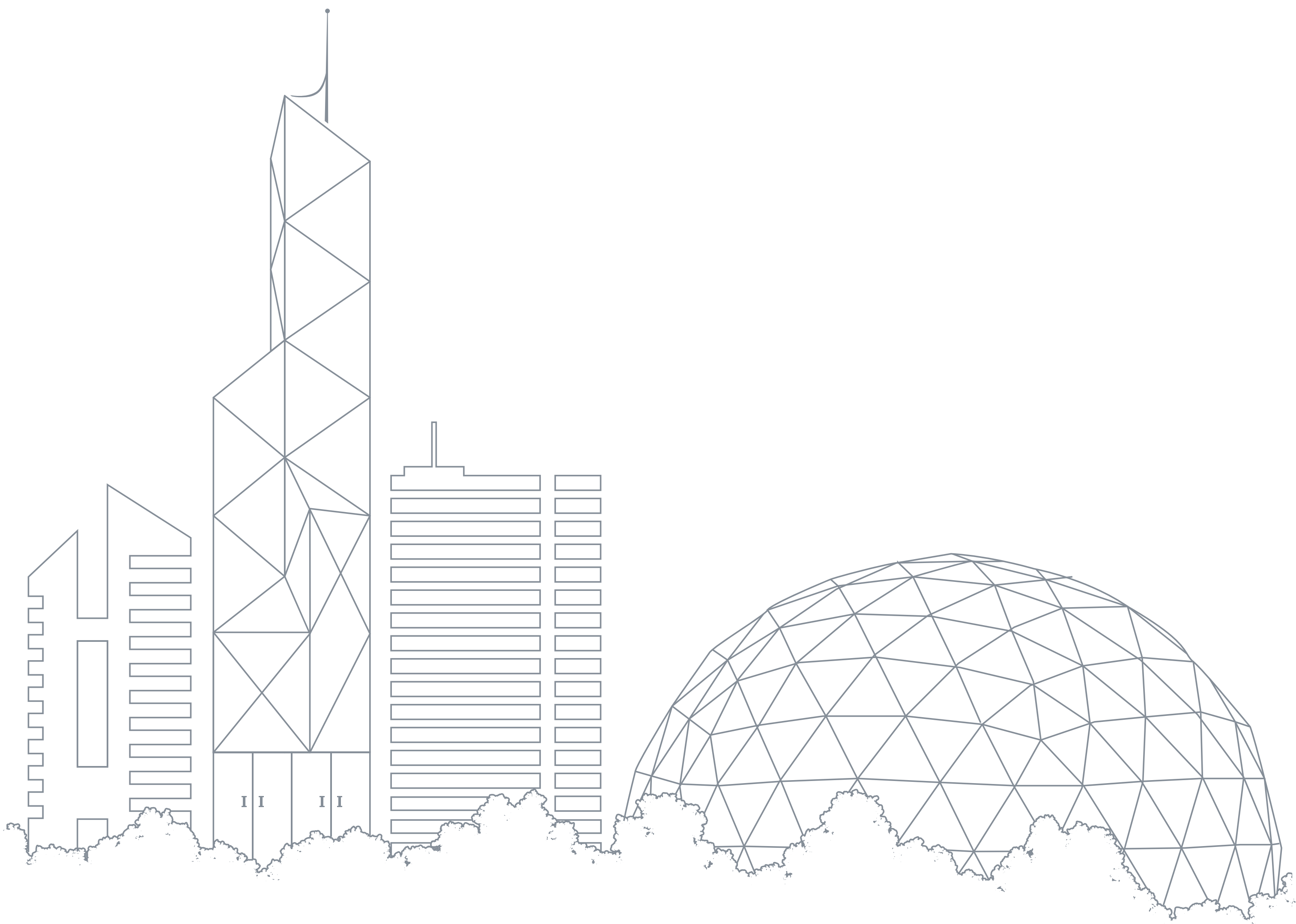
The Aluminum Association

ALUMINUM DESIGN MANUAL 2015



$395.00
ISBN 978-0-9863631-0-8

2015 Aluminum Design Manual

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FOREWORD

The *Aluminum Design Manual* includes an aluminum structural design specification and accompanying commentary, a supplemental design guide, material properties, properties of common shapes, design aid tables, illustrative design examples, and guidelines for aluminum sheet metal used in construction.

This edition of the *Aluminum Design Manual* is the product of the efforts of the Aluminum Association Engineering and Design Task Force, whose members are listed below.

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Please check **www.aluminum.org** for postings of 2015 *Aluminum Design Manual* errata.

Aluminum Design Manual

PART I

Specification for Aluminum Structures

FOREWORD

The first edition of the *Specification for Aluminum Structures* was published in November, 1967, followed by subsequent editions in 1971, 1976, 1982, 1986, 1994, 2000, 2005, 2010, and 2015. This 10th edition of the *Specification*, developed as a consensus document, includes new or revised provisions concerning

- material specifications (A.3.1)
- modulus of elasticity, compressive yield strength and shear ultimate strength (A.3.1)
- cast alloy strengths (A.3.3)
- effective net area (D.3.2)
- axial compression member buckling strength (E.2)
- alternative methods for determining column and beam elastic strengths (E.2, F.2.1.4)
- flexural strength (F.1, F.2, F.3, F.4)
- shear in webs supported on one edge (G.3)
- shear strengths of rods (G.5)
- shear and torsional strengths (G.1, H.2)
- welded connections (J.2)
- slip-critical connections (J.3.7)
- pins (J.6)
- fabrication of edges (M.2, M.4)
- contact with dissimilar materials (M.7)
- quality control and quality assurance (Chapter N)
- testing (Appendix 1)
- fatigue (Appendix 3)

The Aluminum Association gratefully acknowledges the efforts of the Engineering Advisory Committee in developing the *Specification*.

THE ALUMINUM ASSOCIATION ENGINEERING ADVISORY COMMITTEE

GUIDELINES FOR THE PREPARATION OF TECHNICAL INQUIRIES ON THE SPECIFICATION FOR ALUMINUM STRUCTURES

Technical inquiries to obtain an interpretation or request a revision to the *Specification for Aluminum Structures* should be directed to:

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Comments on other parts of the *Aluminum Design Manual* are also welcome.

Inquiries should include the inquirer's name, affiliation, and address. Each inquiry should address a single section of the *Specification* unless the inquiry involves two or more interrelated sections. The section and edition of the *Specification* should be identified.

Requests for interpretations should be phrased, where possible, to permit a "yes" or "no" answer and include the necessary background information, including figures where appropriate.

