List of Symbol Definitions

a long dimension for a section subjected to torsion (in, mm);
acceleration due to gravity, 32.17 ft/sec^2, 9.81 m/sec^2;
unit area (in^2, ft^2, mm^2, m^2);
distance used in beam formulas (ft, m);
depth of the effective compression block in a concrete beam (in, mm)

$\large a$ area bounded by the centerline of a thin walled section subjected to torsion (in^2, mm^2)

A area, often cross-sectional (in^2, ft^2, mm^2, m^2)

A_e net <u>effective</u> area, equal to the total area ignoring any holes and modified by the lag factor, U, (in^2, ft^2, mm^2, m^2) *(see A_{net})*

A_g gross area, equal to the total area ignoring any holes (in^2, ft^2, mm^2, m^2)

A_{gv} gross area subjected to shear for block shear rupture (in^2, ft^2, mm^2, m^2)

A_{net} net <u>effective</u> area, equal to the gross area subtracting any holes (in^2, ft^2, mm^2, m^2) *(see A_e)*

A_{nt} net area subjected to tension for block shear rupture (in^2, ft^2, mm^2, m^2)

A_{nv} net area subjected to shear for block shear rupture (in^2, ft^2, mm^2, m^2)

A_p bearing area (in^2, ft^2, mm^2, m^2)

A_{throat} area across the throat of a weld (in^2, ft^2, mm^2, m^2)

A_s area of steel reinforcement in concrete beam design (in^2, ft^2, mm^2, m^2)

$A_{s'}$ area of compression steel reinforcement in concrete beam design (in^2, ft^2, mm^2, m^2)

A_v area of concrete shear stirrup reinforcement (in^2, ft^2, mm^2, m^2)

A_{web} web area in a steel beam equal to the depth x web thickness (in^2, ft^2, mm^2, m^2)

A_1 area of column in spread footing design ((in^2, ft^2, mm^2, m^2)

A_2 projected bearing area of column load in spread footing design ((in^2, ft^2, mm^2, m^2)

ASD Allowable Stress Design

b width, often cross-sectional (in, ft, mm, m);
narrow dimension for a section subjected to torsion (in, mm);
number of truss members;
rectangular column dimension in concrete footing design (in, mm, m);
distance used in beam formulas (ft, m)

b_E effective width of the flange of a concrete T beam cross section (in, mm)

b_f width of the flange of a steel or concrete T beam cross section (in, mm)

b_o perimeter length for two-way shear in concrete footing design (in, ft, mm, m)

b_w width of the stem of a concrete T beam cross section (in, mm)

B spread footing dimension in concrete design (ft, m);
dimension of a steel base plate for concrete footing design (in, mm, m)

B_1 factor for determining M_u for combined bending and compression

B_s width within the longer dimension of a rectangular spread footing that reinforcement must be concentrated within for concrete design (ft, m)

c distance from the neutral axis to the top or bottom edge of a beam (in, mm, m);
rectangular column dimension in concrete footing design (in, mm, m)

c_i distance from the center of a circular shape to the inner surface under torsional shear strain (in, mm, m)

c_o distance from the center of a circular shape to the outer surface under torsional shear strain (in, mm, m)

c_1 coefficient for shear stress for a rectangular bar in torsion

c_2 coefficient for shear twist for a rectangular bar in torsion

$CL, \mathbb{C}$ center line

C compression label;
compression force (lb, kips, N, kN);
dimension of a steel base plate for concrete footing design (in, mm, m)

C_b modification factor for LRFD steel beam design

C_c column slenderness classification constant for steel column design;
compressive force in the concrete of a doubly reinforced concrete beam (lb, k, N, KN)

C_D

C_D load duration factor for wood design

C_F size factor for wood design

C_f form factor for circular sections or or square sections loaded in plane of diagonal for wood design

C_{fu} flat use factor for wood design

C_F size factor for wood design

C_H shear stress factor for wood design

C_i incising factor for wood design

C_L beam stability factor for wood design

C_m modification factor for combined stress in steel design

C_M wet service factor for wood design

C_p column stability factor for wood design

C_r repetitive member factor for wood design

C_v web shear coefficient for steel design

C_V glulam volume factor for wood design

C_s compressive force in the compression steel of a doubly reinforced concrete beam (lb, k, N, KN)

