

AS/NZS 5100.6:2017
Bridge design
Part 6: Steel and composite construction
Amendment No. 1
Revised text amendment

Publishing and Approval Dates

Council of Standards Australia Approval: 11 March 2024

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Summary

This Amendment applies to the following elements:

- Preface
- Sections 13, 16, 17
- Clauses 1.4, 1.7, 2.2.5, 2.2.6, 2.2.6.1, 2.2.6.2, 2.3, 2.4, 2.6, 2.7, 3.10.7, 4.2.2.2, 4.4.2, 5.1.2, 5.1.4, 5.3.2.4, 5.6.1.2, 5.6.2, 5.12.1, 5.12.3, 5.12.4, 5.12.5, 5.13.2, 5.13.5, 5.14.7.1, 6.2.3, 6.5.3, 6.5.3.1, 6.5.3.2, 6.6, 6.8.2, 6.8.4.4, 6.8.5.2.1, 6.8.5.2.2, 6.8.5.3, 7.3.3.2, 7.4.3.4, 7.6.5.2.1, 7.8, 10.4.1, 11.3.2, 11.3.3, 11.3.4, 11.4.2.1, 11.4.3.1, 12.3.6, 12.5.2.9, 12.5.3.2, 12.5.4.2, 12.5.5.1, 12.5.5.2, 12.6.3, 12.6.10.1, 12.6.10.2, 14.4, 14.5.1, 14.5.2, 14.7, 15.1, 15.4.5, A4, A5, I1.4, I1.5, I1.6, I2, J1, J2, J3
- Tables 1.5, 2.2.6.1, 2.1, 5.6.1, 5.10.5.2, 6.8.5.2.1, 12.5.1, 12.5.4.1, 12.6.10.2(A), 14.5.1, I2, L3
- Figures 2.2.6.2, 5.12.1(C), 6.8.5.2.1, 6.8.5.2.2, 7.3.3.2, 7.6.5.2.1, 7.8.3, 12.6.3(C), 14.4, I1.1
- Appendix M
- Bibliography

Amendment details

AS/NZS 5100.6:2017 is amended as follows. The amendments should be inserted in the locations as instructed.

Element	Instruction/New text	
Preface	Delete second last paragraph.	
CI 1.4	1	Delete "AS/NZS ISO 4671, <i>Steel reinforcing materials</i> " and replace with "AS/NZS 4671, <i>Steel for the reinforcement of concrete</i> ".
	2	After "NZS 3404.1 <i>Steel Structures Standard</i> ", add "NZS 3101 <i>Concrete Structures Standard</i> "
	3	Delete "AASHTO LRFD Bridge Design Specifications", and replace with: AASHTO <i>Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals</i> AASHTO <i>LRFD Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals</i>
CI 1.7	1	Delete clause title and replace with " FABRICATION AND ERECTION ".

Element	Instruction/New text
	2 Clause text, <i>delete</i> "AS/NZS 5131" and <i>replace</i> with "Section 16 and 17".
Tbl 1.5	1 <i>Delete</i> the table from its location after Clause 1.8 and <i>add</i> it after Clause 1.5.
	2 Notation table, <i>delete</i> " A_{bs} area of bottom slab reinforcement, shown in Figure 6.8.5.2.1" and " A_{bt} area of bottom transverse reinforcement, shown in Figure 6.8.5.2.1".
	3 Notation table, after A_g , <i>add</i> the following: A_{gv} gross area subject to shear at rupture
	4 Notation table, after A_n , <i>add</i> the following: A_{nt} net area subject to tension at rupture
	5 Notation table, after A_{nt} , <i>add</i> the following: A_{nv} net area subject to shear at rupture
	6 Notation table, <i>delete</i> the definition for E_c and <i>replace</i> with the following: elastic modulus of slab concrete, calculated in accordance with AS 5100.5 for Australia and NZS 3101 for New Zealand
	7 Notation table, after F , <i>add</i> the following: F_{yc} yield stress of the shear connector
	8 Notation table, after definition of f'_c <i>add</i> the following: f'_{ct} characteristic uniaxial/direct tensile strength of concrete, calculated in accordance with AS 5100.5 for Australia and NZS 3101 for New Zealand
	9 Notation table, after k_{bo} , <i>add</i> the following: k_{bs} factor to account for the effect of eccentricity on the block shear capacity
	10 Notation table, after R_{bb} , <i>add</i> the following: R_{bs} nominal design capacity in block shear
	11 Notation table, after Z_{ec} , <i>add</i> the following: Z_{Ed} design Z-value resulting from the magnitude of strains from restrained metal shrinkage under the weld beads

Cl 2.2.5 *Delete* clause and *replace* with the following:

2.2.5 Properties of steel

The following properties shall be assumed for all grades of steel for design purposes:

Grades of steel	AS/NZS 5100.6	NZS 3404
Modulus of elasticity (E)	200×10^3 MPa	205×10^3 MPa
Shear modulus of elasticity (G)	80×10^3 MPa	80×10^3 MPa
Poisson's ratio (ν)	0.25	0.30
Coefficient of thermal expansion (α_T)	$11.7 \times 10^{-6}/^\circ\text{C}$	$11.7 \times 10^{-6}/^\circ\text{C}$

Cl 2.2.6 *Delete* clause text.

Cl 2.2.6.1 (new) After Clause 2.2.6, *add* the following:

2.2.6.1 General

Through-thickness deformation properties shall be as specified to improve deformation capacity perpendicular to the surface to provide ductility and toughness against lamellar tearing. For products in accordance with AS/NZS 3678, the minimum values for reduction of area for the specified quality class shall conform to the relevant requirements of AS/NZS 3678 and as given in Table 2.2.6.1. For flat products, the minimum values for reduction of area shall apply to the whole product.

Tbl 2.2.6.1 (new) After Clause 2.2.6.1, *add* the following table:

TABLE 2.2.6.1
MINIMUM REDUCTION IN AREA

Grade suffix	%	Range of Z_{Ed}
Z15	15	$11 \leq Z_{Ed} \leq 20$
Z25	25	$21 \leq Z_{Ed} \leq 30$
Z35	35	>30

NOTE: See Clause 14.7 for determination of Z_{Ed} . See Clause 2.2.6.2 for exemptions.

Cl 2.2.6.2 (new) After Table 2.2.6.1, *add* the following:

2.2.6.2 Exemption from through thickness testing

For prequalified continuously cast steels where the sulfur is $<0.020\%$, Z quality steel (or through-thickness Z testing) is not required where—

- (a) $Z_{Ed} \leq 15$ and where steel thickness is 40 mm or less;
- (b) $Z_{Ed} \leq 20$ and where steel thickness is 40 mm or less and sulfur is $\leq 0.008\%$; or
- (c) historical records of similar joints on similar steels from the same manufacturer or through the operation of a suitable quality assurance program, can demonstrate freedom from lamellar tearing.

NOTE 1: Sulfur content may be verified via the steel manufacturer's heat certificate.

