



## Concrete structures



This Australian Standard® was prepared by Committee BD-002, Concrete Structures. It was approved on behalf of the Council of Standards Australia on 22 June 2018. This Standard was published on 29 June 2018.

---

The following are represented on Committee BD-002:

- Australian Building Codes Board
  - Bureau of Steel Manufacturers of Australia
  - Cement Concrete and Aggregates Australia—Cement
  - Cement Concrete and Aggregates Australia—Concrete
  - Concrete Institute of Australia
  - Consult Australia
  - Engineers Australia
  - La Trobe University
  - Master Builders Australia
  - National Precast Concrete Association Australia
  - Steel Reinforcement Institute of Australia
  - University of Melbourne
  - University of New South Wales
  - University of Sydney
- 

This Standard was issued in draft form for comment as DR AS 3600:2018.

Standards Australia wishes to acknowledge the participation of the expert individuals that contributed to the development of this Standard through their representation on the Committee and through the public comment period.

---

### **Keeping Standards up-to-date**

Australian Standards® are living documents that reflect progress in science, technology and systems. To maintain their currency, all Standards are periodically reviewed, and new editions are published. Between editions, amendments may be issued.

Standards may also be withdrawn. It is important that readers assure themselves they are using a current Standard, which should include any amendments that may have been published since the Standard was published.

Detailed information about Australian Standards, drafts, amendments and new projects can be found by visiting **[www.standards.org.au](http://www.standards.org.au)**

Standards Australia welcomes suggestions for improvements, and encourages readers to notify us immediately of any apparent inaccuracies or ambiguities. Contact us via email at **[mail@standards.org.au](mailto:mail@standards.org.au)**, or write to Standards Australia, GPO Box 476, Sydney, NSW 2001.

---

# Australian Standard<sup>®</sup>

## Concrete structures

First published in part as AS CA2—1934.  
AS A26 first published 1934.  
AS CA2 redated 1937.  
MP 13 first published 1957.  
AS CA2—1937 and AS A26—1934 revised, amalgamated and redesignated AS CA2—1958.  
Third edition 1963.  
MP 13—1957 revised and redesignated AS CA35—1963.  
Second edition 1973.  
Fourth edition AS CA2—1973.  
AS CA2—1973 revised and redesignated AS 1480—1974.  
AS CA35—1973 revised and redesignated AS 1481—1974.  
Second edition AS 1481—1978.  
Second edition AS 1480—1982.  
AS 1480—1982 and AS 1481—1978 revised, amalgamated and redesignated AS 3600—1988.  
Fourth edition 2009.  
Fifth edition 2018.  
Reissued incorporating Amendment No. 1 (November 2018).

### **COPYRIGHT**

© Standards Australia Limited

All rights are reserved. No part of this work may be reproduced or copied in any form or by any means, electronic or mechanical, including photocopying, without the written permission of the publisher, unless otherwise permitted under the Copyright Act 1968.

ISBN 978 1 76072 146 6

## 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). 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 .....	50
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 .....	126
8.5	DEFLECTION OF BEAMS.....	128
8.6	CRACK CONTROL OF BEAMS.....	131
8.7	VIBRATION OF BEAMS .....	134
8.8	T-BEAMS AND L-BEAMS .....	134
8.9	SLENDERNESS LIMITS FOR BEAMS .....	135

**SECTION 9 DESIGN OF SLABS FOR STRENGTH AND SERVICEABILITY**

9.1	STRENGTH OF SLABS IN BENDING.....	136
9.2	STRUCTURAL INTEGRITY REINFORCEMENT .....	139
9.3	STRENGTH OF SLABS IN SHEAR.....	140
9.4	DEFLECTION OF SLABS.....	144
9.5	CRACK CONTROL OF SLABS.....	146
9.6	VIBRATION OF SLABS .....	150
9.7	MOMENT RESISTING WIDTH FOR ONE-WAY SLABS SUPPORTING CONCENTRATED LOADS.....	150
9.8	LONGITUDINAL SHEAR IN COMPOSITE SLABS.....	150

**SECTION 10 DESIGN OF COLUMNS FOR STRENGTH AND SERVICEABILITY**

10.1	GENERAL.....	151
10.2	DESIGN PROCEDURES .....	151
10.3	DESIGN OF SHORT COLUMNS.....	152
10.4	DESIGN OF SLENDER COLUMNS .....	153
10.5	SLENDERNESS.....	154
10.6	STRENGTH OF COLUMNS IN COMBINED BENDING AND COMPRESSION .....	158
10.7	REINFORCEMENT REQUIREMENTS FOR COLUMNS.....	161
10.8	TRANSMISSION OF AXIAL FORCE THROUGH FLOOR SYSTEMS.....	169
10.9	CRACK CONTROL .....	170