C_t temperature factor for wood design

d diameter of a circle (in, mm, m);
depth, often cross-sectional (in, mm, m);
perpendicular distance from a force to a point in a moment calculation (in, mm, m);
critical cross section dimension of a rectangular timber column cross section related to the profile (axis) for buckling (in, mm, m);
effective depth from the top of a reinforced concrete beam to the centroid of the tensile steel

(in, mm);
symbol in calculus to represent a very small change (like the greek letters for d, *see* δ & Δ)

d'   effective depth from the top of a reinforced concrete beam to the centroid of the compression steel (in, mm)

d_b depth of a steel W beam section (in, mm);
bar diameter of concrete reinforcement (in, mm)
nominal bolt diameter (in, mm)

d_f depth of a steel W column flange (in, mm)

d_x difference in the x direction between an area centroid and the centroid of the composite shape (in, mm)

d_y difference in the y direction between an area centroid and the centroid of the composite shape (in, mm)

D   diameter of a circle (in, mm, m);
dead load for LRFD design

DL   dead load

e   dimensional change to determine strain *(see s or ε)* (in, mm);
eccentric distance of application of a force (P) from the centroid of a cross section (in, mm)

E   modulus of elasticity (psi; ksi, kPa, MPa, GPa);
earthquake load for LRFD design

E_c modulus of elasticity of concrete (psi; ksi, kPa, MPa, GPa)

E_s modulus of elasticity of steel (psi; ksi, kPa, MPa, GPa)

f   symbol for stress (psi, ksi, kPa, MPa)
symbol for function with respect to some variable; ie. *f*(t)

f_a calculated axial stress (psi, ksi, kPa, MPa)

f_b calculated bending stress (psi, ksi, kPa, MPa)

f_c calculated compressive stress (psi, ksi, kPa, MPa)

f_c' concrete design compressive stress (psi, ksi, kPa, MPa)

f_{cr} calculated column stress based on the critical column load P_{cr} (psi, ksi, kPa, MPa)

f_m calculated compressive stress in masonry (psi, ksi, kPa, MPa)

f_m' masonry design compressive stress (psi, ksi, kPa, MPa)

f_p calculated bearing stress (psi, ksi, kPa, MPa)

f_s calculated steel stress for reinforced masonry (psi, ksi, kPa, MPa)

f_t calculated tensile stress (psi, ksi, kPa, MPa)

f_x combined stress in the direction of the major axis of a column (psi, ksi, kPa, MPa)

f_v calculated shearing stress (psi, ksi, kPa, MPa)

f_y yield stress (psi, ksi, kPa, MPa)

F force (lb, kip, N, kN);
capacity of a nail in shear (lb, kip, N, kN);
hydraulic fluid load for LRFD design

F_a allowable axial stress (psi, ksi, kPa, MPa)

F_b allowable bending stress (psi, ksi, kPa, MPa)

F_b' allowable bending stress for combined stress for wood design (psi, ksi, kPa, MPa)

F_c allowable compressive stress (psi, ksi, kPa, MPa);
critical unfactored compressive stress for LRFD steel design

$F_{c\perp}$ allowable compressive stress perpendicular to the wood grain (psi, ksi, kPa, MPa)

$F_{connector}$ resistance capacity of a connector (lb, kips, N, kN)

F_{cE} intermediate compressive stress for ASD wood column design dependant on material (psi, ksi, kPa, MPa)

F_{cr} flexural buckling (column) stress in ASD and LRFD (psi, ksi, kPa, MPa)

F_c' allowable compressive stress for ASD wood column design (psi, ksi, kPa, MPa)

F^*_c intermediate compressive stress for ASD wood column design dependant on load duration (psi, ksi, kPa, MPa)

F_e elastic critical buckling stress is steel design

F_h force component in the horizontal direction (lb, kip, N, kN)

$F_{horizontal\text{-}resist}$ resultant frictional force resisting sliding in a footing or retaining wall (lb, kip, N, kN)

F_n nominal strength in LRFD steel design (psi, ksi, kPa, MPa)
nominal tension or shear strength of a bolt (psi, ksi, kPa, MPa)

F_p allowable bearing stress parallel to the wood grain (psi, ksi, kPa, MPa)

