

Australian Standard™

Composite structures

Part 1: Simply supported beams

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Australian Standard™

Composite structures

Part 1: Simply supported beams

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PREFACE

This Standard was prepared by the Standards Australia Committee BD-032, Composite Construction, to supersede AS 2327.1—1996 *Composite structures in structural steel and concrete*, Part 1—*Simply supported beams*.

This revision incorporates a number of technical and editorial changes. The principal differences are briefly outlined in the following:

1 *Shear connectors:*

- (a) The value of the density reduction factor (k_r), used in the calculation of the design shear capacity (f_{ds}) of shear connectors with lightweight concrete, has been changed to equal 1.0 for welded-studs (since the effect of lower concrete density is already taken into account in the calculation of nominal shear capacity (f_{vs}) using Equation 8.3.2.1(2)), and a constant value of 0.8 for channels and high-strength structural bolts.
- (b) A procedure for calculating the nominal shear capacity (f_{vs}) of channel or high-strength structural bolt shear connectors during the initial part of Construction Stage 5 when $15 \leq f'_{cj} < 20$ MPa, previously omitted from AS 2327.1, has been included, viz. at $f'_{cj} = 15$ MPa, f_{vs} equals 80% of the values given in Table 8.2 and Table 8.3 $f'_c = 20$ MPa, and linear interpolation is used for values of f'_{cj} between 15 and 20 MPa.
- (c) The Grade 300, 100 PFC (parallel flange channel) may now be used as a fully equivalent shear connector to the Grade 250, 100 TFC (channel).

- 2 *Open-rib and closed-rib profiles* Distinction is made between open-rib and closed-rib profile steel sheeting when designing the shear connection of the composite beam.
- 3 *Welded stud locations* Clause 8.4.2 clarifies that when automatically welded studs are placed in the pans of sheeting ribs deemed to be perpendicular to the steel beam, no more than two studs are permitted between adjacent sheeting ribs. New rules have been written to allow shear connectors to be placed closer to steel ribs of closed-rib profiles.
- 4 *New reference material* New reference material has been provided for designers regarding the design of beams with large web penetrations and design for occupant-induced vibrations.
- 5 *Reinforcement* $f_{yr} = 500$. The maximum design yield strength has been increased to 500 MPa for the longitudinal shear reinforcement in the composite slab.

The terms 'normative' and 'informative' are used in this Standard to define the application of the appendix 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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STANDARDS AUSTRALIA**Australian Standard
Composite structures****Part 1: Simply supported beams****SECTION 1 SCOPE AND GENERAL****1.1 SCOPE**

This Standard sets out minimum requirements for the design, detailing and construction of simply supported composite beams composed of a steel beam and a concrete slab interconnected with shear connectors, including applications where the slab incorporates profiled steel sheeting, as defined in Clause 1.2.

This Standard does not cover the design of composite beams—

- (a) where the elements of the steel beam are less than 3 mm thick or the value of the yield stress (f_{yb}) assumed in design exceeds 450 MPa (see Note 1);
- (b) where the strength grade of the slab concrete exceeds 40 MPa;
- (c) where the slab is precast or prestressed;
- (d) with negative design moments (see Note 2);
- (e) subjected to dynamic loads;
- (f) for road or railway bridges (see Note 3); or
- (g) for fatigue.

NOTE:

- 1 This does not preclude the use of steels with a minimum yield strength greater than 450 MPa.
- 2 For the design of composite beams with negative design moments reference may be made to BS 5950:3:1990, Code of Practice for Design of Simple and Continuous Composite Beams.
- 3 For the design of composite bridge beams, reference should be made to HB 77 the AUSTROADS Bridge Design Code.

1.2 GENERAL**1.2.1 Components**

This Standard applies only to composite beams for which the components satisfy the requirements specified in Clauses 1.2.2 to 1.2.5.

1.2.2 Steel beam

The steel beam shall be entirely below, but in contact with, the soffit of the concrete slab, and shall be of structural steel, symmetrical about its vertical axis (i.e., doubly symmetric or monosymmetric), suitably proportioned (see Note) and have one of the following forms (see Figure 1.2.2)—

- (a) a hot-rolled I-section, or channel section;
- (b) a welded I-section;
- (c) a rectangular cold-formed hollow section;

- (d) a fabricated I-section, Tee section, channel section or rectangular hollow section; or
- (e) any of the above sections as appropriate with an additional plate welded to the bottom flange.

NOTE: Steel beams with a slender section (i.e., $\lambda_e > \lambda_{ey}$ for any top flange or web plate element either partially or fully in compression (see Clause 5.2.3.3)) are not permitted.

When a fire resistance level (FRL) must be achieved, a fire protection material may be used to protect the exposed surfaces of the steel beam.

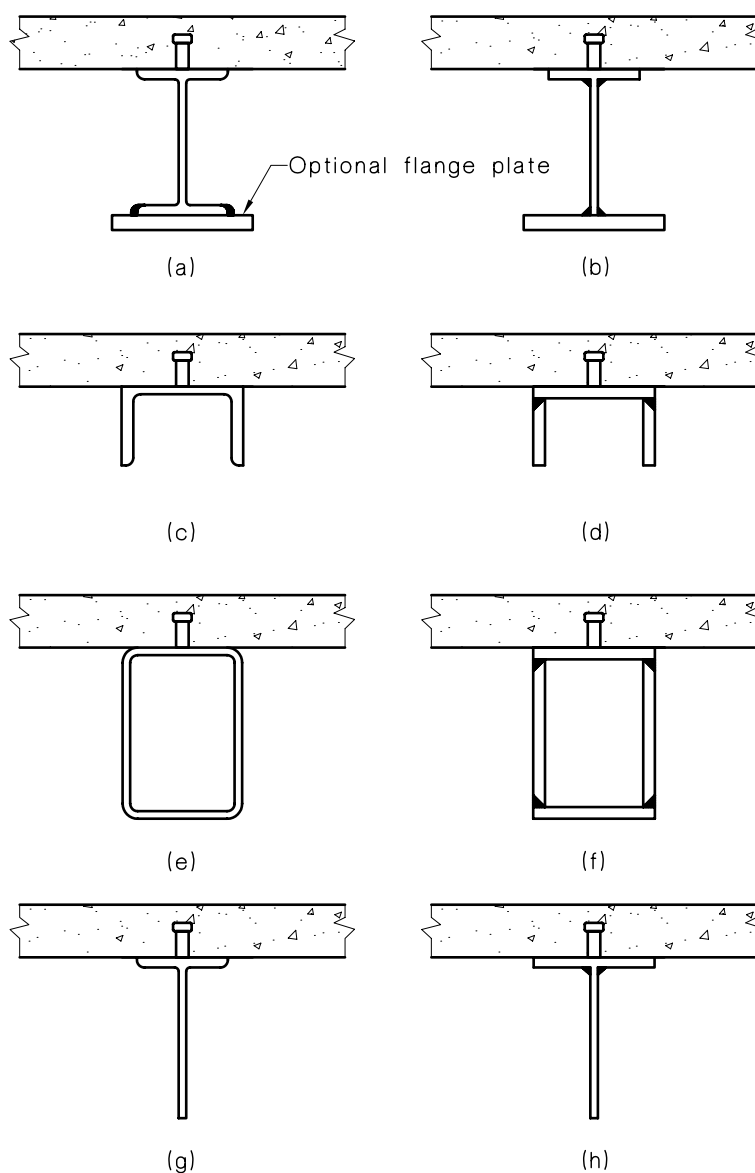


FIGURE 1.2.2 ALTERNATIVE STEEL BEAM TYPES

1.2.3 Concrete slab

The concrete slab shall be of reinforcement in accordance with AS/NZS 4671, non-prestressed concrete complying with AS 3600, and be either a solid slab (without a haunch) or a composite slab (see Figure 1.2.3).