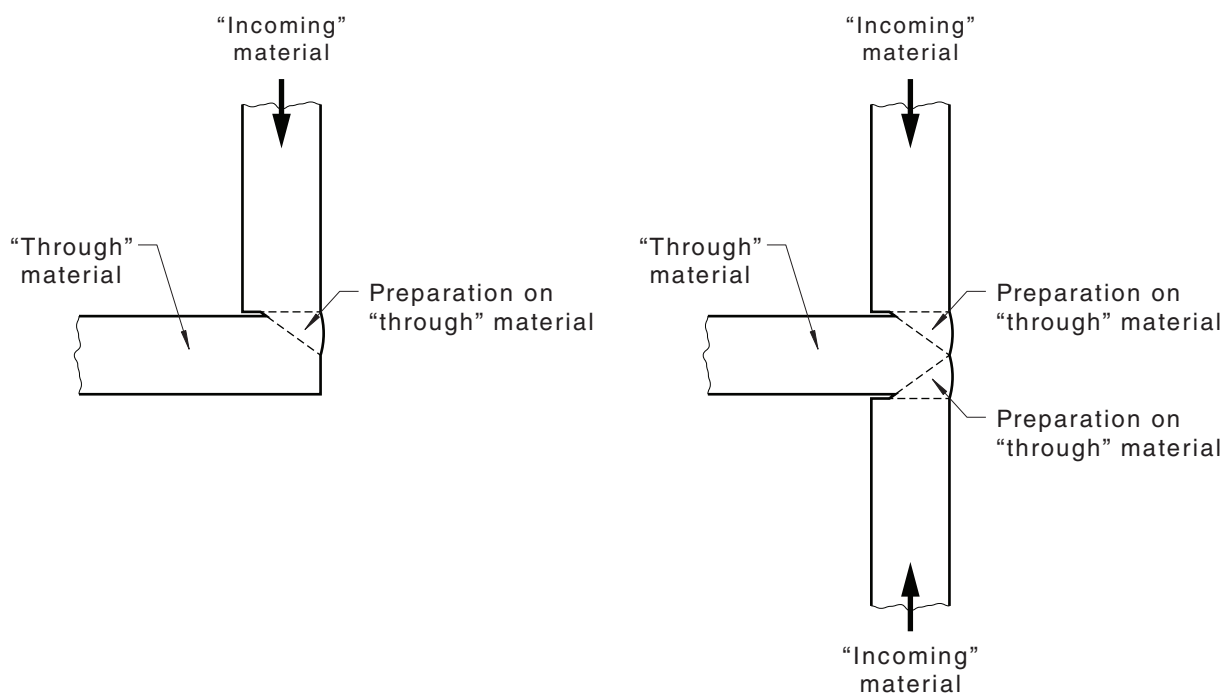
The following joints are at high risk of lamellar tearing

- (i) Cruciform joints.
- (ii) Tubular node joints, including T-K-Y joints.

NOTE 2: Joints manufactured from rolled hollow sections conforming to AS/NZS 1163 and $Z_{Ed} \leq 20$ are typically not susceptible to lamellar tearing due to their limited wall thickness.

- (iii) Corner and set-in joints, for other than where the weld preparation is within the through material (see Figure 2.2.6.2).

Fig 2.2.6.2 (new) After Clause 2.2.6.2, *add* the following:



NOTE Joints may be complete or incomplete penetration welds.

FIGURE 2.2.6.2 EXAMPLE OF PREFERRED LOCATION OF WELDS FOR CORNER JOINT AND SET-IN JOINTS

- CI 2.3**
- 1 First paragraph, after “AS 5100.5”, *add* “for Australia and NZS 3101 for New Zealand”.
 - 2 After second paragraph, *add* the following:
For site bending and rebending requirements, refer to AS 5100.5 (for Australia) and NZS 3101 (for New Zealand).
- CI 2.4** Item (h), *delete* “AS/NZS 1252” and *replace* with “AS/NZS 1252.1”.
- CI 2.6**
- 1 First sentence, *delete* “AS/NZS 1554.2” and *replace* with “AS 1554.2”.
 - 2 Second sentence, *delete* “ISO 13918” and *replace* with “AS/NZS ISO 13918”.
- CI 2.7** *Delete* “shall” and *replace* with “should”.
- Tbl 2.1**
- 1 *Delete* the table from its location after Clause 2.11 and *add* it after Clause 2.1 title.
 - 2 *Delete* “(Note 2)” and *replace* with “a” in all instances in the table.
 - 3 *Delete* “(Note 3)” and *replace* with “b” in all instances in the table.
 - 4 *Delete* the notes and *replace* with the following:
^a Welded I-sections conforming to AS/NZS 3679.2 are manufactured from hot-rolled structural steel plates conforming to AS/NZS 3678, so the values listed for steel grades to AS/NZS 3678 shall be used for welded I-sections to AS/NZS 3679.2.
^b AS/NZS 3678, AS/NZS 3679.1 and AS/NZS 1163 all contain, within each grade, a variety of impact grades not individually listed in the Table. All impact-tested grades within the one grade have the same yield stress and tensile strength as the grade listed.
- Tbl 3.2**
- Column 3, row “(c) Connections”, after “0.90”, *add* “0.75”.
- Column 2, row “(d) Shear connection”, *delete* “6.8.3” and *replace* with “6.8.4”.
- Column 2, row “(d) Shear connection”, *delete* “6.6” and *replace* with “6.8.5”.
- CI 3.10.7** *Delete* note text, and *replace* with “For methods of enhancement, refer to Weld Australia’s Technical Guidance Note TGN-PG02, *Minimisation of Fatigue in Welds*.”
- CI 4.2.2.2** After notation β_m for Equation 4.2.2.2(4), *delete* “= 0”.
- CI 4.4.2** Item (b), notations after Equation 4.4.2(1), *delete* the definition for b_{ei} and *replace* with the following:
value of the effective width of the concrete flange on each side of the web and taken as $L_{ef,i}/8$ (but not greater than the geometric width b_i)
The geometric breadth (b_i) of each portion shall be taken as the distance from the outstanding shear connector to a point midway between adjacent webs, measured at mid-depth of the concrete flange, except that at a free edge the actual breadth is the distance from the beam to free edge.
For typical continuous composite beams, where a moment envelope from various load arrangements governs the design (and for cantilevers), the equivalent span $L_{ef,i}$ shall be assumed to be as shown in Figure 4.4.2.
Otherwise L_{ef} should be taken as the approximate distance between points of zero bending moment.
- CI 4.4.3**
- 1 First paragraph, after “AS 5100.5”, *add* “or NZS 3101”.
 - 2 In (a), after “AS 5100.5”, *add* the following “or NZS 3101”.
- CI 5.1.2** In note, *delete* “Clause 5.1.5”, and *replace* with “Clause 5.15”.
- CI 5.1.4** Second paragraph, *delete* “ Z_e ”, and *replace* with “ Z_{en} ”.
- CI 5.3.2.4** Item (c), *delete* equation and *replace* with the following:

$$\frac{l}{r_y} \leq (80 + 50\beta_m) \left[\sqrt{\frac{2\rho A d_f}{2.5Z_{ex}}} \right] \sqrt{\left(\frac{250}{f_y} \right)}$$

- Tbl 5.6.1**
- 1 Column 3, row 1, *delete* “ $1.75+1.05\beta_m+0.3\beta_{m2}$ ” and *replace* with the following:

$$1.75 + 1.05\beta_m + 0.3\beta_m^2$$
 - 2 Column 3, row 3, *delete* “1.0” from equation and *replace* with “1.35”.
 - 3 Column 3, row 10, *delete* “3.50” and *replace* with “2.50”.

Cl 5.6.1.2 Item (a), *delete* equation and *replace* with the following:

$$M_o = \sqrt{\frac{\pi^2 EI_y}{L_e^2}} \left\{ \sqrt{\left[(GJ) + \left(\frac{\pi^2 EI_w}{L_e^2} \right) + \left(\frac{\beta_x^2}{4} \frac{\pi^2 EI_y}{L_e^2} \right) \right]} + \frac{\beta_x}{2} \sqrt{\left(\frac{\pi^2 EI_y}{L_e^2} \right)} \right\} \quad 5.6.1.2(1)$$

Cl 5.6.2 *Delete* Item (b), including Items (i) and (ii) and *replace* with the following:

- (b) laterally continuous or restrained against lateral rotation, shall be determined using either—
 - (i) the provisions of Clause 5.6.1.1(a) with M_{oa} equal to the appropriate value of M_o and the appropriate value of α_m given in Table 5.6.2; or
 - (ii) $M_b = \alpha_s M_s \leq M_s$, where the slenderness reduction factor (α_s) shall be determined as follows:

- Tbl 5.10.5.2**
- 1 Column “1.25”, row “100”, *delete* “1.998” and *replace* with “0.989”.
 - 2 Column “1.0”, row “110”, *delete* “0.989” and *replace* with “0.998”.