$F_{sliding}$ resultant force causing sliding in a footing or retaining wall (lb, kip, N, kN)

F_t allowable tensile stress (psi, ksi, kPa, MPa)

F_v allowable shear stress (psi, ksi, kPa, MPa);
allowable shear stress in a welded connection;
force component in the vertical direction (lb, kip, N, kN)

F_x force component in the x coordinate direction (lb, kip, N, kN)

F_w allowable weld stress (psi, ksi, kPa, MPa)

F_y force component in the y coordinate direction (lb, kip, N, kN);
yield stress (psi, ksi, kPa, MPa)

F_u ultimate stress a material can sustain prior to failure (psi, ksi, kPa, MPa)

$F.S.$ factor of safety *(also see SF)*

g acceleration due to gravity, 32.17 ft/sec^2, 9.807 m/sec^2;
transverse center-to-center spacing (gage) between fastener gage lines (in, mm,)

G shear modulus (psi; ksi, kPa, MPa, GPa);
relative stiffness of columns to beams in a rigid connection *(see Ψ)*

h depth, often cross-sectional (in, ft, mm, m);
height (in, ft, mm, m);

sag of a cable structure (ft, m);
effective height of a wall or column (*see* ℓ_e)

h' effective height of a wall or column (*see* ℓ_e)

h_c height of the web in a W section (in, ft, mm, m) (*also see t_w*)

h_f depth of a flange in a T section (in, ft, mm, m);
height of a concrete spread footing (in, ft, mm, m)

H hydraulic soil load for LRFD design

H_A horizontal load from active soil or water pressure (lb, k, N, kN)

I moment of inertia (in^4, mm^4, m^4)

$\bar{I}$ moment of inertia about the centroid (in^4, mm^4, m^4))

$\hat{I}$ moment of inertia about the centroid of a composite shape (in^4, mm^4, m^4)

I_c moment of inertia about the centroid of a composite shape (in^4, mm^4, m^4)

I_{min} minimum moment of inertia of I_x and I_y (in^4, mm^4, m^4)

I_o moment of inertia about the centroid (in^4, mm^4, m^4)

$I_{transformed}$ moment of inertia of a multi-material section transformed to one material (in^4, mm^4, m^4)

I_x moment of inertia with respect to an x-axis (in^4, mm^4, m^4)

I_y moment of inertia with respect to a y-axis (in^4, mm^4, m^4)

j multiplier by effective depth of masonry section for moment arm, jd (*see d*)

J, J_o polar moment of inertia (in^4, mm^4, m^4)

k kips (1000 lb);
shape factor for steel beams, M_p/M_y:
effective length factor for columns (*also K);*
distance from outer face of W flange to the web toe of fillet (in, mm);
multiplier by effective depth of masonry section for neutral axis, kd

kg kilograms

klf kips per linear foot

kN kiloNewtons (10^3 N)

kPa kiloPascals (10^3 Pa)

K effective length factor with respect to column end conditions;
masonry mortar strength designation

K_{cE} material factor for wood column design

ℓ length (in, ft, mm, m);
cable span (ft, m)

ℓ_d development length of concrete reinforcement (in, ft, mm, m)

ℓ_{dc} development length of compression reinforcement in concrete footing design (in, ft, mm, m)

l_{dh} development length for hooks (in, ft, mm, m)

ℓ_e effective length that can buckle for wood column design (in, ft, mm, m)

ℓ_n effective clear span for concrete one-way slab design (ft, m)

lb   pound force

L   length (in, ft, mm, m);
live load for LRFD design;
spread footing dimension in concrete design (ft, m)

L_b unbraced length of a steel beam in LRFD design (ft, m)

L_c maximum unbraced length of a steel beam in ASD design for compression buckling limit (ft, m);
clear distance between the edge of a hole and edge of next hole or edge of the connected steel plate (in, ft, mm, m)

L_d development length of reinforcement in concrete (ft, m)

L_e effective length that can buckle for column design (ft, m)

L_m projected length for bending in concrete footing design (ft, m)

L_p limiting length of a steel beam in LRFD design for full plastic strength (ft, m)

L_r roof live load in LRFD design;
limiting length of a steel beam in LRFD design for inelastic lateral-torsional buckling (ft, m)

