

AS 5100.5:2017 Bridge design Part 5: Concrete

Amendment No. 2

Revised text amendment

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Summary

This Amendment applies to the following elements:

- Preface
- Section 4
- Clauses 1.2, 1.3, 1.4, 1.5, 1.9, 2.1.3, 2.2.1, 2.2.2, 2.2.4, 2.2.5, 2.2.6, 2.3.2, 2.4.3.2, 2.5.2, 3.1.1.4.1, 3.1.1.4.5, 3.1.7.1, 3.1.7.2, 3.1.8.3, 3.2.1, 3.3.4.2, 3.3.4.4, 3.4.3.2, 5.4.2.1, 6.1.3, 6.2.3, 6.2.5, 6.2.6.2, 6.2.7.1, 8.1.6.2, 8.1.8, 8.1.9.1, 8.1.9.2, 8.1.9.3, 8.1.9.4, 8.1.9.5, 8.2.1.2, 8.2.1.3, 8.2.1.6, 8.2.1.7, 8.2.1.9, 8.2.2.1, 8.2.3.1, 8.2.3.2, 8.2.3.3, 8.2.4.1, 8.2.4.2, 8.2.4.3, 8.2.4.4, 8.2.4.5, 8.2.5, 8.2.5.2, 8.2.8, 8.2.9.2, 8.3.1.3, 8.3.2.1, 8.3.2.2, 8.3.2.4, 8.4.3, 8.6.1, 8.10.3.2.3, 9.1.5, 9.2, 10.2.4.1, 10.2.4.3, 10.6.1, 10.7.1, 10.7.3.3, 10.7.4.3, 10.7.4.4, 10.7.6.1, 10.7.6.2.2, 10.7.6.3, 10.7.6.4, 10.7.6.5, 11.7.5, 13.1.2.2, 13.1.2.6, 13.2.2, 13.2.6, 14.3, 14.3.1, 14.3.2, 16.1, 16.3.3.4, 16.4.5.3, 17.3.8.1, 17.4.3.1, 17.4.3.1.1, 17.4.3.2, 17.4.5.2, A1, C3
- Tables 2.2.5, 2.3.2, 2.3.3, 3.1.7.2, 3.1.8.3, 3.2.1, 5.4.2.1(A), 5.4.2.1(B), 9.4.1(A), 10.7.4.3, 13.1.2.3, 16.7.3
- Figures 3.1.8.3, 3.3.4.3, 9.2.2.1, 9.2.2.3, 10.7.3.3, 10.7.6.2.2, 10.7.6.4, 13.2.2
- Bibliography

Amendment details

AS/NZS 5100.5:2017 is amended as follows. The amendments should be inserted in the locations as instructed.

Element	Instruction/New text	
Preface	<i>Delete</i> second last paragraph.	
CI 1.2	1	After Item (d), <i>delete</i> Items (i) and (ii) and renumber Items (iii), (iv) and (v) as (i), (ii) and (iii).
	2	After Item (f), <i>add</i> the following:
	(g)	Higher reinforcing steel grades from 500 MPa to 750 MPa meeting the requirements of Table 3.2.1. For ultimate limit states the yield strength of the reinforcement shall not be taken as greater than 600 MPa unless noted otherwise.
	(h)	Manufactured pozzolans in accordance with AS 3582.4 are alternative materials and subject to the provisions of Clause 1.9.
CI 1.3	1	After “AS 3799, <i>Liquid membrane-forming curing compounds for concrete</i> ”, <i>add</i> “AS 3582.4, <i>Part 4: Pozzolans — Manufactured</i> ”.

- CI 1.4**
- 2 Delete "AS/NZS ISO 4671 Steel reinforcing materials" and replace with "AS/NZS 4671 Steel for the reinforcement of concrete".
- 1 Delete entry 1.4.3.9 and replace with the following:
- 1.4.3.9 Cement material**
- Cementitious material**
- Hydraulic binder composed of general purpose or blended cements used alone or combined with one or more supplementary cementitious materials (SCMs).
- Note 1 to entry: For requirements on cement material/cementitious material see Clause 4.4.1.
- 2 Delete entry 1.4.3.10.
- 3 After entry 1.4.3.64.3, add the following:
- 1.4.3.64.4 Manufactured pozzolans**
- Pozzolan which can be a by-product of mineral processing, manufacturing, waste to energy, recovered resources or processed or calcined natural materials.
- 4 Entry 1.4.3.73, delete "cementitious" from entry title and replace with "cement".
- CI 1.5**
- 1 Notation table, after A_s , add the following:
 $A_{s,fit}$ cross sectional area of fitment reinforcement
- 2 Notation table, delete definition of " b_l ", and replace with:
dimension of the critical perimeter measured in the direction of the span for which moments are determined
- 3 Notation table, delete definition of " b_t " and replace with:
dimension of the critical perimeter measured perpendicular to b_l
- 4 Notation table, definition of " d_b ", delete "; or"
nominal internal diameter of reinforcement bend or hook"
- 5 Notation table, after d_g , add the following:
 d_i nominal internal diameter of reinforcement bend or hook
- 6 Notation table, after k_{cs} , add the following:
 k_{dg} maximum nominal aggregate size
- 7 Notation table, after k_{uo} , add the following:
 k_v coefficient for concrete contribution to shear capacity
- 8 Notation table, after k_v , add the following:
 k_{vs} constant related to the size effect on the shear strength of a slab without shear reinforcement
- 9 Notation table, after k_{vs} , add the following:
 k_{vu} constant related to the shear strength upper limit of a slab from concrete cracking near shear fitments
- 10 Notation table, after k_{vu} , add the following:
 k_{vuc} constant related to the shear strength reduction in a slab with shear reinforcement from concrete cracking
- 11 Notation table, after k_{vuc} , add the following:
 k_{vuCs} constant related to the influence of aggregate size and slab depth on the shear strength of a slab without shear reinforcement
- 12 Notation table, after L_{pa} , add the following:
 L_{pe} effective length of tendon for determining stress in tendon at ultimate moment capacity
- 13 Notation table, after M^* , add the following:

M_f^* portion of M_v^* resisted by flexure in the slab

- 14 Notation table, after M_v^* , *add* the following:

M_{vv}^* portion of M_v^* resisted by eccentric shear on the critical perimeter

- 15 Notation table, *delete* p_c and its definition.

- 16 Notation table, after u , *add* the following:

u_c length of the outside perimeter of concrete cross-section

- 17 Notation table, after V^* , *add* the following:

V_v^* shear force that crosses a critical perimeter

- 18 Notation table, *delete* V_{cq}^* and its definition.

- 19 Notation table, definition for $V_{u,min}$, *delete* “beam” and *replace* with “member”.

- 20 Notation table, *delete* “ V_{u0} ” and its definition.

- 21 Notation table, definition for V_{us} , *delete* “beam or wall” and *replace* with “member”.

- 22 Notation table, after ϕ_{cc} , *add* the following:

$\phi_{cc,j}$ creep coefficient at time j

- Cl 1.9** *Delete* clause text and *replace* with the following:

Where alternative materials, methods of design or construction are used, they shall conform to AS 5100.1:2017 Section 7.

- Cl 2.1.3** *Delete* clause text and note and *replace* with the following:

Where structures are required to be designed for earthquake actions, they shall conform to AS 5100.2 and this Section (2).

- Cl 2.2.1** After the second paragraph, *add* the following:

Concrete structures shall be designed for fatigue effects in accordance with —

- (a) the simplified approach to fatigue design in this Clause (2.2); or
- (b) the more detailed method provided in AS 3600.

Alternative fatigue design methods to those in this Clause (2.2) and AS 3600 may be used if approved by the relevant authority.

- Cl 2.2.2** *Delete* clause and *replace* with the following:

2.2.2 Maximum range in concrete compressive stresses

The fatigue design stress range in concrete compressive stress under the combination of—

- (a) long-term permanent effects; and
- (b) the fatigue design traffic loading specified in AS 5100.2,

shall be determined from the following equations.

For sections with a triangular distribution of stress:

$$(\sigma_{\max} - \sigma_{\min}) \leq 0.45 (\phi_{c,fat} f'_c - \sigma_{\min}) \quad 2.2.2.1$$

For sections with a rectangular distribution of stress:

$$(\sigma_{\max} - \sigma_{\min}) \leq 0.30 (\phi_{c,fat} f'_c - 1.7\sigma_{\min}) \quad 2.2.2.2$$

where

$\sigma_{\min}$ = minimum compressive stress at the extreme fibre at the section under consideration, taken as zero if tensile

$\sigma_{\max}$ = maximum compressive stress at the extreme fibre at the section under consideration

$\phi_{c,fat}$ = capacity reduction factor for fatigue in concrete, taken as 0.65

Equations 2.2.2.1 and 2.2.2.2 are valid for the number of effective stress cycles n , where $10^4 \leq n \leq 10^8$.

The concrete compressive stress due to long-term permanent effects shall not exceed $0.7\phi_{c.fat}f'_c$.

σ_{max} and σ_{min} shall be calculated using the same PE load combination such that the fatigue design stress range ($\sigma_{max} - \sigma_{min}$) is the stress from the fatigue design traffic loading.

CI 2.2.4 Last paragraph, *delete* " ϕV_{uo} " and *replace* with " ϕV_u ".

CI 2.2.5 1 First paragraph, first sentence, *after* "tendons and reinforcement" add:

, including stainless steel reinforcement,

2 *Delete* final paragraph and note, and *replace* with the following:

The verification of fatigue capacity of welded reinforcement, welded mesh and mechanical splices shall be in accordance with AS 3600.

Other verification methods for fatigue capacity may be applied, if approved by the relevant authority.