Cl 5.12.1 First sentence, after “and square hollow sections”, *add* “conforming to AS/NZS 1163”.

Fig 5.12.1(C) *Delete* the figure and *replace* with the following:

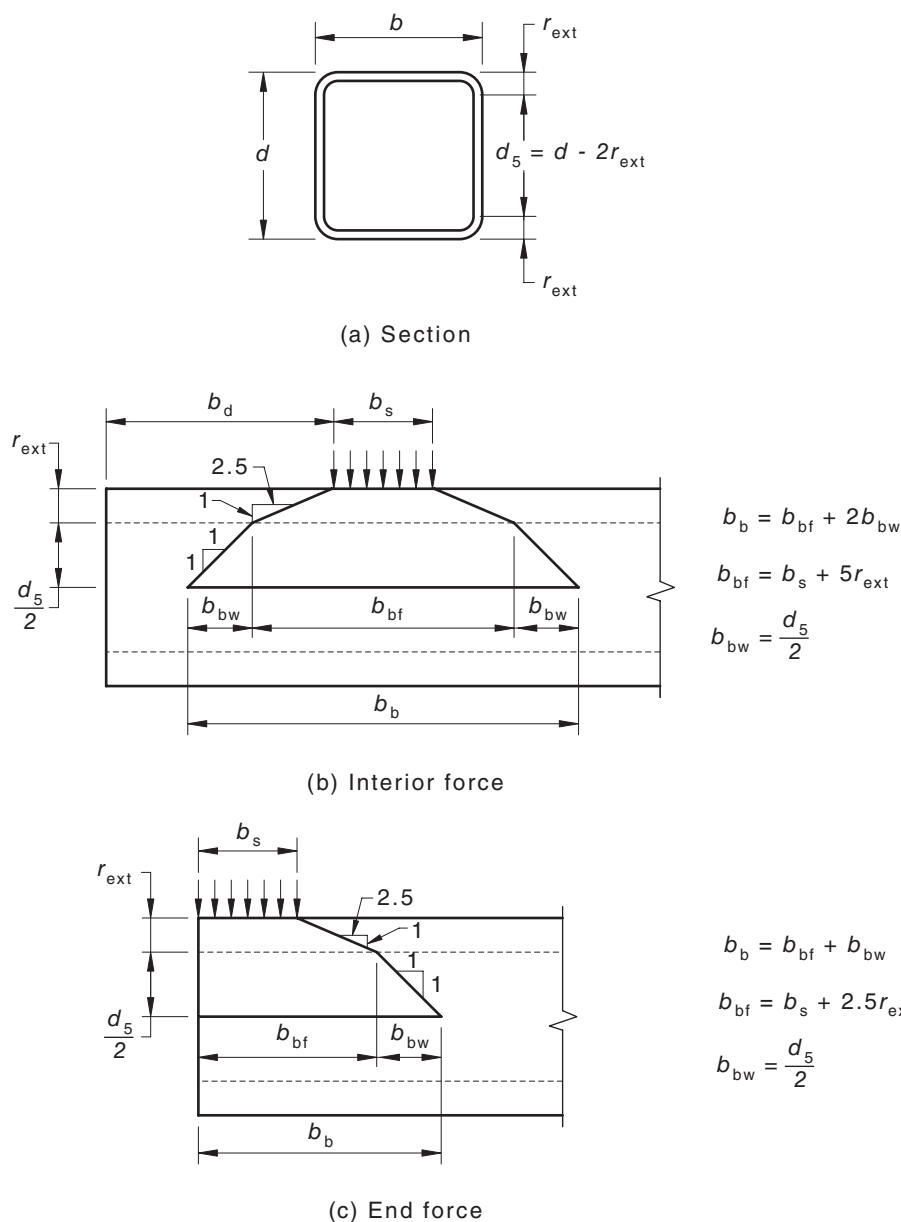
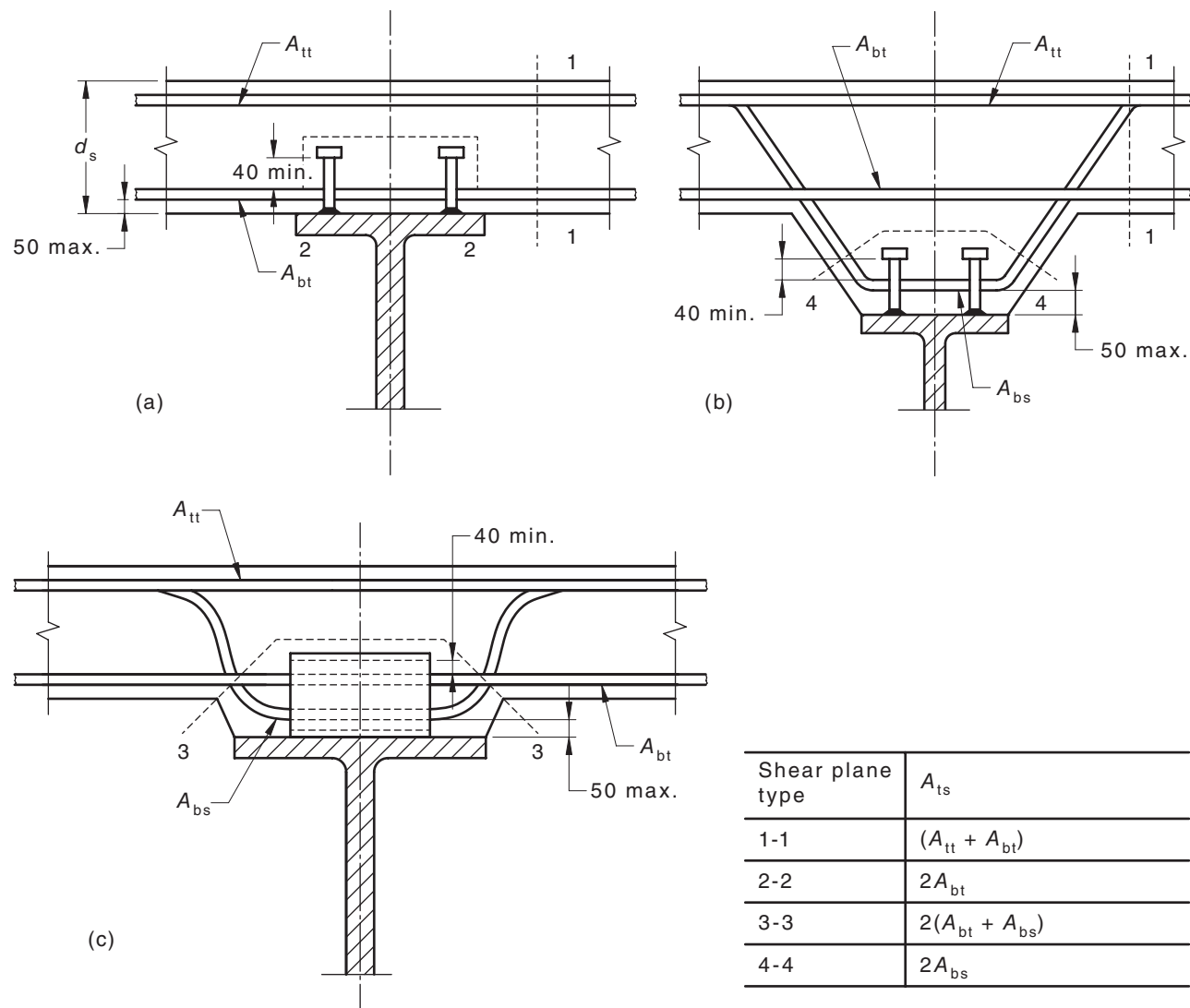


