11.3.2 Design values

11.3.2.1
The factored resistance for welded joints shall be as given in Table 11.2, unless otherwise specified in an applicable design standard acceptable to the engineer.

11.3.2.2
The factored compressive resistance of joints utilizing partial joint penetration groove welds shall be based on the area of the effective fusion face projected normal to the compression plus the area of the base metal fitted in contact bearing.

11.3.2.3
The vector sum of factored longitudinal and transverse shear loads shall not exceed the factored fillet weld resistances given in Table 11.2, Column 4 or 6, unless an ultimate strength analysis is used that is acceptable to the engineer. The factored resistance for welded joints with multi-oriented fillet welds shall be as given in Table 11.2.

11.3.2.4
Plug and slot welds shall be considered only to provide shear resistances in the plane of the connected parts.

11.3.3 Base metal and matching electrode classification
Base metals and matching electrode classifications shall be as given in Table 11.1, with the exceptions noted in Column 5 of Table 11.2.

11.4 Structural details

11.4.1 General
Details shall be such as to minimize constraint against ductile behaviour to avoid undue concentration of welding and to afford ample access for the placing of the weld metal.

11.4.2 Combination of welds
If two or more of the general types of welds are used separately in a single joint, the capacity of each shall be separately computed with reference to the axis of the group, in order to determine the allowable capacity of the combination.

11.4.3 Welds in combination with bolts
Joints using bolts and welds to transfer loads shall be proportioned in accordance with the requirements of the applicable design standard, e.g., CSA S16.

In the absence of an applicable design standard, ordinary bolts or high-strength bolts used in bearing-type connections shall not be considered as sharing the load in combination with welds in the same shear plane. Welds, if used, shall be provided to carry the entire load in the connection.

Connections that are welded to one member and bolted to the other member may be used. (For strengthening and repair of existing structures, see Clause 9.)

11.4.4 Strength under temporary loads

Welds shall be checked for adequate capacity to resist temporary loads due to handling and erection.

11.4.5 Eccentricity of connections

11.4.5.1

Eccentricity between intersecting parts and members shall be avoided insofar as practicable.

11.4.5.2

If eccentricity cannot be avoided, adequate provisions shall be made for the resulting stresses except for connections designated in Clause 11.4.5.3.

11.4.5.3

For end connections of single angles, double angles, and similar type members, it is not necessary to completely balance the welds about the neutral axis or axes of such members.

11.4.6 Fillet weld details

11.4.6.1

Side or end fillet welds terminating at ends or sides, respectively, of parts or members shall, wherever practicable, be returned continuously around the corners for a distance at least twice the nominal size of the weld. There shall be end returns for side and top fillet welds connecting header angles, beam seats, and other similar connections. End returns shall be indicated on the fabrication and erection documents.

11.4.6.2

Intermittent fillet welds may be used to carry calculated load.

11.4.7 Lap joints

11.4.7.1

The minimum overlap of parts in stress-carrying lap joints shall be five times the thickness of the thinner part joined, and not less than 25 mm (1 in). Unless lateral deflection of the parts is prevented, they shall be connected by two transverse lines of fillet welds or by longitudinal fillet welds along the edges or in slots (see Figure 11.1).

11.4.7.2

Unless there is a requirement that an all-around seal be provided, fillet welds deposited on the opposite sides of a common plane of contact between two parts shall be interrupted at the corner common to both welds (see Figure 11.2). If all-around sealing is required, the provisions of Clause 5.4.10 shall apply. Both strength and seal welds shall be identified on the drawing. (See also Clause 4.7.)

11.4.7.3

Fillet welds in holes or slots shall be made in accordance with Clause 4.4.1.3. The strength of the part shall be determined from the critical net section of the base metal.

11.4.8 Transition of thickness or width

11.4.8.1

Except as provided in Clause 11.4.8.2, tension butt joints between axially aligned members of different material thicknesses or widths shall be made in such a manner that the slope through the transition zone is not steeper than 4 in 10. The transition shall be accomplished by chamfering the thicker part, tapering the wider part, sloping the weld metal, or by any combination of these (see Figure 11.3).

11.4.8.2

The transition requirements of Clause 11.4.8.1 do not apply to butt joints subjected to tensile stresses less than one-third the allowable or to factored tensile loads less than one-third the factored resistance of the weaker member.

11.4.8.3

Compression butt joints do not require a transition zone in members of different thickness or width.

