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(Incorporating Amendment No. 1)



STANDARDS
Australia



Steel structures



AS 4100:2020

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- Australian Chamber of Commerce and Industry
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- Australian Steel Association
- Australian Steel Institute
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- Bureau of Steel Manufacturers of Australia
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Preface

This Standard was prepared by the Standards Australia Committee BD-001, Steel Structures, to supersede AS 4100—1998.

[A₁] *This Standard incorporates Amendment No. 1 (September 2021). The start and end of changes introduced by the Amendment are indicated in the text by tags including the Amendment number 1. [A₁]*

The objective of this Standard is to provide designers of steel structures with specifications for steel structural members used for load-carrying purposes in buildings and other structures.

Major changes to the 1998 edition include the following:

- (a) Reference to the “construction specification” (as the document containing the particular design data and details to be provided) as one deliverable from the design process. A definition of the construction specification consistent with that in AS/NZS 5131 has also been provided ([Clauses 1.3.16](#) and [1.6.2](#)).
- (b) Introduction of the definition of “construction category” and an informative appendix providing guidance on selection of the appropriate construction category, both consistent with AS/NZS 5131 ([Clauses 1.3.15](#) and [1.7.2](#), and [Appendix L](#)).
- (c) Definition and description of “architecturally exposed structural steelwork” (AESS) ([Clauses 1.3.3](#) and [1.7.3](#)).
- (d) Definition and treatment of “lamellar tearing” consistent with AS/NZS 1554.1 ([Clauses 1.3.40](#) and [3.8](#), and [Appendix M](#)).
- (e) Alignment with AS/NZS 5100.6:2017 (various clauses).
- (f) Referencing of AS/NZS 5131:2016 for the majority of requirements in the fabrication and erection sections of this Standard ([Sections 14](#) and [15](#)).
- (g) Alignment with AS/NZS 1252.1:2016, which includes introduction of an “alternative bolt assembly type” to EN 14399-3 System HR for grade 8.8 bolts and an “additional bolt assembly type” to EN 14399-3 System HR for grade 10.9 bolts. The Australian Steel Institute (ASI), Technical Note TN-001, *High strength structural bolt assemblies to AS/NZS 1252:2016*, provides background and basis for the revision to AS/NZS 1252:1996 ([Clauses 9.1.6](#), [9.3](#), [15.2](#)).
- (h) New specification of geometrical tolerances for fabrication and erection aligned with AS/NZS 5131 ([Clauses 14.4](#) and [15.3](#)).
- (i) New [Appendix K](#) “Statistical data”, aligned with AS/NZS 5100.6.
- (j) Inclusion of shear modulus G at elevated temperature in [Clause 12.4.2](#) and a new [Clause 12.4.3](#), Slenderness at elevated temperature

[Table M.2](#), Criteria affecting the target value of Z_{Ed} , was adapted with permission from Table 3.2 of EN 1993-1-10. Copyright © 2005. CEN, Belgium. www.cen.eu

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.

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Section 1 Scope and general

1.1 Scope and exclusions

1.1.1 Scope

This Standard sets out minimum requirements for the design and the engineering aspects of fabrication and erection, and modification of steelwork in structures in accordance with the limit states design method.

This Standard applies to buildings, structures and cranes constructed of steel.

NOTE For design of box and longitudinally stiffened girders, refer to AS/NZS 5100.6.

1.1.2 Exclusions

This Standard does not apply to the following structures and materials:

- (a) Steel elements less than 3 mm thick, with the exception of sections in accordance with AS/NZS 1163 and packers.
- (b) Steel members for which the value of the yield stress used in design (f_y) exceeds 690 MPa.
- (c) Cold-formed members, other than those in accordance with AS/NZS 1163, which are designed in accordance with AS/NZS 4600.
- (d) Composite steel-concrete members, which are designed in accordance with AS/NZS 2327.
- (e) Road, railway and pedestrian bridges, which are designed in accordance with AS 5100.1, AS 5100.2 and AS/NZS 5100.6.

NOTE The general principles of design, fabrication, erection, and modification embodied in this Standard may be applied to steel-framed structures or members not specifically mentioned herein.

1.2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document.

NOTE Documents for informative purposes are listed in the Bibliography.

AS 1101.3, *Graphical symbols for general engineering, Part 3: Welding and non-destructive examination*

AS 1110.1, *ISO metric hexagon bolts and screws—Product grades A and B, Part 1: Bolts*

AS 1110.2, *ISO metric hexagon bolts and screws—Product grades A and B, Part 2: Screws*

AS 1111.1, *ISO metric hexagon bolts and screws—Product grade C, Part 1: Bolts*

AS 1111.2, *ISO metric hexagon bolts and screws—Product grade C, Part 2: Screws*

AS 1112.1, *ISO metric hexagon nuts, Part 1: Style 1—Product grades A and B*

AS 1112.2, *ISO metric hexagon nuts, Part 2: Style 2—Product grades A and B*

AS 1112.3, *ISO metric hexagon nuts, Part 3: Product grade C*

AS 1112.4, *ISO metric hexagon nuts, Part 4: Chamfered thin nuts—Product grades A and B*

AS 1170.4, *Structural design actions, Part 4: Earthquake actions in Australia*

AS 1237.1, *Plain washers for metric bolts, screws and nuts for general purposes, Part 1: General plan*

AS 1275, *Metric screw threads for fasteners*

AS 1391, *Metallic materials—Tensile testing at ambient temperature*

AS 1418.1, *Cranes, hoists and winches, Part 1: General requirements*

AS 1418.3, *Cranes, hoists and winches, Part 3: Bridge, gantry and portal (including container cranes) and jib cranes*

AS 1418.5, *Cranes, hoists and winches, Part 5: Mobile cranes*

AS 1418.18, *Cranes, hoists and winches, Part 18: Crane runways and monorails*

AS 1530.4, *Methods for fire tests on building materials, components and structures, Part 4: Fire-resistance test of elements of construction*

AS 1657, *Fixed platforms, walkways, stairways and ladders—Design, construction and installation*

AS 1735, *Lifts, escalators and moving walks (series)*

AS 1858.1, *Electrodes and fluxes for submerged-arc welding, Part 1: Carbon steels and carbon manganese steels*

AS 1858.2, *Electrodes and fluxes for submerged-arc welding, Part 2: Low and intermediate alloy steels*

AS 2074, *Cast steels*

AS 2670, *Evaluation of human exposure to whole-body vibration (series)*

AS 3597, *Structural and pressure vessel steel—Quenched and tempered plate*

AS 5100.1, *Bridge design, Part 1: Scope and general principles*

AS 5100.2, *Bridge design, Part 2: Design loads*

AS 5216, *Design of post-installed and cast-in fastenings in concrete*

AS/NZS 1170.0, *Structural design actions, Part 0: General principles*

AS/NZS 1170.1, *Structural design actions, Part 1: Permanent, imposed and other actions*

AS/NZS 1170.2, *Structural design actions, Part 2: Wind actions*

AS/NZS 1170.3, *Structural design actions, Part 3: Snow and ice actions*

AS/NZS 1252.1, *High strength steel fastener assemblies for structural engineering—Bolts, nuts and washer, Part 1: Technical requirements*

AS/NZS 1163, *Cold-formed structural steel hollow sections*

AS/NZS 1554.1, *Structural steel welding, Part 1: Welding of steel structures*

AS/NZS 1554.2, *Structural steel welding, Part 2: Stud welding (steel studs to steel)*

AS/NZS 1554.4, *Structural steel welding, Part 4: Welding of high strength quenched and tempered steels*

AS/NZS 1554.5, *Structural steel welding, Part 5: Welding of steel structures subject to high levels of fatigue loading*

AS/NZS 1559, *Hot-dip galvanized steel bolts with associated nuts and washers for tower construction*

AS/NZS 1594, Hot-rolled steel flat products

AS/NZS 1873, Powder-actuated (PA) hand-held fastening tools (All parts)

AS/NZS 2327, Composite structures—Composite steel-concrete construction in buildings

AS/NZS 2717.1, Welding—Electrodes—Gas metal arc, Part 1: Ferritic steel electrodes

AS/NZS 3678, Structural steel—Hot-rolled plates, floorplates and slabs

AS/NZS 3679.1, Structural steel, Part 1: Hot-rolled bars and sections

AS/NZS 3679.2, Structural steel, Part 2: Welded I sections

AS/NZS 4600, Cold-formed steel structures

AS/NZS 4855, Welding consumables—Covered electrodes for manual metal arc welding of non-alloy and fine grain steels—Classification

AS/NZS 4857, Welding consumables—Covered electrodes for manual metal arc welding of high-strength steels—Classification

AS/NZS 5100.6, Bridge design, Part 6: Steel and composite construction

AS/NZS 5131, Structural steelwork—Fabrication and erection

AS ISO/IEC 17025, General requirements for the competence of testing and calibration laboratories