FIGURE 5.12.1(C) RECTANGULAR AND SQUARE HOLLOW SECTIONS DISPERSION OF FORCE THROUGH FLANGE, RADIUS AND WEB

- CI 5.12.3** 1 Second paragraph, *delete* “AS 1163” and *replace* with “AS/NZS 1163”.
- 2 Definition for α_p , *delete* “AS 1163” and *replace* with “AS/NZS 1163”.
- CI 5.12.4** 1 First paragraph, *delete* “Section 6” and *replace* with “Section 10”.
- 2 Second paragraph, *delete* “Section 6” and *replace* with “Section 10”.
- 3 Item (iv), *delete* both instances of “ $b_d \geq 1.5d_5$ ”, and *replace* with “ $b_d < 1.5d_5$ ”.
- CI 5.12.5** Definition for b , *delete* “length” and *replace* with “width”.
- CI 5.13.2** Add “the lesser of” to the end of the sentence above list item (a).
- CI 5.13.5** *Delete* “ α_s ”, and *replace* with “ α_t ”.
- CI 5.14.7.1** *Delete* first paragraph and *replace* with the following:

Where an intermediate stiffener is used to transfer design forces (F_n^*) normal to the web or design moments ($M^* + F_p^* e$) acting normal to the web [including moments ($F_p^* e$) caused by any eccentric force F_p^* parallel to the web], the minimum value of I_s in Clause 5.14.5 shall be increased by—

- Cl 6.2.3** First paragraph, after “AS 5100.5”, add “for Australia and NZS 3101 for New Zealand”.
- Cl 6.5.3 (new)** After Clause 6.5.2, add a new clause heading as follows:
6.5.3 Flexural torsional buckling
- Cl 6.5.3.1 (new)** After Clause 6.5.3, add the following:
6.5.3.1 Sagging moment regions
 Flexural torsional buckling of the composite beam in sagging moment regions shall be assumed to be restrained when shear connection is provided between the steel beam and slab.
- Cl 6.5.3.2 (new)** After Clause 6.5.3.1, add the following:
6.5.3.2 Hogging moment regions
 In hogging moment regions, the lateral stability of the steel section shall be checked using the provisions of AS 4100 for Australia and NZS 3404 for New Zealand.
- Cl 6.6** Delete clause text and replace with the following:
 The vertical shear capacity of a composite section shall comprise the summation of the contribution from the steel section and the concrete slab, where—
 (a) the steel section capacity is determined in accordance with Clauses 5.8 to 5.11; and
 (b) the concrete slab capacity is determined in accordance with AS/NZS 2327.
- Cl 6.8.2** Delete Item (h) and replace with the following:
 (h) The minimum pitch of stud shear connectors in any direction shall be 75 mm. The pitch of stud shear connectors in the direction of the longitudinal shear force shall be not less than 5 times the shank diameter, and not less than the height of the stud shear connectors.
- Cl 6.8.4.4** Delete the definition for E_c and replace with the following:
 elastic modulus of slab concrete, shall be calculated in accordance with AS 5100.5 for Australia and NZS 3101 for New Zealand
- Cl 6.8.5.2.1** 1 Delete the definition for A_{tc} and replace with the following:
 cross-sectional area per unit length of the beam for the concrete shear surface under consideration.
 2 Delete definition for f'_{ct} and replace with the following:
 characteristic uniaxial/direct tensile strength of concrete and shall be calculated in accordance with AS 5100.5 for Australia and NZS 3101 for New Zealand
 3 After the definition for f'_{ct} , add “ $\Phi = 0.7$ ”
- Tbl 6.8.5.2.1** 1 Third row, delete (b).
 2 Fourth row, delete “Monolithic construction” and replace with “Monolithic construction or mechanical shear keys”
- Fig 6.8.5.2.1** Delete the figure, and replace with the following:



CI 6.8.5.2.2 Delete clause text and *replace* with the following:
As an alternative to Equation 6.8.5.2.1, the shear strength of the concrete flange shall be evaluated using a truss analogy in accordance with AS 5100.5 for Australia and NZS 3101 for New Zealand.

Fig 6.8.5.2.2 Delete the figure.

CI 6.8.5.3 Delete clause text and *replace* with the following:
In the case of combined shear between the flange and the web, and transverse bending, the area of steel shall be the greater of that given by Equation 6.8.5.2.1 or the truss analogy specified in Clause 6.8.5.2.2. Alternatively, it may be half the area of steel that is given by Equation 6.8.5.2.1 or the truss analogy specified in Clause 6.8.5.2.2 in addition to that required for transverse bending.

CI 7.3.3.2 After Item (c), *add* the following:
The value of K_c in Figure 7.3.3.2 shall be the higher of the values obtained, using either—

(i) curve 1 or 2, as relevant with $\lambda = \frac{b}{t} \sqrt{\left(\frac{f_y}{355}\right)}$; or 7.3.3.2(1)

(ii) curve 3 with $\lambda = \frac{a}{t} \sqrt{\left(\frac{f_y}{355}\right)}$ 7.3.3.2(2)

where

b = panel dimension normal to the direction of the stress being considered

a = panel dimension in the direction of the stress being considered

Equation 7.3.3(5) will always give the higher value of K_c when $a/b \geq 0.5$.

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Fig 7.3.3.2

1 Delete the note.

2 Delete the figure from its location after Clause 7.3.3.4 and add it after Clause 7.3.3.2.

Cl 7.4.3.4

Delete Equation 7.4.3.4(6) and replace with the following:

$$m_c = \sqrt{(m_1 + m_2)} \text{ for positive values of } (m_1 + m_2) \\ = -\left\{\sqrt{-(m_1 + m_2)}\right\} \text{ for negative values of } (m_1 + m_2)$$

Cl 7.6.5.2.1

After clause text, add the following:

L_r shall be taken as the least of—

$$6t_d = \sqrt{\frac{355}{f_{yd}}}, \frac{d}{8} \text{ or } \frac{L}{2}$$

Fig 7.6.5.2.1

1 Delete the note.

2 Delete the figure from its location after Clause 7.6.5.2.2 and add it after Clause 7.6.5.2.1.

Cl 7.8 (new)

After Clause 7.7.5, add the following:

7.8 LONGITUDINAL SHEAR

7.8.1 General

In addition to the requirements of Clause 6.8, the requirements specified in Clauses 7.8.2 and 7.8.3 apply to the design of shear connectors for longitudinal shear in composite box girders.

7.8.2 Spacing of shear connectors

The shear connectors required for closed box girders shall be provided over the whole area of the top flange plate at spacings longitudinally and transversely not greater than the least of—

- (a) 600;
- (b) three times the thickness of the concrete deck slab; or
- (c) four times the height of the connector.

The longitudinal spacing of the shear connectors shall be not greater than 25 times, and the transverse spacing shall be not greater than 40 times, the thickness of the top flange plate.

For open-top box girders, the spacing requirements for shear connectors shall be as specified in Clause 6.8.2 for composite I-girders.

The distance from the edge of the top flange plate to the near edge of the nearest row of shear connectors shall be not greater than 12 times the thickness of the plate.