Tbl 2.2.5 *Delete* table and *replace* with the following:

TABLE 2.2.5
PERMISSIBLE TENSILE FATIGUE STRESS RANGES IN STEEL

Type of steel embedded in concreted	Fatigue design stress range limit, MPa
Reinforcement for straight bar	150
Reinforcement at bar bend	$150 (0.35 + 0.026 d_i/d_b) \leq 150$
Prestressing wires and strands in grouted plastic ducts	150
Prestressing wires, strands and bars in grouted steel ducts	100
Straight pretensioned strands	150
Deflected pretensioned strands	70

LEGEND:

d_b = nominal diameter of a reinforcing bar

d_i = nominal internal diameter of reinforcement bend or hook

CI 2.2.6 *Delete* clause, and *replace* with the following:

2.2.6 Calculation of stresses in the reinforcement and tendons of flexural members for members with at least minimum transverse shear reinforcement

2.2.6.1 General

When assessing steel stresses for fatigue in flexural members with minimum transverse shear reinforcement in accordance with Clause 8.2.5, the stress variations in both the longitudinal reinforcement and tendons and shear reinforcement shall be calculated in accordance with either Clause 2.2.6.2 or Clause 2.2.6.3.

The calculated maximum stress range in tensile reinforcements due to the fatigue loading shall be not greater than the stress range limits given in Clause 2.2.5.

2.2.6.2 Determination by strut and tie modelling

The stress variations in —

(a) longitudinal reinforcement and tendons; and

(b) shear reinforcement,

shall be calculated using a strut and tie model in accordance with Section 7.

The angle between the compression struts and the longitudinal axis of the member shall be —

- (i) between 40° and 55° for non-prestressed slabs; and
- (ii) between 35° and 55° for all other applications.

2.2.6.3 Determination by simplified calculation

The stress variations in longitudinal reinforcement and tendons shall be calculated by elastic cracked section analysis.

The stress variations in the shear reinforcement shall be calculated in accordance with Clause 8.2, with the shear force carried by concrete taken as $0.5V_{uc}$, where V_{uc} is determined from Clause 8.2.4 for the combination of unfactored permanent effects and fatigue vehicle loading.

In the calculation of shear and longitudinal forces, the angle of the compression strut with the longitudinal axis in Clause 8.2.5.2 shall be replaced with θ_{fat} where:

$$\theta_{fat} = \arctan\left(\sqrt{\tan\theta_v}\right) \quad 2.2.6.3$$

When $\theta_v < 45$ degrees; $\theta_{fat} = \theta_v$,

In Equation 2.2.6.3, θ_v is calculated in accordance with Clause 8.2.4.2.

- Cl 2.3.2** 1 In Item (iii)(C), *delete* “Clause 6.9” and *replace* with “Clause 6.4.”
- 2 *Delete* second last paragraph and *replace* with the following:
- The capacity reduction factor (ϕ) in Item (ii) and load combinations in Item (iii) above shall not apply when using displacement-based earthquake design for assessing the flexural strength of plastic hinge zones of bridge columns in seismic design categories BEDC-2 to BEDC-4.
- Tbl 2.3.2** 1 Rows (c) and (d), *delete* “ N_{uot} ” and *replace* with “ N_{ub} ”.
- 2 *Delete* note.
- Tbl 2.3.3** *Delete* note.
- Cl 2.4.3.2** Item (d), *delete* “Clause 12.8” and *replace* with “Clause 12.7”.
- Cl 2.5.2** *Delete* note.
- Cl 3.1.1.4.1** *Delete* clause text.
- Cl 3.1.1.4.5 (new)** After Clause 3.1.1.4.4, *add* the following:

3.1.1.4.5 Manufactured pozzolans

Pozzolan, which can be a by-product of mineral processing, manufacturing, waste to energy, recovered resources or processed or calcined natural materials, shall conform to AS 3582.4.

- Cl 3.1.7.1** *Delete* (b) and (c), and *replace* with the following:
- (b) by calculation in accordance with Clause 3.1.7.2;
 - (c) by calculation in accordance with Clause 3.1.7.2 where the value for $\epsilon_{csd,b}^*$ is evaluated from testing.

NOTE: Refer to Clause 3.1.7.2 of AS 3600:2018 Sup 1:2022 for guidance on the evaluation from testing method.

- Cl 3.1.7.2** *Delete* clause text and notes and *replace* with the following:

The design shrinkage strain of concrete (ϵ_{cs}) shall be calculated as the sum of the chemical (autogenous) shrinkage strain (ϵ_{cse}) and the drying shrinkage strain (ϵ_{csd}), as follows:

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

The autogenous shrinkage strain shall be taken as—

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

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

$$\begin{aligned} \text{For } f'_c \leq 50 \text{ MPa, } \varepsilon_{cse}^* &= (0.07f'_c - 0.5) \times 50 \times 10^{-6} \\ \text{For } f'_c > 50 \text{ MPa, } \varepsilon_{cse}^* &= (0.08f'_c - 1) \times 50 \times 10^{-6} \end{aligned} \quad 3.1.7.2(3)$$

NOTE 1: The effect of temperature on autogenous shrinkage may be taken into account by adjusting time t in Equation 3.1.7.2(2).