AS/NZS ISO 17632, Welding consumables—Tubular cored electrodes for gas shielded and non-gas shielded metal arc welding of non-alloy and fine grain steels—Classification

AS/NZS ISO 18276, Welding consumables—Tubular cored electrodes for gas shielded and non-gas-shielded metal arc welding of high-strength steels—Classification

NZS 1170.5, Structural design actions—Part 5: Earthquake actions—New Zealand

NZS 3404, Steel structures standard—Parts 1 and 2

ISO 636, Welding consumables — Rods, wires and deposits for tungsten inert gas welding of non-alloy and fine-grain steels — Classification

ISO 13918, Welding — Studs and ceramic ferrules for arc stud welding

ISO 14341, Welding consumables — Wire electrodes and weld deposits for gas shielded metal arc welding of non alloy and fine grain steels — Classification

ISO 16834, Welding consumables — Wire electrodes, wires, rods and deposits for gas shielded arc welding of high strength steels — Classification

EN 13381-4, Test methods for determining the contribution to the fire resistance of structural members — Part 4: Applied passive protection products to steel members

EN 13381-8, Test methods for determining the contribution to the fire resistance of structural members — Part 8: Applied reactive protection to steel members

1.3 Terms and definitions

For the purposes of this document, the following terms and definitions apply. Definitions peculiar to a particular Clause or Section are given in that Clause or Section.

1.3.1 action

cause of stress or deformations in a structure

1.3.2**action effect or load effect**

internal force or bending moment due to actions or loads

1.3.3**architecturally exposed structural steelwork****AESS**

structural steelwork that is exposed to view and considered a fundamental component of the architectural intent of the structure

1.3.4**authority**

body having statutory powers to control the design and erection of a structure

1.3.5**bearing-type connection**

connection effected using either snug-tight bolts, or high-strength bolts tightened to induce a specified minimum bolt tension, in which the design action is transferred by shear in the bolts and bearing on the connected parts at the strength limit state

1.3.6**bearing-wall system**

see AS 1170.4

1.3.7**braced frame**

see AS 1170.4

1.3.8**braced frame, concentric**

see AS 1170.4

1.3.9**braced frame, eccentric**

see AS 1170.4

1.3.10**braced member**

one for which the transverse displacement of one end of the member relative to the other is effectively prevented

1.3.11**capacity factor**

factor used to multiply the nominal capacity to obtain the design capacity

1.3.12**complete penetration butt weld**

butt weld in which fusion exists between the weld and parent metal throughout the complete depth of the joint

1.3.13**connection**

joint between components of a structural member or a joint between separate structural members, including splices

1.3.14**constant stress range fatigue limit**

highest constant stress range for each detail category at which fatigue cracks are not expected to propagate (see [Figure 11.6.1](#))

1.3.15**construction category**

classified set of requirements specified for construction of the works as a whole, of an individual component or of a detail of a component

Note 1 to entry: Both ISO 2394 and European Standards use the term “execution” to describe all activities performed for the physical completion of the works (i.e. procurement, fabrication, welding, mechanical fastening, transportation, erection, surface treatment and the inspection and documentation) and this term may be assumed to be equivalent to “fabrication and erection”. “Execution Class” (EXC) is the term used in European Standards to refer to a risk-based categorization of a structure, similar in intent to the construction category adopted in this Standard. It should be noted, however, that the two categorizations are not based on the same risk matrix assessment and cannot be used interchangeably.

1.3.16**construction specification**

set of documents covering technical data and other requirements for a particular steel structure, including those specified to supplement and qualify the provisions of this Standard

1.3.17**cut-off limit**

for each detail category, the highest variable stress range which does not require consideration when carrying out cumulative damage calculations (see [Figures 11.6.1](#) and [11.6.2](#))

1.3.18**design action effect****design load effect**

action or load effect computed from the design actions or design loads

1.3.19**design action****design load**

combination of the nominal actions or loads and the load factors specified in AS/NZS 1170.0, AS/NZS 1170.1, AS/NZS 1170.2, AS/NZS 1170.3, AS 1170.4 or other standards referenced in [Clause 3.2.1](#)

1.3.20**design capacity**

product of the nominal capacity and the capacity factor

1.3.21**design life**

period over which a structure or structural element is expected to fulfil its intended function

1.3.22**design resistance effect**

resistance effect computed from the loads and design capacities contributing towards the stability limit state resistance

1.3.23**design spectrum**

sum of the stress spectra from all of the nominal loading events expected during the design life

1.3.24**detail category**

designation given to a particular detail to indicate which of the S-N curves is to be used in the fatigue assessment

Note 1 to entry: The detail category takes into consideration the local stress concentration at the detail, the size and shape of the maximum acceptable discontinuity, the loading condition, metallurgical effects, residual stresses, the welding process and any post weld improvement.

Note 2 to entry: The detail category number is defined by the fatigue strength at 2×10^6 cycles on the S-N curve (see [Figures 11.6.1](#) and [11.6.2](#)).

1.3.25**discontinuity**

absence of material, causing a stress concentration

Note 1 to entry: Typical discontinuities include cracks, scratches, corrosion pits, lack of penetration, slag inclusions, cold laps, porosity and undercut.

1.3.26**ductility**

<of structure> see AS 1170.4

1.3.27**exposed surface area to mass ratio**

ratio of the surface area exposed to the fire to the mass of steel

1.3.28**fatigue**

damage caused by repeated fluctuations of stress leading to gradual cracking of a structural element

1.3.29**fatigue loading**

set of nominal loading events described by the distribution of the loads, their magnitudes and the numbers of applications of each nominal loading event

1.3.30**fatigue strength**

stress range defined in [Clause 11.6](#) for each detail category (see [Figures 11.6.1](#) and [11.6.2](#)) varying with the number of stress cycles

1.3.31**fire exposure condition**

extent of exposure of member surfaces to the fire

1.3.31.1**three-sided fire exposure condition**

steel member incorporated in or in contact with a concrete or masonry floor or wall

1.3.31.2**four-sided fire exposure condition**

steel member exposed to fire on all sides

1.3.32**fire protection system**

fire protection material and its method of attachment to the steel member

1.3.33**fire-resistance level****FRL**

fire-resistance grading period for structural adequacy only, in minutes, which is required to be attained in the standard fire test

1.3.34**firm contact**

condition that exists between plies in a bolted connection where the plies are solidly seated against each other, but may not be in continuous contact

1.3.35**friction-type connection**

connection effected using high-strength bolts tightened to induce a specified minimum bolt tension such that the resultant clamping action transfers the design shear forces at the serviceability limit state acting in the plane of the common contact surfaces by the friction developed between the contact surfaces

1.3.36**full tensioning**

method of installing and tensioning a bolt in accordance with AS/NZS 5131

1.3.37**geometrical slenderness ratio**

l_e/r

ratio taken as the effective length (l_e), specified in [Clause 6.3.2](#), divided by the radius of gyration (r) computed for the gross section about the relevant axis

1.3.38**incomplete penetration butt weld**

butt weld in which the depth of penetration is less than the complete depth of the joint

1.3.39**in-plane loading**

loading for which the design forces and bending moments are in the plane of the connection, so that the design action effects induced in the connection components are shear forces only

1.3.40**lamellar tearing**

cracking in the parent metal adjacent to the weld and arising from weld stresses in the through thickness direction of the plate. The cracking occurs in a stepped configuration, associated with lamellar non-metallic inclusions in the plate, parallel to the fusion boundary

[SOURCE: AS 2812—2005, 8.043]

1.3.41**length**

<of a compression member> actual length (l) of an axially loaded compression member, taken as the length centre-to-centre of intersections with supporting members, or the cantilevered length in the case of a free-standing member

1.3.42**limit state**

any limiting condition beyond which the structure ceases to fulfil its intended function

1.3.43**load**

externally applied force

1.3.44**miner's summation**

cumulative damage calculation based on the Palmgren-Miner summation or equivalent

1.3.45**moment-resisting frame**

see AS 1170.4

1.3.46**moment-resisting frame, intermediate**

see AS 1170.4

1.3.47**moment-resisting frame, ordinary**

see AS 1170.4

1.3.48**moment-resisting frame, special**

see AS 1170.4

1.3.49**nominal action or load**

action or load, as specified in [Clause 3.2.1](#) or [3.2.2](#)

1.3.50**nominal capacity**

capacity of a member or connection computed using the parameters specified in this Standard

1.3.51**nominal loading event**

loading sequence for the structure or structural element

Note 1 to entry: One nominal loading event may produce one or more stress cycles depending on the type of load and the point in the structure under consideration.