Requests for revisions should include proposed wording for the revision and technical justification.

Inquiries are considered at the first meeting of the Aluminum Association Engineering and Design Task Force following receipt of the inquiry.

Specification for Aluminum Structures

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Symbols

The section numbers in which the symbol appears is given in parentheses after the symbol.

A_b = nominal cross-sectional area of the bolt (unthreaded body area) (J.3.7.4)

A_{BM} = cross-sectional area of the base metal (J.2.5, Table J.2.2)

A_e = effective net area (D.2, D.3.2, J.7.1)

A_{ewz} = effective net area in the weld-affected zone (D.2)

A_f = area of the member farther than 2*c*/3 from the neutral axis, where *c* is the distance from the neutral axis to the extreme compression fiber (F.4)

A_g = gross cross-sectional area (B.5.4, D.2, E.2, E.2.2, E.3.1, E.3.2, E.4, H.2, J.7.1, J.7.2)

A_{gc} = gross cross sectional area of the element in compression (B.5.5)

A_{gt} = gross cross sectional area of the element in tension (J.7.3)

A_{gv} = gross area in shear (J.7.3)

A_i = area of element *i* (E.3.1)

A_L = cross-sectional area of the longitudinal stiffener (B.5.5.3)

A_n = net area (D.3.1, D.3.2, G.2, G.3, G.4, G.5, J.7.1)

A_{nt} = net area in tension (J.7.3)

A_{nv} = net area in shear (J.7.2, J.7.3)

A_{pb} = projected bearing area (J.8)

A_r = root area of the screw (J.5.4.3, J.5.5.3)

A_s = area of the intermediate stiffener (B.5.4.4)

A_{sn} = thread stripping area of internal thread per unit length of engagement (J.5.4.1.1)

A_v = web area (G.1, G.2, G.3, G.4, G.5)

A_{we} = effective area of a weld (J.2.3, J.2.5, Table J.2.2)

A_{wz} = cross-sectional area of the weld-affected zone, which extends 1 in. (25 mm) to each side of the centerline of a weld (B.5.4, D.2, E.2, F.4, G.1, G.2, G.3, G.4, G.5, H.2)

A_{wzc} = cross sectional area of the weld-affected zone in compression (B.5.5)

B_{br} = buckling constant intercept for flexural compression in flat elements (Table B.4.1, Table B.4.2, B.5.5.1, B.5.5.2, B.5.5.3, F.5)

B_c = buckling constant intercept for member buckling (Table B.4.1, Table B.4.2, B.5.4.4, E.2)

B_p = buckling constant intercept for uniform compression in flat elements (Table B.4.1, Table B.4.2, B.5.4.1, B.5.4.2, B.5.4.6, B.5.5.5, F.5)

B_s = buckling constant intercept for shear in flat elements (Table B.4.1, Table B.4.2, G.2, G.3, G.4, H.2.1)

B_t = buckling constant intercept for uniform compression in curved elements (Table B.4.1, Table B.4.2, B.5.4.5, B.5.5.4)

B_{tb} = buckling constant intercept for flexural compression in curved elements (Table B.4.1, Table B.4.2, B.5.5.4)

C = torsional shear constant (H.2.2)

C_b = coefficient that accounts for moment gradient along a beam's length (F.4.1, F.4.1.1, F.4.1.2, F.4.2.1, F.4.2.3, F.4.2.4, F.4.2.5, F.4.3, F.5(c), F.5.1, F.5.2, 6.3.2.1)

C_{br} = buckling constant intersection for flexural compression in flat elements (Table B.4.1, Table B.4.2, B.5.5.2, F.5)

C_c = buckling constant intersection for member buckling (Table B.4.1, Table B.4.2, B.5.4.4, E.2, F.4)

C_d = brace coefficient (6.3.1.1, 6.3.1.2)

C_f = coefficient used to determine the allowable stress range for fatigue (Table 3.2, 3.2, 3.3)

C_n = correction factor for the number of tests (1.3.2)

C_p = buckling constant intersection for uniform compression in flat elements (Table B.4.1, Table B.4.2, B.5.4.1, B.5.5.5, F.5)

C_{pov} = coefficient for determining the pull-over strength of a screw (J.5.4.2)

C_s = buckling constant intersection for shear in flat elements (Table B.4.1, Table B.4.2, G.2, G.3, G.4, H.2.1)

C_t = buckling constant intersection for uniform compression in curved elements (Table B.4.1, Table B.4.2, B.5.4.5, B.5.5.4)

C_{tb} = buckling constant intersection for flexural compression in curved elements (Table B.4.1, Table B.4.2, B.5.5.4)

C_w = warping constant (E.2.2, F.4.2.1, F.4.2.5)

C_{wa}, C_{wb}, C_{w1}, C_{w2}, C_{w3}
= coefficients used to determine web crippling strength (J.9.1)

C_1 = coefficient used to determine *U* (F.4.2.5)

C_2 = coefficient used to determine *U* (F.4.2.5)

D = nominal diameter of the fastener (Table J.2.2, J.3.1, J.3.4, J.3.5, J.3.6, J.5, J.5.4.1.1, J.5.4.1.2, J.5.4.2, J.5.5.1, J.5.5.2, J.6.4, J.6.5)

D = diameter of a rod (H.2.3, G.5)

D = outside diameter of a tube (Table 3.1)

D_{br} = buckling constant slope for flexural compression in flat elements (Table B.4.1, Table B.4.2, B.5.5.1, B.5.5.2, B.5.5.3, F.5)

D_c = buckling constant slope for member buckling (Table B.4.1, Table B.4.2, B.5.4.4, E.2)

D_h = nominal diameter of the hole (J.4.5, J.4.6, Table J.5.1, Table J.5.2, J.5.4.2)

D_i = inside diameter of the pipe or tube (G.4)

D_n = nominal dead load (1.3.2, 4.1.3, 5.4)

D_o = outside diameter of the pipe or tube (G.4)

D_p = buckling constant slope for uniform compression in flat elements (Table B.4.1, Table B.4.2, B.5.4.1, B.5.4.2, B.5.4.6, B.5.5.5, F.5)

D_S = depth of a stiffener (B.5.4.3)

D_s = buckling constant slope for shear in flat elements (Table B.4.1, Table B.4.2, G.2, G.3, G.4, H.2.1)

D_{ss} = screw slot inside diameter (Table J.5.3, J.5.4.1.2)

D_t = buckling constant slope for uniform compression in curved elements (Table B.4.1, Table B.4.2, B.5.4.5, B.5.5.4)