7.8.3 Design of shear connectors

The number and distribution of the shear connectors of closed box girders shall, in addition to meeting the requirements of Clause 6.8, conform to the following:

- (a) The longitudinal shear force on a connector at a distance x from the web centre-line shall be determined from the following equation:

$$V_{Lx}^* = \frac{V_L^*}{n} \left[k \left(1 - \frac{x}{b_{fo}} \right) 2 + 0.15 \right] \quad 7.8.3$$

where

V_L^* = design longitudinal shear force per unit length for the web considered

n = number of shear connectors per unit length of girder within breadth b_{f0}

k = coefficient shown in Figure 7.8.3

b_{f0} = half the clear distance between the centre-lines of adjacent webs, or the distance from the centre-line of a web to the free edge of the steel flange

In Figure 7.8.3, n' is the number of shear connectors per unit length placed within 200 of the centre-line of the web being considered

In calculating n , the number of shear connectors per unit area of steel flange shall not be taken to be greater than that which exists in the area of the effective width at that cross-section.

Fig 7.8.3 (new)

After Clause 7.8, *add* the following:

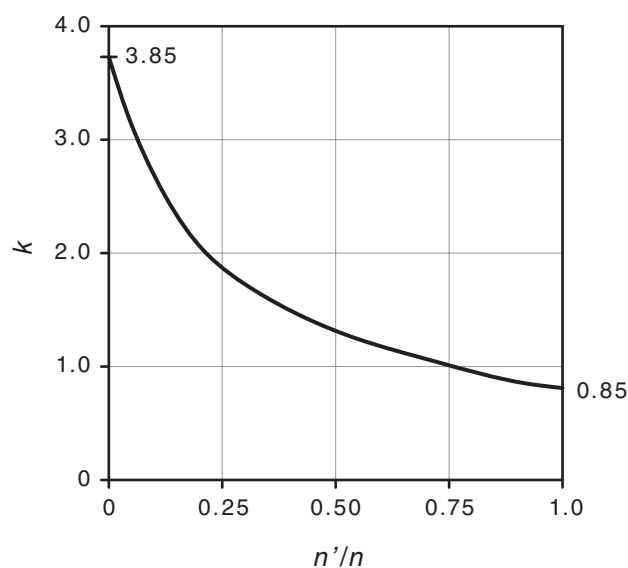


FIGURE 7.8.3 COEFFICIENT k

- CI 10.4.1** Last sentence of first paragraph, *delete* “using the following equation” and *replace* with “calculated as follows”.
- CI 11.3.2** Second paragraph, *delete* “AS 1163” and *replace* with “AS/NZS 1163”.
- CI 11.3.3** Item (b), *delete* “AS 1163” and *replace* with “AS/NZS 1163”.
- CI 11.3.4** Second paragraph, *delete* “AS 1163” and *replace* with “AS/NZS 1163”.
- CI 11.4.2.1** *Delete* the paragraph immediately above Equation 11.4.2.1(3) and *replace* with the following:
Alternatively, for doubly symmetric I-sections and rectangular and square hollow sections that are compact as defined in Clause 5.2.1, and where the form factor (k_f) determined in accordance with Clause 10.2.2 is unity, (M_i) may be calculated as follows:
- CI 11.4.3.1** Equation 11.4.3.1(5), *delete* definition for L , and *replace* with “distance between partial or full torsional restraints”.
- CI 12.3.6** *Delete* clause, and *replace* with the following:
Connection components (cleats, gusset plates, brackets and the like) other than connectors shall have their design capacities assessed as follows:
- Connection components subject to shear — in accordance with Clause 5.11.
 - Connection components subject to tension — in accordance with Clause 10.2.
 - Connection components subject to compression — in accordance with Section 9.
 - Connection components subject to bending — in accordance with Section 5.

- (e) Connection components, including a member framing onto the connection component, subject to a design shear force or design tension force (R_{bs}) shall satisfy the following equation:

$$R_{bs}^* \leq \phi R_{bs} \quad 12.3.6$$

where

ϕ = capacity factor
= 0.75

R_{bs} = nominal design capacity in block shear
= $0.6 f_{uc} A_{nv} + k_{bs} f_{uc} A_{nt}$
 $\leq 0.6 f_{yc} A_{gv} + k_{bs} f_{uc} A_{nt}$

f_{uc} = tensile strength of the connection element

f_{yc} = yield stress of the connection element

A_{nv} = net area subject to shear at rupture

A_{nt} = net area subject to tension at rupture

A_{gv} = gross area subject to shear at rupture

k_{bs} = factor to account for the effect of eccentricity on the block shear capacity
= 1.0 when tension stress is uniform
= 0.5 when tension is non-uniform

Tbl 12.5.1 Delete the table and replace with the following:

TABLE 12.5.1
BOLTS AND BOLTING CATEGORY

Bolting category	Bolt Standard	Bolt grade	Method of tensioning	Minimum tensile strength (f_{uf})(see Note 2), MPa
4.6/S	AS 1111 (series), AS 1110 (series)	4.6	Snug tight	400
8.8/S	AS/NZS 1252.1, AS 1110 (series)	8.8	Snug tight	830
8.8/TB	AS/NZS 1252.1	8.8	Full tensioning	830
8.8/TF (see Note 1)	AS/NZS 1252.1	8.8	Full tensioning	830
10.9/S (see Note 4)	AS/NZS 1252.1	10.9	Snug tight	1040
10.9/TB (see Note 4)	AS/NZS 1252.1	10.9	Full tensioning	1040
10.9/TF (see Notes 1 and 4)	AS/NZS 1252.1	10.9	Full tensioning	1040

NOTE 1: Special category used in connections where slip in the serviceability limit state is to be restricted (see Clauses 3.3.6 and 12.3.2).

NOTE 2: f_{uf} is the minimum tensile strength of the bolt as specified in AS 4291.1:2015 except for grade 8.8 bolts less than 16 mm diameter where the minimum tensile strength is 800 MPa.

NOTE 3: Bolts to AS 1110 (series) and AS 1111 (series) are not suitable for full tensioning.

NOTE 4: Post-manufacture treatment of high strength bolts may adversely affect material properties.

Cl 12.5.2.9 After "8.8/TF", add "or 10.9/TF".

Cl 12.5.3.2 Delete "AS/NZS 1275" and replace with "AS 1275".

Tbl 12.5.4.1 Delete the table and replace with the following:

TABLE 12.5.4.1
MINIMUM BOLT TENSION

Nominal diameter of bolt	Minimum bolt tension, kN	
	Bolt grade	
	8.8	10.9
M16	95	130
M20	145	205
M24	210	295
M30	335	465
M36	490	680

NOTE: The minimum bolt tensions given in this Table are approximately equivalent to the minimum proof loads derived from a proof load stress of 600 MPa for grade 8.8 bolts and 830 MPa for grade 10.9 bolts, as specified in AS 4291.1.

CI 12.5.4.2 Delete Equation 12.5.4.2(1) and *replace* with the following:

$$\frac{V_{sf}^*}{\phi V_{sf}} + \frac{N_{tf}^*}{\phi N_{tf}} \leq 1.0 \quad 12.5.4.2(1)$$

CI 12.5.5.1 1 Delete Equation 12.5.5.1(2), and *replace* with the following:

$$V_f = 0.62 f_{yp} n_s A_p \quad 12.5.5.1(2)$$

2 Delete “ f_{up} = tensile strength of the pin” and *replace* with “ f_{yp} = yield stress of pin”.

CI 12.5.5.2 1 Delete Equation 12.5.5.2(2) and *replace* with the following:

$$V_b = 1.4 k_p f_{yp} d_f t_p \quad 12.5.5.2(2)$$

2 Delete “ f_{up} = tensile strength of the pin” and *replace* with: “ f_{yp} = yield stress of pin”.

CI 12.6.3 1 Item (b)(i), after “AS/NZS 1554.1”, *add* “and AS/NZS 1554.4”.