1.3.52**non-slip fasteners**

fasteners that do not allow slip to occur between connected plates or members at the serviceability limit state so that the original alignment and relative positions are maintained

1.3.53**out-of-plane loading**

loading for which the design forces or bending moments result in design action effects normal to the plane of the connection

1.3.54**period of structural adequacy****PSA**

<fire> time (t), in minutes, for the member to reach the limit state of structural adequacy in the standard fire test

1.3.55**pin**

unthreaded fastener manufactured out of round bar

1.3.56**plastic hinge**

yielding zone with inelastic rotation which forms in a member when the plastic moment is reached

1.3.57**ply**

plate that forms part of a bolted connection

1.3.58**prequalified weld preparation**

joint preparation prequalified in terms of AS/NZS 1554.1

1.3.59**proof testing**

application of test loads to a structure, sub-structure, member or connection to ascertain the structural characteristics of only that one unit under test

1.3.60**prototype**

<fire> test specimen representing a steel member and its fire protection system which is subjected to the standard fire test

1.3.61**prototype testing**

application of test loads to one or more structures, sub-structures, members or connections to ascertain the structural characteristics of that class of structures, sub-structures, members or connections which are nominally identical to the units tested

1.3.62**prying force**

additional tensile force developed as a result of the flexing of a connection component in a connection subjected to tensile force. External tension force reduces the contact pressure between the component and the base, and bending in part of the component develops a prying force near the edge of the connection component

1.3.63**quenched and tempered steel**

high strength steel manufactured by heating, quenching, tempering and levelling steel plate

1.3.64**segment**

<in a member subjected to bending> length between adjacent cross-sections which are fully or partially restrained, or the length between an unrestrained end and the adjacent cross-section which is fully or partially restrained

1.3.65**serviceability limit state**

limit state of acceptable in-service condition

1.3.66**shall**

indicates that a statement is mandatory

1.3.67**should**

indicates a recommendation

1.3.68**shear wall**

wall designed to resist lateral forces parallel to the plane of the wall

1.3.69**S-N curve**

curve defining the limiting relationship between the number of stress cycles and stress range for a detail category

1.3.70**snug tight**

tightness in the bolts in a bolted connection attained by a few impacts of an impact wrench or by the full effort of a person using a standard podger spanner to bring the plies into firm contact

1.3.71**space frame**

see AS 1170.4

1.3.72**splice**

connection between two parts of a structural member

1.3.73**stability limit state**

limit state corresponding to the loss of static equilibrium of a structure considered as a rigid body

1.3.74**standard fire test**

fire-resistance test specified in AS 1530.4

1.3.75**stickability**

ability of the fire protection system to remain in place as the member deflects under load during a fire test

1.3.76**strength limit state**

limit state of collapse or loss of structural integrity

1.3.77**stress cycle**

one cycle of stress defined by stress cycle counting

1.3.78**stress cycle counting method**

any rational method used to identify individual stress cycles from the stress history

1.3.79**stress range**

algebraic difference between two extremes of stress

1.3.80**stress spectrum**

histogram of the stress cycles produced by a nominal loading event

1.3.81**structural adequacy**

<fire> ability of the member exposed to the standard fire test to carry the test load specified in AS 1530.4

1.3.82**structural ductility factor**

see AS 1170.4

1.3.83**structural performance factor**

see AS 1170.4

1.3.84**sway member**

one for which the transverse displacement of one end of the member relative to the other is not effectively prevented

1.3.85**tensile strength**

minimum ultimate strength in tension specified for the grade of steel in the appropriate Australian Standard

1.3.86**yield stress**

minimum yield stress in tension specified for the grade of steel in the appropriate Australian Standard

1.4 Notation

Symbols used in this Standard are listed below.

Where non-dimensional ratios are involved, both the numerator and denominator are expressed in identical units.

The dimensional units for length and stress in all expressions or equations are to be taken as millimetres (mm) and megapascals (MPa) respectively, unless specifically noted otherwise.

An asterisk “*” placed after a symbol denotes a design action effect due to the design load for the strength limit state.

A	=	area of cross-section
A_c	=	minor diameter area of a bolt, as defined in AS 1275
A_e	=	effective sectional area of a hollow section in shear; <i>or</i>
	=	effective area of a compression member
A_{ep}	=	area of an end post
A_{fc}	=	flange area at critical cross-section
A_{fg}	=	gross area of a flange
A_{fm}	=	flange area at minimum cross-section; <i>or</i>
	=	lesser of the flange effective areas
A_{fn}	=	net area of a flange
A_g	=	gross area of a cross-section
A_{gv}	=	gross area subject to shear at rupture
A_n	=	net area of a cross-section
A_{nt}	=	net area subject to tension at rupture
A_{nv}	=	net area subject to shear at rupture
A_o	=	nominal plain shank area of a bolt
A_p	=	cross-sectional area of a pin
A_s	=	tensile stress area of a bolt as defined in AS 1275; <i>or</i>
	=	area of a stiffener or stiffeners in contact with a flange; <i>or</i>
	=	area of an intermediate web stiffener
A_w	=	gross sectional area of a web; <i>or</i>
	=	effective shear area of a plug or slot weld
a_e	=	minimum distance from the edge of a hole to the edge of a ply measured in the direction of the component of a force plus half the bolt diameter
a_o	=	length of unthreaded portion of the bolt shank contained within the grip
a_t	=	length of threaded portion of the bolt contained within the grip
a_0, a_1	=	out-of-square dimensions of flanges

a_2, a_3	=	diagonal dimensions of a box section
b	=	width; <i>or</i>
	=	lesser dimension of a web panel; <i>or</i>
	=	clear width of an element outstand from the face of a supporting plate element; <i>or</i>
	=	clear width of a supported element between faces of supporting plate elements
b_b, b_{bf}, b_{bw}, b_o	=	bearing widths defined in Clause 5.13
b_d	=	distance from the stiff bearing to the end of the member
b_e	=	effective width of a plate element
b_{es}	=	stiffener outstand from the face of a web
b_f	=	width of a flange
b_{fo}	=	half the clear distance between the webs; <i>or</i>
	=	least of 3 dimensions defined in Clause 5.11.5.2
b_s	=	stiff bearing length
b_w	=	web depth
b_1, b_2	=	greater and lesser leg lengths of an angle section
C_3, C_4, C_{4r}	=	factors given in Table H.3 and Clause H.5
c_h	=	perpendicular distance to centroid of an angle section from the face of the loaded leg of the angle
c_m	=	factor for unequal end moments
d	=	depth of a section; <i>or</i>
	=	depth of preparation for incomplete penetration butt weld; <i>or</i>
	=	maximum cross-sectional dimension of a built-up compression member
d_b	=	lateral distance between centroids of the welds or fasteners connecting battens to main components
d_c	=	depth of a section at a critical cross-section
d_e	=	effective outside diameter of a circular hollow section; <i>or</i>
	=	factor defined in Appendix I
d_f	=	diameter of a fastener (bolt or pin); <i>or</i>
	=	distance between flange centroids
d_m	=	depth of a section at minimum cross-section
d_o	=	overall section depth including out-of-square dimensions; <i>or</i>
	=	overall section depth of a segment; <i>or</i>

	=	outside diameter of a circular hollow section
d_p	=	clear transverse dimension of a web panel; <i>or</i>
	=	depth of deepest web panel in a length
d_x, d_y	=	distances of the extreme fibres from the neutral axes
d_1	=	clear depth between flanges ignoring fillets or welds
d_2	=	twice the clear distance from the neutral axis to the compression flange
d_3, d_4	=	depths of preparation for incomplete penetration butt welds
d_5	=	flat width of web of hollow sections
E	=	Young's modulus of elasticity
$E(T), E(20)$	=	E at temperature T , and 20 °C, respectively
e	=	eccentricity; <i>or</i>
	=	web off-centre dimension; <i>or</i>
	=	distance between an end plate and a load-bearing stiffener
e_c, e_t	=	eccentricities of compression and tension angles (Clause 8.4.6)
F	=	action in general, force or load
F^*	=	total design load on a member between supports
F_n^*	=	design force normal to a web panel
F_p^*	=	design force parallel to a web panel
f_c	=	fatigue strength corrected for thickness of material
f_f	=	uncorrected fatigue strength
f_{rn}	=	detail category reference fatigue strength at n_r cycles — normal stress
f_{rnc}	=	corrected detail category reference fatigue strength — normal stress
f_{rsc}	=	corrected detail category reference fatigue strength — shear stress
f_{rs}	=	detail category reference fatigue strength at n_r cycles — shear stress
f_u	=	tensile strength used in design
f_{uc}	=	minimum tensile strength of connection element
f_{uf}	=	minimum tensile strength of a bolt
f_{up}	=	tensile strength of a ply
f_{uw}	=	nominal tensile strength of weld metal
f_y	=	yield stress used in design
f_{yc}	=	yield stress of connection element