11.4.9 Beams and girders

11.4.9.1

Stiffeners may be welded to tension and compression flanges; however, when used on only one side of the web, they shall be welded to the compression flange.

11.4.9.2

Connections or splices in beams or girders when made by groove welds shall be complete penetration groove welds, unless otherwise approved by the engineer.

11.4.9.3

Splices between sections of rolled beams or built-up girders shall preferably be made in the same cross-section. Shop splices of webs and flanges of built-up girders, made before the webs and flanges are joined to each other, may be located in the same or different cross-sections.

11.4.9.4

Welded beam end connections shall be designed in accordance with the assumptions as to the degree of restraint in the type of construction used.

11.4.10 Splices in compression members

11.4.10.1

Where members (other than building columns) subject to compression only throughout their cross-section under all conditions of loading are finished to bear at splices, the splice material and its welding shall be arranged to hold all parts in alignment and shall be proportioned to carry 50% of the computed load in the member, unless otherwise stipulated by the engineer or the applicable design specifications. Where such members are in full milled bearing on base plates, there shall be sufficient welding to hold all parts securely in place.

11.4.10.2

Where columns subject to compression only throughout their cross-section under all conditions of loading are finished to bear at splices, there shall be sufficient welds to hold all parts securely in place.

11.4.11 Splices in tension members

Splices of tension members made by groove welds shall be complete joint penetration groove welds, unless otherwise approved by the engineer.

11.4.12 T- and corner joints

The size of fillet welds on top of groove welds, when required for smoother transition in T- and corner joints, shall be not less than $t/4$, where t is the thickness of the groove welded member, but need not be more than 10 mm (3/8 in). Fillet welds on top of the groove welds shall be mandatory for T-joints subject to tension normal to the axis of the weld.

11.4.13 Connection of components of built-up members

11.4.13.1

All component parts in contact with one another at the ends of built-up compression members shall be connected by continuous welds having a length not less than the width of the member.

11.4.13.2

Except as otherwise required by the applicable design specification, or unless closer spacing is required for transfer of load or for sealing inaccessible surfaces, the clear longitudinal spacing between intermittent welds in built-up compression members shall not exceed the following, as applicable*:

a) For compression members composed of two or more rolled shapes in contact or separated from one another by intermittent fillers, the slenderness ratio of any shape between points of interconnection shall not exceed the slenderness ratio of the built-up member. The least radius of gyration of each component part shall be used in computing the slenderness ratio of that part between points of interconnection with other component parts;

b) $330t/\sqrt{F_y}$ $\left(125t/\sqrt{F_y}\right)$ but not more than 300 mm (12 in), when the outside component of the built-up section consists of a plate and the intermittent welds along the component edges are not staggered [t = thickness of outside plate in mm (in); F_y = specified minimum yield stress in MPa (ksi)]; and

c) $525t/\sqrt{F_y}$ $\left(200t/\sqrt{F_y}\right)$ but not more than 450 mm (18 in), when the outside component of the built-up section consists of a plate and the intermittent welds are staggered on adjacent lines [t = thickness of outside plate in mm (in); F_y = specified minimum yield stress in MPa (ksi)].

* *The spacing requirements are maximum spacing that will not always provide a continuous tight fit between components in contact. When the environment is such that corrosion could be a serious problem, the spacing of welds may be less than the specified maximum.*

11.4.13.3

Except as otherwise required by the applicable design specification, tension members composed of two or more shapes, plates, or bars separated from one another by intermittent fillers shall have the components interconnected at fillers spaced so that the slenderness ratio of any component between points of interconnection shall not exceed the smaller of 300 or the design slenderness ratio of the tension member. Tension members composed of two plate components in contact or a shape and a plate component in contact shall have the components interconnected so that the clear spacing between welds does not exceed 36 times the thickness of the thinner plate nor 450 mm (18 in). Tension members composed of two or more shapes in contact shall have the components interconnected so that the clear spacing between welds does not exceed 600 mm (24 in), except where it can be determined that a greater spacing would not affect the satisfactory performance of the member.

11.5 Workmanship

11.5.1 Termination of groove welds

Extensions or run-off bars used at termination of groove welds need not be removed unless required by the engineer.

11.5.2 Groove weld backing

Steel backing in groove welds need not be removed unless required by the engineer.