D_{tb} = buckling constant slope for flexural compression in curved elements (Table B.4.1, Table B.4.2, B.5.5.4)

D_{ws} = larger of the nominal washer diameter and the screw head diameter, but no greater than 5/8 in. (16 mm) (J.5.4.2)

E = modulus of elasticity (Table A.3.1, Table B.4.1, Table B.4.2, B.5.4.1, B.5.4.2, B.5.4.3, B.5.4.4, B.5.4.5, B.5.4.6, B.5.5.1, B.5.5.2, B.5.5.3, B.5.5.4, B.5.5.5, B.5.6, E.2, E.2.2, E.4, F.4, F.4.2.5, F.4.3, F.5, F.5.1, F.5.2, G.2, G.3, G.4, H.2.1, J.9.1, Table 4.1, 6.3.2.1, 6.3.2.2)

E_m = modulus of elasticity at elevated temperatures (4.2.3.1, Table 4.1)

F_b = stress corresponding to the flexural strength (B.5.5, B.5.5.1, B.5.5.2, B.5.5.3, B.5.5.4, F.4.3, F.3.1, F.3.2, H.3.1, H.3.2)

F_{bo} = stress corresponding to the flexural compressive strength for an element if no part of the cross section were weld-affected (B.5.5)

F_{bw} = stress corresponding to the flexural compressive strength for an element if the entire cross section were weld-affected (B.5.5)

F_c = stress corresponding to the uniform compressive strength (B.5.4, B.5.4.1, B.5.4.2, B.5.4.3, B.5.4.4, B.5.4.5, B.5.4.6, E.2, E.3.2, E.4, F.3.1, H.3.1, H.3.2)

F_{ci} = local buckling stress of element i computed per Section B.5.4.1 through B.5.4.5 (E.3.1)

F_{co} = stress corresponding to the uniform compressive strength for an element if no part of the cross section were weld-affected (B.5.4)

F_{cw} = stress corresponding to the uniform compressive strength for an element if the entire cross section were weld-affected (B.5.4)

F_{cy} = compressive yield strength (Table A.3.1, Table B.4.1, Table B.4.2, B.5.4.1, B.5.4.2, B.5.4.3, B.5.4.4, B.5.4.5, B.5.4.6, B.5.5.1, B.5.5.2, B.5.5.3, B.5.5.4, B.5.5.5, E.2, E.3.1, F.2, F.3.1, F.4, F.5, J.9.1)

F_{cyw} = compressive yield strength of weld-affected zones (E.2)

F_e = elastic buckling stress (B.5.4.6, B.5.5.5, Table B.5.1, E.2.2, E.4, F.4.3, L.3)

F_{ex} = elastic buckling stress for buckling about the x-axis (E.2.2)

F_{ey} = elastic buckling stress for buckling about the y-axis (E.2.2)

F_{ez} = elastic buckling stress for torsional buckling (E.2.2)

F_m = mean value of the fabrication factor (1.3.2)

F_n = strength of an A 325 bolt (J.3.7.4)

F_{nBM} = nominal stress of the base metal corresponding to its welded ultimate strength from Table A.3.3 or Table A.3.3M (J.2.5)

F_{nt} = tensile strength of an A 325 bolt determined in accordance with the *Specification for Structural Steel Buildings(ANSI/AISC 360)* (J.3.7.4)

F_{nv} = shear strength of an A 325 bolt determined in accordance with the *Specification for Structural Steel Buildings(ANSI/AISC 360)* (J.3.7.4)

F_{nw} = nominal stress of the weld metal corresponding to its ultimate strength from Table A.3.6 (J.2.5)

F_s = shear stress corresponding to the shear strength (G.1, G.2, G.3, G.4, G.5, H.2, H.2.1, H.2.2, H.3.1, H.3.2)

F_{so} = shear stress corresponding to the unwelded shear strength (G.1, H.2)

F_{ST} = stress corresponding to the uniform compressive strength of an element supported on both edges (B.5.4.3)

F_{su} = shear ultimate strength (Table A.3.1, A.3.5, A.3.6, G.2, G.3, G.4, G.5, H.2, J.3.5, J.4.5, J.5.5.3, J.6.4, J.7.2, J.7.3)

F_{suw} = shear ultimate strength of weld-affected zones (G.2, G.3, G.4, G.5, H.2)

F_{sw} = shear stress corresponding to the welded shear strength (G.1, H.2)

F_{sy} = shear yield strength (Table A.3.1, Table B.4.1, Table B.4.2, G.2, G.3, G.4, H.2.1, H.2.3, J.6.4, J.7.2, J.7.3)

F_{syw} = shear yield strength of weld-affected zones (G.2, H.2.3)

F_{tu} = tensile ultimate strength (Table A.3.1, Table A.3.3, A.3.2, A.3.3, A.3.5, D.2, F.2, J.3.4, J.3.6, J.4.6, J.5.4.1.2, J.5.4.3, J.5.5.1, J.6.4, J.6.5, J.7.3, J.8, Table 4.2)

F_{tum} = tensile ultimate strength at elevated temperatures (4.2.3.1)

F_{tuw} = tensile ultimate strength of weld-affected zones (A.3.2, A.3.4, D.2, Table J.2.2)

F_{tu1} = tensile ultimate strength of the part in contact with the screw head or washer (J.5.4.2)

F_{tu2} = tensile ultimate strength of member not in contact with the screw head (J.5.4.1.1, J.5.5.2)

F_{ty} = tensile yield strength (Table A.3.1, Table A.3.3, Table A.3.4, A.3.2, A.3.3, D.2, F.2, J.6.4, J.7.3, 1.4, Table 4.2)

F_{tym} = tensile yield strength at elevated temperatures (4.2.3.1)

F_{tyw} = tensile yield strength of weld-affected zones (A.3.2, D.2)

F_{ty1} = tensile yield strength of the part in contact with the screw head (J.5.4.2)

F_{ty2} = tensile yield strength of member not in contact with the screw head (J.5.4.1.1)

F_{UT} = stress corresponding to the uniform compressive strength of an element supported on one edge only (B.5.4.3)

G = shear modulus of elasticity (Table A.3.1, E.2.2)

G_f = the grip of a bolt (J.3.5)

$$H = 1 - \frac{x_0^2 + y_0^2}{r_0^2} \qquad \text{(E.2.2)}$$

I_f = moment of inertia of the flange group about the cross section's neutral axis. The flange group consists of the flat elements in uniform compression or uniform tension and their edge or intermediate stiffeners (F.3.1)

I_L = moment of inertia of the longitudinal stiffener about the web of the beam (B.5.5.3)