$f_y(T), f_y(20)$	=	yield stresses of steel at temperature T , and 20 °C, respectively
f_{yp}	=	yield stress of a pin used in design
f_{ys}	=	yield stress of a stiffener used in design
f_3	=	detail category fatigue strength at constant amplitude fatigue limit
f_{3c}	=	corrected detail category fatigue strength at constant amplitude fatigue limit
f_5	=	detail category fatigue strength at cut-off limit
f_{5c}	=	corrected detail category fatigue strength at cut-off limit
f^*	=	design stress range
f_i^*	=	design stress range for loading event i
f_{va}^*	=	average design shear stress in a web
f_{vm}^*	=	maximum design shear stress in a web
f_w^*	=	equivalent design stress on a web panel (Appendix I)
G	=	shear modulus of elasticity; <i>or</i>
	=	nominal dead load
$G(T)$	=	shear modulus of steel at T degrees Celsius
h	=	rectangular centroidal axis for angle parallel to the loaded leg
h_b	=	vertical distance between tops of beams
h_e	=	effective thickness of fire protection material
h_i	=	thickness of fire protection material
h_s	=	storey height
I	=	second moment of area of a cross-section
I_{cy}	=	second moment of area of compression flange about the section minor principal y -axis
I_m	=	I of the member under consideration
I_r	=	I of a restraining member
I_s	=	I of a pair of stiffeners or a single stiffener
I_w	=	warping constant for a cross-section
I_x	=	I about the cross-section major principal x -axis
I_y	=	I about the cross-section minor principal y -axis
i	=	number of loading event (Section 11)
J	=	torsion constant for a cross-section

K	=	$\sqrt{\left[\pi^2 EI_w / (GJL^2) \right]}$
K_d	=	deflection amplification factor
k	=	coefficient used in Appendix J
k_b	=	elastic buckling coefficient for a plate element
k_{bo}	=	basic value of k_b
k_{bs}	=	a factor to account for the effect of eccentricity on the block shear capacity
k_e	=	member effective length factor
k_f	=	form factor for members subject to axial compression
k_h	=	factor for different hole types
k_l	=	effective length factor for load height
k_p	=	factor for pin rotation
k_r	=	effective length factor for restraint against lateral rotation; <i>or</i>
	=	effective length factor for a restraining member; <i>or</i>
	=	reduction factor to account for the length of a bolted or welded lap splice connection
k_{rd}	=	reduction factor to account for the reduced ductility of grade 10.9 bolts when subjected to shear where threads intercept the shear plane
k_s	=	ratio used to calculate α_p and α_{pm}
k_{sm}	=	exposed surface area to mass ratio
k_t	=	effective length factor for twist restraints; <i>or</i>
	=	correction factor for distribution of forces in a tension member
k_v	=	ratio of flat width of web (d_5) to thickness (t) of hollow section
k_0 - k_6	=	regression coefficients (Section 12)
l	=	span; <i>or</i>
	=	member length; <i>or</i>
	=	member length from centre to centre of its intersections with supporting members; <i>or</i>
	=	segment or sub-segment length
l_b	=	length between points of effective bracing or restraint
l_c	=	distance between adjacent column centres
l_e	=	effective length of a compression member; <i>or</i>
	=	effective length of a laterally unrestrained member

$\frac{l_e}{r}$	=	geometrical slenderness ratio
$\left(\frac{l_e}{r}\right)_{bn}$	=	slenderness ratio of a battened compression member about the axis normal to the plane of the battens
$\left(\frac{l_e}{r}\right)_{bp}$	=	slenderness ratio of a battened compression member about the axis parallel to the plane of the battens
$\left(\frac{l_e}{r}\right)_c$	=	slenderness ratio of the main component in a laced or battened compression member
$\left(\frac{l_e}{r}\right)_m$	=	slenderness ratio of the whole battened compression member
l_j	=	length of a bolted lap splice connection
l_m	=	length of the member under consideration
l_r	=	length of a restraining member; <i>or</i>
	=	length of a segment over which the cross-section is reduced
l_s	=	distance between points of effective lateral support
l_w	=	greatest internal dimension of an opening in a web; <i>or</i>
	=	length of a fillet weld in a welded lap splice connection
l_z	=	distance between partial or full torsional restraints
M_b	=	nominal member moment capacity
M_{bx}	=	M_b about major principal x-axis
M_{bxo}	=	M_{bx} for a uniform distribution of moment
M_{cx}	=	lesser of M_{ix} and M_{ox}
M_f	=	nominal moment capacity of flanges alone
M_i	=	nominal in-plane member moment capacity
M_{ix}	=	M_i about major principal x-axis
M_{iy}	=	M_i about minor principal y-axis
M_o	=	nominal out-of-plane member moment capacity; <i>or</i>
	=	reference elastic buckling moment for a member subject to bending
M_{oa}	=	amended elastic buckling moment for a member subject to bending
M_{ob}	=	elastic buckling moment determined using an elastic buckling analysis
M_{obr}	=	M_{ob} decreased for elastic torsional end restraint
M_{oo}	=	reference elastic buckling moment obtained using $l_e = l$

M_{os}	=	M_{ob} for a segment, fully restrained at both ends, unrestrained against lateral rotation and loaded at shear centre
M_{ox}	=	nominal out-of-plane member moment capacity about major principal x-axis
M_p	=	nominal moment capacity of a pin
M_{pr}	=	nominal plastic moment capacity reduced for axial force
M_{prx}	=	M_{pr} about major principal x-axis
M_{pry}	=	M_{pr} about minor principal y-axis
M_{rx}	=	M_s about major principal x-axis reduced by axial force
M_{ry}	=	M_s about minor principal y-axis reduced by axial force
M_s	=	nominal section moment capacity
M_{sx}	=	M_s about major principal x-axis
M_{sy}	=	M_s about minor principal y-axis
M_{tx}	=	lesser of M_{rx} and M_{ox}
M_w	=	nominal section moment capacity of a web panel
M^*	=	design bending moment
M_e^*	=	second-order or amplified end bending moment
M_f^*	=	design end bending moment
M_{fb}^*	=	braced component of M_f^* obtained from a first-order elastic analysis of a frame with sway prevented
M_{fs}^*	=	sway component of M_f^* obtained from $(M_f^* - M_{fb}^*)$
M_h^*	=	design bending moment on an angle, acting about the rectangular h -axis parallel to the loaded leg
M_m^*	=	maximum calculated design bending moment along the length of a member or in a segment
M_w^*	=	design bending moment acting on a web panel
M_x^*	=	design bending moment about major principal x-axis
M_y^*	=	design bending moment about minor principal y-axis
M_2^*, M_3^*, M_4^*	=	design bending moments at quarter and mid points of a segment
N_c	=	nominal member capacity in axial compression
N_{ch}	=	N_c for angle buckling about h -axis, parallel to the loaded leg
N_{cy}	=	N_c for member buckling about minor principal y-axis

N_{ol}	=	$\frac{\pi^2 EI}{l^2}$
N_{olr}	=	$\frac{\pi^2 EI}{l_r^2}$
N_{om}	=	elastic buckling load
N_{omb}	=	N_{om} for a braced member
N_{oms}	=	N_{om} for a sway member
N_{oz}	=	nominal elastic torsional buckling capacity of a member
N_s	=	nominal section capacity of a compression member; <i>or</i> nominal section capacity for axial load
N_t	=	nominal section capacity in tension
N_{tf}	=	nominal tension capacity of a bolt
N_{ti}	=	minimum bolt tension at installation; <i>or</i> tension induced in a bolt during installation
N_{wo}	=	nominal axial load capacity of a web panel
N^*	=	design axial force, tensile or compressive
N_r^*	=	design axial force in a restraining member
N_{tf}^*	=	design tensile force on a bolt
N_w^*	=	design axial force acting on a web panel
n	=	number of specimens tested
n_b	=	number of parallel planes of battens
n_{ei}	=	number of effective interfaces
n_i	=	number of cycles of nominal loading event i
n_n	=	number of shear planes with threads intercepting the shear plane — bolted connections
n_r	=	reference number of stress cycles
n_s	=	number of shear planes
n_{sc}	=	number of stress cycles
n_w	=	number of webs
n_x	=	number of shear planes without threads intercepting the shear plane — bolted connections
Q	=	nominal live load

Q^*	=	design transverse force; <i>or</i>
	=	design live load
R_b	=	nominal bearing capacity of a web
R_{bb}	=	nominal bearing buckling capacity of a web
R_{bs}	=	nominal design capacity in block shear
R_{by}	=	nominal bearing yield capacity of a web
R_{sb}	=	nominal buckling capacity of a stiffened web
R_{sy}	=	nominal yield capacity of a stiffened web
R_u	=	nominal capacity
R^*	=	design bearing force; <i>or</i>
	=	design reaction
R_{bs}^*	=	design reaction
R_w^*	=	design bearing force or reaction on a web panel
r	=	radius of gyration
r_{ext}	=	outside radius of hollow section
r_f	=	ratio of design action on the member under design load for fire to the design capacity of the member at room temperature
r_r	=	ratio defined in Clause 5.6.1.1
r_s	=	ratio defined in Clause 5.6.1.1
r_y	=	radius of gyration about minor principal y -axis
S	=	plastic section modulus
S_p	=	structural performance factor
S^*	=	design action effect
s	=	spacing of stiffeners; <i>or</i>
	=	width of a web panel
s_b	=	longitudinal centre-to-centre distance between battens
s_g	=	gauge of bolts
s_p	=	staggered pitch of bolts
T	=	steel temperature in degrees Celsius
T_l	=	limiting steel temperature in degrees Celsius
t	=	thickness; <i>or</i>