11.5.3 Dimensional tolerances

11.5.3.1

The dimensions of structural members shall be within the tolerances specified in Clause 5.8. In addition, deviations from flatness of webs having a depth D and a thickness t in panels bounded by stiffeners and/or flanges whose least panel dimension is d shall not exceed the following:

a) intermediate stiffeners on both sides of web:
   - i) where $D/t < 150$ — maximum deviation = $d/100$; and
   - ii) where $D/t \geq 150$ — maximum deviation = $d/80$;

b) intermediate stiffeners on one side only of web:
   - i) where $D/t < 100$ — maximum deviation = $d/100$; and
   - ii) where $D/t \geq 100$ — maximum deviation = $d/67$; and

c) no intermediate stiffeners: maximum deviation = $D/150$.

If architectural considerations require tolerances more restrictive than those described above, specific reference shall be included in the bid documents.

Deviation from flatness of girder webs shall be determined by measuring offsets from a straight-edge whose length is not less than the least dimension of any panel. The straight-edge shall be placed in any position of maximum deviation on the web, with the ends of the straight-edge adjacent to opposite panel boundaries (see Annex I).

11.5.3.2

Ends of girder webs that have been drilled or subpunched and reamed either during assembly or to a template may have distortion greater than the tolerances of Clause 11.5.3.1, provided that, when the splice plates are bolted, the web assumes an acceptable dimensional tolerance.

11.5.4 Quality of welds

11.5.4.1 General

All welds shall be visually inspected.

Note: *A minimum acceptable level of workmanship is implicit in the overall provisions of this Standard. However, to verify this quality, specific criteria have been established separately for each of the methods of inspection. They appear in Clause 11.5.4. In case of defects constituting gross nonconformance with the Standard, the provisions of Clause 7.3.4 apply.*

11.5.4.2 Visual examination

A weld subject to visual inspection shall be considered acceptable if visual inspection shows

a) no surface cracks;
b) no visible lack of fusion between welds and base metal;
c) no craters;
d) weld profiles in accordance with Clause 5.9;
e) that the sum of diameters of visible porosity does not exceed 10 mm (3/8 in) in any linear 25 mm (1 in) length of weld and does not exceed 20 mm (3/4 in) in any 300 mm (12 in) length of weld. Any individual pore shall have a dimension not exceeding 2.5 mm (3/32 in); and
f) for material less than 25 mm (1 in) thick, undercut not exceeding 1 mm (1/32 in) for any length of weld, with the following exception: undercut shall not exceed 1.6 mm (1/16 in) for any accumulated length up to 50 mm (2 in) in any 300 mm (12 in). For material equal to or greater than 25 mm (1 in) thick, undercut shall not exceed 1.6 mm (1/16 in) for any length of weld.

11.5.4.3 High restraint joints and quenched and tempered steels

Visual inspection of welded joints subject to high restraint and/or joints of quenched and tempered steels shall be delayed as long as practicable and preferably not less than 48 h after completion of the welds.

11.5.4.4 Radiographic and magnetic particle examination

Welds that are subject to radiographic or magnetic particle examination, in addition to visual inspection, shall have no cracks and shall be unacceptable if porosity* or fusion-type discontinuities† that are 2.5 mm (3/32 in) or larger in greatest dimension exceed any of the following limits in size or frequency of occurrence:

a) any such individual discontinuity having its greatest dimension larger than two-thirds the joint or weld throat thickness involved, except that, regardless of joint or weld throat thickness, no such discontinuity shall be larger than 20 mm (3/4 in) in greatest dimension;
b) any group of such discontinuities in line where the sum of the greatest dimension of all such discontinuities is larger than t (t being the weld throat thickness involved) in a length of $6t$, and if the space between each pair of adjacent discontinuities is less than 3 times the greatest dimension of the larger of the discontinuities. When the length of the weld being examined is less than $6t$, the permissible sum of the greatest dimensions of all such discontinuities shall be proportionately less than t;
c) any such discontinuity closer than 3 times its greatest dimension to the end of a groove welded joint carrying primary tensile stress or to the edge of a transverse weld; or
d) independent of the requirements of Items a), b), and c), the sum of the greatest dimension of scattered porosity and fusion-type discontinuities less than 2.5 mm (3/32 in) in greatest dimension shall not exceed 10 mm (3/8 in) in any linear 25 mm (1 in) of weld.