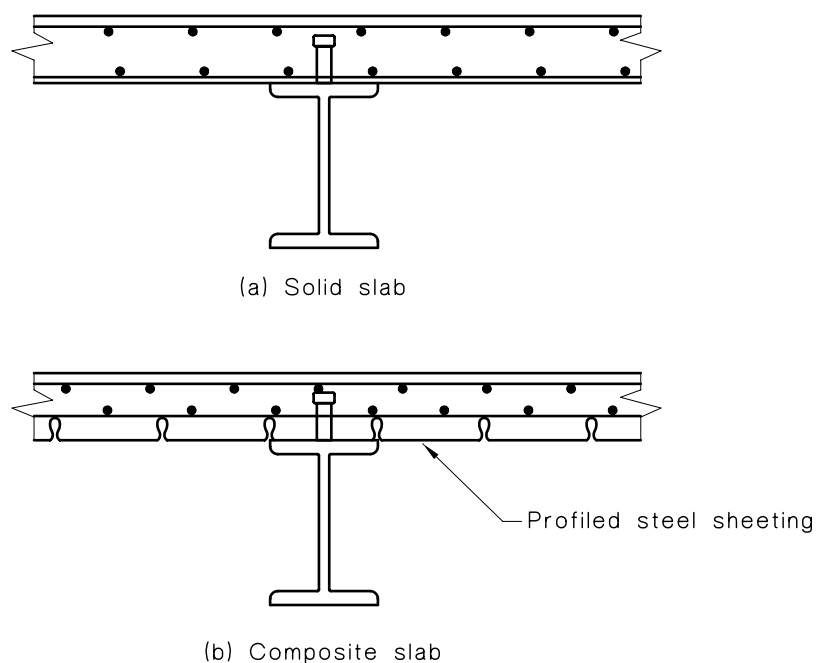


FIGURE 1.2.3 ALTERNATIVE CONCRETE SLAB TYPES

1.2.4 Profiled steel sheeting

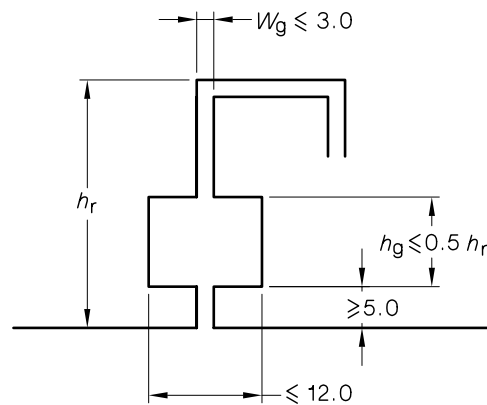
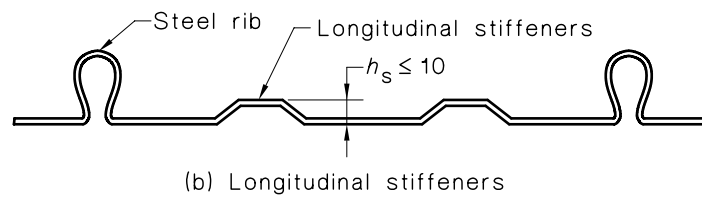
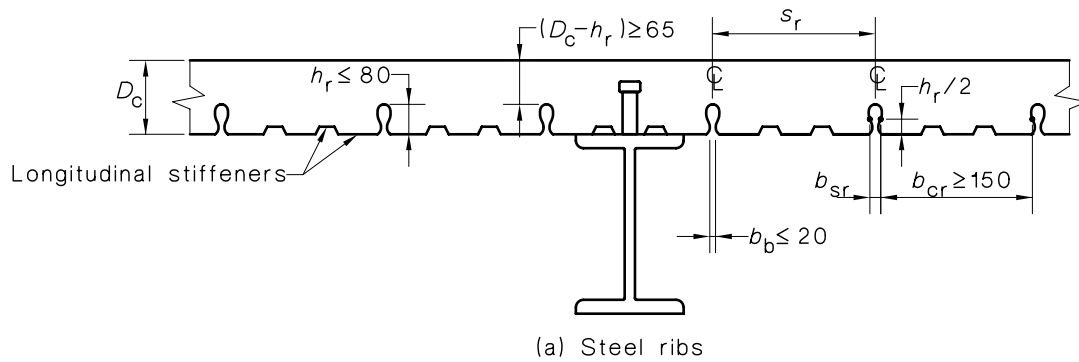
The geometry of the profiled steel sheeting incorporated in a composite slab shall satisfy all of the following requirements (see Figure 1.2.4(a)):

- (a) The overall height of a steel rib (h_r) shall be not greater than 80 mm, excluding any embossments.
- (b) The width of the opening at the base of a steel rib (b_b) shall be not greater than 20 mm.
- (c) The area of the voids formed by the steel ribs in the concrete shall be not greater than 20% of the area of the concrete within the depth of the steel ribs.
- (d) The width of the concrete between the mid-height of adjacent steel ribs (b_{cr}) shall be not less than 150 mm.
- (e) The cover slab thickness (that is, the thickness of the concrete above the steel ribs, which equals $D_c - h_r$) shall be not less than 65 mm.

Longitudinal stiffeners in the pans of the sheeting with an overall height (h_s) greater than 10 mm, measured from the same face of the sheet (see Figure 1.2.4(b)), shall be deemed to be steel ribs for the purpose of this Standard.

Open-rib and closed-rib profiles shall be defined as follows:

- (i) *Closed-rib profiles* All of the steel ribs of a closed-rib profile shall satisfy the geometric requirements shown in Figure 1.2.4 (c).
- (ii) *Open-rib profiles* A profile that is not a closed-rib profile shall be treated as an open-rib profile.



NOTE: Dimensions are to be taken between adjacent sheeting surfaces

FIGURE 1.2.4 PROFILED STEEL SHEETING GEOMETRY

1.2.5 Shear connectors

The shear connectors attached to the top flange of the steel beam shall be any one of the following three types (see Figure 1.2.5):

- (a) Headed studs.
- (b) Channels.
- (c) High-strength structural bolts.

1.3 REFERENCED DOCUMENTS

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

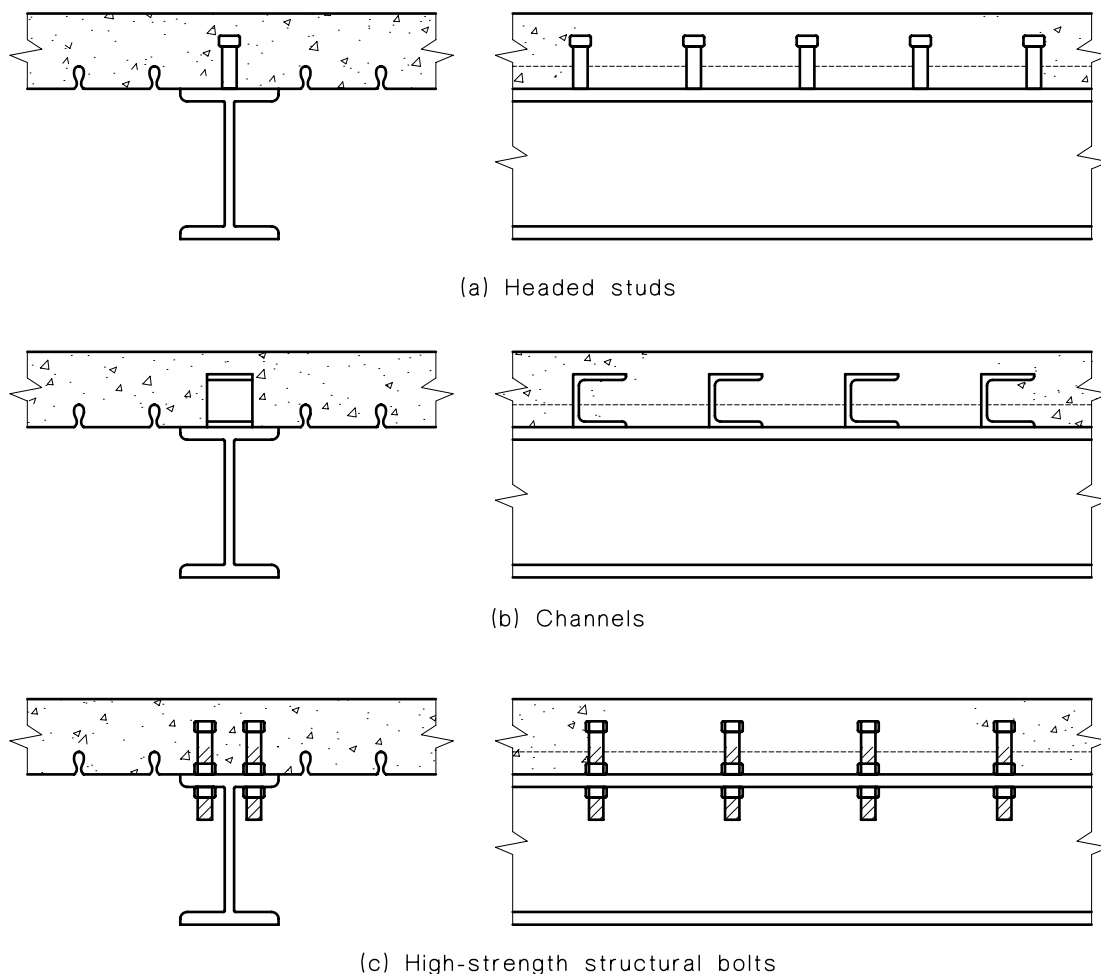


FIGURE 1.2.5 ACCEPTABLE SHEAR CONNECTOR TYPES

1.4 DEFINITIONS

1.4.1 General

For the purpose of this Standard, the definitions below apply. Definitions applying only to a particular clause or section are given in that clause or section and referred to below.

1.4.2 Administrative definitions

1.4.2.1 Authority

A body having regulatory powers, in the area in which the structure is to be erected, to control the design and erection of the structure.

1.4.2.2 Drawings

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

1.4.2.3 May

Indicates the existence of an option.

1.4.2.4 Principal

The purchaser or owner of the structure being constructed or his nominated representative.

1.4.2.5 Shall

Indicates that a statement is mandatory.

1.4.2.6 *Should*

Indicates a recommendation.

1.4.2.7 *Specification*

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

1.4.3 **Technical definitions****1.4.3.1** *Action*

The cause of stress, deformation or displacement in a structure, or in a component member of the structure.

1.4.3.2 *Action effect*

The force, moment, deformation, or like effect, produced in the members of a structure (or its foundations) by an action or combination of actions.

1.4.3.3 *Capacity factor*

A factor by which the nominal capacity or strength is multiplied to obtain the design capacity or strength.

1.4.3.4 *Characteristic strength*

The value of a material strength, as assessed by a standard test, which has a 95% probability of being exceeded in all such tests on the same material.

1.4.3.5 *Closed-rib profile*

A profiled steel sheeting where the geometry of all of the steel ribs satisfies the geometric requirements of Figure 1.2.4 (c).

1.4.3.6 *Complete shear connection ($\beta = 1$)*

The condition where the moment capacity of the cross-section of the composite beam is not governed by the strength of the shear connection.