	=	element thickness; <i>or</i>
	=	thickness of thinner part joined; <i>or</i>
	=	wall thickness of a circular hollow section; <i>or</i>
	=	thickness of an angle section; <i>or</i>
	=	time
t_f	=	thickness of a flange; <i>or</i>
	=	thickness of the critical flange
t_n	=	thickness of a nut
t_p	=	thickness of a ply; <i>or</i>
	=	thickness of thinner ply connected; <i>or</i>
	=	thickness of a plate; <i>or</i>
	=	connecting plate thickness(es) at a pin
t_s	=	thickness of a stiffener
t_t, t_{t1}, t_{t2}	=	design throat thickness of a weld
t_w	=	thickness of a web or web panel
t_w, t_{w1}, t_{w2}	=	leg lengths of a fillet weld used to define the size of a fillet weld
V_b	=	nominal bearing capacity of a ply or a pin; <i>or</i>
	=	nominal shear buckling capacity of a web
V_f	=	nominal shear capacity of a bolt or pin — strength limit state
V_{sf}	=	nominal shear capacity of a bolt — serviceability limit state
V_{si}	=	measured slip-load at the i th bolt
V_u	=	nominal shear capacity of a web with a uniform shear stress distribution
V_v	=	nominal shear capacity of a web
V_{vm}	=	nominal web shear capacity in the presence of bending moment
V_w	=	nominal shear yield capacity of a web; <i>or</i>
	=	nominal shear capacity of a plug or slot weld
V^*	=	design shear force; <i>or</i>
	=	design horizontal storey shear force at column ends; <i>or</i>
	=	design transverse shear force
V_b^*	=	design bearing force on a ply at a bolt or pin location
V_f^*	=	design shear force on a bolt or a pin — strength limit state

V_l^*	=	design longitudinal shear force
V_{sf}^*	=	design shear force on a bolt — serviceability limit state
V_w^*	=	design shear force acting on a web panel; <i>or</i>
	=	design shear force on a plug or slot weld
v_w	=	nominal capacity of a fillet weld per unit length
v_w^*	=	design force per unit length on a fillet weld
x	=	major principal axis coordinate
y	=	minor principal axis coordinate
y_L	=	distance of the gravity loading below the centroid
y_o	=	coordinate of shear centre
Z	=	elastic section modulus
Z_c	=	Z_e for a compact section
Z_e	=	effective section modulus
Z_{we}	=	elastic section modulus of a web panel
α	=	angle between x - and h -axes for an angle section
α_a	=	compression member factor, as defined in Clause 6.3.3
α_b	=	compression member section constant, as defined in Clause 6.3.3
α_{bc}	=	moment modification factor for bending and compression
α_c	=	compression member slenderness reduction factor
α_d	=	tension field coefficient for web shear buckling
α_f	=	flange restraint factor for web shear buckling
$\alpha_l \alpha_{lc} \alpha_{mc}$	=	factors for bending defined in Clauses H.2 and H.3
α_m	=	moment modification factor for bending
α_p	=	coefficient used to calculate the nominal bearing yield capacity (R_{by}) for square and rectangular hollow sections to AS/NZS 1163
α_{pm}	=	coefficient used to calculate α_p
α_{ry}	=	elastic stiffness of a flexural end restraint
α_{rz}	=	elastic stiffness of a torsional end restraint
α_s	=	slenderness reduction factor; <i>or</i>
	=	inverse of the slope of the S-N curve for fatigue
α_{sr}	=	stability function multiplier

α_{st}	=	reduction factor for members of varying cross-section
α_T	=	coefficient of thermal expansion for steel
α_t	=	factor for torsional end restraint defined in Clause 5.14.5
α_v	=	shear buckling coefficient for a web
α_w	=	factor defined in Appendix I
β_e	=	modifying factor to account for conditions at the far ends of beam members
β_m	=	ratio of smaller to larger bending moment at the ends of a member; <i>or</i>
	=	ratio of end moment to fixed end moment
β_t	=	measure of elastic stiffness of torsional end restraint used in Appendix H
β_{tf}	=	thickness correction factor for fatigue
β_x	=	monosymmetry section constant
β_w	=	factor defined in Appendix I
γ	=	index used in Clause 8.3.4 ; <i>or</i>
	=	factor for transverse stiffener arrangement in stiffened web (Clause 5.15.3)
$\gamma, \gamma_1, \gamma_2,$	=	ratios of compression member stiffness to end restraint stiffness used in Clause 4.6.3.3
Δ	=	deflection; <i>or</i>
	=	deviation from nominated dimension; <i>or</i>
	=	measured total extension of a bolt when tightened
Δ_{ct}	=	mid-span deflection of a member resulting from transverse loading together with both end bending moments
Δ_{cw}	=	mid-span deflection of a member resulting from transverse loading together with only those end bending moments which produce a mid-span deflection in the same direction as the transverse load
Δ_f	=	out-of-flatness of a flange plate
Δh_b	=	deviation from h_b
Δl_c	=	deviation from l_c
Δ_s	=	translational displacement of the top relative to the bottom for a storey height
Δ_v	=	deviation from verticality of a web at a support
Δ_w	=	out-of-flatness of a web
δ	=	standard deviation
δ_b	=	moment amplification factor for a braced member
δ_m	=	moment amplification factor, taken as the greater of δ_b and δ_s

δ_p	=	moment amplification factor for plastic design
δ_s	=	moment amplification factor for a sway member
ζ	=	compression member factor defined in Clause 6.3.3
η	=	compression member imperfection factor defined in Clause 6.3.3
θ	=	angle of preparation of an incomplete penetration butt weld
π	=	pi (approximately 3.14159)
λ	=	slenderness ratio; <i>or</i>
	=	elastic buckling load factor
λ_c	=	elastic buckling load factor
λ_e	=	plate element slenderness
λ_{ed}	=	plate element deformation slenderness limit
λ_{ep}	=	plate element plasticity slenderness limit
λ_{ey}	=	plate element yield slenderness limit
λ_m	=	elastic buckling load factor for a member
λ_{ms}	=	elastic buckling load factor for the storey under consideration
λ_n	=	modified compression member slenderness
λ_s	=	section slenderness
λ_{sp}	=	section plasticity slenderness limit
λ_{sy}	=	section yield slenderness limit
λ_w, λ_{ew}	=	values of λ_e and λ_{ey} for the web
μ	=	slip factor
	=	structural ductility factor
μ_m	=	mean value of the slip factor
μ_i	=	individual test result from test for slip factor
ν	=	Poisson's ratio
ρ	=	ratio of design axial force in a restraining member to the elastic buckling load for a member of length l (Appendix G); <i>or</i>
	=	I_{cy}/I_y
ϕ	=	capacity factor
ϕR_u	=	design capacity

1.5 Use of alternative materials or methods

1.5.1 General

This Standard shall not be interpreted so as to prevent the use of materials or methods of design or construction not specifically referred to herein, provided that the requirements of [Section 3](#) are conformed to.

1.5.2 Existing structures

Where the strength or serviceability of an existing structure is to be evaluated, the general principles of this Standard may be applied. The actual properties of the materials in the structure shall be used.

NOTE 1 AS 5104 (ISO 2394) covers design by testing and may be utilized for assessment of existing structures.

NOTE 2 AS 5100.7 and AS 5100.8 cover assessment and rehabilitation of existing structures.

1.6 Design

1.6.1 Design data

The following design data shall be shown in the drawings:

- (a) The reference number and date of issue of applicable design Standards used.
- (b) The nominal loads.
- (c) The corrosion protection, if applicable.
- (d) The fire-resistance level, if applicable.
- (e) The steel grades used.

1.6.2 Design details

The drawings or construction specification, or both, for steel members and structures shall include, as appropriate, the following:

- (a) The size and designation of each member.
- (b) The number, sizes and categories of bolts used in the connections.
- (c) The sizes, types, strength and categories of welds used in the connections, together with the level of visual examination and other non-destructive examination required.
- (d) The sizes of the connection components.
- (e) The locations and details of planned joints, connections and splices.
- (f) Any constraint on construction assumed in the design.
- (g) The camber of any members.
- (h) Details of the construction category or categories required ([Clause 1.7.2](#)).
- (i) Details of the corrosion protection required ([Clause 3.5.6](#)).
- (j) Any requirement for architecturally exposed structural steelwork (AESS) ([Clause 1.7.3](#))
- (k) Any specific tolerances if different to those specified in AS/NZS 5131 ([Clauses 14.4, 15.3](#)), including selection of the functional tolerance class if different to Class 1.