* *Porosity signifies gas pockets and any similar generally globular-type voids.*

† *Fusion-type defect signifies slag inclusions, incomplete fusion, inadequate penetration, and similar generally elongated defects.*

11.5.4.5 Ultrasonic examination

Welds that are subject to ultrasonic examination in addition to visual inspection shall have no cracks. Other weld discontinuities shall be accepted or rejected on the basis of their defect ratings and their lengths in accordance with Table 11.3 (FA technique) or Table X.6 (TCG technique).

11.5.4.6 Liquid penetrant examination

Welds that are subject to liquid penetrant examination shall be evaluated on the basis of the requirements for visual inspection. The evaluation shall compare the physical size of the discontinuity with the acceptance standard defined for visual inspection.

11.5.4.7 Examination of high restraint joints or quenched and tempered steels

When nondestructive examination is specified, the examination of welded joints subject to high restraint and/or joints of quenched and tempered steels shall be delayed as long as practicable and preferably not less than 48 h after completion of the welds.

ΔΔ

Table 11.1
Base metals and matching electrode classification for statically loaded structures

(See Clauses 3.2.3, 3.2.4, 3.2.5, 3.2.6, 3.2.7, 5.2.1.2, 5.2.1.3, 5.2.1.5, 6.3.2, 6.3.3, 11.2, 11.3.3, and L.4 and Tables 5.3, 11.2, and S.1.)

Note: *For mandatory use of low-hydrogen (SMAW) or FCAW and MCAW electrodes with diffusible hydrogen designators, see Clauses 5.2.2.2 and 5.2.4.3 and Table 5.3.*

Base metal									CSA W48 electrode and electrode-flux classifications(1,2)				
									SMAW				SAW
Steel group	Specified min. tensile strength of base metal, MPa (ksi)	CSA G40.21	CSA G40.21	ASTM	ABS	Lloyd's	IACS	API	Carbon steel	Low-alloy steel	GMAW, GTAW	FCAW, MCAW (7,8)	
1	Up to 400 incl. when $F_y < 250$ (up to 60 incl. when $F_y < 36$)			A36 [t > 203 mm (8 in)] A53 Grade B A106 Grade B A131 Grades A, B, D, and E A139 Grade B A381 Grade Y35 A441 [Normalized t > 102 mm (4 in)] A500 Grade A A515 Grades 55 and 60 A516 Grades 55 and 60 A524 Grade I and II A573 Grade 58 A709 Grade 36 [≤ 20 mm (3/4 in)] A1008 SS Grades 30 and 33 Type 1 A1011 SS Grades 30 and 33 A1018 SS Grades 30 and 33	Grades A, B, D, E	Grades A, B, D, E	Grades A, B, D, E		E43XX E49XX	E49XX-X	B-G 43A X XXX B-G 49A X XXX	E43XT-X E49XT-X E43XC-X E49XC-X	F43XX-EXXX F49XX-EXXX
2	Up to 400 including when $F_y \geq 250$ (up to 60 incl. when $F_y \geq 36$)	260W 260WT 300W (HSS)	38W 38WT 44W (HSS)	A36 [$t \leq$ 203 mm (8 in)] A441 [102 mm $\leq t \leq$ 203 mm (8 in) or normalized 38 mm (1-1/2 in) < t < 102 mm (4 in)] A500 Grade B A501 Grade A				5L Grade X42 5L Grade B	E43XX E49XX	E49XX-X	B-G 43A X XXX B-G 49A X XXX	E49XT-X E43XT-X E49XC-X E43XC-X	F49XX-EXXX F43XX-EXXX

(Continued)

Table 11.1 (Continued)