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

$$\varepsilon_{csd} = k_1 k_4 \varepsilon_{csd.b} \quad 3.1.7.2(4)$$

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 environment.

The basic drying shrinkage strain ($\varepsilon_{csd.b}$) shall be taken as—

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

where $\varepsilon_{csd.b}^* = 800 \times 10^{-6}$.

NOTE 2: Typical final design shrinkage strains after 30 years are found in Table 3.1.7.2.

NOTE 3: Consideration should be given to the fact that ε_{cs} has a range of $\pm 30\%$.

NOTE 4: 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. Excessive drying of concrete between the commencement of casting and the application of curing at the completion of finishing should therefore be avoided.

Tbl 3.1.7.2 Delete table and replace with the following:

TABLE 3.1.7.2
TYPICAL FINAL DESIGN SHRINKAGE STRAINS AFTER 30 YEARS

f'_c (MPa)	Final design shrinkage strain $\varepsilon_{cs}^* \left(\times 10^{-6} \right)$															
	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

Cl 3.1.8.3 Delete clause and replace with the following:

3.1.8.3 Design creep coefficient

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

In the absence of more accurate methods, ϕ_{cc} at any time (t) shall be taken as—

$$\phi_{cc} = k_2 k_3 k_4 k_5 \phi_{cc,b} \quad 3.1.8.3$$

where k_2 is obtained from Figure 3.1.8.3 and k_3 depends on the age of the concrete (τ) at the time of loading (in days) and is given by the following:

$$k_3 = 2.7/[1 + \log(\tau)] \text{ for } \tau \geq 1 \text{ day}$$

NOTE 1: The effect of temperature prior to loading may be taken into account by adjusting the age of the concrete at the time of loading τ in the determination of k_3 in Equation 3.1.8.3.

$k_4 = 0.70$ for an arid environment, 0.65 for an interior environment, 0.60 for a temperate inland environment and 0.50 for a tropical or near-coastal environment;

k_5 is a modification factor for high strength concrete taken as—

$$k_5 = 1.0 \text{ when } f'_c \leq 50 \text{ Mpa ; or}$$

$$k_5 = (2.0 - \alpha_3) - 0.02(1.0 - \alpha_3) f'_c \text{ when } 50 \text{ Mpa} < f'_c \leq 100 \text{ Mpa}$$

the factor $\alpha_3 = 0.7/(k_4 \alpha_2)$ and α_2 is defined in Figure 3.1.8.3.

k_9 accounts for the nonlinear creep that develops at sustained stress levels in excess of $0.45f_{cmi}$ as follows:

$$k_9 = 1.0 \text{ when } \sigma_o \leq 0.45f_{cmi}$$

$$k_9 = e^{1.5 \left(\frac{\sigma_o}{f_{cmi}} - 0.45 \right)} \text{ when } \sigma_o > 0.45f_{cmi}$$

Consideration shall be given to the fact that ϕ_{cc} has a range of approximately $\pm 30\%$. This range is likely to be exceeded if the concrete member is subjected to prolonged periods of temperature in excess of 25°C .

The final design creep coefficients (ϕ_{cc}^*) (after 30 years) predicted by this method for concrete first loaded at 28 days with a sustained stress level not exceeding $0.45f_{cmi}$ are given in Table 3.1.8.3.

NOTE 2: The maximum compressive stress under permanent effects should not exceed $0.45f'_c$.

Fig 3.1.8.3

Delete figure and replace with the following:

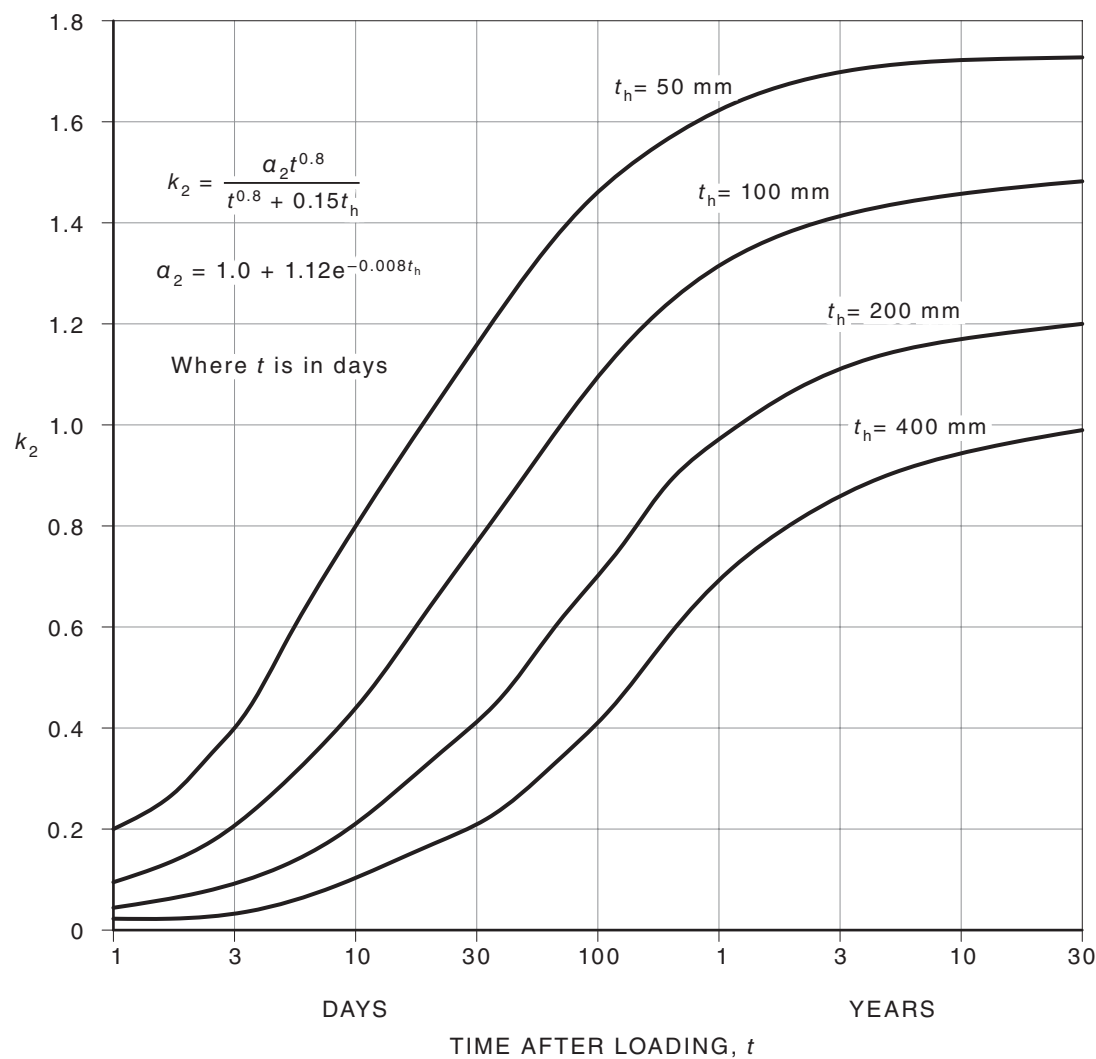


FIGURE 3.1.8.3 COEFFICIENT k_2

Tbl 3.1.8.3 Delete table and replace with the following:

TABLE 3.1.8.3
FINAL CREEP COEFFICIENTS (AFTER 30 YEARS) FOR CONCRETE
FIRST LOADED AT 28 DAYS

f'_c (MPa)	Final creep coefficient (ϕ_{cc}^*)											
	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)		
	100	200	400	100	200	400	100	200	400	100	200	400
25	4.82	3.90	3.27	4.48	3.62	3.03	4.13	3.34	2.80	3.44	2.78	2.33
32	3.90	3.15	2.64	3.62	2.93	2.46	3.34	2.70	2.27	2.79	2.25	1.90
40	3.21	2.60	2.18	2.98	2.41	2.02	2.75	2.23	1.87	2.30	1.86	1.56
50	2.75	2.23	1.89	2.56	2.07	1.73	2.36	1.91	1.60	1.97	1.59	1.33
65	2.07	1.75	1.53	1.95	1.66	1.46	1.84	1.59	1.38	1.61	1.38	1.23
80	1.56	1.40	1.29	1.50	1.36	1.25	1.45	1.32	1.22	1.33	1.23	1.14

100	1.15	1.14	1.11	1.15	1.14	1.11	1.15	1.14	1.11	1.15	1.14	1.11
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Cl 3.2.1 Delete all clause text after the third paragraph.

Tbl 3.2.1 Delete table, including notes, and replace with the following:

TABLE 3.2.1
YIELD STRENGTH AND DUCTILITY CLASS OF REINFORCEMENT

Reinforcement		Characteristic yield strength (f_{sy}) MPa	Uniform strain (ϵ_{su})	Ductility class
Type	Designation grade			
Bar plain to AS/NZS 4671	R250N	250	0.05	N
	R750N	750	0.04	N
Bar plain deformed or indented to AS/NZS 4671	D500L	500	0.015	L
	D500N	500	0.05	N
	D500E	500	0.10	E
	D600N	600	0.05	N
Welded mesh, plain, deformed or indented to AS/NZS 4671	D500L	500	0.015	L
	D500N	500	0.05	N
Stainless steel bar to BS 6744	500	500	0.05	N or E

Cl 3.3.4.2 Delete clause text and replace with the following:

The basic relaxation of a tendon (R_b) after 1000 h at 20°C with an initial force of $0.8f_{pb}$ for wire and strand and $0.7f_{pb}$ for hot rolled steel bars shall be determined in accordance with AS/NZS 4672.1.