I_o = moment of inertia of a section comprising the stiffener and one half of the width of the adjacent sub-elements and the transition corners between them taken about the centroidal axis of the section parallel to the stiffened element (B.5.4.4)

I_s = moment of inertia of the transverse stiffener (G.2)

I_w = moment of inertia of the web group about the cross section's neutral axis. The web group consists of the flat elements in flexure and their intermediate stiffeners. (F.3.1)

I_w = moment of inertia about the major principal axis (F.5.2)

I_x = moment of inertia about the *x*-axis (E.2.2, F.4.2.5)

I_y = moment of inertia about the *y*-axis (E.2.2, F.4.1.2, F.4.2.1, F.4.2.2, F.4.2.3, F.4.2.5, 6.3.2.1)

I_{yc} = moment of inertia of the compression flange about the *y*-axis (F.4.1.2, F.4.2.2, F.4.2.5)

I_{yt} = moment of inertia of the tension flange about the *y*-axis (F.4.2.2)

I_z = moment of inertia about the minor principal axis (F.5.2)

J = torsion constant (E.2.2, F.4.2.1, F.4.2.2, F.4.2.3, F.4.2.5, H.2.1)

K = statistical coefficient based on the number of tests *n* (1.3.1)

K_s = a coefficient used to determine the pull-out strength of a screw (J.5.4.1.1)

L = member length (E.2, E.2.1, F.4, J.1.3, 6.1, 6.2.2, 6.3.2.1, 6.3.2.2)

L_b = length of a beam between brace points or between a brace point and a cantilever's free end (F.4.2.1, F.4.2.3, F.4.2.4, F.4.2.5, F.4.3, F.5.1, F.5.2, 6.1, 6.2.1, 6.2.2, 6.3.1.1, 6.3.1.2, 6.3.2.1, 6.3.2.2, 6.4)

L_C = length of the connection in the direction of load, measured from the center of fasteners or the end of welds (D.3.2)

L_e = length of full thread engagement of a screw in a hole or screw slot not including tapping or drilling point (J.5.4.1.1, J.5.4.1.2)

L_n = nominal live load (1.3.2, 4.1.3, 5.4)

L_s = length of pipe or tube between transverse stiffeners, or overall length if no transverse stiffeners are present (H.2.1)

L_v = length of pipe or tube from maximum to zero shear force (G.4)

L_{we} = effective length of a weld (J.2.1.3, J.2.2.2, Table J.2.2)

L_x = unbraced length for buckling about the *x*-axis (E.2.2)

L_y = unbraced length for buckling about the *y*-axis (E.2.2)

L_z = unbraced length for twisting (E.2.2)

M_A = absolute value of the moment at the quarter point of the unbraced segment (F.4.1.1)

M_B = absolute value of the moment at the midpoint of the unbraced segment (F.4.1.1)

M_C = absolute value of the moment at the three-quarter point of the unbraced segment (F.4.1.1)

M_c = design or allowable flexural strength (H.1, J.6.4, J.9.3)

M_e = elastic lateral-torsional buckling moment (F.4.2.5, F.5, F.5.1, F.5.2)

M_i = flexural strength of member of intermediate thickness t_i (1.4.2)

M_m = mean value of the material factor (1.3.2)

M_{max} = absolute value of the maximum moment in the unbraced segment (F.4.1.1, F.4.1.2)

M_n = nominal strength moment (F.1, F.5, F.5.1, F.5.2, J.6.4)

M_{nlb} = nominal flexural strength for the limit state of local buckling (F.3, F.3.1, F.3.2, F.3.3)

M_{nmb} = nominal flexural strength for the limit state of lateral-torsional buckling (F.4, F.4.3)

M_{nmbo} = lateral-torsional buckling strength if no part of the cross section were weld-affected (F.4)

M_{np} = nominal flexural strength for the limit state of yielding (B.5.5.4, B.5.5.5, F.2, F.4)

M_{nmbw} = lateral-torsional buckling strength if the entire cross section were weld-affected (F.4)

M_r = required flexural strength using LRFD or ASD load combinations (H.1, J.6.4, J.9.3, 6.3.1.1, 6.3.1.2, 6.3.2.1, 6.3.2.2, 6.4)

M_{rb} = required bracing flexural strength using LRFD or ASD load combinations (6.3.2.1)

M_y = yield moment about the axis of bending (F.5)

M_1 = flexural strength of member of thinnest material (1.4.2)

M_2 = flexural strength of member of thickest material (1.4.2)

N = number of stress cycles (3.2, 3.3, Table 3.2)

N_S = number of stress ranges in the spectrum (3.3)

P_c = available axial force (H.1)

P_{nc} = nominal axial compressive strength (E.1, E.2, E.3.1, E.3.2, E.4)

P_{no} = nominal member buckling strength if no part of the cross section were weld-affected (E.2)

P_{nt} = nominal axial tensile strength (D.1, D.2)

P_{nw} = nominal member buckling strength if the entire cross section were weld-affected (E.2)