1.4.3.7 *Composite action*

Interaction between the steel beam and the concrete slab to resist action effects as a single structural member; assumed to commence when the concrete in the slab has attained a compressive strength of at least 15 MPa (i.e., at the start of Construction Stage 5). It is assumed to be fully developed once the compressive strength of the concrete (estimated by f'_{cj} (see Clause 4.2.2)) is equal to or greater than its specified design value f'_c (i.e., at or after the start of Construction Stage 6).

1.4.3.8 *Composite beam*

A steel beam and a solid or composite slab, interconnected by shear connection to act together to resist action effects as a single structural member.

1.4.3.9 *Composite slab*

A cast in situ concrete slab that incorporates profiled steel sheeting as permanent soffit formwork.

1.4.3.10 *Concrete*

A mixture of cement, aggregates and water, with or without the addition of chemical admixtures, which conforms to both AS 1379 and AS 3600.

1.4.3.11 *Concrete slab*

A slab cast monolithically with in situ concrete and reinforcement, with or without profiled steel sheeting.

1.4.3.12 Connector group

(See Clause 9.2).

1.4.3.13 Connector set

(See Clause 9.2).

1.4.3.14 Construction stage

One of the periods defined in Clause 4.2.

1.4.3.15 Cover

The least distance between the surface of reinforcement or shear connectors and the nearest permanent surface of the concrete, excluding any applied surface finish.

1.4.3.16 Cover slab

Concrete above the steel ribs in a composite slab.

1.4.3.17 Critical cross-section

A transverse cross-section at which the ratio of either the design bending moment (M^*) to the design moment capacity (ϕM_{bv}), or the design vertical shear force (V^*) to the design vertical shear capacity (ϕV_u) is a maximum.

1.4.3.18 Degree of shear connection (β)

The value obtained when the compressive force in the concrete at the strength limit state (F_{cp}) is divided by the compressive force in the concrete corresponding to complete shear connection in the absence of vertical shear force (E_{cc}) (see Figure 6.1).

1.4.3.19 Design action effect

The action effect computed from the design action (load).

1.4.3.20 Design capacity

The product of the nominal capacity and the capacity factor.

1.4.3.21 Design life

The period over which a structure or structural element is required to perform its intended function without undue maintenance.

1.4.3.22 Design load

The combination of loads and load factors as specified in AS/NZS 1170.0.

1.4.3.23 Effective section

The portion of a composite beam cross-section considered effective in resisting action effects in bending (see Clause 5.2).

1.4.3.24 Effective span

See Clause 5.3.2.

1.4.3.25 Effective width of concrete flange

The overall width of the portion of a concrete slab, at a composite beam cross-section, considered effective in resisting compression after allowing for shear lag.

1.4.3.26 Effective width of steel flange

The overall width of the portion of a flange of a steel beam, at a composite beam cross-section, considered effective in resisting compression after allowing for flange buckling.

1.4.3.27 *Exposed surface area to mass ratio*

See Clause 10.2.

1.4.3.28 *Fire exposure condition*

See Clause 10.2.

1.4.3.29 *Fire protection system*

See Clause 10.2.

1.4.3.30 *Fire-resistance level (FRL)*

See Clause 10.2.

1.4.3.31 *Fire-resistance period*

See Clause 10.2.

1.4.3.32 *Full interaction*

The condition of a composite beam assuming no slip occurs along the length of the beam at the concrete/steel interface.

1.4.3.33 *In-service condition*

Period after completion of construction when the structure is serving its intended function.

1.4.3.34 *Insulation*

See Clause 10.2.

1.4.3.35 *Integrity*

See Clause 10.2.

1.4.3.36 *Lightweight concrete*

Concrete, as previously defined, having a saturated surface-dry density in the range 1800 kg/m³ to 2100 kg/m³.

1.4.3.37 *Limit state*

Any limiting condition or criterion beyond which a structure, or a member, fails to fulfil its intended function.

1.4.3.38 *Load*

An externally applied force.

1.4.3.39 *Longitudinal shear plane*

See Clause 9.2.

1.4.3.40 *Longitudinal shear reinforcement*

See Clause 9.2.

1.4.3.41 *Longitudinal shear surface*

See Clause 9.2.

1.4.3.42 *Nominal capacity*

The capacity of a member or component calculated, without the capacity factor, in accordance with this Standard.

1.4.3.43 *Nominal load*

A load as specified in Clause 4.1.1.

1.4.3.44 *Normal-weight concrete*

Concrete, as previously defined, having a saturated surface-dry density greater than 2100 kg/m³ and less than or equal to 2800 kg/m³.

1.4.3.45 *One-way action*

Flexural action significant in one direction only.

1.4.3.46 *One-way slab*

A solid or composite slab characterized by one-way action.

1.4.3.47 *Open-rib profile*

A profiled steel sheeting with open and possibly closed steel ribs.

1.4.3.48 *Partial shear connection ($\beta < 1.0$)*

The condition for which the moment capacity of the cross-section of the composite beam is governed by the strength of the shear connection.

1.4.3.49 *Period of structural adequacy (PSA) (fire)*

See Clause 10.2.

1.4.3.50 *Ponding*

Appreciably non-uniform depth of slab as a result of the steel beam or formwork deflecting under the weight of the plastic concrete and slab reinforcement.

1.4.3.51 *Potentially critical cross-section*

A transverse cross-section that is likely to be critical (see Clause 6.3).

1.4.3.52 *Precast slab*

Slab incorporating precast concrete units with or without cast in situ concrete.

1.4.3.53 *Prestressed slab*

Slab incorporating prestressed tendons.

1.4.3.54 *Profiled steel sheeting*

Steel sheeting cold-formed into a profile used as permanent formwork for the soffit of composite slabs.

1.4.3.55 *Proof testing*

The application of specified test loads to a member or assemblage of members, to demonstrate adequate structural performance of only that member or assemblage.

1.4.3.56 *Prop*

A temporary support fitted beneath a steel beam or formwork to support loads during construction.

1.4.3.57 *Prototype (fire)*

See Clause 10.2.

1.4.3.58 *Prototype testing*

The application of limit-state test actions to two or more prototype members or assemblages, which are representative of a group of members or assemblages nominally identical with those tested, for the purpose of demonstrating conformance of the group with specified limit-state criteria.

1.4.3.59 Reinforcement, reinforcing steel

Steel bar, wire, or fabric (but not tendons or fibres) placed in a concrete slab.

1.4.3.60 Serviceability limit state

The loss of fitness for intended use under specified in-service conditions.

1.4.3.61 Shear connection

The interconnection between the steel beam and concrete slab of a composite beam, which enables the two components to act together as a single structural member, comprising the shear connectors, slab concrete and longitudinal shear reinforcement.

1.4.3.62 Shear connector

A mechanical device attached to the top flange of a steel beam which forms part of the shear connection.

1.4.3.63 Shear ratio (γ)

The ratio at a cross-section of the design vertical shear force (V^*) to the design vertical shear capacity (ϕV_u).

1.4.3.64 Simply supported beam

A beam assumed to act as a single-span member without negative design moments.

1.4.3.65 Solid slab

A concrete slab with a flat soffit and without a haunch, cast in situ on removable formwork and reinforced in accordance with AS 3600.

1.4.3.66 Standard fire test

See Clause 10.2.

1.4.3.67 Stickability (fire)

See Clause 10.2.

1.4.3.68 Strength limit state

Collapse, or loss of structural integrity, under specified extreme-load conditions.

1.4.3.69 Structural adequacy (fire)

See Clause 10.2.

1.4.3.70 Tensile strength

The maximum strength in tension specified for the relevant grade and type of steel in the appropriate Australian Standard.

1.4.3.71 Tributary area

See Clause 5.3.2.

1.4.3.72 Two-way action

Flexural action significant in two directions, usually at right angles to one another.

1.4.3.73 Two-way slab

A solid slab characterized by two-way action.

1.4.3.74 Yield strength (or stress)

The minimum yield stress in tension specified for the grade and type of steel in the appropriate Australian Standard.

1.5 EXISTING STRUCTURES

When the strength or serviceability of an existing structure is to be evaluated, the general principles of this Standard may be applied using the actual properties of the materials in the structure. The evaluation may include the proof testing of beams in accordance with Clause 12.2.

1.6 DESIGN INFORMATION

1.6.1 Design data

The following design details shall be shown on the drawings:

- (a) The reference number and date of issue of applicable and current design Standards and, if applicable, any amendments to them.
- (b) The nominal design live loads during construction and in-service, as appropriate.
- (c) The durability exposure classification for the concrete and, if applicable, the corrosion protection for the exposed steelwork and profiled steel sheeting.
- (d) The required fire-resistance level, if applicable.
- (e) The grades and types of reinforcement.
- (f) The grades of steel in the steel beams.
- (g) The types and, if applicable, grades of shear connectors and their method of attachment.
- (h) The type, class and strength designation of the concrete.

1.6.2 Design details

The project drawings or the specification, or both, shall include the following design details as appropriate:

- (a) The dimensions and, if applicable, camber and designation of each steel member.
- (b) The support or connection details for the steel beams including location, size, grade and category of bolts or welds, as applicable.
- (c) Details of the type, size, location and spacing of shear connectors, particularly in relation to the position of profiled steel sheeting ribs.
- (d) The overall thickness of the slab inclusive of profiled steel sheeting, if applicable, and the size and location of any openings, rebates, major voids or conduits in the slab.
- (e) The grade, size, quantity and location of all reinforcement, and other structural embedments, as appropriate.
- (f) The finish and method of control for unformed concrete surfaces.
- (g) In the case of solid slabs, the class of formwork for the surface finish specified in accordance with AS 3610.
- (h) In the case of composite slabs, the proprietary name, base metal thickness, coating class and similar relevant data for the profiled steel sheeting, or appropriate selection or performance criteria.
- (i) The concrete curing procedure.
- (j) The location and details of any movement joints or planned construction joints in the concrete slabs.
- (k) The minimum period of time before stripping of forms or removal of props, as appropriate.