L_u maximum unbraced length of a steel beam in ASD design for stress limit of $0.6F_y$

L'   length of the one-way shear area in concrete footing design (ft, m)

LL   live load

LRFD   Load and Resistance Factor Design

m   mass (lb-mass, g, kg);
meters

mm   millimeters

M   moment of a force or couple (lb-ft, kip-ft, N-m, kN-m);
bending moment (lb-ft, kip-ft, N-m, kN-m);
masonry mortar strength designation

M_a required bending moment in steel ASD beam design (unified) (lb-ft, kip-ft, N-m, kN-m)

M_A moment value at quarter point of unbraced beam length for LRFD beam design (lb-ft, kip-ft, N-m, kN-m)

M_B nominal moment capacity of a reinforced concrete beam at the balanced steel ratio (ρ_b) for limiting strains in both concrete and steel (lb-ft, kip-ft, N-m, kN-m)
moment value at half point of unbraced beam length for LRFD beam design (lb-ft, kip-ft, N-m, kN-m)

M_c nominal moment capacity of a reinforced concrete beam based on compression force in a concrete section (lb-ft, kip-ft, N-m, kN-m) *(also see M_n)*

M_C moment value at three quarter point of unbraced beam length for LRFD beam design (lb-ft, kip-ft, N-m, kN-m)

M_m moment capacity of a reinforced masonry beam (lb-ft, kip-ft, N-m, kN-m)

M_n nominal moment capacity of a reinforced concrete beam based on steel yielding and concrete design strength (lb-ft, kip-ft, N-m, kN-m)

$M_{overturning}$ resulting moment from all forces on a footing or retaining wall causing overturning (lb-ft, kip-ft, N-m, kN-m)

M_p internal bending moment when all fibers in a cross section reach the yield stress (lb-ft, kip-ft, N-m, kN-m) *(also see M_{ult})*

M_r required nominal moment capacity based on design moment for reinforced concrete (lb-ft, kip-ft, N-m, kN-m) *(also see M_n)*

M_{resis} resulting moment from all forces on a footing or retaining wall resisting overturning (lb-ft, kip-ft, N-m, kN-m)

M_t nominal moment capacity of a reinforced concrete beam based on tensile force in the steel reinforcement (lb-ft, kip-ft, N-m, kN-m) *(also see M_n)*

M_u factored moment calculated in concrete design from load factors (lb-ft, kip-ft, N-m, kN-m)

M_{ult} internal bending moment when all fibers in a cross section reach the yield stress (lb-ft, kip-ft, N-m, kN-m) *(also see M_p)*

M_y internal bending moment when the extreme fibers in a cross section reach the yield stress (lb-ft, kip-ft, N-m, kN-m)

n number of truss joints, nails or bolts;
modulus of elasticity transformation coefficient from steel to concrete

n.a.   neutral axis (axis connecting beam cross-section centroids)

N Newtons;
bearing-type connection with bolt threads included in shear plane;
normal load (lb, kip, N, kN);
bearing length on a wide flange steel section (in, mm)
masonry mortar strength designation

o.c.   on-center

O point of origin;
masonry mortar strength designation

p pitch of nail or bolt spacing (in, mm) *(also see s)*;
pressure (lb/in^2, lb/ft^2, kip/in^2, kip/ft^2, Pa, MPa);
reinforcement ratio in concrete beam design = A_s/bd (or possibly A_s/bt, A_s/bh) (no units) *(see ρ)*

p_A active soil pressure (lb/ft^3, kN/m^3)

p_b balanced reinforcement ratio in concrete beam design *(see ρ_b)*

plf   pounds per linear foot

P force, concentrated (point) load (lb, kip, N, kN)

P_a required axial force in ASD steel design (unified) (lb, kip, N, kN)

P_c available axial strength for steel unified design (lb, kip, N, kN)

P_{cr} critical (failure) load in column calculations (lb, kip, N, kN)

P_{e1} Euler buckling strength in steel unified design (lb, kip, N, kN)

P_n maximum column load capacity in LRFD steel and concrete design (lb, kip, N, kN)

P_o maximum axial force with no concurrent bending moment in a reinforced concrete column (lb, kip, N, kN)

P_r required axial force in steel unified design (lb, kip, N, kN)