P_r = required axial force using LRFD or ASD load combinations (C.2, H.1, 6.2.1, 6.2.2, 6.4)
P_{rb} = required bracing strength (6.2.1, 6.2.2, 6.3.1.1, 6.3.1.2)
P_y = axial yield strength (C.2)
R = outside radius of a pipe or tube (H.2.1)
R = transition radius of a fatigue detail (Table 3.1)
R_a = required strength for ASD (B.3.2.2)
R_b = radius of curved elements taken at the mid-thickness of the element (B.5.2, B.5.4.5, B.5.5.4, Table B.5.1, G.4, H.2.1)
R_c = available concentrated force determined in accordance with Section J.9.1 (J.9.3)
R_i = inside bend radius at the juncture of the flange and web; for extruded shapes, $R_i = 0$ (J.9.1)
R_{ti} = strength of ith test (1.3.2)
R_{tm} = mean strength of all tests (1.3.1, 1.3.2)
R_n = nominal strength (B.3.2.1, B.3.2.2, J.2, J.2.5, J.3.4, J.3.5, J.3.6, J.3.7.4, J.4.5, J.4.6, J.5.4, J.5.4.1.1, J.5.4.1.2, J.5.4.2, J.5.4.3, J.5.5, J.5.5.1, J.5.5.2, J.5.5.3, J.6.4, J.6.5, J.7.1, J.7.2, J.7.3, J.7.4, J.8, J.9.1, 1.3.1)
R_r = required concentrated force (J.9.3)
R_S = the ratio of minimum stress to maximum stress for fatigue design (Table 3.1)
R_u = required strength for LRFD (B.3.2.1)
S = section modulus (B.5.5.4)
S_c = section modulus on the compression side of the neutral axis (F.2, F.5, F.5.1)
S_n = nominal snow load (4.1.3)
S_{ra} = applied stress range, the algebraic difference between the minimum and maximum nominal stresses perpendicular to the plane of expected cracking determined by elastic methods (3.2)
S_{rd} = design stress range (3.2, 3.3)
S_{re} = equivalent applied stress range (3.3)
S_{ri} = ith applied stress range in the spectrum (3.3)
S_t = section modulus on the tension side of the neutral axis (F.2)
S_w = size of a weld (J.2.1.2, J.2.2.2, Table J.2.2)
S_{we} = effective throat of a fillet weld (J.2.2.1)
S_x = section modulus about the x-axis (F.4.2.1, F.4.2.2)
S_{xc} = section modulus about the compression side of the x-axis (B.5.5.5, F.3.2, F.4, F.4.2.3, F.4.2.5, F.4.3)
T, T_1, T_2 = temperature (A.3.1.1)
T = nominal forces and deformations due to the design-basis fire defined in Section 4.2.1 (4.1.3)
T_n = nominal torsional strength (H.2, H.2.1, H.2.2, H.2.3, H.2.4)
U = coefficient used to determine M_e (F.4.2.5)
V = shear force on the web at the transverse stiffener (G.2)
V_c = available shear strength (J.6.4)
V_F = coefficient of variation of the fabrication factor (1.3.2)
V_M = coefficient of variation of the material factor (1.3.2)
V_n = nominal shear strength (G.1, G.2, G.3, G.4, G.5, J.6.4)
V_P = coefficient of variation of the ratio of the observed failure loads divided by the average value of all the observed failure loads (1.3.2)
V_Q = coefficient of variation of the loads (1.3.2)
V_r = required shear strength (J.6.4)
X_i = result of the ith test (1.3.2)
Z = plastic section modulus (F.2)
a = fatigue detail dimension parallel to the direction of stress (Table 3.1)
a_1 = shorter dimension of rectangular panel (G.2)
a_2 = longer dimension of rectangular panel (G.2)
b = element width (B.5.1, B.5.3, B.5.4, B.5.4.1, B.5.4.2, B.5.4.3, B.5.4.4, B.5.5.1, B.5.5.2, B.5.5.3, Table B.5.1, F.5, F.5.1, F.5.2, G.2, G.3, J.1.3, L.3)
b = fatigue detail dimension normal to the direction of stress and the surface of the base metal (Table 3.1)
b_e = element's effective width for determining deflections (L.3)
b_s = stiffener width (6.3.2.1)
c = distance from the neutral axis to the extreme fiber (F.4)
c_c = distance from neutral axis to the element extreme fiber with the greatest compressive stress (B.5.5.1)
c_{cf} = distance from the centerline of the compression flange to the cross section's neutral axis (F.3.1)
c_{cs} = distance from the cross section's neutral axis to the extreme fiber of compression flange stiffeners (F.3.1)
c_{cw} = distance from the web group's extreme compression fiber to the cross section's neutral axis (F.3.1)
c_o = distance from neutral axis to other extreme fiber of the element (see c_c) (B.5.5.1)
d = full depth of the section (F.4.2.1, F.4.2.2, F.4.2.4, G.2, J.9.1, J.10.1)
d_e = distance from the center of the fastener to the edge of the part in the direction of force (J.3.6, J.4.6, J.5.5.1, J.6.5)
d_f = the distance between the flange centroids; for T-shapes d_f is the distance between the flange centroid and the tip of the stem. (F.4.2.5)
d_s = stiffener's flat width (B.5.4.3)
d_1 = distance from the neutral axis to the compression flange (B.5.5.3)
e = base for natural logarithms = 2.71828… (1.3.2)
f = compressive stress at the toe of the flange (B.5.5.3)
f_a = maximum compressive stress in the element from the service load combinations (L.3)
f_b = compressive stress due to flexure (H.3.1, H.3.2)
f_c = compressive stress due to axial compression (H.3.1, H.3.2)
f_s = shear stress due to shear and torsion (H.3.1, H.3.2)
g = transverse center-to-center spacing (gage) between fastener gage lines (D.3.1, J.1.3)

g_o = distance from the shear center to the point of application of the load; g_o is positive when the load acts away from the shear center and negative when the load acts towards the shear center. If there is no transverse load (pure moment cases) g_o = 0. (F.4.2.5)

h_o = distance between flange centroids (6.3.1.1, 6.3.1.2, 6.3.2.1, 6.3.2.2)

k = effective length factor for buckling (C.3, E.2.1, J.1.3, 6.1, 6.2.2)

k_t = tension coefficient (Table A.3.3, A.3.2, D.2, F.2, G.2, G.3, G.4, G.5, H.2, H.2.3, J.6.4, J.7.2, J.7.3)

k_x = effective length factor for flexural buckling about the x-axis (E.2.2)

k_y = effective length factor for flexural buckling about the y-axis (E.2.2)

k_z = effective length factor for torsional buckling (E.2.2)

k_1 = coefficient for determining the λ_2 slenderness limit for elements with postbuckling strength (Table B.4.3, B.5.4.1, B.5.4.2, B.5.4.6, B.5.5.1, B.5.5.3)

k_2 = coefficient for determining postbuckling strength (Table B.4.3, B.5.4.1, B.5.4.2, B.5.4.6, B.5.5.1, B.5.5.3, B.5.5.5)

l_b = length of the bearing at the concentrated force (J.9.1)

m = coefficient for elements in flexure and supported on both edges (B.5.5.1)

m = coefficient used to determine the allowable stress range for fatigue (Table 3.2, 3.2, 3.3)

n = number of threads/in. (mm) (Table J.2.2, J.3.4, J.3.5, J.5.4.1.1)

n = number of nodal braced points in the span (6.3.2.1, 6.3.2.2)

n = number of tests (1.3.1, 1.3.2)

q = design pressure load for roofing and siding (1.4)

r = radius of gyration (E.2.1)

r_o = polar radius of gyration of the cross section about the shear center (E.2.2)

r_s = stiffener's radius of gyration about the stiffened element's mid-thickness (B.5.4.3)

r_x = radius of gyration about the x-axis (E.2.2, F.4.2.1)

r_y = radius of gyration about the y-axis (E.2.2, F.4.2.1)

r_{ye} = effective radius of gyration about the y-axis for lateral-torsional buckling (F.4.2.1, F.4.2.2, F.4.3)