- (l) The values of the nominal live loads used in design.
- (m) The assumed construction sequence.
- (n) The climatic or other local conditions relevant to the durability design of the structure.
- (o) The design life of the structure (if applicable).
- (p) Any other constraint on construction assumed in the design.
- (q) Fire-resistance requirements and fire-protection details, if applicable.
- (r) Any other requirements.

1.7 CONSTRUCTION

Composite beams designed in accordance with this Standard shall be constructed so that all the requirements of the design, as contained in the project drawings and specification, are satisfied.

1.8 NOTATION

The symbols used in this Standard are listed below. Symbols that occur in more than one clause are defined below and used in the various clauses without further reference. Symbols which occur only in one clause are defined in that clause as well as being listed below.

Unless otherwise specified, the following rules apply:

- (a) Where non-dimensional ratios are involved, both the numerator and denominator are expressed in identical units.
- (b) The dimensional units for length, force and stress in all expressions or equations are to be taken as millimetres (mm), newtons (N) and megapascals (MPa) respectively.
- (c) The units of fractional powers of stress (e.g. $\sqrt{f'_c}$) are to be taken as those for stress.
- (d) An asterisk superscript placed after a symbol (e.g. M^*) denotes a design action effect resulting from the design load for the strength limit state.

A	=	tributary area associated with a steel or composite beam for the calculation of nominal live load
A_f	=	cross-sectional area of a flange of the steel beam
A_{f1}, A_{f2}	=	values of A_f for top and bottom flanges, respectively
A_s	=	cross-sectional area of the steel beam
A_{sc}	=	cross-sectional area of the shank of a headed stud, or the minor diameter area of a high-strength structural bolt as defined in AS 1275
$A_{sp,b}$	=	cross-sectional area of bottom-face reinforcement crossing a longitudinal shear plane through the concrete flange (see Figure 9.4.1(a))
$A_{sp,t}$	=	cross-sectional area of top-face reinforcement crossing a longitudinal shear plane through the concrete flange (see Figure 9.4.1(a))
A_{sv}	=	cross-sectional area of reinforcement crossing a longitudinal shear surface through the concrete flange
$A_{sv,min}$	=	the minimum cross-sectional area required of reinforcement crossing a longitudinal shear surface through the concrete flange

$A_{sv.1}, A_{sv.2}, A_{sv.3}$	=	values of A_{sv} corresponding to shear surface types 1, 2 and 3, respectively
A_w	=	cross-sectional area of the web(s) of the steel beam
b	=	clear width of plate element outstand
b_1, b_2	=	centre-to-centre spacing of adjacent beams or distance from centre of steel beam to edge of slab outstand (see Figure 5.2.2.1)
b_b	=	width of opening at base of steel rib in a composite slab (see Figure 1.2.4(a))
b_{cf}	=	effective width of the concrete slab compression flange (see Figure 5.2.2.1)
b_{cr}	=	width of the concrete rib in a composite slab at mid-height of the steel ribs
	=	$s_r - b_{sr}$
b_{e1}, b_{e2}	=	concrete slab effective width outstands on opposite sides of steel beam centre-line (see Figures 5.2.2.1 and 9.5)
b_f	=	width of a steel beam flange
b_s	=	support width
b_{sf1}	=	effective width of steel beam top flange
b_{sf2}	=	overall width of steel beam bottom flange
b_{sr}	=	width of steel rib in a composite slab at its mid-height (see Figure 1.2.4(a))
b_x	=	overall width of shear connectors at a beam cross-section (see Figure 9.4.1)
b_{y1}, b_{y2}	=	segment lengths of shear surface perimeter (see Figure 9.4.2.5)
c_1, c_2	=	constants (see Paragraph B3.2, Appendix B)
D_b	=	overall depth of a composite beam
D_c	=	overall depth of a concrete slab including the thickness of any profiled steel sheeting if present
D_s	=	overall depth of a steel beam
d_1	=	clear depth between flanges of a steel beam ignoring fillets or welds
d_b	=	nominal diameter of a reinforcing bar (see Clause 9.7.3)
d_{bs}	=	nominal shank diameter of a headed-stud or a high-strength structural bolt shear connector
d_c	=	depth of the assumed uniform compressive stress block in the concrete slab at the strength limit state
d_h	=	calculated depth of the compressive zone below the top of the concrete slab at the strength limit state
d_{sg}	=	distance from the top of the concrete slab to the centroid of the steel beam
d_{sr}	=	distance from the top of the concrete slab to the line of action of either F_{st} or F_{stf}
E_c	=	elastic modulus of the slab concrete

E_{cT}	=	elastic modulus of the slab concrete at $T^{\circ}\text{C} > 20^{\circ}\text{C}$
E_s	=	elastic modulus of steel at 20°C ($= 2 \times 10^5$ MPa)
E_{sT}	=	elastic modulus of steel at $T^{\circ}\text{C} > 20^{\circ}\text{C}$
F_b	=	balancing compressive force in steel beam [either $(F_{sc} - 2F_{scf})$ or $(F_{sc} - 2F_{scf} - 2F_{scw})$]
F_c	=	compressive force in the concrete slab at a cross-section at the strength limit state
	=	F_{cc} or F_{cp} as appropriate
F_{c1}	=	longitudinal compressive capacity of concrete cover slab within slab effective width
F_{c2}	=	longitudinal compressive capacity of concrete between steel sheeting ribs within slab effective width
F_{cc}	=	compressive force in concrete slab at a cross-section with complete shear connection where $\gamma \leq 0.5$ at the strength limit state
$F_{cc,i}$	=	value of F_{cc} corresponding to potentially critical cross-section (i)
F_{ccf}	=	compressive force in concrete slab at a cross-section with complete shear connection where $\gamma = 1.0$ at the strength limit state
F_{cp}	=	compressive force in concrete slab at a cross-section with partial shear connection where $\gamma \leq 0.5$ at the strength limit state
$F_{cp,i}$	=	value of F_{cp} corresponding to potentially critical cross-section (i)
F_{cpf}	=	compressive force in concrete slab at a cross-section with partial shear connection where $\gamma = 1.0$ at the strength limit state
F_s	=	resultant tensile force in steel beam at the strength limit state
F_{sc}	=	balancing compressive force in steel beam [either $(F_{st} - 2F_{cp})$ or $(F_{stf} - F_{ccf})$]
F_{scf}	=	compressive capacity of steel beam top flange, assuming entire effective flange area is at yield stress f_{yf}
F_{scw}	=	compressive capacity of steel beam web(s), assuming entire effective portion is at yield stress f_{yw}
F_{st}	=	tensile capacity of steel beam, assuming that the entire cross-sectional area has yielded in tension
F_{stf}	=	tensile capacity of the steel beam ignoring web(s), assuming that the entire cross-sectional area of the flanges has yielded in tension
f'_c	=	28 day characteristic compressive cylinder strength of concrete
f'_{cj}	=	estimated characteristic compressive strength of concrete at j days (see Clause 4.2.2) but taken as not greater than f'_c
f_{cmj}	=	average compressive strength of sample cylinders after j days of site curing (see Clause 4.2.2)
f_{ds}	=	design shear capacity of a shear connector (see Clause 8.3.4)
$f_{\max}$	=	maximum stress in steel beam (see Paragraph B4)
f_{uc}	=	tensile strength of the shear-connector material used in design
f_{vs}	=	nominal shear capacity of a shear connector (see Clause 8.3.2)

f_y	=	yield strength of steel used in design
f_{yb}	=	yield strength of steel beam used in design
f_{yf}, f_{yw}	=	yield strength of the flange and web, respectively, of the steel beam
f_{yr}	=	yield strength of the steel reinforcement used in design
f_{yT}	=	yield strength of steel beam at $T^\circ\text{C}$
G	=	total dead load
G_{sup}	=	superimposed dead load
$G_{\text{C1.3}}$	=	permanent dead load which arises during Construction Stages 1 to 3
h_c	=	overall height of a shear connector (see Clause 9.4.2.4)
h_e	=	effective thickness of concrete slab
h_i	=	thickness of fire protection material
h_r	=	height of the steel ribs in profiled steel sheeting
h_s	=	height of longitudinal stiffener in profiled steel sheeting (see Figure 1.2.4(b))
I_{et}	=	effective second moment of area of a composite cross-section
I_{eti}	=	value of I_{et} under immediate loads
$I_{\text{et}\ell}$	=	value of I_{et} under long-term loads
I_s	=	second moment of area of the steel beam about its centroid of area
I_t	=	second moment of area of transformed section with respect to steel
I_{ti}	=	transformed second moment of area of a composite beam cross-section under immediate loads, taken about the centroid of the transformed area
$I_{\text{t}\ell}$	=	transformed second moment of area of a composite beam cross-section under long-term loads, taken about the centroid of the transformed area
k	=	elastic neutral axis parameter
k_0 to k_6	=	regression coefficients (see Section 10)
k_n	=	a load-sharing factor (see Clause 8.3.4)
k_{sm}	=	exposed surface area to mass ratio
k_{sm1}	=	exposed surface area to mass ratio above a penetration
k_{sm2}	=	exposed surface area to mass ratio below a penetration
L	=	distance between the centre-lines of adjacent members supporting a composite beam; or
	=	distance available for reinforcement anchorage (see Clause 9.7.3)
L_{ef}	=	effective span of a composite beam (see Clause 5.3.3); or
	=	effective span of profiled steel sheeting (see Paragraph C2, Appendix C)
L_n	=	clear distance between the flanges of adjacent steel beams spanning in the same direction