2 Item (b)(ii)(A), *delete* “<” and *replace* with “≤”.

3 Item (b)(ii)(B), *delete* “<” and *replace* with “≤”.

Fig 12.6.3(C) Delete figure title and *replace* with “COMPOUND WELDS”.

CI 12.6.10.1 Item (a), after “AS/NZS 1554.1”, *add* the following:

, AS/NZS 1554.4 or AS/NZS 1554.5. The butt weld shall be made using a welding consumable which will produce butt tensile test specimens in accordance with AS 2205.2.1 for which the minimum strength is not less than that given in Table 2.1 for the parent material.

CI 12.6.10.2 At the end of the paragraph immediately after V_w^* , *add* the following:

The effective area of a fillet weld shall be the product of the effective length and the design throat thickness.

Tbl 12.6.10.2(A) Delete the table and *replace* with the following:

TABLE 12.6.10.2(A)
NOMINAL TENSILE STRENGTH OF WELD METAL (f_{uw})

Manual metal arc (AS/NZS 4855)	Submerged arc (AS 1858.1)	Flux cored arc (AS/NZS ISO 17632)	Gas metal arc (AS/NZS 2717.1, ISO 14341)	Gas tungsten arc (ISO 636)	Nominal tensile strength of weld metal (f_{uw})
Structural steel welding to AS/NZS 1554.1 and AS/NZS 1554.5—Steel Types 1–8C					
A E35, A 38 B E43XX	W40X	A-T35, A-T38 B-T43	A-G35, A-G38 B-G43	A-W35, A-W38 B-W43	430

A E42, A E46 B E49XX	W50X	A-T42, A-T46 B-T49	A-G42, A-G46 B-G49, W500	A-W42, A-W46 B-W49	490
A E50 B E55XX	W55X	A-T50 B-T55, B-T57	A-G50 B-G55, B-G57 W55X, W62X	A-W50 B-W55, B-W57	550

Structural steel welding to AS/NZS 1554.4—Steel Types 8Q–10Q

Manual metal arc (AS/NZS 4855, AS/NZS 4857)	Submerged arc (AS 1858.1, AS 1858.2)	Flux cored arc (AS/NZS ISO 17632, AS/ NZS ISO 18276)	Gas metal arc (AS/NZS 2717.1, ISO 14341, ISO 16834)	Gas tungsten arc (ISO 636, ISO 16834)	Nominal tensile strength of weld metal (f_{uw})
A E35, A 38 B E43XX	W40X	A-T35, A-T38 B-T43	A-G35, A-G38 B-G43	A-W35, A-W38 B-W43	430
A E42, A E46 B E49XX	W50X	A-T42, A-T46 B-T49	A-G42, A-G46 B-G49 W50X	A-W42, A-W46 B-W49	490
A E50 B E55XX B E57XX B E59XX	W55X	A-T50 B-T55, B-T57, B-T59	A-G50 B-G55, B-G57, B-G59 W55X	A-W50 B-W55 B-W57, B-W59	550
A E55 B E62XX	W62X	A-T55 B-T62	A-G55 B-G62 W62X	A-W55 B-W62	620
A E62 B E69XX	W69X	A-T62 B-T69	A-G62 B-G69 W69X	A-W62 B-W69	690
A E69 B E76XX B E78XX	W76X	A-T69 B-T76, B-78	A-G69 B-G76, B-G78 W76X	A-W69 B-W76, B-W78	760
A E79 B E83XX	W83X	A-T79 B-T83	A-G79 B-G83, W83X	A-W79 B-W83	830

NOTE 1: The minimum tensile strength of the European type A classification series consumables is slightly higher than that shown in this Table.

NOTE 2: The B-E57XX, B-E59XX, B-E78XX and equivalent strength consumables for other welding processes, may be difficult to source commercially.

NOTE 3: The letter 'X' represents any flux type (manual metal arc welding process) or impact energy value (submerged arc and gas metal arc welding processes).

Sec 13

Delete the section and replace with the following:

13 FATIGUE

13.1 SCOPE

This Section sets out requirements for fatigue design, which are based on international best practice. It includes damage equivalent factors for the road and rail traffic fatigue loads given in AS 5100.2 for Australia and Waka Kotahi NZTA Bridge Manual (SP/M/022) for New Zealand.

The requirements of this Section are applicable to structures where execution conforms to AS/NZS 1554.1, AS/NZS 1554.3 or AS/NZS 1554.5 and AS/NZS ISO 3834.2 (see Note 2).

This Section applies to materials that conform to the toughness requirements of AS/NZS 5100.6. The assessment methods given in this Section are applicable to all grades of structural stainless steels and unprotected weathering steel, except where noted otherwise in the detail category tables.

Structural supports for highway signs, luminaires and traffic signals fatigue design provisions are given in Clause 13.11.7.

The fatigue strengths given in this Section apply to structures operating under normal atmospheric conditions and with sufficient corrosion protection and regular maintenance.

NOTE 1: For the determination of fatigue load parameters, including verification formats, see Appendix I.

NOTE 2: Where appropriate, supplementary requirements are indicated in the detail category tables, [Table 13.10.1\(B\)](#) to [Table 13.10.1\(K\)](#).

13.2 EXCLUSIONS

This Section does not cover the following:

- (a) Fatigue assessment using the notch stress or notch strain method.

- (b) Fatigue assessment using fracture mechanics.
- (c) Post fabrication treatments to improve the fatigue strength, other than stress relief.
- (d) The effect of seawater corrosion.
- (e) Microstructural damage from high temperature (>150°C).
- (f) High stress-low cycle fatigue.
- (g) Stress corrosion cracking.

13.3 DEFINITIONS

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

13.3.1 General

13.3.1.1 *Fatigue*

The process of initiation and propagation of cracks through a structural part due to action of fluctuating stress.

13.3.1.2 *Geometrical (hot spot) stress (action)*

The maximum elastic stress in the parent material adjacent to the weld toe, taking into account stress concentration effects due to the overall geometry of a particular constructional detail but disregarding the stress concentration effect of the notch geometric detail at the weld toe.

NOTE: Local stress concentration effects, e.g. from the weld profile shape (which is already included in the detail categories in Appendix I), need not be considered.

13.3.1.3 *Modified nominal stress (action)*

A nominal stress multiplied by an appropriate stress concentration factor k_t , to allow for a geometric discontinuity and/or concentrated load effect that has not been taken into account in the classification of a particular constructional detail.

NOTE: The detail categories in [Table 13.10.1\(B\)](#) to [Table 13.10.1\(K\)](#) and in Appendix I include allowance for stress concentration due to the constructional detail (including the direction of loading) and for the weld geometry and the minimum fabrication requirements of this Standard. Values of stress concentration factors for details not provided in [Table 13.10.1\(B\)](#) to [Table 13.10.1\(K\)](#) and in Appendix I can be obtained from published data.

13.3.1.4 *Nominal stress (action)*

A stress in the parent material or in a weld adjacent to a potential crack location calculated in accordance with elastic theory, excluding all stress concentration effects and all stress rising effects of the structural detail of the joint.

NOTE: The nominal stress as specified in this Section can be a normal stress, a shear stress, a principal stress or an equivalent stress.

13.3.2 Fatigue loading parameters

13.3.2.1 *Design life*

The reference period of time for which a structure is required to perform safely with an acceptable probability that failure by fatigue cracking will not occur.

13.3.2.2 *Design spectrum*

The total spectrum of all stress ranges in the design life of a structure relevant to the fatigue assessment.

13.3.2.3 *Equivalent constant amplitude fatigue loading (action)*

Simplified constant amplitude loading causing the same fatigue damage effects as a series of actual variable amplitude loading events.