- (l) Any requirement for selection of materials to avoid lamellar tearing ([Clause 2.2.5](#)).
- (m) Any other requirements for fabrication, erection and operation.

1.7 Workmanship

1.7.1 General

All steel structures, designed in accordance with this Standard, shall be constructed to ensure that all the requirements of the design, as contained in the drawings and construction specification, are satisfied.

Requirements relating to fabrication and erection are a function of the nominated construction category.

1.7.2 Construction category

Four construction categories denoted CC1, CC2, CC3, CC4 are nominated in this Standard, for which requirements increase in strictness from CC1 to CC4.

NOTE 1 The requirements for CC4 are additional to CC3. CC4 applies to unusual or special structures for which it is expected that requirements additional to those for CC3 will be defined at a project specific level or by a particular organization, agency or business.

A construction category shall apply to either the whole structure or to parts of the structure or to specific details. A structure may therefore have multiple construction categories, provided that all parts of the structure are categorized. A detail or group of details shall be ascribed one construction category.

NOTE 2 The choice of construction category does not necessarily have to be the same for all components.

The construction category shall be nominated in the construction specification. If no construction category is specified, then CC2 shall apply.

The list of requirements for fabrication and erection and related to construction categories is specified in AS/NZS 5131.

NOTE 3 Guidance on the selection of construction category is given in [Appendix L](#). The choice of construction category is related to the importance factor, the service category and the fabrication category as set out in [Appendix L](#).

1.7.3 Architecturally exposed structural steelwork

Any requirement for architecturally exposed structural steelwork (AESS) shall be designated in the construction specification. The requirements for AESS are defined in AS/NZS 5131 based on five categories:

- (a) AESS 1 — Basic elements which require enhanced workmanship.
- (b) AESS 2 — Feature elements viewed at a distance greater than 6 m requiring good fabrication practices with enhanced treatment of weld, connection, fabrication detail, tolerances for gaps and copes.
- (c) AESS 3 — Feature elements viewed at a distance of less than 6 m requiring welds that are generally smooth but visible, some grind marks are acceptable. Tolerances are tighter than normal standards.
- (d) AESS 4 — Showcase or dominant elements used where the form is the only feature showing in an element. All welds which have ground and filled edges are ground smooth and true. All surfaces are sanded and filled to be smooth to the touch. Tolerances of fabricated items are more stringent.
- (e) AESS C — Custom elements.

1.7.4 Fabrication and erection

The minimum requirements for fabrication and erection of structural steelwork shall be in accordance with [Sections 14](#) and [15](#) respectively.

NOTE Minimum required standards of workmanship ensure that the design assumptions remain valid.

Section 2 Materials

2.1 Yield stress and tensile strength used in design

2.1.1 Yield stress

The yield stress used in design (f_y) shall not exceed that given in [Table 2.1](#).

2.1.2 Tensile strength

The tensile strength used in design (f_u) shall not exceed that given in [Table 2.1](#).

Table 2.1 — Strengths of steels in accordance with AS/NZS 1163, AS/NZS 1594, AS/NZS 3678, AS/NZS 3679.1, AS/NZS 3679.2 (see Note) and AS 3597

Steel Standard	Form	Steel grade	Thickness of material (t) mm	Yield stress (f_y) MPa	Tensile strength (f_u) MPa
AS/NZS 1163 (See Note)	Hollow sections	C450	All	450	500
		C350	All	350	430
		C250	All	250	320
AS/NZS 1594	Plate, strip, sheet floorplate	HA400	All	380	460
		HW350	All	340	450
		HA350	All	350	430
		HA300/1 HU300/1	All	300	430
		HA300 HU300	All	300	400
		HA250 HU250	All	250	350
		HA200	All	200	300
	Plate and strip	XF500	$t \leq 8$	480	570
		XF400	$t \leq 8$	380	460
		XF300	All	300	440
AS/NZS 3678 (See requirement and Note below)	Plate and floorplate	450	$t \leq 20$	450	520
		450	$20 < t \leq 32$	420	500
		450	$32 < t \leq 50$	400	500
		400	$t \leq 12$	400	480
		400	$12 < t \leq 20$	380	480
		400	$20 < t \leq 80$	360	480
		350	$t \leq 12$	360	450
		350	$12 < t \leq 20$	350	450
AS/NZS 3678 (See Note)	Plate and floorplate	350	$20 < t \leq 80$	340	450
		350	$80 < t \leq 150$	330	450
		WR350	$t \leq 50$	340	450
		300	$t \leq 8$	320	430
		300	$8 < t \leq 12$	310	430

Table 2.1 (continued)

Steel Standard	Form	Steel grade	Thickness of material (t) mm	Yield stress (f _y) MPa	Tensile strength (f _u) MPa
		300	12 < t ≤ 20	300	430
		300	20 < t ≤ 50	280	430
		300	50 < t ≤ 80	270	430
		300	80 < t ≤ 150	260	430
		250	t ≤ 8	280	410
		250	8 < t ≤ 12	260	410
		250	12 < t ≤ 50	250	410
		250	50 < t ≤ 80	240	410
		250	80 < t ≤ 150	230	410
		200	t ≤ 12	200	300
AS/NZS 3679.1 (see Note)	Flats and sections	350	t ≤ 11	360	480
		350	11 < t < 40	340	480
		350	t ≥ 40	330	480
		300	t < 11	320	440
		300	11 ≤ t ≤ 17	300	440
		300	t > 17	280	440
	Hexagons, rounds and squares	350	t ≤ 50	340	480
		350	50 < t < 100	330	480
		350	t ≥ 100	320	480
		300	t ≤ 50	300	440
		300	50 < t < 100	290	440
		300	t ≥ 100	280	440
AS 3597	Plate	500	5 ≤ t ≤ 110	500	590
		600	5 ≤ t ≤ 110	600	690
		700	t ≤ 5	650	750
		700	5 < t ≤ 65	690	790
		700	65 < t ≤ 110	620	720

Welded I-sections in accordance with AS/NZS 3679.2 are manufactured from hot-rolled structural steel plates in accordance with 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.

NOTE 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.

2.2 Structural steel

2.2.1 Australian Standards

Except as otherwise permitted in [Clause 2.2.3](#), all structural steel covered by the scope of this Standard shall, before fabrication, be in accordance with the requirements of the following Standards, as appropriate:

AS 3597, *Structural and pressure vessel steel—Quenched and tempered plate*

AS/NZS 1163, *Cold-formed structural steel hollow sections*

AS/NZS 1594, *Hot-rolled steel flat products*

AS/NZS 3678, *Structural steel—Hot-rolled plates, floorplates and slabs*

AS/NZS 3679.1, *Structural steel, Part 1: Hot-rolled bars and sections*

AS/NZS 3679.2, *Structural steel, Part 2: Welded I sections*

2.2.2 Acceptance of steels

Test reports or test certificates that conform to the minimum requirements of the appropriate Standard listed in [Clause 2.2.1](#) shall constitute sufficient evidence of conformance of the steel to the Standards listed in [Clause 2.2.1](#).

NOTE Requirements for test reports or test certificates are provided in the relevant Standards listed in [Clause 2.2.1](#).

2.2.3 Unidentified steel

If unidentified steel is used, it shall be free from surface imperfections, and shall be used only where the particular physical properties of the steel and its weldability shall not adversely affect the strength and serviceability of the structure. Unless a full test in accordance with AS 1391 is made, the yield stress of the steel used in design (f_y) shall be taken as not exceeding 170 MPa, and the tensile strength used in design (f_u) shall be taken as not exceeding 300 MPa.

2.2.4 Properties of steel

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

- | | | |
|-----|---|--|
| (a) | Modulus of elasticity (E) | 200×10^3 MPa. |
| (b) | Shear modulus of elasticity (G) | 80×10^3 MPa. |
| (c) | Poisson's ratio (ν) | 0.25. |
| (d) | Coefficient of thermal expansion (α_T) | $11.7 \times 10^{-6}/^\circ\text{C}$. |

2.2.5 Through-thickness deformation properties

The specified through-thickness deformation properties are necessary to guarantee adequate deformation capacity perpendicular to the surface to provide ductility and toughness against lamellar tearing. For product in accordance with AS/NZS 3678, the minimum values for reduction of area for the specified quality class should be in accordance with the relevant requirements of AS/NZS 3678 and as given in [Table 2.2.5](#). For flat products, the minimum values for reduction of area should apply to the whole product.

Table 2.2.5 — Minimum reduction in area

Grade suffix	%	Range of Z_{Ed} (see Notes)
Z15	15	$11 \leq Z_{Ed} \leq 20$
Z25	25	$21 \leq Z_{Ed} \leq 30$
Z35	35	> 30
NOTE 1 See also Clause 3.8 and Appendix M .		
NOTE 2 Z quality steel is not required where Z_{Ed} is ≤ 10 or where steel thickness is 16 mm or less.		