$L_{sy,t}$	=	development length for reinforcement in tension (see Clause 9.7.3)
L_w	=	greatest internal dimension of holes drilled or cut in steel beam web
l	=	length of channel shear connector (see Figure 8.2)
M^*	=	design bending moment at a cross-section
M_b	=	nominal moment capacity of a composite cross-section where $\gamma \leq 0.5$ and $0 < \beta < 1.0$
$M_{b,0.5}$	=	value of M_b corresponding to $\beta = 0.5$
$M_{b,\psi}$	=	value of M_b corresponding to $\beta = \psi$
M_{bc}	=	nominal moment capacity of a composite beam cross-section where $\gamma \leq 0.5$ and $\beta = 1.0$
M_{bf}	=	nominal moment capacity of a composite beam cross-section where $\gamma = 1.0$ and $0 < \beta < \psi$, neglecting any contribution of the steel beam web(s)
M_{bfc}	=	nominal moment capacity of a composite beam cross-section where $\gamma = 1.0$ and $\beta = 1.0$, neglecting any contribution of the steel beam web(s)
M_{bv}	=	nominal moment capacity of a composite beam cross-section where $0 \leq \gamma \leq 1.0$ and $0 \leq \beta \leq 1.0$
$M_{bv,0}$	=	value of M_{bv} corresponding to $\beta = 0$
$M_{bv,\psi}$	=	value of M_{bv} corresponding to $\beta = \psi$
M_{bvc}	=	nominal moment capacity of a composite beam cross-section where $0 \leq \gamma \leq 1.0$ and $\beta = 1.0$
M_s	=	nominal moment capacity of steel beam section
M_{sf}	=	nominal moment capacity of steel beam section neglecting any contribution of the web(s)
n	=	total number of shear connectors provided between a cross-section and an end of the composite beam
n_A	=	number of shear connectors between a potentially critical cross-section (i) and end A of a beam (see Figure 6.1)
n_B	=	number of shear connectors between a potentially critical cross-section (i) and end B of a beam (see Figure 6.1)
n_i	=	minimum number of shear connectors (with the same design shear capacity f_{ds}) between a potentially critical cross-section i and the ends of the beam to satisfy the design requirement $\phi M_{bv} \geq M^*$
n'_i	=	number of shear connectors provided which are considered fully effective in contributing to the design moment capacity (ϕM_{bv}) of a potentially critical cross-section (i)
n_{ic}	=	minimum number of shear connectors (with the same design shear capacity f_{ds}) required between a potentially critical cross-section (i) and the ends of the beam to achieve complete shear connection
$n_{i,min}$	=	the lesser number of shear connectors provided between a composite beam cross-section and the ends of the beam
n_x	=	number of shear connectors in a group at a transverse cross-section of a composite beam

Q	=	live load
R_u	=	nominal capacity of a composite member, or a component of the member, to resist action effects at the strength limit state
R_s	=	nominal capacity of a composite member, or a component of the member, to resist action effects at the serviceability limit state
r_e	=	elastic neutral axis parameter measured from below the steel beam top flange (see Table 5.1)
r_f	=	maximum value along the length of the beam of the ratio of the design bending moment (M^*) under design load for fire to the design moment capacity (ϕM_{bv}) at room temperature
r_p	=	plastic neutral axis parameter (see Table 5.1)
r_l	=	the corner outside radius of a rectangular hollow section (see Figure 8.4.3.1)
S^*	=	design action effects in general
s	=	standard deviation
s_c	=	longitudinal spacing of shear connectors between adjacent groups
s_r	=	transverse spacing of steel ribs in a profiled steel sheet (see Figure 1.2.4(a))
T	=	steel temperature in degrees Celsius
T_l	=	limiting steel temperature in degrees Celsius
t	=	plate element thickness; or time
t_f	=	thickness of the flange of a steel beam
t_{f1}, t_{f2}	=	values of t_f corresponding to the top and bottom flanges, respectively
t_w	=	thickness of the web(s) of a steel beam
t'_w	=	effective thickness of non-compact web(s) of a steel beam (see Figure 5.2.3.3(b))
u	=	perimeter length of a shear surface
u_1, u_2, u_3	=	values of u corresponding to Type 1, 2 and 3 shear surfaces (see Figure 9.4.2.5)
V^*	=	design vertical shear force acting at a composite beam cross-section
V^*_L	=	design longitudinal shear force per unit length acting on a longitudinal cross-section of a concrete slab flange
$V^*_{L,tot}$	=	total design longitudinal shear force per unit length of beam
V_L	=	nominal longitudinal shear capacity per unit length of the concrete slab at the strength limit state
V_u	=	nominal vertical shear capacity of a composite beam cross-section at the strength limit state

x	= distance from outside edge of effective width to centre of longitudinal shear surface (see Clause 9.5); or
	= depth of non-compact portion of web to be ignored in design (see Figure 5.2.3.3(a))
Z_{cb}	= section modulus of the composite beam corresponding to the extreme bottom fibres of the steel beam
Z_{ct}	= section modulus of the composite beam corresponding to the extreme top fibres of the steel beam
Z_{sb}	= section modulus of the steel beam corresponding to the extreme bottom fibres of the steel beam
Z_{st}	= section modulus of the steel beam corresponding to the extreme top fibres of the steel beam
α	= modular ratio E_s/E_c or E_{sT}/E_{cT}
β	= degree of shear connection at a cross-section
	= F_{cp}/F_{cc} (see Figure 6.1)
β_i	= minimum degree of shear connection at a potentially critical cross-section i to satisfy the design requirement $\phi M_{bv} \geq M^*$
β_m	= degree of shear connection at the maximum moment cross-section of a composite beam
γ	= shear ratio at a composite beam cross-section
	= $V^*/(\phi V_u) \leq 1.0$
Δ	= maximum deflection of a composite beam under serviceability loads
$\delta_{C1.3}$	= immediate deflection of steel beam during Construction Stages 1 to 3
$\delta_{C5.6}$	= immediate deflection of composite beam during Construction Stages 5 to 6
δ_{li}	= immediate deflection of composite beam during in-service condition
δ_{lt}	= long-term creep deflection of composite beam during in-service condition
δ_{lsh}	= long-term shrinkage deflection of composite beam during in-service condition
δ_{inc}	= incremental deflection (see Paragraph B1)
δ_{tot}	= total deflection (see Paragraph B1)
ε	= yield stress factor (see Figure 5.2.3.3(a))
θ	= acute angle between the steel ribs of a composite slab and the longitudinal axis of the steel beam
λ	= factor accounting for the inclination of profiled steel sheeting ribs with respect to longitudinal axis of steel beam (see Figure 5.2.2.2(b))
λ_e	= plate element slenderness (see Clause 5.2.3.3)
λ_{ep}	= plate element plasticity slenderness limit
λ_{ey}	= plate element yield slenderness limit

ρ_c	=	density of concrete
ϕ	=	capacity factor relevant to a strength limit state (see Clause 3.3.1)
ψ	=	value of β corresponding to complete shear connection of a composite beam ignoring the presence of the steel beam web(s)
	=	F_{ccf}/F_{cc} (see Paragraph D3.3, Appendix D)
ψ_ℓ	=	long-term live load factor used in assessing the design load for the serviceability limit state
ψ_s	=	short-term live load factor used in assessing the design load for the serviceability limit state

SECTION 2 MATERIALS

2.1 STEEL

2.1.1 Structural steel

Structural steel used in the steel beam component of the composite beam shall comply with AS 1163, AS/NZS 1594, AS 3678, AS 3679.1 or AS 3679.2, as appropriate. Cold-formed rectangular hollow steel sections manufactured in accordance with AS 1163 shall be grades C350, C350L0, C450 or C450L0.

2.1.2 Bolts, nuts and washers

Bolts, nuts and washers used for fabricating and erecting the steel beam shall comply with AS 1110, AS 1111, AS 1112 or AS/NZS 1252, as appropriate.

2.1.3 Welds and welding

Welding consumables, deposited weld metal and welding used to fabricate the steel beam or attach channel shear connectors to the top flange shall comply with AS 1554.1, and welding of headed-stud shear connectors shall comply with AS 1554.2.

2.1.4 Shear connectors

Shear connectors shall comply with AS 1554.2, AS/NZS 1252 or AS 3679.1, as appropriate.

Alternatively, shear connectors not complying with the above may be used, provided that—

- (a) their mechanical and other physical properties are not inferior; and
- (b) they comply with the other relevant requirements of this Standard.

2.1.5 Profiled steel sheeting

The steel strip used to produce the profiled steel sheeting shall comply with AS/NZS 1365 and AS 1397. As an additional requirement, the amount of oil residue on the surface of profiled steel sheeting after manufacture shall not exceed 200 mg/m².

2.2 CONCRETE AND REINFORCEMENT

2.2.1 Concrete

The ingredients for, and the manufacture of, fresh (plastic) concrete used for the in situ concrete slab of a composite beam, shall comply with AS 1379. The resulting hardened concrete shall comply with AS 3600.

2.2.2 Reinforcement

Reinforcement used in the concrete slab of a composite beam shall comply with AS/NZS 4671.