Cl 3.3.4.4 Delete list item (b), and replace with the following:

- (b) for low relaxation strands —
- (i) 4 % for strands stressed to $0.7f_p$;
 - (ii) 7 % for strands stressed to $0.8f_p$; and
 - (iii) determined by linear interpolation for strands stressed between $0.7f_p$ and $0.8f_p$.

Fig 3.3.4.3 Delete figure and replace with the following:

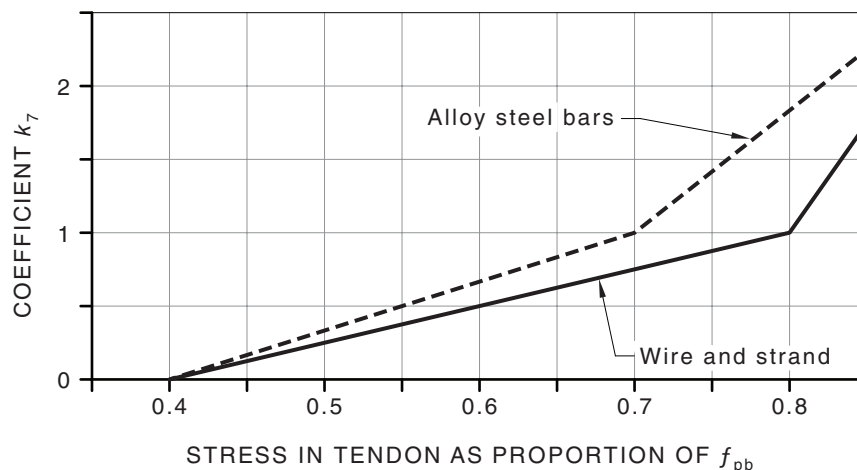


FIGURE 3.3.4.3 COEFFICIENT k_7

Cl 3.4.3.2 First paragraph, delete "Clause 3.1.7.2" and replace with "Clause 3.1.7.1".

Sec 4

Delete section and replace with the following:

4 DESIGN FOR DURABILITY**4.1 GENERAL**

The requirements of this Section apply to plain, steel fibre reinforced, steel bar reinforced and prestressed concrete structures and members with a design life of 100 years in accordance with AS 5100.1.

For structures with design life of 50 (± 20 %) years, the durability requirements of AS 3600 may be adopted.

NOTE 1: More stringent requirements may be appropriate for structures with a design life in excess of 100 years (e.g. monumental structures or high risk significant structures crossing major waterways), while some relaxation of the requirements may be acceptable for structures with a design or service life of less than 40 years (e.g. temporary structures).

NOTE 2: Durability is a complex topic and conformance to these requirements might not be sufficient to ensure a durable structure.

NOTE 3: Design life is defined in Clause 1.4.3.19.

4.2 METHOD OF DESIGN FOR DURABILITY

Durability shall be allowed for in design by determining the exposure classification in accordance with Clause 4.3 and, for that exposure classification, conforming to the appropriate requirements for concrete quality and curing, in accordance with Clauses 4.4 and 4.5. In addition—

- (a) members subject to abrasion from traffic (e.g. pavements and bridge decks) shall satisfy the requirements of Clause 4.6;
- (b) members subject to cycles of freezing and thawing shall satisfy the requirements of Clause 4.7;
- (c) members subject to aggressive sulfate or acid sulfate soils and members in acidic or saline soils shall satisfy the requirements of Clause 4.8;
- (d) members subject to marine exposure conditions shall satisfy the requirements of Clause 4.9;
- (e) members susceptible to damage due to alkali aggregate reaction (AAR) shall satisfy the requirements of Clause 4.10;
- (f) early-age maximum concrete temperature shall be controlled in accordance with the requirements of Clause 4.11 to prevent delayed ettringite formation (DEF);
- (g) early-age thermal cracking of concrete for large and restrained members shall be controlled in accordance with the requirements of Clause 4.12;
- (h) members containing steel fibres, steel reinforcement and/or tendons, the chemical content restrictions of the concrete shall satisfy the requirements of Clause 4.13;
- (i) cover to reinforcement and tendons shall satisfy the requirements of Clause 4.14;
- (j) the effects of all types of concrete cracking shall be considered, in accordance with the requirements of Clause 4.15; and
- (k) provision for stray current corrosion shall be considered in accordance with Clause 4.16.

4.3 EXPOSURE CLASSIFICATION

The following requirements apply:

- (a) The exposure classification for a surface of a member shall be determined from Table 4.3 and Figure 4.3.
- (b) Exposure classification and durability design of concrete piles shall be in accordance with this document.
- (c) Surfaces of members without permanent steel casing in non-aggressive soil and below the water table shall be classified as surfaces of members in water in Table 4.3 Items 4 and 5 unless it is proved by geotechnical investigation that no part of the surface of the member is below the permanent water table level.