P_u factored column load calculated from load factors in LRFD steel and concrete design (lb, kip, N, kN)

Pa Pascals (N/m^2)

q shear flow (lb/in, kips/ft, N/m, kN/m)

$q_{allowed}$ allowable soil bearing pressure (lb/ft^2, kips/ft^2, N/m^2, Pa, MPa)

q_{net} net allowed soil bearing pressure (lb/ft^2, kips/ft^2, N/m, Pa, MPa)

q_u factored soil bearing pressure in concrete design from load factors (lb/ft^2, kips/ft^2, N/m, Pa, MPa)

Q first moment area used in shearing stress calculations (in^3, mm^3, m^3)

$Q_{connected}$ first moment area used in shear calculations for built-up beams (in^3, mm^3, m^3)

Q_x first moment area about an x axis (using y distances) (in^3, mm^3, m^3)

Q_y first moment area about an y axis (using x distances) (in^3, mm^3, m^3)

r radius of a circle (in, mm, m);
radius of gyration (in, mm, m)

r_o polar radius of gyration (in, mm, m)

r_x radius of gyration with respect to an x-axis (in, mm, m)

r_y radius of gyration with respect to a y-axis (in, mm, m)

R force, reaction or resultant (lb, kip, N, kN);
radius of curvature of a beam (ft, m);
rainwater or ice load for LRFD design

R_a required strength (ASD-unified) *(also see V_a, M_a)*

R_n concrete beam design ratio = M_u/bd^2 (lb/in^2, MPa)
nominal value for LRFD design to be multiplied by ϕ *(also see P_n, M_n)*
nominal value for ASD design to be divided by the safety factor Ω

R_x reaction or resultant component in the x coordinate direction (lb, kip, N, kN)

R_y reaction or resultant component in the y coordinate direction (lb, kip, N, kN)

s strain (change in length divided by length (no units);
displacement with respect to time (ft, m);
length of a segment of a thin walled section (in, mm);
pitch of nail spacing (in, mm) *(also see p)*;
spacing of stirrups in reinforced concrete beams (in, mm);
longitudinal center-to-center spacing of any two consecutive holes (in, mm)

s.w.   self-weight

S section modulus (in^3, mm^3, m^3);
snow load for LRFD design;
allowable strength of a weld for a given size (lb/in, kips/in, N/mm, kN/m);
masonry mortar strength designation

$S_{required}$ section modulus required to not exceed allowable bending stress (in^3, mm^3, m^3)

S_x section modulus with respect to the x-centroidal axis (in^3, mm^3, m^3)

S_y section modulus with respect to the y-centroidal axis (in^3, mm^3, m^3)

SC slip critical bolted connection

SF safety factor *(also see F.S.)*

$S4S$ surface-four-sided

t thickness (in, mm, m);
time (sec, hrs)

t_f thickness of the flange of a steel beam cross section (in, mm, m)

t_w thickness of the web of a steel beam cross section (in, mm, m)

T tension label;
tensile force (lb, kip, N, kN);
torque (lb-ft, kip-ft, N-m, kN-m);
throat size of a weld (in, mm);
effect of thermal load for LRFD design

U shear lag factor for bolted connections

U_{bs} reduction coefficient for block shear rupture

v velocity (ft/sec, m/sec, mi/h);
shear force per unit length (lb/ft, k/ft, N/m, kN/m) *(see q)*

V shear force (lb, kip, N, kN)

V_a required shear in steel ASD design (unified) (lb, kip, N, kN)

V_c shear force capacity in concrete (lb, kip, N, kN)

V_n nominal shear force capacity for concrete design (lb, kip, N, kN)

V_s shear force capacity in steel (lb, kip, N, kN)

V_u factored shear calculated in concrete design from load factors (lb, kip, N, kN)

V_{u1} factored one-way shear calculated in concrete footing design from load factors (lb, kip, N, kN)

V_{u2} factored two-way shear calculated in concrete footing design from load factors (lb, kip, N, kN)

w load per unit length on a beam (lb/ft, kip/ft, N/m, kN/m);
load per unit area on a surface (lb/ft^2, kip/ft^2, N/m^2, kN/m^2):
width dimension (in, ft, mm, m)

w_c weight of reinforced concrete per unit volume (lb/ft^3, N/m^3)

w_u factored load per unit length on a beam from load factors (lb/ft, kip/ft, N/m, kN/m);
factored load per unit area on a surface from load factors (lb/ft^2, kip/ft^2, N/m^2, kN/m^2)