13.3.2.4 *Equivalent constant amplitude stress range (action)*

The constant-amplitude stress range that would result in the same fatigue life as for the design spectrum, when the comparison is based on a Miner's summation.

NOTE: For the mathematical determination, see Appendix I.

13.3.2.5 *Fatigue life*

The predicted period of time to cause fatigue failure under the application of the design spectrum.

13.3.2.6 Fatigue loading

A set of action parameters based on typical loading events described by the positions of loads, their magnitudes, frequencies of occurrence, sequence and relative phasing.

NOTE: The fatigue actions in AS 5100.2 are upper bound values based on evaluations of measurements of loading effects according to Appendix I. Dynamic effects are included in these parameters unless otherwise stated.

13.3.2.7 Loading event

A defined loading sequence applied to the structure and giving rise to a stress history, which is normally repeated a defined number of times in the life of the structure.

13.3.2.8 Miner's summation

A linear cumulative damage calculation based on the Palmgren-Miner rule.

13.3.2.9 Rainflow method

Particular cycle counting method of producing a stress range spectrum from a given stress history.

13.3.2.10 Reservoir method

Particular cycle counting method of producing a stress range spectrum from a given stress history.

NOTE: For the mathematical determination, see Appendix I.

13.3.2.11 Stress history

A record, a tabulation or a calculation of the stress variation at a particular point in a structure during a loading event

13.3.2.12 Stress range (action)

The algebraic difference between the two extremes of a particular stress cycle derived from a stress history

13.3.2.13 Stress range spectrum

Histogram of the number of occurrences for all stress ranges of different magnitudes recorded or calculated for a particular loading event.

13.3.3 Fatigue strength

13.3.3.1 Constant amplitude fatigue limit (CAFL) (resistance)

A constant amplitude fatigue limit (limiting stress range value below which no fatigue damage is assumed to occur under constant amplitude stress conditions) is not used in this Standard.

13.3.3.2 Cut-off limit (resistance)

A cut-off limit (assumed limit below which stress ranges of the design spectrum do not contribute to the calculated cumulative damage) is not used in this Standard.

13.3.3.3 Detail category

The numerical designation of fatigue resistance given to a particular detail for a given direction of stress fluctuation, in order to indicate which fatigue strength curve is applicable for the fatigue assessment.

NOTE: The detail category number indicates the reference fatigue strength $\Delta\sigma_C$ or $\Delta\tau_C$ in MPa.

13.3.3.4 Endurance (resistance)

The life to failure expressed in number of cycles for a particular detail category, under a constant amplitude stress history.

13.3.3.5 Fatigue strength curve

The quantitative relationship between the stress range and number of stress cycles to fatigue failure, used for the fatigue assessment of a particular detail category.

NOTE: The fatigue strengths given in AS/NZS 5100.6 are lower bound values based on the evaluation of fatigue tests with large scale test specimens in accordance with AS 5104 or ISO 2394.

13.3.3.6 Relevant authority

The purchaser or owner of the structure being fabricated or erected, or a nominated representative.

NOTE: The nominated representative should be suitably qualified to deal with the technical issues of this Standard.

13.3.3.7 Reference fatigue strength

The constant amplitude resistance stress range of $\Delta\sigma_C$ or $\Delta\tau_C$, for a particular detail category for an endurance of $N_R = 2$ million cycles.

13.3.4 Designation of weld category

For bridges other than railway bridges, the following minimum requirements shall apply:

- (a) Weld categories up to and including category 112 shall conform to category SP, as specified in AS/NZS 1554.1 and AS/NZS 1554.4.
- (b) Weld categories above 112 shall conform to category FP, as specified in AS/NZS 1554.4 and AS/NZS 1554.5.

For railway bridges, the following minimum requirements shall apply:

- (i) Weld categories less than category 71 shall conform to category SP, as specified in AS/NZS 1554.1 and AS/NZS 1554.4.
- (ii) Weld category 71 and above shall conform to category FP, as specified in AS/NZS 1554.4 and AS/NZS 1554.5.

13.4 NOTATION

For the purpose of this Section (13), the following apply.

k_{hs} = geometric stress concentration factor determined at the hot spot by direct measurement of an appropriate physical model, or through parametric equations or by adopting FEA with reference to detail geometry not included in the reference fatigue strength $\Delta\sigma_C$ or $\Delta\tau_C$

k_s = reduction factor for characteristic fatigue strength to account for size effects (resistance)

k_t = stress concentration factor to take account of the local stress magnification in relation to detail geometry not included in the reference $\Delta\sigma_R$ - N_R curve (action)

k_1 = magnification factor for nominal stress ranges to account for secondary bending moments in hollow section latticed girders (action)

m = slope of fatigue strength curve

N_R = endurance for a particular detail category under the action of a constant amplitude stress range $\Delta\sigma$ or $\Delta\tau$ (resistance)

n = effective number of cycles

$\Delta\sigma$ = stress range (normal stress) (action)

$\Delta\tau$ = stress range (shear stress) (action)

$\Delta\sigma_{E,2}$, $\Delta\tau_{E,2}$ = equivalent constant amplitude stress range (action) at 2 million cycles

$\Delta\sigma_C$, $\Delta\tau_C$ = characteristic reference fatigue strength at 2 million cycles (resistance) and also the numerical designation of the detail category (resistance)

$\Delta\sigma_{C,red}$ = characteristic reduced reference fatigue strength at 2 million cycles (resistance)

$\Delta\sigma_{max}$, $\Delta\tau_{max}$ = maximum stress range caused by the fatigue loads (action)

$\Delta\sigma_R$, $\Delta\tau_R$ = characteristic fatigue strength for a particular detail category under n cycles of loading (resistance)

λ_i = damage equivalent factors

ϕ_{Mf} = capacity reduction factor for fatigue strength (resistance)

13.5 GENERAL REQUIREMENTS

Structural members shall be designed for fatigue such that there is an acceptable level of probability that their performance will be satisfactory throughout their design life.

NOTE 1: Structures designed using fatigue actions from AS 5100.2 and fatigue resistance according to this Standard are deemed to satisfy this requirement.

Appendix I shall be used to determine a specific loading model, if—

- (a) no appropriate fatigue load model is available in AS 5100.2; or
- (b) a more realistic fatigue load model is required.

NOTE 2: Requirements for determining specific fatigue loading models may be confirmed by the relevant authority or owner of a bridge or associated structure.

Fatigue tests may be carried out—

- (i) to determine the fatigue strength for details not included in this Section; and
- (ii) to determine the fatigue life of prototypes, for actual or for damage equivalent fatigue loads.

In performing and evaluating fatigue tests, AS 5104 shall be taken into account.

NOTE 3: Requirements for determining fatigue strength from tests may be confirmed by the relevant authority or owner of a bridge or associated structure.

The methods for the fatigue assessment given in this Section follow the principle of design verification by comparing action effects and fatigue strengths; such a comparison is only possible when fatigue actions are determined with parameters of fatigue strengths contained in this Standard.

NOTE 4: Any fatigue cracks that develop during service life do not necessarily mean the end of the service life. Cracks should first be investigated for causes and then repaired with particular care for execution to avoid introducing more severe notch conditions.

NOTE 5: Fatigue actions are determined according to the requirements of the fatigue assessment. They are different from actions for ultimate limit state and serviceability limit state verifications.

13.6 ASSESSMENT METHODS

13.6.1 General

Fatigue assessment shall be undertaken using either—

- (a) the safe life method; or
- (b) the damage tolerant method.

The safe life method shall be used, unless otherwise agreed with the relevant authority.

The damage tolerant method may only be used when in the event of fatigue damage occurring a load redistribution between components of structural elements could occur.

