (B) and (C) of Item (i) above, to determine the peak design action effects at each critical section.
 - (iii) Notwithstanding Items (i) and (ii), for beams and slabs at the strength limit state, for which the imposed action (live load) (Q) is less than three-quarters of the permanent action (dead load) (G), the factored imposed action (live load) on all spans.

NOTE: The load arrangements listed are the minimum to be considered for design. In particular, for deflection or vibration-sensitive structures and slender floor systems, additional load arrangements need to be considered.

SECTION 3 DESIGN PROPERTIES OF MATERIALS

3.1 PROPERTIES OF CONCRETE

NOTE: Provided that materials properties are determined by testing in accordance with the relevant provisions of AS 1012, characteristic compressive strengths at 28 days of above 100 MPa and up to 120 MPa may be used with the following sections of this Standard: 2 to 8, 10, 13 to 15, 17 and Appendix B.

3.1.1 Strength

3.1.1.1 Characteristic compressive strengths

- (a) The characteristic cylinder compressive strength of concrete at 28 days (f'_c) shall be either—
- (i) taken as equal to the specified strength grade, provided that curing is ensured and that the concrete conforms with AS 1379; or
 - (ii) determined statistically from compressive cylinder strength tests carried out in accordance with AS 1012.9.

The characteristic compressive cylinder strengths of the standard strength grades are 20 MPa, 25 MPa, 32 MPa, 40 MPa, 50 MPa, 65 MPa, 80 MPa, 100 MPa and 120 MPa.

- (b) The characteristic cube compressive strength of grout at 28 days ($f'_{c,cube}$) shall be ascertained in accordance with any of the following methods:
- (i) Taken as equal to the specified strength grade, provided that curing is ensured.
or
 - (ii) Determined statistically from compressive cylinder strength tests carried out in accordance with AS 1012.9 and converted to cube strength using Table 3.1.1.1.
or
 - (iii) Determined statistically from compressive cube strength tests carried out in accordance with AS 1012.9. The cube strength test result shall be modified to an equivalent cylinder strength in accordance with Table 3.1.1.1.

TABLE 3.1.1.1
RELATIONSHIP BETWEEN CYLINDER AND
CUBE STRENGTH AT 28 DAYS

f'_c MPa	20	25	32	40	50	65	80	100	120
$f'_{c,cube}$ MPa	25	32	40	50	60	80	95	120	150

3.1.1.2 Mean in situ compressive strength

In the absence of more accurate data, the mean value of the in situ compressive strength (f_{cmi}) shall be taken as 90% of the mean value of the cylinder strength (f_{cm}) or shall be taken as those given in Table 3.1.2.

3.1.1.3 Tensile strength

The uniaxial tensile strength (f_{ct}) is the maximum stress that concrete can withstand when subjected to uniaxial tension.

The uniaxial tensile strength shall be determined from either the measured flexural tensile strength ($f_{ct,f}$) or from the measured splitting tensile strength ($f_{ct,sp}$) using—

$$f_{ct} = 0.6f_{ct,f} \quad \text{or} \quad f_{ct} = 0.9f_{ct,sp}$$

where $f_{ct,f}$ and $f_{ct,sp}$ are determined statistically from—

- (a) flexural strength tests carried out in accordance with AS 1012.11; or
- (b) indirect tensile strength tests carried out in accordance with AS 1012.10, respectively.

In the absence of more accurate data, the characteristic flexural tensile strength of concrete ($f'_{ct,f}$) and the characteristic uniaxial tensile strength of concrete (f'_{ct}) shall be taken as—

$$f'_{ct,f} = 0.6\sqrt{f'_c} \quad \text{and} \quad f'_{ct} = 0.36\sqrt{f'_c} \quad \text{at 28 days and standard curing,}$$

and where the mean and upper characteristic values are obtained by multiplying these values by 1.4 and 1.8, respectively.

3.1.2 Modulus of elasticity

The mean modulus of elasticity of concrete at the appropriate age (E_{cj}) shall be either—

- (a) taken as equal to—
 - (i) $(\rho^{1.5}) \times (0.043\sqrt{f_{cmi}})$ (in megapascals) when $f_{cmi} \leq 40$ MPa; or
 - (ii) $(\rho^{1.5}) \times (0.024\sqrt{f_{cmi}} + 0.12)$ (in megapascals) when $f_{cmi} > 40$ MPa,
 consideration being given to the fact that this value has a range of $\pm 20\%$;
- (b) determined by test in accordance with AS 1012.17; and
- (c) for standard strength grades at 28 days determined from Table 3.1.2.

TABLE 3.1.2
CONCRETE PROPERTIES AT 28 DAYS

f'_c MPa	20	25	32	40	50	65	80	100	120
f_{cm} MPa	25	31	39	48	59	75	91	110	128
f_{cmi} MPa	22	28	35	43	53	68	82	99	115
E_c MPa	24 000	26 700	30 100	32 800	34 800	37 400	39 600	42 200	44 400

3.1.3 Density

The density of concrete (ρ) shall be determined by test in accordance with either AS 1012.12.1 or AS 1012.12.2.