2.3 MECHANICAL PROPERTIES

The mechanical properties used for calculating the nominal (unfactored) strengths of the component parts of the composite beam shall be determined in accordance with the following:

- (a) *Steel sections* AS 4100, Section 2.
- (b) *Bolts and nuts* AS 1111 and AS 1112.
- (c) *Welds* AS 1554.1 and AS 1554.4.

- (d) *Shear connectors* of the following types (see also Clause 8.2.1):
 - (i) *Channels* AS/NZS 3679.1.
 - (ii) *Headed studs* AS 1554.2.
 - (iii) *High-strength structural bolts (Grade 8.8)* AS/NZS 1252.
- (e) *Concrete and reinforcement* AS 3600 and AS/NZS 4671.
- (f) *Galvanized steel strip for profiled steel sheeting* AS 1397.

SECTION 3 GENERAL DESIGN REQUIREMENTS

3.1 DESIGN

3.1.1 Aim

The aim of structural design in accordance with this Standard is to provide a composite beam that has adequate strength, is serviceable, stable, durable and fire-resistant (if required), and satisfies other objectives such as economy and ease of construction.

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

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

3.1.2 Requirements

The design of a composite beam and its components shall take into account, as appropriate, the limit states of stability, strength, serviceability, fire resistance and any other relevant design criteria, in accordance with the procedures specified in this Section.

Prior to the commencement of composite action, the design of the composite beam components shall be in accordance with Clause 3.1.3.

NOTES:

- 1 A flowchart showing the sequence of the overall design process with respect to the various limit states and construction stages is given in Appendix E.
- 2 Relevant construction stages are described in Appendix F.

3.1.3 Design of composite beam components

3.1.3.1 Steel beam

Prior to the development of composite action (i.e., Construction Stages 1 to 4), the steel beam shall be designed in accordance with AS 4100 for the loads and other actions specified in Clause 3.2. During construction and the in-service condition, end supports and connections of the steel beam shall satisfy the relevant requirements of AS 4100.

NOTE: Where the formwork consists of profiled steel sheeting, the degree of lateral restraint provided to the steel beam by the sheeting will depend on, amongst other things, the flexural stiffness of the sheeting, the orientation of the sheeting ribs and the strength of the connection between the sheeting and the beam.

3.1.3.2 Concrete slab

The concrete slab may be either a solid slab, or a composite slab (see Clause 1.2.3). The slab shall be designed in accordance with AS 3600 if it is either a solid slab, or a composite slab but no composite action between the concrete and the profiled steel sheeting is considered. When composite action between the concrete and the profiled steel sheeting is taken into account in design, appropriate design information shall be used.

NOTE: Design provisions for composite slabs are currently being prepared. In the interim, the proprietary literature of profiled steel sheeting manufacturers may be used, provided it is supported by adequate test data.

3.1.3.3 *Profiled steel sheeting*

Prior to the development of composite action (i.e., Construction Stages 1 to 4), the profiled steel sheeting in a composite slab shall be designed in accordance with an appropriate method for the loads and other actions defined in Clause 3.2. The calculated deflections under these conditions shall not exceed the limits specified in Clause 7.2.

NOTE: In the absence of an appropriate Australian Standard, methods given in the proprietary literature of the profiled steel sheeting manufacturer may be used, provided that they are supported by adequate test data.

3.1.4 Composite beam minimum slab outstand

The outstand of a concrete slab (either solid or composite), which forms the flange of a composite edge beam, shall be at least 150 mm wide measured from the vertical outside edge of the slab to the edge of the nearest shear connector (see Figure 3.1.4).

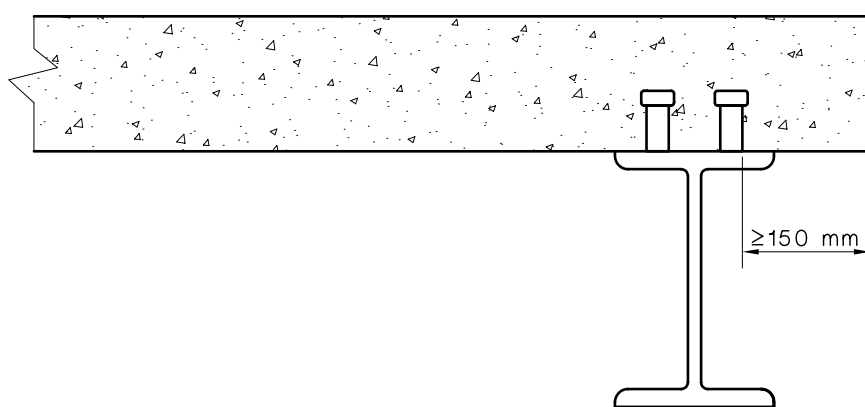


FIGURE 3.1.4 COMPOSITE BEAM MINIMUM SLAB OUTSTAND

3.2 LOADS AND OTHER ACTIONS

3.2.1 Loads

The design of a composite beam for strength, serviceability, stability and fire resistance shall take account of the action effects arising directly from the nominal loads specified in Clause 4.1.1.

3.2.2 Other actions

Any other actions which significantly affect the strength, serviceability, stability or fire resistance of the composite beam including but not limited to those actions specified in Clause 4.1.2, shall be taken into account when determining the design loads.

3.2.3 Design loads

The design loads for the limit states of strength, serviceability, stability and fire resistance shall be determined from Clause 4.1.4.

3.3 DESIGN FOR LIMIT STATES

3.3.1 Design for strength

Once composite action is fully developed (i.e., after Construction Stage 5 when $f'_{cj} \geq f'_c$), the composite beam shall be proportioned and the shear connection between the steel beam and the concrete slab detailed, so that, under the design actions for the strength limit state (S^*), the design capacity (ϕR_u) at every cross-section satisfies the following inequality:

$$\phi R_u \geq S^*$$

where

- ϕ = an appropriate capacity factor not greater than the value given in Table 3.1
- R_u = the relevant nominal capacity determined in accordance with Sections 6, 8 and 9
- S^* = the corresponding design action effect determined in accordance with Section 5 for the appropriate design loads

TABLE 3.1
CAPACITY FACTOR FOR THE STRENGTH LIMIT STATE

Type of action effect	Capacity factor (ϕ)
Bending	
(a) Propped construction: Construction Stage 5 (see Clause 4.2.3)	0.70
(b) All other cases	0.90
Vertical shear	0.90
Longitudinal shear	
(a) Concrete slab	0.70
(b) Shear connectors	0.85

3.3.2 Design for serviceability

The composite beam shall be designed so that, under the design actions for the serviceability limit state, its deflection and vibration, as well as cracking of the concrete slab, shall each be controlled in accordance with Section 7.

3.3.3 Design for durability

The durability requirements of AS 3600 and AS 4100 shall be satisfied for the concrete slab and the steel beam respectively. For composite slabs, the manufacturer's recommendations regarding the durability of profiled steel sheeting shall be followed. Concrete cover to shear connectors shall satisfy the requirements of Clause 8.4.4.

3.3.4 Design for fire resistance

Where appropriate, the composite beam shall be designed and detailed in accordance with Section 10 so that its fire-resistance period for structural adequacy is not less than the corresponding period specified for the required fire-resistance level. The concrete slab component of the composite beam shall be designed and detailed in accordance with Appendix G, so that its fire-resistance periods for structural adequacy, insulation and integrity are not less than the corresponding periods specified by the required fire-resistance level.

3.3.5 Design by prototype testing

Notwithstanding the requirements of Clauses 3.3.1 and 3.3.2, a composite beam may be designed for strength or deflection, or both, by load testing two or more prototypes in accordance with Clause 12.3, using appropriate design loads determined from Clause 4.1.4. If this alternative procedure is adopted, the beam shall also be designed for vibration, durability and fire resistance, as necessary, in accordance with the requirements of Clauses 3.3.2, 3.3.3 and 3.3.4 respectively.

SECTION 4 ACTIONS AND DESIGN SITUATIONS

4.1 GENERAL

4.1.1 Actions

The design of the member for the limit states specified in Clause 3.3 shall take account of the action effects directly arising from the following actions:

- (a) Permanent and imposed, wind, snow and earthquake loads determined in accordance with AS/NZS 1170.1, AS/NZS 1170.2, AS/NZS 1170.3 and AS 1170.4, respectively.
- (b) Construction loads, determined in accordance with Appendix F.
- (c) Other specific loads, as required.

Uniformly distributed imposed loads for the in-service condition may be reduced in accordance with Clause 4.1.3.

4.1.2 Other actions

Any other action that may significantly affect the stability, strength, or serviceability of the member, including but not limited to the following, shall be taken into account:

- (a) Removal of construction props.
- (b) Foundation movement.
- (c) Temperature changes and gradients.
- (d) Transient dynamic actions.
- (e) Shrinkage or creep of concrete.

4.1.3 Reduction of uniformly distributed imposed loads

Uniformly distributed imposed loads acting on the composite beam during the in-service condition may be reduced, when appropriate, in accordance with AS/NZS 1170.1, taking into account the magnitude of the tributary area (see Clause 5.3.5).

NOTE: Tributary area (A) should be calculated in accordance with Clause 5.3.5 considering whether the concrete slab exhibits either one-way or two-way action.

4.1.4 Design loads

Except as noted herein, the design loads for the relevant limit state shall be determined from the appropriate combinations of actions specified in AS/NZS 1170.0 and AS 1170.4 and, if applicable, shall include any other actions, appropriately factored.

4.2 CONSTRUCTION STAGES

4.2.1 General

For the purpose of determining the design actions, action effects and member capacities, due account shall be taken of the construction stages given in Clauses 4.2.2 and 4.2.3, which are affected by the development of composite action (see also Appendix F).