See [Clause 3.8](#) for requirements to address lamellar tearing.

2.3 Fasteners

2.3.1 Steel bolts, nuts and washers

Steel bolts, nuts and washers shall be in accordance with the following Standards, as appropriate:

AS 1110, *ISO metric hexagon bolts and screws—Product grades A and B (series)*

AS 1111, *ISO metric hexagon bolts and screws—Product grade C (series)*

AS 1112, *ISO metric hexagon nuts (series)*

AS 1237.1, *Plain washers for metric bolts, screws and nuts for general purposes — Part 1: General plan*

AS/NZS 1252.1, *High strength steel fastener assemblies for structural engineering — Bolts, nuts and washers — Part 1: Technical requirements*

AS/NZS 1559, *Hot-dip galvanized steel bolts with associated nuts and washers for tower construction*

NOTE 1 AS/NZS 1559 has been written specifically for tower design and may not be suitable for use in all structures.

Test certificates that state that the bolts, nuts and washers conform to all the provisions of the appropriate Standard listed in this Clause shall constitute sufficient evidence of conformance to the appropriate Standard.

NOTE 2 Requirements for test reports or test certificates are provided in the relevant Standards listed in this Clause.

Where the Standards listed in this Clause do not specify requirements for laboratories, the laboratories that perform tests outlined in this Standard shall meet the requirements of AS ISO/IEC 17025.

NOTE 3 By way of example, Accreditation bodies which are signatories to the International Laboratory Accreditation Cooperation (ILAC) Mutual Recognition Arrangement (MRA) for testing laboratories may be able to offer accreditation against the requirements of AS ISO/IEC 17025. A listing of ILAC signatories is available from the ILAC website (www.ilac.org). In Australia, the National Association of Testing Authorities (NATA) is a signatory to the ILAC MRA.

Acceptable bolts and associated bolting categories are specified in [Table 9.2.1](#).

2.3.2 Equivalent high strength fasteners

The use of other high strength fasteners having special features in lieu of bolts to AS/NZS 1252.1 shall be permitted provided that evidence of their equivalence to high strength bolts in accordance with AS/NZS 1252.1 and installation in accordance with this Standard is available.

Equivalent fasteners shall meet the following requirements:

- (a) The chemical composition and mechanical properties of equivalent fasteners shall be in accordance with AS/NZS 1252.1 for the relevant bolt, nut and washer components.
- (b) The body diameter, head or nut bearing areas, or their equivalents, of equivalent fasteners shall not be less than those provided by a bolt and nut in accordance with AS/NZS 1252.1 of the same nominal dimensions. Equivalent fasteners may differ in other dimensions from those specified in AS/NZS 1252.1.
- (c) The method of tensioning and the inspection procedure for equivalent fasteners may differ in detail from those specified in [Clause 15.2.2.2](#), provided that the minimum fastener tension is not less than the minimum bolt tension given in [Table 15.2.2.2](#) and that the tensioning procedure is able to be checked.

2.3.3 Welds

Welding shall be undertaken in accordance with AS/NZS 5131.

2.3.4 Welded studs

Welded studs shall conform to, and shall be installed in accordance with AS/NZS 1554.2. The weld collars of welded studs in non-prequalified stud applications shall be in accordance with the requirements of ISO 13918.

2.3.5 Explosive fasteners

All explosive fasteners shall conform to, and shall be installed in accordance with AS/NZS 1873.

2.3.6 Anchor bolts

Anchor bolts shall conform to either the bolt Standards of [Clause 2.3.1](#) or shall be manufactured from rods in accordance with the steel Standards of [Clause 2.2.1](#) provided that the threads are in accordance with AS 1275.

2.3.7 Mechanical and chemical anchors

All mechanical and chemical fasteners shall be designed and specified in the construction specification in accordance with AS 5216.

2.4 Steel castings

All steel castings shall be in accordance with AS 2074.

Section 3 General design requirements

3.1 Design

3.1.1 Aim

The aim of structural design is to provide a structure which is stable, has adequate strength, is serviceable and durable, and which satisfies other objectives such as economy and ease of construction.

A structure is stable if it does not overturn, tilt or slide throughout its intended life.

A structure has adequate strength and is serviceable if the probabilities of structural failure and of loss of serviceability throughout its intended life are acceptably low.

A structure is durable if it withstands the expected wear and deterioration throughout its intended life without the need for undue maintenance.

3.1.2 Requirements

The structure and its component members and connections shall satisfy the design requirements for stability, strength, serviceability, brittle fracture, lamellar tearing, fatigue, fire and earthquake in accordance with the procedures given in this Standard.

3.2 Loads and other actions

3.2.1 Loads

The design of a structure for the stability, strength and serviceability limit states shall account for the action effects directly arising from the following loads:

- (a) Dead, live, wind, snow, ice and earthquake loads specified in AS/NZS 1170.1, AS/NZS 1170.2, AS/NZS 1170.3 and AS 1170.4.
- (b) For the design of cranes, any relevant loads specified in AS 1418 series.
- (c) For the design of fixed platforms, walkways, stairways and ladders, any relevant loads specified in AS 1657.
- (d) For the design of lifts, any relevant loads specified in AS 1735 series.
- (e) Other specific loads, as required.

NOTE 1 For the design of bridges, loads specified in AS 5100.2 should be used.

NOTE 2 For multi-storey building structures, see also [Clause 3.2.4](#).

3.2.2 Other actions

Any action which may significantly affect the stability, strength or serviceability of the structure, including the following, shall be taken into account:

- (a) Foundation movements.
- (b) Temperature changes and gradients.
- (c) Axial shortening.
- (d) Dynamic effects.
- (e) Construction loading.

3.2.3 Design load combinations

The design load combinations for the stability, strength and serviceability limit states shall be those specified in AS/NZS 1170.0.

NOTE For the design of bridges, load combinations specified in AS 5100.2 should be used.

3.2.4 Notional horizontal forces

For multi-storey building structures only, notional horizontal forces, each equal to 0.002 times the total design vertical loads applied at a floor level, shall be applied at that floor level. These notional horizontal forces shall act in conjunction with only the design dead and live loads from AS/NZS 1170.1 for the strength and serviceability limit states. These notional horizontal forces shall not be included for the stability limit state.

3.2.5 Structural robustness

All steel structures, including members and connection components, shall conform to the structural robustness requirements of AS/NZS 1170.0.

3.3 Stability limit state

The structure as a whole (and any part of it) shall be designed to prevent instability due to overturning, uplift or sliding as follows:

- (a) The loads determined in accordance with [Clause 3.2](#) shall be subdivided into the components tending to cause instability and the components tending to resist instability.
- (b) The design action effect (S^*) shall be calculated from the components of the loads tending to cause instability, combined in accordance with the load combinations for the strength limit state specified in AS/NZS 1170.0.
- (c) The design resistance effect shall be calculated as 0.9 times the part of the dead load tending to resist the instability plus the design capacity (ϕR_u) of any elements contributing towards resisting the instability, where ϕ is a capacity factor which shall not exceed the appropriate value given in [Table 3.4](#).
- (d) The whole or part of the structure shall be proportioned so that the design resistance effect is not less than the design action effect.

3.4 Strength limit state

The structure and its component members and connections shall be designed for the strength limit state as follows:

- (a) The loads and actions shall be determined in accordance with [Clauses 3.2.1](#) and [3.2.2](#), and the strength limit state design loads shall be determined in accordance with [Clauses 3.2.3](#) and [3.2.4](#).
- (b) The design action effects (S^*) resulting from the strength limit state design loads shall be determined by an analysis in accordance with [Section 4](#).
- (c) The design capacity (ϕR_u) shall be determined from the nominal capacity (R_u) determined from [Sections 5](#) to [9](#), where the capacity factor (ϕ) shall not exceed the appropriate value given in [Table 3.4](#).
- (d) All members and connections shall be proportioned so that the design capacity (ϕR_u) is not less than the design action effect (S^*), i.e. —

$$S^* \leq \phi R_u$$

Table 3.4 — Capacity factors (ϕ) for strength limit states

Design capacity for	Clauses	Capacity factor (ϕ)	
Member subject to bending			
— full lateral support	5.1 , 5.2 and 5.3	0.90	
— segment without full lateral support	5.1 and 5.6	0.90	
— web in shear	5.11 and 5.12	0.90	
— web in bearing	5.13	0.90	
— stiffener	5.14 , 5.15 and 5.16	0.90	
Member subject to axial compression			
— section capacity	6.1 and 6.2	0.90	
— member capacity	6.1 and 6.3	0.90	
Member subject to axial tension	7.1 and 7.2	0.90	
Member subject to combined actions			
— section capacity	8.3	0.90	
— member capacity	8.4	0.90	
Connection component other than a bolt, pin or weld	9.1.9(a) , (b) , (c) , and (d) 9.1.9(e)	0.90 0.75	
Bolted connection			
— bolt in shear	9.2.2.1	0.80	
— bolt in tension	9.2.2.2	0.80	
— bolt subject to combined shear and tension	9.2.2.3	0.80	
— ply in bearing	9.2.2.4	0.90	
— bolt group	9.3	0.80	
Pin connection			
— pin in shear	9.4.1	0.80	
— pin in bearing	9.4.2	0.80	
— pin in bending	9.4.3	0.80	
— ply in bearing	9.4.4	0.90	
Welded connection		SP Category	GP Category
— complete penetration butt weld	9.6.2.7	0.90	0.60
— longitudinal fillet weld in RHS ($t < 3$ mm)	9.6.3.10	0.70	—
— other fillet weld and incomplete penetration butt weld	9.6.3.10	0.80	0.60
— plug or slot weld	9.6.4	0.80	0.60
— weld group	9.7	0.80	0.60

3.5 Serviceability limit state

3.5.1 General

The structure and its components shall be designed for the serviceability limit state by controlling or limiting deflection, vibration, bolt slip and corrosion, in accordance with the relevant requirements of [Clauses 3.5.2](#) to [3.5.6](#).