NOTE: For normal-weight concrete, the density may be taken as 2400 kg/m³.

3.1.4 Stress-strain curves

The stress-strain curve for concrete shall be either—

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- (a) assumed to be of curvilinear form defined by recognized simplified equations; or
- (b) determined from test data.

For design purposes, the shape of the in situ uniaxial compressive stress-strain curve shall be modified so that the maximum stress is $0.9f'_c$.

3.1.5 Poisson's ratio

Poisson's ratio for concrete (ν) shall be either—

- (a) taken as equal to 0.2; or
- (b) determined by test in accordance with AS 1012.17.

3.1.6 Coefficient of thermal expansion

The coefficient of thermal expansion of concrete shall be either—

- (a) taken as equal to $10 \times 10^{-6}/^{\circ}\text{C}$, consideration being given to the fact that this value has a range of $\pm 20\%$; or
- (b) determined from test data.

3.1.7 Shrinkage

3.1.7.1 Calculation of design shrinkage strain

The design shrinkage strain of concrete (ϵ_{cs}) shall be determined—

- (a) from measurements on similar local concrete;
- (b) by tests after eight weeks of drying modified for long-term value, in accordance with AS 1012.13; or
- (c) by calculation in accordance with Clause 3.1.7.2.

3.1.7.2 Design shrinkage strain

When the design shrinkage strain of concrete (ϵ_{cs}) is to be calculated, it shall be determined as the sum of the chemical (autogenous) shrinkage strain (ϵ_{cse}) and the drying shrinkage strain (ϵ_{csd})—

$$\epsilon_{cs} = \epsilon_{cse} + \epsilon_{csd} \quad \dots 3.1.7.2(1)$$

The autogenous shrinkage strain shall be taken as—

$$\epsilon_{cse} = \epsilon_{cse}^* \times (1.0 - e^{-0.07t}) \quad \dots 3.1.7.2(2)$$

where t is the time (in days) after setting and ϵ_{cse}^* is the final autogenous shrinkage strain given by—

$$\text{For } f'_c \leq 50 \text{ MPa } \epsilon_{cse}^* = (0.07f'_c - 0.5) \times 50 \times 10^{-6} \quad \dots 3.1.7.2(3)$$

$$\text{For } f'_c > 50 \text{ MPa } \epsilon_{cse}^* = (0.08f'_c - 1.0) \times 50 \times 10^{-6}$$

At any time t (in days) after the commencement of drying, the drying shrinkage strain shall be taken as—

$$\epsilon_{csd} = k_1 k_4 \epsilon_{csd,b} \quad \dots 3.1.7.2(4)$$

and k_1 is obtained from Figure 3.1.7.2 and k_4 is equal to 0.7 for an arid environment, 0.65 for an interior environment, 0.6 for a temperate inland environment and 0.5 for a tropical or near-coastal or coastal environment.

The basic drying shrinkage strain ($\epsilon_{csd,b}$) is given by—

$$\varepsilon_{\text{csd.b}} = (0.9 - 0.005 f'_c) \times \varepsilon_{\text{csd.b}}^* \quad \dots 3.1.7.2(5)$$

where $\varepsilon_{\text{csd.b}}^* = 800 \times 10^{-6}$ or determined by testing.

NOTE: Concrete exposed to early drying undergoes shrinkage due to capillary suction. This can result in cracking and poor service performance, particularly of exposed slabs. The amount of shrinkage from suction depends on the ambient conditions and the concrete mix, and can exceed the combined shrinkage from other causes. Therefore, it is important to prevent excessive drying of concrete between the commencement of casting and the application of curing at the completion of finishing.

Consideration shall be given to the fact that ε_{cs} has a range of $\pm 30\%$.

Typical final design shrinkage strains after 30 years are found in Table 3.1.7.2.