- (d) For determining concrete quality requirements in accordance with Clauses 4.4 to 4.13 as appropriate, the exposure classification shall be taken as the most severe exposure of that surface.
- (e) For determining cover requirements for corrosion protection for reinforcing steel and tendons in accordance with Clause 4.14, the exposure classification shall be taken as the classification for the surface from which the cover is measured.
- (f) Members that do not contain steel reinforcement, tendons and/or metallic embedments that rely on the concrete for protection shall be exposure classification A, unless the environment is aggressive to the concrete (see Clause 4.2(b) to (e) for examples).

TABLE 4.3
EXPOSURE CLASSIFICATIONS

Surface and exposure environment		Exposure classification reinforced or prestressed concrete members (see Notes 1 and 9)
1	Surface of members in contact with the ground [see Clause 4.3(b) and (c)]: (a) Members protected by a damp-proof membrane in non-aggressive soils (b) Members in non-aggressive soils (see Note 2) (c) Members in aggressive soils	A B1 See Clause 4.8 and Table 4.8
2	Surfaces of members in interior environments: Fully enclosed within a structure except for a brief period of weather exposure during construction (see Note 10)	A
3	Surfaces of members in above-ground exterior environments in areas that are: (a) Inland (>50 km from coastline) environment being: (i) Non-industrial and arid climatic zone (see Notes 3 and 4) (ii) Non-industrial and temperate climatic zone (iii) Non-industrial and tropical climatic zone (iv) Industrial (see Note 4) and any climatic zone (b) Near-coastal (1 km to 50 km from coastline), any climatic zone (c) Coastal (see Note 5) and any climatic zone	A A B1 B1 B1 B2
4	Surfaces of members in water: (a) In fresh water continuously (chloride content < 1000 ppm) (b) In brackish water continuously (chloride content 1000–6000 ppm) (c) In soft water	B1 B2 U
5	Surfaces of members in sea water or in brackish water with chloride content > 6000 ppm: (a) Permanently submerged (b) In spray zone (see Note 6) (c) In tidal/splash zone (see Note 7)	B2 C1 C2
6	Surfaces of members in other environments, i.e. any exposure environment not specified in Items 1 to 5 above (see Notes 8 and 9)	U

NOTE 1: In this context, reinforced concrete includes any concrete containing metals that rely on the concrete for protection against environmental degradation. Plain concrete members containing metallic embedments should be treated as reinforced members when considering durability.

NOTE 2: For the purposes of this Table, a non-aggressive soil is defined as the least aggressive exposure condition in Table 4.8. If testing has been undertaken to ascertain that the soil in contact with concrete is non-aggressive, exposure classification A may be used, provided the soil is not subject to wetting and drying. Typically, surfaces of members in the top 500 mm of soil would not qualify for this reduction.

NOTE 3: The climatic zones referred to are those given in Figure 4.3, which is based on the Bureau of Meteorology map, Major seasonal rainfall zones of Australia, Commonwealth of Australia, 2005.

NOTE 4: Industrial refers to areas that are within 3 km of industries that discharge atmospheric pollutants.

NOTE 5: For the purpose of this table, the coastal zone includes locations within 1 km of the shoreline of large expanses of seawater. Where there are strong prevailing winds or vigorous surf, the distance should be increased beyond 1 km and higher levels of protection should be considered. AS 4312 provides guidance on airborne chloride levels within Australia.

NOTE 6: Where wave action is present in seawater, the spray zone is the zone from 1 m above wave crest level to the tidal/splash zone.

NOTE 7: The tidal/splash zone is immediately below the spray zone and includes: (a) the zone 1 m below lowest astronomical tide (LAT) and up to 1 m above highest astronomical tide (HAT) on vertical members such as piers and walls in seawater or brackish water; and (b) all exposed soffits of horizontal members such as bridge decks over seawater where wave action is present.

NOTE 8: Further guidance on measures appropriate in exposure classification U may be obtained from AS 3735 and AS 3735 Supp 1 respectively which cover exposure classifications and aggressiveness of various liquids and ground environments in contact with a concrete surface.

NOTE 9: In this Table, classifications A, B1, B2, C1 and C2 represent increasing degrees of severity of exposure, while classification U represents an exposure environment not specified in this Table but for which a degree of severity of exposure should be appropriately assessed. Protective surface coatings may be taken into account in the assessment of the exposure classification.

NOTE 10: The interior of a box girder or voided member is typically exposure classification A. Where the exterior of a box girder or voided member is exposed to salt spray, the interior should be at least exposure classification B1. A project specific assessment should be carried out for segmental box girders and box girders or voided members that have unusual penetrations or are located in unusual environmental conditions.