4.2.2 Prior to development of composite action

Until such time as the concrete in the slab has attained a compressive strength of 15 MPa, no composite action between the steel beam and the concrete shall be assumed. This encompasses Construction Stages 1 to 4, which are distinguished as follows:

- (a) *Stage 1* Period between when the steelwork is erected, and the formwork is placed and, if appropriate, fixed to the steel beams.
- (b) *Stage 2* Period between the end of Construction Stage 1 and immediately prior to the commencement of casting the slab concrete.
- (c) *Stage 3* Period between commencement of casting the slab concrete and its initial set under the prevailing site conditions.
- (d) *Stage 4* Period from the initial set of the slab concrete until its compressive strength (estimated by f'_{cj}) reaches 15 MPa.

NOTES:

- 1 An estimate of the characteristic compressive strength of the slab concrete, at an age of 'j' days (f'_{cj}) may be obtained from compression tests on cylinder specimens of the concrete that have been subjected to the same curing conditions as the slab for that period, using the following equation:

$$f'_{cj} = f_{cmj} - 1.65 s \leq f'_c$$

where

- f'_{cj} = the estimated characteristic compressive strength of concrete at j days
- f_{cmj} = the average compressive strength of sample cylinders after j days of site curing
- s = the standard deviation of sample strengths of the grade of concrete used

- 2 The 7 day mean strength of normal class concrete can be estimated using AS 1379. For example, if the concrete has been continuously moist cured, an average compressive strength of not less than 15 MPa may be expected in 7 days by Grades N32 and stronger grades; however, if 15 MPa is required at a time less than 7 days, special class concrete may need to be specified.

4.2.3 After development of composite action

Once the concrete in the slab has attained a compressive strength of 15 MPa, development of composite action between the steel beam and the concrete may be assumed. This encompasses Construction Stages 5 and 6, which are distinguished as follows:

- (a) *Stage 5* Period from the end of Construction Stage 4 until the characteristic strength of the slab concrete reaches its specified design value (f'_c) (see Note 1).
- (b) *Stage 6* Period following the end of Construction Stage 5 to the end of construction immediately prior to the in-service condition (see Note 2).

NOTES:

- 1 Props to either the concrete slab or steel beam may be removed during Construction Stage 5, provided the strength of the composite beam is checked in accordance with Clause 3.3.1.
- 2 By the end of Construction Stage 6 any props present should have been removed.
- 3 The construction stages defined in Clauses 4.2.2 and 4.2.3 assume that the principal construction activities and processes are as shown in Figure F1, Appendix F.

SECTION 5 EFFECTIVE SECTION AND DESIGN ACTION EFFECTS FOR STRENGTH DESIGN

5.1 GENERAL

The effective section of a composite beam cross-section shall be determined in accordance with Clause 5.2 and used for strength design in accordance with Section 6. The effective section shall be determined for each potentially critical cross-section defined in Clause 6.3, except at the ends of the beam where the steel beam alone shall be assumed to act.

The design action effects arising from the design loads specified in Clause 4.1.4 for the strength limit state after the development of composite action, (i.e., Construction Stages 5 and 6 as defined in Clause 4.2.3 and for the in-service condition) shall be determined in accordance with the procedure given in Clause 5.3.

NOTE: The design action effects relevant here are the design vertical shear force V^* and the design bending moment M^* .

5.2 EFFECTIVE SECTION OF A COMPOSITE BEAM CROSS-SECTION

5.2.1 General

Allowance shall be made for the in-plane shear flexibility (shear-lag) of a concrete compression flange, by using an effective width of flange calculated in accordance with Clause 5.2.2.

The region of the concrete slab within the effective width shall be designed for longitudinal shear in accordance with Section 9.

The portion of the steel beam considered to form part of the effective section of the composite beam cross-section shall be determined in accordance with Clause 5.2.3.

Any vertical construction joint that falls within the effective width shall be designed in accordance with Section 9, taking into account the surface condition of the original concrete face. Any concrete that falls above a horizontal construction joint (e.g., when a screed is poured on top of an existing slab) shall be ignored when calculating the effective section, unless the joint is designed for longitudinal shear and the specified compressive strength f'_c of the concrete is at least as great as that assumed in design for the remainder of the slab.

NOTE: The procedure that should be followed is shown in Figure E2 of Appendix E.

5.2.2 Effective width of concrete compression flange

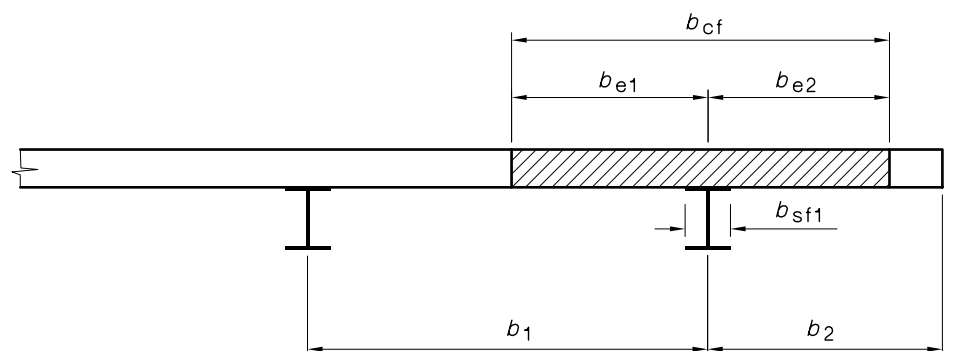
5.2.2.1 Solid slab

Where the concrete flange is a solid slab, its effective width (b_{ef}) shall be calculated as the sum of the distances b_e measured on each side of the centre-line of the steel beam (see Figure 5.2.2.1), where b_e is in each case the smallest of—

- (a) $L_{ef}/8$, where L_{ef} is the effective span of the beam calculated in accordance with Clause 5.3.3;
- (b) in the case of a concrete slab with a free edge (i.e., an edge beam situation), either the perpendicular distance to the edge measured from the centre-line of the beam, or 6 times the overall depth D_c of the concrete slab plus half the width of the steel beam flange b_{sf1} ; and

- (c) in the case of a concrete slab that spans between two steel beams (i.e., either an edge beam or internal beam situation), either half the centre-to-centre distance between the steel beams or 8 times the overall depth D_c of the concrete slab plus half the width of the steel beam flange b_{sf1} .

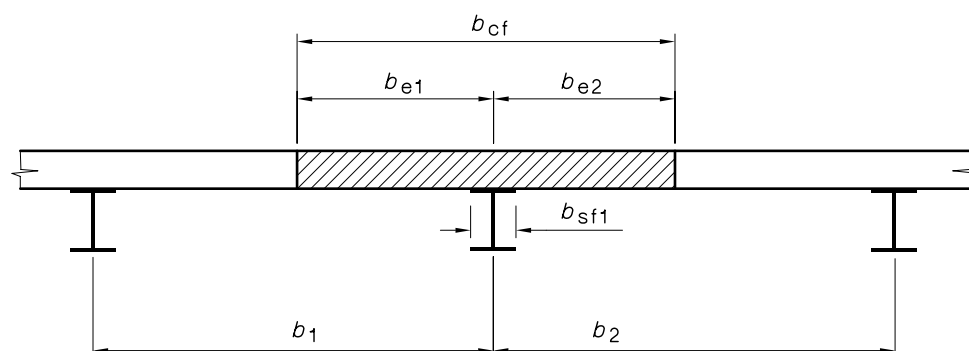
When a slab has pockets or cut-outs within its effective width then, at the cross-sections of concern, b_{cf} shall be reduced by the width they encroach into this region.



$$b_{e1} = \min. \left\{ \left(\frac{L_{ef}}{8} \right) \text{ or } \left(\frac{b_1}{2} \right) \text{ or } \left(\frac{b_{sf1}}{2} + 8D_c \right) \right\}$$

$$b_{e2} = \min. \left\{ \left(\frac{L_{ef}}{8} \right) \text{ or } (b_2) \text{ or } \left(\frac{b_{sf1}}{2} + 6D_c \right) \right\}$$

(a) Edge beam



$$b_{e1} = \min. \left\{ \left(\frac{L_{ef}}{8} \right) \text{ or } \left(\frac{b_1}{2} \right) \text{ or } \left(\frac{b_{sf1}}{2} + 8D_c \right) \right\}$$

$$b_{e2} = \min. \left\{ \left(\frac{L_{ef}}{8} \right) \text{ or } (b_2) \text{ or } \left(\frac{b_{sf1}}{2} + 8D_c \right) \right\}$$

(b) Internal beam

FIGURE 5.2.2.1 EFFECTIVE WIDTH OF CONCRETE COMPRESSION FLANGE AT A COMPOSITE BEAM CROSS-SECTION — SOLID SLAB CASE

5.2.2.2 Composite slab

Where the concrete flange is a composite slab, the effective width of the flange (b_{cf})—

- (a) for the portion of the slab above the ribs, shall be determined in accordance with Clause 5.2.2.1; and