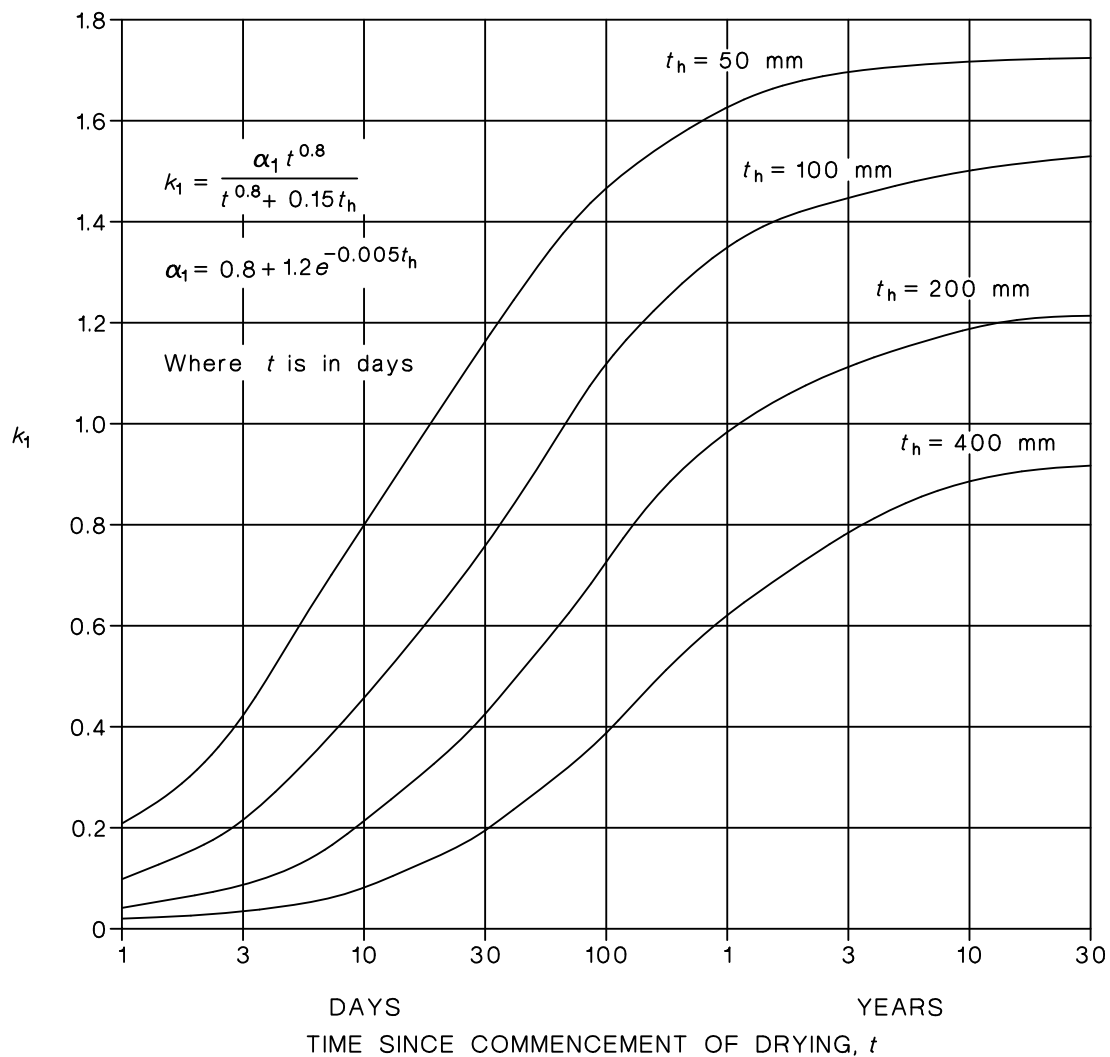


FIGURE 3.1.7.2 SHRINKAGE STRAIN COEFFICIENT (k_1) FOR VARIOUS VALUES OF t_h

TABLE 3.1.7.2
TYPICAL FINAL DESIGN SHRINKAGE STRAINS AFTER 30 YEARS

f'_c (MPa)	Final design shrinkage strain ε_{cs}^* ($\times 10^{-6}$)															
	Arid environment				Interior environment				Temperate inland environment				Tropical, near-coastal and coastal environment			
	t_h (mm)				t_h (mm)				t_h (mm)				t_h (mm)			
	50	100	200	400	50	100	200	400	50	100	200	400	50	100	200	400
25	810	720	590	470	760	670	550	440	710	630	520	410	600	530	440	350
32	800	720	590	470	750	670	560	440	700	630	520	420	600	540	450	360
40	790	710	590	480	740	670	560	450	700	620	530	430	600	540	460	380
50	780	700	590	490	730	660	560	460	690	620	530	440	600	540	470	390
65	770	700	600	510	730	660	570	490	690	630	550	470	610	560	490	420
80	750	690	610	530	720	660	590	510	680	630	560	490	620	570	510	460
100	740	690	620	560	710	660	600	540	680	640	580	530	630	590	540	500

3.1.8 Creep

3.1.8.1 General

The creep strain at any time (t) caused by a constant sustained stress (σ_o) shall be calculated from—

$$\varepsilon_{cc} = \varphi_{cc} \sigma_o / E_c \quad \dots 3.1.8.1$$

where

E_c = mean modulus of elasticity of the concrete at 28 days

φ_{cc} = design creep coefficient at time (t) determined in accordance with Clause 3.1.8.3

3.1.8.2 Basic creep coefficient

The basic creep coefficient of concrete ($\varphi_{cc,b}$) is the mean value of the ratio of final creep strain to elastic strain for a specimen loaded at 28 days under a constant stress of $0.4f'_c$ and shall be—

- determined from measurements on similar local concrete; or
- determined by tests in accordance with AS 1012.16; or
- taken as the value given in Table 3.1.8.2.

TABLE 3.1.8.2
BASIC CREEP COEFFICIENT

Characteristic strength (f'_c), MPa	20	25	32	40	50	65	80	100
Basic creep coefficient ($\varphi_{cc,b}$)	5.2	4.2	3.4	2.8	2.4	2.0	1.7	1.5

3.1.8.3 Design creep coefficient

The design creep coefficient for concrete at any time, t , (φ_{cc}) shall be determined from the basic creep coefficient ($\varphi_{cc,b}$) by any accepted mathematical model for creep behaviour, calibrated such that $\varphi_{cc,b}$ is also predicted by the chosen model.