Base metal									CSA W48 electrode and electrode-flux classifications[1,2]				
									SMAW				SAW
Steel group	Specified min. tensile strength of base metal, MPa (ksi)	CSA G40.21	CSA G40.21	ASTM	ABS	Lloyd's	IACS	API	Carbon steel	Low-alloy steel	GMAW, GTAW	FCAW, MCAW[7,8]	
				A572 Grade 42 A709 Grade 36 [> 20 mm (3/4 in)] A1008 SS Grade 40 Type 1 A1008 HSLAS Grade 45 Class 1 and 2 A1008 HSLAS Grade 50 Class 2 A1008 HSLAS-F Grade 50 A1011SS Grade 36 Type 1, 40 and 45 A1011 HSLAS Grade 45 Class 1 and 2 A1011 HSLAS Grade 50 Class 2 A1011 HSLAS-F Grade 50 A1018 SS Grades 36 and 40 A1018 HSLAS Grade 45 Class 1 and 2 A1018 HSLAS Grade 50 Class 2 A1018 HSLAS-F Grade 50									
3	Over 400 to 480 inclusive (over 60 to 70 inclusive)	300W 300WT 345WM 345WMT 350W 350WT 350A[3] 350AT[3] 380W 380WT	44W 44WT 50WM 50WMT 50W 50WT 50A[3] 50AT[3] 55W 55WT	A131 Grades AH32, DH32 and EH32 A242[3][4] A441 [$t \le 102$ mm (4 in) or normalized $t \le 38$ mm (1-1/2 in)] A500 Grade C A501 Grade B A516 Grades 65 and 70 A529 Grades 50 and 55	Grades AH32, DH32, EH32	Grades AH32, DH32, EH32, FH32	Grades A32, D32, E32, F32	5L Grade X52 2H Grade 42 2W Grade 42 2Y Grade 42 and 50	E49XX	E49XX-X	B-G 49A X XXX	E49XT-X E49XC-X	F49XX-EXXX

(Continued)

Table 11.1 (Continued)

Base metal									CSA W48 electrode and electrode-flux classifications[1,2]				
									SMAW				SAW
Steel group	Specified min. tensile strength of base metal, MPa (ksi)	CSA G40.21	CSA G40.21	ASTM	ABS	Lloyd's	IACS	API	Carbon steel	Low-alloy steel	GMAW, GTAW	FCAW, MCAW[7,8]	
		345WM 345WMT	50WM 50WMT	A537 Class 1 A572 Grades 50 and 55 A573 Grade 65 A1085 A588[3] A595 Grades A, B, and C A606 A618 Grades Ia and Ib, II, and III A633 Grades A, C, and D A709 Grades 50, 50W, 50S, HPS 50W A710 Grade A, Class 2 > 50 mm A808 [t < 65mm] A847 A913 Grade 50 A992 A1008 HSLAS Grade 50 Class 1 A1008 HSLAS Grade 55 Class 1 and 2 A1011 SS Grades 50 and 55 A1011 HSLAS Grade 50 Class 1 A1011 HSLAS Grade 55 Classes 1 and 2 A1018 HSLAS Grade 50 Class 1 A1018 HSLAS Grade 55 Class 1 and 2									

(Continued)

Table 11.1 (Continued)

Base metal									CSA W48 electrode and electrode-flux classifications[1,2]				
									SMAW				SAW
Steel group	Specified min. tensile strength of base metal, MPa (ksi)	CSA G40.21	CSA G40.21	ASTM	ABS	Lloyd's	IACS	API	Carbon steel	Low-alloy steel	GMAW, GTAW	FCAW, MCAW[7,8]	
				A1018 HSLAS Grade 60 Class 2 A1018 HSLAS-F Grade 60 Class 2 A1085									
4	Over 480 to 550 inclusive (over 70 to 80 inclusive)	400W 400WT 400A[3] 400AT[3] 450W 450WT	60W 60WT 60A[3] 60AT[3] 65W 65WT	A131 Grades AH36, DH36 and EH36 A537 Class 2 A572 Grades 60 and 65 A633 Grade E A710 Grade A, Class 2 ≤ 50 mm A710 Grade A, Class 3 > 50 mm A913 Grade 60, 65 A1011 Grades 60 and 65 A1018 HSLAS Grade 70 Class 2 A1018 HSLAS-F Grade 70 Class 2	Grades AH36, DH36, EH36, FH36	Grades AH36, DH36, EH36, FH36	Grades A36, D36, E36, F36	2H Grade 50 2MTI Grade 50 and 52 2W Grade 50 2W Grade 50T 2Y Grade 50T 2W Grade 60 2Y Grade 60		E55XX-X	ER55S-XX E55C-XX	E55XTX-X E55C-X-X	F55XX-EXXX F55XX-ECXXX
5	Over 550 to 620 inclusive (over 80 to 90 inclusive)	480W 480WT 480A[3] 480AT[3] 550W 550WT	70W 70WT 70A[3] 70AT[3] 80W 80WT	A709 Grade HPS70W A852 A1011 Grade 70 A913 Grade 70						E62XX-X	ER62S-XX	E62XTX-X E62C-X-X	F62XX-EXXX F62XX-ECXXX

(Continued)