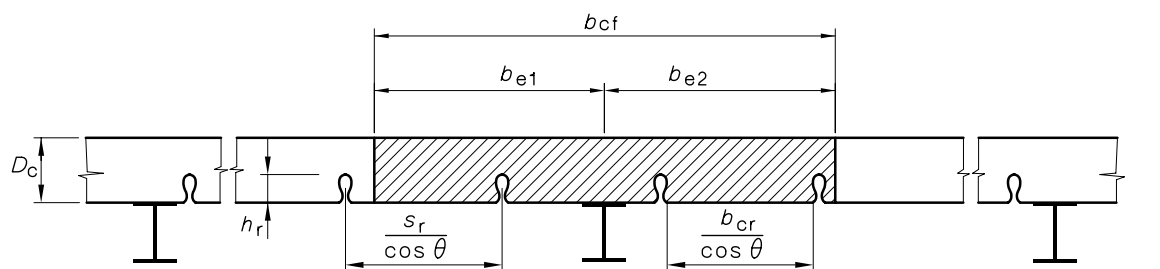
- (b) for the portion of the slab within the depth of the ribs, shall be taken as the value obtained from (a) multiplied by the factor λ , where—

$$\lambda = 1.0, \text{ for } 0 < \theta \leq 15^\circ; \quad \dots 5.2.2.2(1)$$

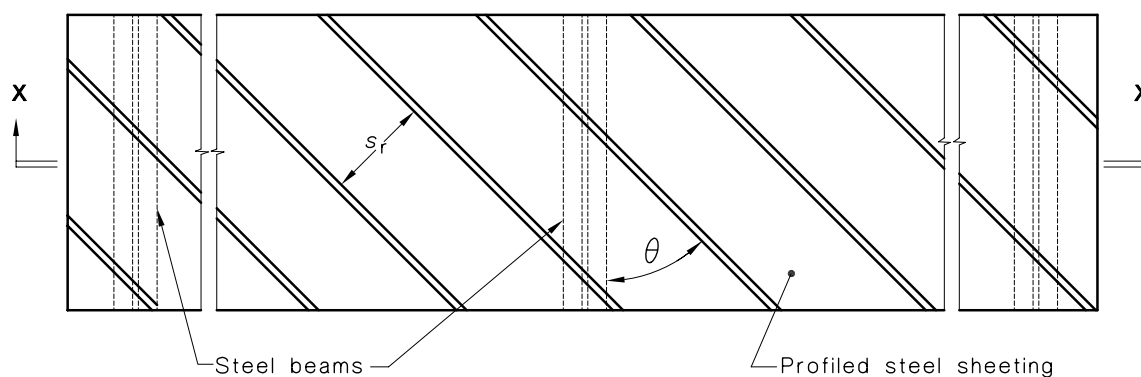
$$\lambda = (b_{cr} \cos^2 \theta) / s_r, \text{ for } 15^\circ < \theta \leq 60^\circ;$$

$$\lambda = 0, \text{ for } \theta > 60^\circ; \text{ and}$$

$$\theta = \text{the acute angle between the sheeting ribs and the longitudinal axis of the steel beam (see Figure 5.2.2.2 including Note).}$$

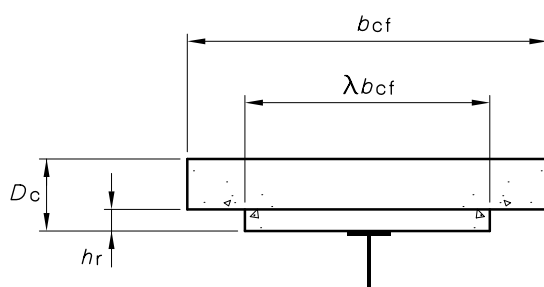


SECTION XX



INVERTED PLAN

(a) Concrete flange



(b) Idealized effective concrete flange

NOTE: The value of θ should be determined for each side of the beam where the orientation of the sheeting is different.

FIGURE 5.2.2.2 EFFECTIVE WIDTHS OF CONCRETE PORTIONS OF A COMPOSITE SLAB

5.2.3 Effective portion of steel beam

5.2.3.1 General

The effective portion of the steel beam cross-section at the strength limit state shall be determined in accordance with—

- (a) Clause 5.2.3.2 if the entire depth of the steel beam is in tension; or
- (b) Clause 5.2.3.3 if only part of the depth of the steel beam is in tension (see Note 1).

The part of the steel beam subject to tension at the strength limit state shall be determined from Section 6.

For fabricated steel beams, or steel beams with an additional plate welded to the bottom flange, the welds connecting the plate elements of the beam together shall be designed to transmit the shear forces that develop on account of the axial tensile forces assumed to be carried by these elements (see Note 2).

The effect of holing of the steel beam may be ignored in the following cases:

- (i) Where holes are drilled in the top flange to accommodate high-strength structural bolts used as shear connectors in accordance with Section 8.
- (ii) Where holes are drilled or cut in the web so that their greatest internal dimension L_w satisfies—

$$L_w/d_1 \leq 0.10 \text{ (see Note 3)} \quad \dots 5.2.3.1(1)$$

NOTES:

- 1 If there is partial shear connection at the cross-section of concern (i.e., $\beta < 1$), Item (b) will always apply.
- 2 Particular attention needs to be given to this issue when designing cross-sections close to where an additional plate welded to the bottom flange is terminated.
- 3 It is beyond the scope of this Standard to provide a method for designing composite beams with larger web penetrations. A method for designing composite beams with larger web penetration is given in Reference 9, Appendix I.

5.2.3.2 Tension in whole of steel beam ($\beta = 1$)

The whole of the steel beam section at a cross-section of a composite beam shall be assumed to be effective.

5.2.3.3 Compression in part of steel beam ($\beta \leq 1$)

When part of the top flange, or the top flange and part or all of the web of the steel beam is in compression, account shall be taken of the slenderness (λ_e) of each of these plate elements either partially or fully in compression, in order to determine the effective portion of the steel beam (see Note 1). The plate element slenderness (λ_e) is given by—

$$\lambda_e = \left(\frac{b}{t} \right) \sqrt{\frac{f_y}{250}} \quad \dots 5.2.3.3(1)$$

where

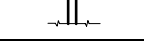
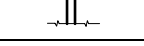
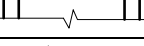
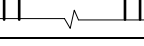
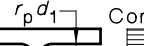
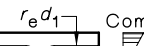
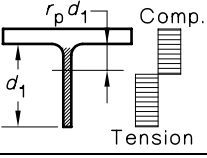
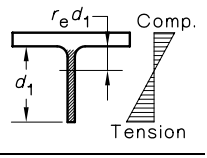
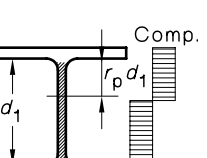
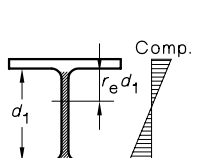
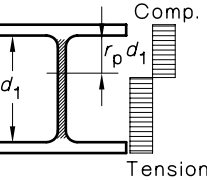
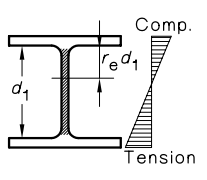
- b = clear width of the element outstand from the face of the supporting plate element or the clear width of the element between faces of supporting plate elements
- t = element thickness
- f_y = yield stress of plate element used in design

NOTES:

- 1 It is assumed that the entire width of the bottom flange will be effective.
- 2 Slender plate elements are such that $\lambda_e > \lambda_{ey}$, where values of the yield slenderness limit λ_{ey} are given in Table 5.1.
- 3 Compact plate elements are such that $\lambda_{ep} \geq \lambda_e$, where values of the plasticity slenderness limit λ_{ep} are given in Table 5.1.
- 4 Non-compact plate elements are such that $\lambda_{ev} \geq \lambda_e > \lambda_{ep}$.



TABLE 5.1
PLATE ELEMENT PLASTICITY AND YIELD SLENDERNESS LIMITS

Plate element	Longitudinal edges supported	Residual stresses (see Notes)	Plasticity limit		Yield limit	
			λ_{ep}	Stress distribution	λ_{ey}	Stress distribution
Flange	One	SR	10		16	
		HR	9		16	
		LW, CF	8		15	
		HW	8		14	
Flange	Both	SR	30		45	
		HR	30		45	
		LW, CF	30		40	
		HW	30		35	
Web	One	any	82		115	
						
Web	Both	any	For $1.0 \geq r_p \geq 0.5$: $\frac{111}{(4.7r_p - 1)}$		For $1.0 \geq r_e \geq 0.5$: $\frac{322}{(3.6r_e + 1)}$	
			For $r_p < 0.5$: $\frac{41}{r_p}$		For $r_e < 0.5$: $\frac{57.5}{r_e}$	

LEGEND:

SR = stress relieved
 HR = hot-rolled or hot-finished
 CF = cold-formed
 LW = lightly welded
 HW = heavily welded

NOTES:

- 1 Welded members with compressive residual stresses of less than 40 MPa may be considered to be lightly welded.
- 2 The value of the parameter r_e , which defines the position of the elastic neutral axis, should be calculated from the elastic stress distribution for the steel section alone, ignoring the presence of the concrete slab.

5.3 CALCULATION OF DESIGN ACTION EFFECTS DUE TO DESIGN LOADS

5.3.1 General

For the purpose of complying with the requirements for the strength limit state, the design action effects in a simply supported composite beam and its connections shall be determined using the calculation procedure in Clause 5.3.4.

NOTE: It is outside the scope of this Standard to provide rules for the design of the composite beam if the steel beam is propped during Construction Stages 5 and 6 when it will act as a continuous member.

5.3.2 Definitions

For the purpose of Clauses 5.3.3 to 5.3.5, the following definitions apply:

- (a) *Effective span* the span used in the calculation of design action effects allowing for different end support conditions of the composite beam (see Clause 5.3.3).
- (b) *Tributary area* the plan area from which dead and live loads acting on the slab will be assumed to be received by a supporting composite beam (see Clause 5.3.5).