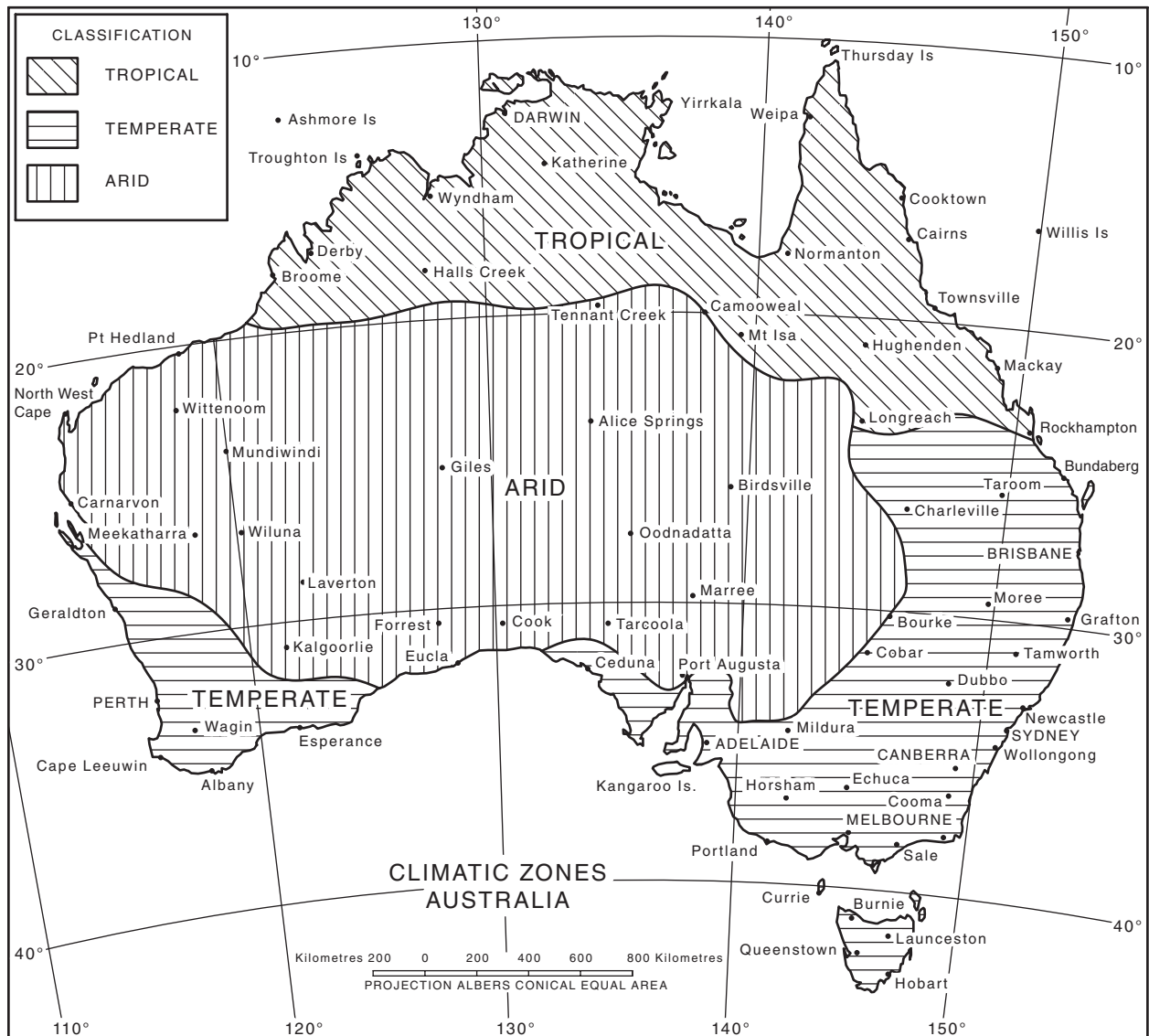


Figure 4.3 CLIMATIC ZONES

4.4 REQUIREMENTS FOR CONCRETE FOR EXPOSURE CLASSIFICATIONS A, B1, B2, C1 AND C2

4.4.1 GENERAL

Members subject to exposure classifications A, B1, B2, C1 and C2 shall—

- have minimum specified f'_c , minimum cement material content and maximum water/cement material (W/C) ratio in accordance with Table 4.4.1(A); and
 - satisfy curing requirements in accordance with Table 4.4.1(B),
- unless otherwise approved by the relevant authority.

NOTE: The relevant authority may specify its own mandatory durability test methods for the penetrability and absorption of concrete in order to demonstrate the required durability performance.

All concrete shall be specified as special class in accordance with AS 1379.

In addition to the requirements of Table 4.4.1(A), all concrete for members shall be produced with cement materials, including supplementary cementitious materials such as fly ash, slag and amorphous silica for improved durability, to address one or a combination of:

- Sulfate attack on concrete (see Table 4.3, especially exposure classification II)