To avoid doubt, the damage tolerant method shall not be used in cases where local formation of cracks in one component could rapidly lead to failure of the structural element or structure.

For the purpose of fatigue assessment using this Section, an acceptable reliability level may be achieved by adjustment of the capacity reduction factor for fatigue strength (ϕ_{MF}) taking into account the consequences of failure and the design assessment used.

Fatigue strengths are determined by considering the structural detail, together with its metallurgical and geometric notch effects.

13.6.2 Damage tolerant methods

The damage tolerant method provides an acceptable level of reliability, as defined in AS 5104, which will ensure that a structure will perform satisfactorily for its design life, provided a prescribed inspection and maintenance regime for detecting and correcting fatigue damage is implemented throughout the design life of the structure.

Provisions for inspection programs shall be given.

Structures that are assessed to this Section, using materials that conform to the toughness requirements of AS/NZS 5100.6 and which are subjected to regular maintenance shall be deemed damage tolerant.

13.6.3 Safe life method

The safe life method provides an acceptable level of reliability that a structure will perform satisfactorily for its design life without the need for regular in-service inspection for fatigue damage.

13.6.4 Capacity reduction factors

The assessment methods given herein use fatigue resistance in terms of fatigue strength curves for—

- (a) standard details applicable to nominal stresses [[Table 13.10.1\(B\)](#) to [Table 13.10.1\(K\)](#)]; and
- (b) reference weld configurations applicable to geometrical (hot spot) stress (Appendix I).

The required reliability may be achieved as follows:

- (i) *Damage tolerant method:*
 - (A) Selecting details, materials and stress levels so that in the event of the formation of cracks a low rate of crack propagation and a long critical crack length would result.
 - (B) Provision of multiple load paths.
 - (C) Provision of crack-arresting details.
 - (D) Provision of readily inspectable details during regular inspections.
- (ii) *Safe-life method:*
 - (A) Selecting details and stress levels resulting in a fatigue life sufficient to achieve the reliability index β -values to be at least equal to those required for ultimate limit state verifications at the end of the design service life.
 - (B) Specifying definition of classes and numerical values for ϕ_{Mf} .

Values for ϕ_{Mf} shall be as given in Table 13.6.4 or as agreed with the relevant authority.

TABLE 13.6.4
VALUES FOR CAPACITY REDUCTION FACTORS (ϕ_{Mf}) FOR FATIGUE STRENGTH

Assessment method	ϕ_{Mf}
Damage tolerant	1.00
Safe life—not fracture critical	0.85
Safe life—fracture critical	0.75

NOTE: Fracture-critical is a constructional detail whose failure would be expected to result in a partial or full collapse of the structure.

13.7 STRESSES FROM FATIGUE ACTIONS

Modelling for nominal stresses shall take into account all action effects, including distortional effects, and shall be based on a linear elastic analysis for members and connections.

13.8 CALCULATION OF STRESS

13.8.1 General

Stresses shall be calculated at the fatigue limit state.

Nominal stresses shall be calculated at the site of potential fatigue initiation. Effects producing stress concentrations at details other than those included in [Table 13.10.1\(B\)](#) to [Table 13.10.1\(K\)](#) shall be accounted for by using a stress concentration factor (SCF) to give a modified nominal stress.

When using geometrical (hot spot) stress methods for details covered by Paragraph I2, Appendix I, the stresses shall be calculated as shown in Clause 13.9.5.

The relevant stresses for details in the parent material are the following:

- (a) Nominal normal stresses σ .
- (b) Nominal shear stresses τ .

NOTE: For effects of combined nominal stresses, see Table 13.11.4.

The relevant stresses in the welds are (see Figure 13.8.1)—

- (i) normal stress of the weld (σ_{wf}): $\sigma_{wf} = 0.5\sigma_{\perp f} \pm 0.5\sqrt{\sigma_{\perp f}^2 + 4\tau_{\perp f}^2}$

- (ii) shear stresses longitudinal to the axis of the weld (τ_{wf}): $\tau_{wf} = \tau_{||f}$
for which two separate checks shall be performed.

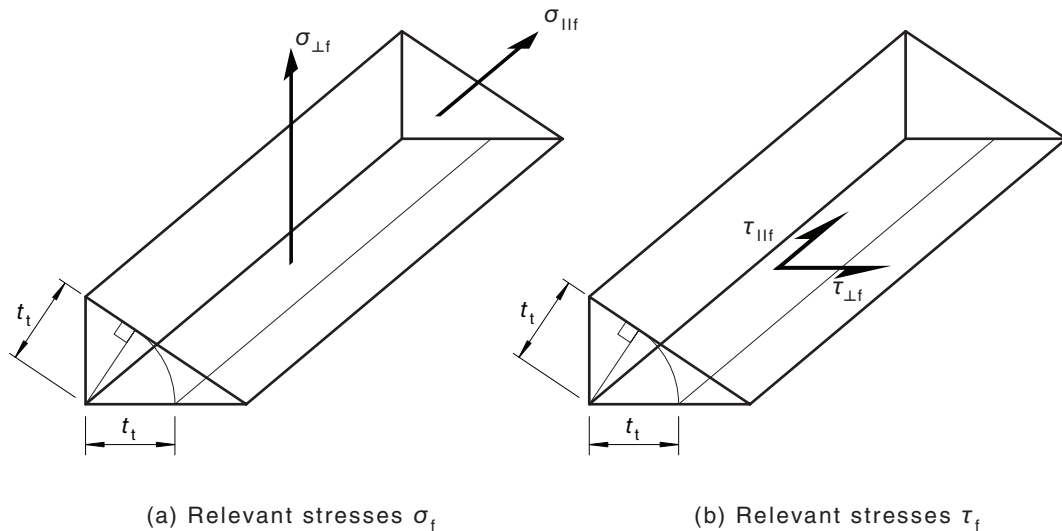


FIGURE 13.8.1 RELEVANT STRESSES IN THE FILLET WELDS

13.8.2 Composite connection

The longitudinal shear per unit length shall be calculated by elastic analysis. In members where cracking of concrete occurs, the effects of tension stiffening shall be taken into account by an appropriate model. For simplification, the longitudinal shear forces at the interface between structural steel and concrete may be determined by using the properties of the uncracked section.

13.9 CALCULATION OF STRESS RANGES

13.9.1 General

The fatigue assessment shall be carried out using—

- nominal stress ranges for details shown in [Table 13.10.1\(B\)](#) to [Table 13.10.1\(K\)](#);
- modified nominal stress ranges where, for example, abrupt changes of section occur close to the initiation site which are not included in [Table 13.10.1\(B\)](#) to [Table 13.10.1\(K\)](#); or
- geometrical (hot spot) stress ranges where high stress gradients occur close to a weld toe in joints covered by Appendix I.

13.9.2 Design value of the nominal stress range

The design value of the nominal stress range shall be determined as follows:

$$\Delta\sigma = \Delta\sigma_{\max} \quad 13.9.2(1)$$

$$\Delta\tau = \Delta\tau_{\max} \quad 13.9.2(2)$$

where

$\Delta\sigma_{\max}, \Delta\tau_{\max}$ = maximum stress range caused by the fatigue loads (action)

13.9.3 Design value of the modified nominal stress range

The design value of the modified nominal stress range shall be determined as follows:

$$\Delta\sigma = k_t \times \Delta\sigma_{\max} \quad 13.9.3(1)$$

$$\Delta\tau = k_t \times \Delta\tau_{\max} \quad 13.9.3(2)$$

where

$\Delta\sigma_{\max}, \Delta\tau_{\max}$ = maximum stress range caused by the fatigue loads (action)

k_t = stress concentration factor to take account of the local stress magnification in relation to detail geometry not included in the reference $\Delta\sigma_R-N_R$ curve (action)