3.5.2 Method

The structure and its components shall be designed for the serviceability limit state as follows:

- (a) The loads and other actions shall be determined in accordance with [Clauses 3.2.1](#) and [3.2.2](#), and the serviceability limit state design loads shall be determined in accordance with [Clauses 3.2.3](#) and [3.2.4](#).
- (b) Deflections due to the serviceability limit state design loads shall be determined by the first-order elastic analysis method of [Clause 4.4.2.1](#) with all amplification factors taken as unity. Deflections shall be in accordance with [Clause 3.5.3](#).
- (c) Vibration behaviour shall be assessed in accordance with [Clause 3.5.4](#).
- (d) Bolt slip shall be limited, where required, in accordance with [Clause 3.5.5](#).
- (e) Corrosion protection shall be provided in accordance with [Clause 3.5.6](#).

3.5.3 Deflection limits

The deflection limits for the serviceability limit state shall be appropriate to the structure and its intended use, the nature of the loading, and the elements supported by it.

NOTE Suggested deflection limits may be found in [Appendix B](#).

3.5.4 Vibration of beams

Beams which support floors or machinery shall be checked to ensure that the vibrations induced by machinery, or vehicular or pedestrian traffic do not adversely affect the serviceability of the structure.

Where there is a likelihood of a structure being subjected to vibration from causes such as wind forces or machinery, measures shall be taken to prevent discomfort or alarm, damage to the structure, or interference with its proper function.

NOTE AS 2670 gives guidance for the evaluation of human exposure to whole-body vibrations of the type likely to be transmitted by structures.

3.5.5 Bolt serviceability limit state

In a connection, where slip under the serviceability design loads shall be avoided, the fasteners shall be selected in accordance with [Clause 9.1.6](#).

For a friction-type connection which is subject to shear force in the plane of the interfaces, and for which slip under serviceability loads shall be avoided, the capacity factor (ϕ) shall be taken as 0.7 and the bolts shall be designed in accordance with [Clause 9.2.3](#).

3.5.6 Corrosion protection

Where steelwork in a structure is to be exposed to a corrosive environment, the steelwork shall be given protection against corrosion. The degree of protection to be employed shall be determined based on the use of the structure, its maintenance, and the climatic or other local conditions.

NOTE 1 Guidance on selection of corrosion protection requirements is included in [Appendix C](#).

NOTE 2 Requirements for surface preparation and application of corrosion protection are defined in AS/NZS 5131.

NOTE 3 The basis for the design of components contained in this Standard makes no allowance for any loss of material due to corrosion.

NOTE 4 A corrosion allowance is not required for structural steel in corrosivity categories C1 and C2 where the coatings are appropriately specified, applied and maintained to AS 2312.1 or the structural steel is hot dip galvanized to AS/NZS 4680 with design details from AS/NZS 2312.2. For corrosivity categories C3, C4, C5 and CX, the selection of a coating system and the maintenance strategy should be the subject of professional advice.

NOTE 5 An estimate of the durability of a coating system can be obtained from AS 2312.1 or, where the structure or elements are hot dip galvanized, from AS/NZS 2312.2.

NOTE 6 The application to weathering steel is beyond the scope of this Standard. For design requirements for weathering steel refer to AS/NZS 5100.6.

3.6 Strength and serviceability limit states by load testing

Notwithstanding the requirements of [Clause 3.4](#) or [3.5](#), a structure or a component member or connection may be designed for the strength or serviceability limit state or both, by load-testing in accordance with [Section 17](#). If this alternative procedure is adopted, the requirements of [Clauses 3.7](#) to [3.11](#) shall also apply.

3.7 Brittle fracture

In order to avoid failure by brittle fracture, the selection of the parent material shall be made in accordance with [Section 10](#).

3.8 Lamellar tearing

Joints whose function is to transmit stress normal to the surface of the connected part, especially when the thickness of the branch member or the required weld size is 20 mm or greater, require special attention during design, parent material selection and detailing. Joint details shall minimize stress intensity on parent materials subject to stress in the through-thickness direction. Weld sizes that are larger than necessary shall not be specified.

The suitability of material for through-thickness requirements should be based on the through-thickness ductility quality criterion as specified in AS/NZS 3678, which is expressed in terms of quality classes identified by Z-values. The choice of materials depends on requirements affected by the design of welded connections and the fabrication technique. [Appendix M](#) provides guidance for the choice of Z-qualities to avoid lamellar tearing in welded connections subject to tension stresses in the through-thickness direction.

NOTE 1 Z quality steel is not required where $Z_{Ed} \leq 10$ or where steel thickness is 16 mm or less.

NOTE 2 Refer also to [Clause 2.2.5](#) and [Appendix M](#).

3.9 Fatigue

For structures and structural elements subject to loadings which could lead to fatigue, the fatigue strength shall be determined in accordance with [Section 11](#).

3.10 Fire

The structure, its component members and connections shall be designed in accordance with [Section 12](#).

3.11 Earthquake

The structure, its component members, connections and any non-structural components shall be designed for earthquake loads in accordance with AS 1170.4 and [Section 13](#).

3.12 Other design requirements

Requirements other than those listed in [Clause 3.1.2](#), such as differential settlement, progressive collapse and any special performance requirements shall be taken into account in the design of the structure in accordance with the principles of this Standard.

The design of bridges for loads resulting from floods or collision shall be carried out in accordance with AS 5100.2.

3.13 Reliability management

For the application of AS/NZS 5131, the selection of construction category should be made in accordance with [Appendix L](#) of this Standard.

If different levels of reliability are specified, these levels should be achieved by an appropriate choice of quality management in design together with fabrication and erection, according to AS/NZS 5131 and AS 5104 (ISO 2394).

Section 4 Methods of structural analysis

4.1 Methods of determining action effects

4.1.1 General

For the purpose of complying with the requirements for the limit states of stability, strength and serviceability specified in [Section 3](#), the design action effects in a structure and its members and connections caused by the design loads shall be determined by structural analysis using the assumptions of [Clauses 4.2](#) and [4.3](#) and one of the methods of —

- (a) elastic analysis, in accordance with [Clause 4.4](#);
- (b) plastic analysis, in accordance with [Clause 4.5](#); or
- (c) advanced analysis, in accordance with [Appendix D](#).

The design action effects for earthquake loads shall be obtained using either the equivalent static analysis of Section 6 of AS 1170.4 or the dynamic analysis of Section 7 of AS 1170.4.

4.1.2 Definitions

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

Braced member — one for which the transverse displacement of one end of the member relative to the other is effectively prevented. This applies to triangulated frames and trusses or to frames where in-plane stiffness is provided by diagonal bracing, or by shear walls, or by floor slabs or roof decks secured horizontally to walls or to bracing systems parallel to the plane of buckling of the member.

Sway member — one for which the transverse displacement of one end of the member relative to the other is not effectively prevented. Such members occur in structures which depend on flexural action to limit the sway.

4.2 Forms of construction assumed for structural analysis

4.2.1 General

The distribution of the design action effects throughout the members and connections of a structure shall be determined by assuming one or a combination of the following forms of construction:

- (a) Rigid.
- (b) Semi-rigid.
- (c) Simple.

4.2.2 Rigid construction

For rigid construction, the connections shall be assumed to have sufficient rigidity to hold the original angles between the members unchanged.

4.2.3 Semi-rigid construction

For semi-rigid construction, the connections may not have sufficient rigidity to hold the original angles between the members unchanged, but shall be assumed to have the capacity to furnish a reliable known degree of flexural restraint.

The relationship between the degree of flexural restraint and the level of the load effects shall be established by methods based on test results.