W weight (lb, kip, N, kN);
total load from a uniform distribution (lb, kip, N, kN);
wind load for LRFD design

x a distance in the x direction (in, ft, mm, m)

$\bar{x}$ the distance in the x direction from a reference axis to the centroid of a shape (in, mm)

$\hat{x}$ the distance in the x direction from a reference axis to the centroid of a composite shape (in, mm)

X bearing-type connection with bolt threads excluded from shear plane

y a distance in the y direction (in, ft, mm, m);
          distance from the neutral axis to the y-level of a beam cross section (in, mm)

$\bar{y}$ the distance in the y direction from a reference axis to the centroid of a shape (in, mm)

$\hat{y}$ the distance in the y direction from a reference axis to the centroid of a composite shape (in, mm)

z the distance from a unit area to a reference axis (in, ft, mm, m) *(also see d_x and d_y)*

Z plastic section modulus of a steel beam (in^3, mm^3)
          lateral design value for a single fastener in a timber connection (lb/nail, k/bolt)

$'$ symbol for feet

$''$ symbol for inches

$\#$ symbol for pounds

$=$ symbol for equal to

$\approx$ symbol for approximately equal to

$\propto$ symbol for proportional to

$\leq$ symbol for less than or equal to

$\int$ symbol for integration

α coefficient of thermal expansion (/°C, /°F);
          angle, in a math equation (degrees, radians)

β angle, in a math equation (degrees, radians)

β_c ratio of long side to short side of the column in concrete footing design

β_1 coefficient to determine the stress block height in concrete beam design

δ elongation (in, mm) *(also see e)*

δ_P elongation due to axial load (in, mm)

δ_s shear deformation (in, mm)

δ_T elongation due to change in temperature (in, mm)

Δ beam deflection (in, mm);
          an increment

Δ_{LL} beam deflection due to live load (in, mm)

Δ_{max} maximum calculated beam deflection (in, mm)

Δ_{TL} beam deflection due to total load (in, mm)

Δ_x beam deflection in beam diagrams and formulas (in, mm)

ΔT change in temperature (°C, °F)

ε strain *(also see s)*

ε_t thermal strain

ϕ diameter symbol;
          angle of twist (degrees, radians);
          resistance factor in LRFD steel design and reinforced concrete design

ϕ_b resistance factor for flexure in LRFD design

ϕ_c resistance factor for compression in LRFD design

ϕ_t resistance factor for tension in LRFD design

ϕ_v resistance factor for shear in LRFD design

λ_c design constant for slenderness evaluation for steel columns in LRFD design

μ Poisson's ratio;
          coefficient of static friction

γ specific gravity of a material (lb/in^3, lb/ft^3, N/m^3, kN/m^3);
          angle, in a math equation (degrees, radians);
          shearing strain (no units);
          load factor in LRFD design

γ_D dead load factor in LRFD steel design

γ_L live load factor in LRFD steel design

θ angle, in a trig equation (degrees, radians);
          slope of the deflection of a beam at a point (degrees, radians)

π pi (180°)

ρ radial distance (in, mm);
          radius of curvature in beam deflection relationships (ft, m);
          reinforcement ratio in concrete beam design = A_s/bd (or possibly A_s/bt, A_s/bh) (no units)

ρ_b balanced reinforcement ratio in concrete beam design

ρ_g reinforcement ratio in concrete column design = A_{st}/A_g

ρ_{max} maximum reinforcement ratio allowed in concrete beam design for ductile behavior

σ engineering symbol for normal stress (axial or bending)

τ engineering symbol for shearing stress

υ_c shearing stress capacity in concrete design (psi; ksi, kPa, MPa)

ω load per unit length on a beam (lb/ft, kip/ft, N/m, kN/m) (*see w*);
          load per unit area (lb/ft^2, kips/ft^2, N/m^2, Pa, MPa)

Σ summation symbol

Ω safety factor for ASD of steel (unified)

Ψ relative stiffness of columns to beams in a rigid connection *(see G)*