r_z = radius of gyration about the minor principal axis (F.5.2)

s = transverse stiffener spacing. For a stiffener composed of a pair of members, one on each side of the web, the stiffener spacing s is the clear distance between the pairs of stiffeners. For a stiffener composed of a member on only one side of the web, the stiffener spacing s is the distance between fastener lines or other connecting lines. (B.5.5.3, G.2)

s = longitudinal center-to-center spacing (pitch) of any two consecutive holes (D.3.1, J.1.3)

t = element thickness (B.5.4, B.5.4.1, B.5.4.2, B.5.4.3, B.5.4.4, B.5.4.5, B.5.5.1, B.5.5.2, B.5.5.3, B.5.5.4, Table B.5.1, F.4.2.4, F.5, F.5.1, F.5.2, G.2, G.3, G.4, H.2.1, J.1.3, J.2.2.1, J.3.6, J.4.6, J.5.5.1, J.6.5, J.9.1)

t = time (A.3.1.1)

t_{avg} = average thickness of a tapered thickness element (B.5.3)

t_i = thickness of intermediate thickness material (1.4.2)

t_{max} = maximum thickness of a tapered thickness element (B.5.3)

t_{max} = thickness of thickest material tested (1.4.2)

t_{min} = minimum thickness of a tapered thickness element (B.5.3)

t_{min} = thickness of thinnest material tested (1.4.2)

t_s = beam web stiffener thickness (6.3.2.1)

t_w = beam web thickness (6.3.2.1, 6.3.2.2)

t_1 = nominal thickness of the part in contact with the screw head or washer (J.5.4.2, J.5.5.2)

t_1 = time corresponding to temperature T_1 (A.3.1.1)

t_2 = nominal thickness of the part not in contact with the screw head or washer (J.5.5.2)

t_2 = time corresponding to temperature T_2 (A.3.1.1)

$\bar{x}$ = eccentricity of the connection in the x-axis direction (D.3.2)

x_o = the shear center's x-coordinate (E.2.2)

$\bar{y}$ = eccentricity of the connection in the y-axis direction (D.3.2)

y_o = the shear center's y-coordinate (E.2.2, F.4.2.5)

z_o = coordinate along the z-axis of the shear center with respect to the centroid (F.5.2)

α = factor used to determine reduced flexural stiffness (C.2)

α = ratio of nominal dead load to nominal live load (1.3.2)

α = coefficient of thermal expansion (Table A.3.1)

α_i = number of stress cycles in the spectrum of the ith stress range divided by the total number of stress cycles (3.3)

α_s = coefficient for a longitudinal stiffener (B.5.5.3)

β_{br} = required bracing stiffness (6.2.1, 6.2.2, 6.3.1.1, 6.3.1.2)

β_o = target reliability index (1.3.2)

β_{sec} = web distortional stiffness (6.3.2.1, 6.3.2.2)

β_T = overall brace system stiffness (6.3.2.1)

β_{Tb} = required bracing torsional stiffness (6.3.2.1)

β_x = coefficient of monosymmetry about the x-axis (F.4.2.5)

β_w = coefficient of monosymmetry (F.5.2)

γ = density (Table A.3.1)

$\delta = \dfrac{(t_{\max} - t_{\min})}{t_{\min}}$ = a measure of taper in tapered thickness elements (B.5.3)

κ = metric conversion factor (Table B.4.1, Table B.4.2)

ν = Poisson's ratio (Table A.3.1)

ϕ = resistance factor (B.3.2.1, D.1, E.1, F.1, G.1, H.2, H.3.1, H.3.2, J.2, J.3.4, J.3.5, J.3.6, J.3.7.4, J.3.7.5, J.4.5, J.4.6, J.5.4, J.5.5, J.6.4, J.6.5, J.7.1, J.7.2, J.7.3, J.7.4, J.8, J.9.1, 1.3.2, 6.1, 6.2.1, 6.2.2, 6.3.1.1, 6.3.1.2, 6.3.2.1)

Ω = safety factor (B.3.2.2, D.1, E.1, F.1, G.1, H.2, H.3.1, H.3.2, J.2, J.3.4, J.3.5, J.3.6, J.3.7.4, J.3.7.5, J.4.5, J.4.6, J.5.4, J.5.5, J.6.4, J.6.5, J.7.1, J.7.2, J.7.3, J.7.4, J.8, J.9.1, 1.3.2, 6.1, 6.2.1, 6.2.2, 6.3.1.1, 6.3.1.2, 6.3.2.1)

θ_s = angle between a stiffener and the stiffened element (B.5.4.3)

θ_w = angle between the plane of web and the plane of the bearing surface ($\theta_w \leq 90^o$) (J.9.1)

ρ_{ST} = stiffener effectiveness ratio (B.5.4.3, B.5.6)

λ = slenderness

λ_1 = slenderness at the intersection of the equations for yielding and inelastic buckling

λ_2 = slenderness at the intersection of the equations for inelastic buckling and elastic buckling

$\lambda_e = 1.28\sqrt{E / F_{cy}}$ (B.5.4.3)

$$\lambda_{eq} = \pi\sqrt{\frac{E}{F_e}}$$

= equivalent slenderness for alternate determination of compressive strength for flexural or axial compression (B.5.4.6, B.5.5.5)

λ_s = slenderness of an element with an intermediate stiffener (B.5.4.4, B.5.6)

σ_x = standard deviation of the test strengths (1.3.1)

τ_b = parameter for reduced flexural stiffness (C.2)

μ = mean slip coefficient (J.3.7.5)

Glossary

allowable strength: nominal strength divided by the safety factor, R_n/Ω.

allowable stress: allowable strength divided by the appropriate section property, such as section modulus or cross section area.

aluminum: aluminum or an aluminum alloy.

analysis: the rational determination of the effects of loads on and the strength of structures, members, and connections based on approprate theory, relevant test data, and sound engineering judgment.

applicable building code: the building code under which the structure is designed.

ASD (Allowable Strength Design): the method of proportioning structural components such that the allowable strength equals or exceeds the required strength of the component under the action of the ASD load combinations.