SECTION 11 DESIGN OF WALLS	
11.1	GENERAL..... 171
11.2	DESIGN PROCEDURES ..... 171
11.3	BRACED WALLS..... 172
11.4	EFFECTIVE HEIGHT..... 172
11.5	SIMPLIFIED DESIGN METHOD FOR WALLS SUBJECT TO VERTICAL COMPRESSION FORCES ..... 173
11.6	DESIGN OF WALLS FOR IN-PLANE SHEAR FORCES ..... 174
11.7	REINFORCEMENT REQUIREMENTS FOR WALLS ..... 175
SECTION 12 DESIGN OF NON-FLEXURAL MEMBERS, END ZONES AND BEARING SURFACES	
12.1	GENERAL..... 177
12.2	STRUT-AND-TIE MODELS FOR THE DESIGN OF NON-FLEXURAL MEMBERS..... 177
12.3	ADDITIONAL REQUIREMENTS FOR CONTINUOUS CONCRETE NIBS AND CORBELS ..... 179
12.4	ADDITIONAL REQUIREMENTS FOR STEPPED JOINTS IN BEAMS AND SLABS ..... 179
12.5	ANCHORAGE ZONES FOR PRESTRESSING ANCHORAGES ..... 179
12.6	BEARING SURFACES ..... 181
12.7	CRACK CONTROL ..... 181
SECTION 13 STRESS DEVELOPMENT OF REINFORCEMENT AND TENDONS	
13.1	STRESS DEVELOPMENT IN REINFORCEMENT ..... 182
13.2	SPLICING OF REINFORCEMENT..... 189
13.3	STRESS DEVELOPMENT IN TENDONS ..... 192
13.4	COUPLING OF TENDONS ..... 193
SECTION 14 DESIGN FOR EARTHQUAKE ACTIONS	
14.1	GENERAL..... 194
14.2	DEFINITIONS..... 194
14.3	STRUCTURAL DUCTILITY FACTOR ( $\mu$ ) AND STRUCTURAL PERFORMANCE FACTOR ( $S_p$ )..... 195
14.4	GENERAL EARTHQUAKE DESIGN REQUIREMENTS ..... 196
14.5	INTERMEDIATE MOMENT-RESISTING FRAMES (IMRFs) ..... 198
14.6	LIMITED DUCTILE STRUCTURAL WALLS ..... 201
14.7	MODERATELY DUCTILE STRUCTURAL WALLS..... 206
SECTION 15 DIAPHRAGMS	
15.1	GENERAL..... 207
15.2	DESIGN ACTIONS..... 207
15.3	CAST IN-PLACE TOPPINGS..... 208
15.4	DIAPHRAGM REINFORCEMENT..... 208
SECTION 16 STEEL FIBRE REINFORCED CONCRETE	
16.1	GENERAL..... 210
16.2	DEFINITIONS..... 210
16.3	PROPERTIES OF SFRC ..... 211
16.4	DESIGN OF SFRC MEMBERS CONTAINING REINFORCEMENT OR TENDONS ..... 216
16.5	DURABILITY ..... 221
16.6	FIRE ..... 221

	<i>Page</i>
16.7 PRODUCTION OF SFRC .....	221
SECTION 17 MATERIAL AND CONSTRUCTION REQUIREMENTS	
17.1 MATERIAL AND CONSTRUCTION REQUIREMENTS FOR CONCRETE AND GROUT .....	225
17.2 MATERIAL AND CONSTRUCTION REQUIREMENTS FOR REINFORCING STEEL .....	227
17.3 MATERIAL AND CONSTRUCTION REQUIREMENTS FOR PRESTRESSING DUCTS, ANCHORAGES AND TENDONS.....	230
17.4 CONSTRUCTION REQUIREMENTS FOR JOINTS AND EMBEDDED ITEMS .....	232
17.5 TOLERANCES FOR STRUCTURES AND MEMBERS .....	232
17.6 FORMWORK.....	233
17.7 PREFABRICATED CONCRETE STRUCTURES .....	237
SECTION 18 DESIGN FOR FATIGUE	
18.1 GENERAL.....	238
18.2 MAXIMUM COMPRESSIVE STRESS IN CONCRETE.....	238
18.3 PLAIN CONCRETE WITH COMPRESSION-TENSION STRESS.....	240
18.4 PLAIN CONCRETE WITH PURE TENSION OR COMBINED TENSION- COMPRESSION STRESS.....	240
18.5 SHEAR LIMITED BY WEB COMPRESSIVE STRESSES .....	240
18.6 SHEAR IN SLABS .....	240
18.7 ADJUSTMENT FACTOR FOR BOND BEHAVIOUR IN REINFORCING AND PRESTRESSING STEEL.....	241
18.8 TENSILE STRESS RANGE IN STEEL .....	242
18.9 CALCULATION OF STRESSES IN REINFORCEMENT AND TENDONS OF FLEXURAL MEMBERS.....	245
SECTION 19 JOINTS, EMBEDDED ITEMS AND FIXINGS	
19.1 JOINTS.....	246
19.2 EMBEDDED ITEMS.....	247
19.3 FIXINGS .....	247
SECTION 20 PLAIN CONCRETE PEDESTALS AND FOOTINGS	
20.1 GENERAL.....	249
20.2 DURABILITY .....	249
20.3 PEDESTALS .....	249
20.4 FOOTINGS.....	249
SECTION 21 SLAB-ON-GROUND FLOORS, PAVEMENTS AND FOOTINGS	
21.1 GENERAL.....	251
21.2 DESIGN CONSIDERATIONS .....	251
21.3 FOOTINGS.....	251
APPENDICES	
A REFERENCED DOCUMENTS.....	252
B TESTING OF MEMBERS AND STRUCTURES.....	254
D RESIDUAL TENSILE STRENGTH TEST FOR SFRC .....	260
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 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/m<sup>3</sup> to 2800 kg/m<sup>3</sup>.

- (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.