ASD load combination: the load combination in the applicable building code intended for allowable strength design.

available strength: for LRFD, design strength; for ASD, allowable strength.

beam: a structural member that has the primary function of resisting bending moments.

bearing-type connection: a bolted connection where shear forces are transmitted by the bolt bearing against the connection elements.

blind rivet: a rivet that can be installed with access to only one side of the parts being joined.

block shear rupture: in a connection, the limit state of tensile fracture or yielding along one path and shear yielding or fracture along another path.

bolt: a headed and externally threaded mechanical device designed for insertion through holes in assembled parts to mate with a nut and normally intended to be tightened or released by turning that nut.

bridge-type structure: a structure not addressed by building codes and designed for highway, pedestrian, or rail traffic.

buckling: the limit state of a sudden change in the geometry of a structure or any of its elements under a critical loading condition.

building-type structure: a structure of the type addressed by a building code.

camber: curvature fabricated into a beam or truss so as to compensate for deflection induced by loads.

closed shape: a hollow shape that resists lateral-torsional buckling primarily by torsional resistance rather than warping resistance, that is, for which C_w is much less than $0.038JL_b^2$. See Section F.4.2.3.

column: a structural member that has the primary function of resisting a compressive axial force.

contract documents: documents that define the responsibilities of the parties that design, fabricate, or erect the structure.

design load: the applied load determined in accordance with either LRFD load combinations or ASD load combinations, whichever is applicable.

design strength: the resistance factor multiplied by the nominal strength, ϕR_n.

design stress: the design strength divided by the appropriate section property, such as section modulus or cross section area.

effective length: the length of an otherwise identical column with the same strength when analyzed with pinned end conditions.

effective length factor: ratio between the effective length and the unbraced length of the member.

effective net area: net area modified to account for the effect of shear lag.

elastic analysis: structural analysis based on the assumption that the structure returns to its original geometry on removal of the load.

element: a component of a shape's cross section. Elements are connected to other elements only along their longitudinal edges. Elements addressed by the *Specification* include flat elements, described by their width b and thickness t, and curved elements, described by their mid-thickness radius R_b and thickness t. An Aluminum Association standard I beam, for example, consists of five flat elements: a web element and two elements in each flange.

engineer of record: engineer responsible for the structural design.

factored load: the product of a load factor and the nominal load.

fastener: a device such as a bolt, rivet, screw, or pin used to mechanically connect two or more parts.

fatigue: the limit state of crack initiation and growth resulting from repeated application of loads.

filler metal: metal to be added in making a welded joint.

fillet weld: weld of generally triangular cross section made between intersecting surfaces of elements.

flexural buckling: a buckling mode in which a compression member deflects laterally without twist or change in cross-sectional shape.

flexural-torsional buckling: a buckling mode in which a compression member bends and twists simultaneously without change in cross-sectional shape.

gage: transverse center-to-center spacing of fasteners.

gauge: a term previously used in referring to the thickness of a wrought product. Thickness is preferred in dimension description.

geometric axis: axis parallel to a web, flange, or angle leg.

grip: thickness of material through which a fastener passes.

lateral-torsional buckling: the buckling mode of a flexural member involving deflection normal to the plane of bending occurring simultaneously with twist about the shear center of the cross-section.

limit state: a condition in which a structure or component becomes unfit for service and is judged either to be no longer useful for its intended function (serviceability limit state) or to have reached its ultimate load-carrying capacity (strength limit state).

load effect: forces, stresses, and deformations produced in a structural component by the applied loads.

load factor: a factor that accounts for deviations of the nominal load from the actual load, for uncertainties in the analysis that transforms the load into a load effect and for the probability that more than one extreme load will occur simultaneously.

local buckling: the limit state of buckling of a compression element within a cross section.

lockbolt: a two-piece fastener consisting of a shaft (bolt) and collar. The softer, smooth bore collar is mechanically swaged (reduced or tapered by squeezing) onto the pin and into either zero pitch, annular lock grooves or special thread form grooves in a tension-tension installation method. Hydraulic or pneumatic installation tools provide the tension and swaging action.

longitudinal centroidal axis: axis through the centroid of a member along its length.

LRFD (Load and Resistance Factor Design): a method of proportioning structural components such that the design strength equals or exceeds the required strength of the component under the action of the LRFD load combinations.

LRFD load combination: a load combination in the applicable building code intended for strength design (load and resistance factor design).

member: an individual, discrete component of a larger structure, such as a beam or column.

member buckling: flexural, torsional, or flexural-torsional buckling of the overall member.

net area: gross area reduced to account for removed material.

nominal dimension: designated or theoretical dimension, as in the tables of section properties.

nominal load: magnitude of the load specified by the applicable building code.

nominal strength: strength of a structure or component (without the resistance factor or safety factor applied) available to resist load effects, as determined in accordance with this *Specification*.

pin: a fastener that is a rod about which the connected parts are free to rotate.

pitch: longitudinal center-to-center spacing of fasteners; center-to-center spacing of bolt threads along the axis of a bolt.

post-buckling strength: the load or force that can be carried by an element, member, or frame after initial elastic buckling has occurred.

pull-out: the tensile load required to pull a screw out of a threaded part.

pull-over: the tensile load required to pull a part over the head of a screw.

quality assurance: monitoring and inspection tasks performed by an agency or firm other than the fabricator or erector to ensure that the material provided and work performed by the fabricator and erector meet the requirements of the approved construction documents and referenced standards. Quality assurance includes those tasks designated “special inspection” by the applicable building code.

quality control: controls and inspections implemented by the fabricator or erector, as applicable, to ensure that the material provided and the work performed meet the requirements of the approved construction documents and referenced standards.

required strength: Forces, stresses and deformations acting on a structural component determined by either structural analysis, for the LRFD or ASD load combinations, as appropriate, or as specified by this *Specification*.

resistance factor: a factor that accounts for unavoidable deviations of the actual strength from the nominal strength and for the manner and consequences of failure.

rivet: a headed and unthreaded mechanical device used to assemble two or more components by an applied force which deforms the plain rivet end to develop a completed mechanical joint.

rod: a solid wrought product that is long in relation to its circular cross section, which is not less than 0.375 in. diameter.

safety factor: a factor that accounts for deviations of the actual strength from the nominal strength, deviations of the actual load from the nominal load, uncertainties in the analysis that transforms the load into a load effect, and for the manner and consequences of failure.

screw: a headed and externally threaded fastener held in place by threading into one of the connected parts.

screw chase: a groove parallel to the longitudinal axis of an extrusion, intended to retain a screw whose axis is perpendicular to the longitudinal axis of the extrusion. (See Figure GL.1).

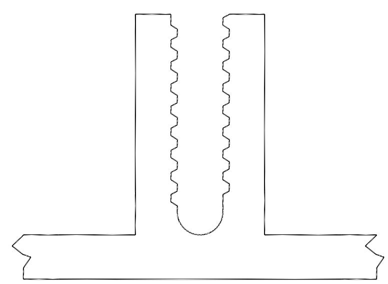

Figure GL.1
TRANSVERSE CROSS SECTION OF A SCREW CHASE

screw slot: a semi-hollow in an extrusion intended to retain a screw parallel to the axis of the extrusion. (See Figure GL.2).

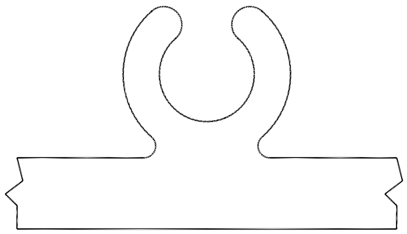

Figure GL. 2
TRANSVERSE CROSS SECTION OF A SCREW SLOT

self-drilling screw: a screw that drills and taps its own hole as it is being driven.

service load: load under which serviceability limit states are evaluated.

service load combination: load combinations under which serviceability limit states are evaluated.

slip-critical connection: a bolted connection designed to resist movement by friction on the faying surface of the connection under the clamping forces of the bolts.

stiffener: a structural element attached or integral to a member to distribute load, transfer shear, or prevent buckling.

structural component: member, connector, connecting element or assemblage.

structure: an object, including but not limited to buildings, walls, fences, towers, bridges, railings, signs, and luminaires, designed to support loads.

tapping screw: a screw that threads a preformed hole as it is being driven.

thread cutting screw: a tapping screw that is installed into a preformed hole, with internal mating threads formed as a result of cutting out the material being tapped to form the relief area of the threaded shank.

thread forming screw: a tapping screw that is installed into a preformed hole, with internal mating threads formed as a result of cold flow of the material being tapped into the relief area of the threaded shank.

torsional buckling: a buckling mode in which a compression member twists about its shear center axis.

unbraced length: the length of a member between brace points or between a brace point and a cantilever's free end, measured between the longitudinal centroidal axes of the bracing members. For columns, brace points are points at which lateral translation is restrained for flexural buckling or twisting is restrained for torsional buckling. For beams, brace points are points at which the compression flange is restrained against lateral deflection or the cross section is restrained against twisting.

weld-affected zone: metal within 1 in. (25 mm) of the centerline of a weld.

Chapter A General Provisions

A.1 SCOPE

The *Specification for Aluminum Structures*, hereafter referred to as the *Specification*, applies to the design of aluminum load-carrying structures, members, and connections.

This *Specification* includes the symbols, glossary, Chapters A through N, and Appendices 1, 3, 4, 5, and 6.

The provisions of this *Specification*, or a more rigorous analysis, shall be used for all cases addressed by this *Specification*. Appropriate analysis shall be used for cases not addressed by this *Specification*.

A.2 REFERENCED DOCUMENTS

The following documents are referenced in this *Specification:*

<u>Aluminum Association</u>

Aluminum Standards and Data 2013

Aluminum Standards and Data 2013 Metric SI

Standards for Aluminum Sand and Pemanent Mold Castings (2008)

<u>American Association of State Highway and Traffic Officials (AASHTO)</u>

Guide Specifications for Design of Pedestrian Bridges (1997)

Standard Specifications for Highway Bridges (2002)

Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals (2013)

<u>American Institute for Steel Construction</u>

Specification for Structural Steel Buildings (ANSI/AISC 360-10)

<u>American Society for Nondestructive Testing (ASNT)</u>

ASNT CP-189, *Standard for the Qualification and Certification of Nondestructive Testing Personnel*

<u>American Society of Civil Engineers (ASCE)</u>

ASCE/SEI 7-10 *Minimum Design Loads for Buildings and Other Structures*

<u>American Society of Mechanical Engineers (ASME)</u>

ASME B18.6.4-1998(R2005) *Thread Forming and Thread Cutting Tapping Screws and Metallic Drive Screws, Inch Series*

ASME B46.1-2009 *Surface Texture (Surface Roughness, Waviness, and Lay*)

<u>American Welding Society (AWS)</u>

AWS A.5.10/A5.10M:2012 *Welding Consumables – Wire Electrodes, Wires and Rods for Welding of Aluminum and Aluminum-Alloys - Classification*

AWS B5.1, *Standard for the Qualification of Welding Inspectors*

AWS D1.2/D1.2M:2014 *Structural Welding Code – Aluminum*

<u>ASTM International (ASTM)</u>

A 194/A 194M-12a *Standard Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both*

A 325-10e1 *Standard Specification for Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength*

A 325M-13 *Standard Specification for Structural Bolts, Steel, Heat Treated 830 MPa Minimum Tensile Strength [Metric]*

A 563-07a *Standard Specification for Carbon and Alloy Steel Nuts*

A 563M-07 *Standard Specification for Carbon and Alloy Steel Nuts [Metric]*

B 26/B 26M-12 *Standard Specification for Aluminum-Alloy Sand Castings*

B 108/B 108M-12e1 *Standard Specification for Aluminum-Alloy Permanent Mold Castings*

B 209-10 *Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate*

B 209M-10 *Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate [Metric]*

B 210-12 *Standard Specification for Aluminum and Aluminum-Alloy Drawn Seamless Tubes*

B 210M-12 *Standard Specification for Aluminum and Aluminum-Alloy Drawn Seamless Tubes [Metric]*

B 211-12e1 *Standard Specification for Aluminum and Aluminum-Alloy Bar, Rod, and Wire*

B 211M-12e1 *Standard Specification for Aluminum and Aluminum-Alloy Bar, Rod, and Wire [Metric]*

B 221-13 *Standard Specification for Aluminum and Aluminum-Alloy Extruded Bars, Rods, Wire, Profiles, and Tubes*

B 221M-13 *Standard Specification for Aluminum and Aluminum-Alloy Extruded Bars, Rods, Wire, Profiles, and Tubes [Metric]*

B 241/B 241M-12e1 *Standard Specification for Aluminum and Aluminum-Alloy Seamless Pipe and Seamless Extruded Tube*

B 247-09 *Standard Specification for Aluminum and Aluminum-Alloy Die Forgings, Hand Forgings, and Rolled Ring Forgings*

B 247M-09 *Standard Specification for Aluminum and Aluminum-Alloy Die Forgings, Hand Forgings, and Rolled Ring Forgings [Metric]*

B 308/B 308M-10 *Standard Specification for Aluminum-Alloy 6061-T6 Standard Structural Profiles*

B 316/B 316M-10 *Standard Specification for Aluminum and Aluminum-Alloy Rivet and Cold-Heading Wire and Rods*

B 429/B 429M-10e1 *Standard Specification for Aluminum-Alloy Extruded Structural Pipe and Tube*