

## Structural Glossary

*Allowable strength:* Nominal strength divided by the safety factor.

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

*Applicable building code:* Building code und which the structure is designed.

*ASD (Allowable Strength Design):* 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:* Load combination in the *applicable building code* intended for allowable strength design (*allowable stress design*).

*ASTM standards:* The American Society of Testing and Materials specifies standards for performance and testing of construction materials.

*Axial force:* A force that is acting along the longitudinal axis of a structural member.

*Base shear:* A lateral (wind or seismic) force acting at the base of a structure.

*Beam:* Structural member that has the primary function of resisting bending moments.

*Beam-column:* Structural member that resists both axial force and bending moment.

*Bearing (local compressive yielding):* Limit state of local compressive yielding due to the action of a member bearing against another member or surface.

*Bending moment:* A force rotating about a point; causes bending in beams, etc.

*Block shear rupture:* In a connection, limit state of tension fracture along one path and shear yielding or shear fracture along another path.

*Bracing:* Diagonal members that are used to stiffen a structure, by utilizing the inherent in-plane stiffness of a triangular framework.

*Braced frame:* An essentially vertical truss system that provides resistance to lateral forces and provides stability for the *structural system*.

*Buckling:* Limit state of sudden change in the geometry of a structure or any of its elements under a critical loading condition.

*Buckling strength:* Nominal strength for buckling or instability limit states.

*Built-up member, cross-section, section, shape:* Member, cross-section, section or shape fabricated from elements that are nailed, welded, glued or bolted together.

*Camber:* Curvature fabricated into a beam or truss so as to compensate for deflection induced by loads.

*Cantilevers:* Structural elements or systems that are supported only at one end.

*Cement:* The generic name for cementitious (binder) materials used in concrete, which is a commonly used building material.

*Center of gravity:* The location of resultant gravity forces on an object or objects.

*Centroid:* The center of mass of a shape or object.

*Chord member*: Primary member that extends, usually horizontally, through a truss *connection*.

*Cold-rolled steel structural member*: Shape manufactured by roll forming cold-or hot- rolled coils or sheets without manifest addition of heat such as would be required for hot forming.

*Collector*: An element that transfers load from a diaphragm to a resisting element.

*Column*: Structural member that has the primary function of resisting axial force.

*Component (of vector)*: One of several vectors combined to a resultant vector.

*Composite*: Condition in which steel and concrete elements and members work as a unit in the distribution of internal forces.

*Composite materials*: Those consisting of a combination of two or more distinct materials, together yielding superior characteristics to those of the individual constituents.

*Compression*: A force that tends to shorten or crush a member or material.

*Concentrated force*: A force acting on a single point.

*Concentrated load*: An external concentrated force (also known as a point load).

*Concrete*: Material composed mainly of cement, crushed rock or gravel, sand and water.

*Concrete crushing*: *Limit state* of compressive failure in concrete having reached the ultimate strain.

*Connection*: A connection joins members to transfer forces or moments from one to the other.

*Cope*: Cutout made in a structural member to remove a flange and conform to the shape of an intersecting member.

*Couple*: A couple is a system of two equal forces of opposite direction offset by a distance. A couple causes a moment whose magnitude equals the magnitude of the force times the offset distance.

*Cover plate*: Plate welded or bolted to the flange of a member to increase cross-sectional area, section modulus or moment of inertia.

*Creep*: Plastic deformation that proceeds with time.

*Damping*: Reduces vibration amplitude, like amplitude seismic vibration.

*Dead load*: The weight of a structure or anything permanently attached to it.

*Deflection*: Deflection is the vertical moment under gravity load of beams for example, while lateral movement under wind or seismic load is called drift.

*Deformation*: A change of the shape of an object or material.

*Design load*: Applied *load* determined in accordance with either *LRFD load combinations* or *ASD load combinations*, whichever is applicable.

*Design strength*: *Resistance factor* multiplied by the *nominal strength*,  $\phi R_n$ .

*Design stress range*: Magnitude of change in stress due to the repeated application and removal of service live *loads*. For locations subject to stress reversal it is the algebraic difference of the peak stresses.

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

*Determinate structure:* A structure with the number of reactions equal to the number of static equations (3).

*Diagonal Bracing:* Inclined structural member carrying primarily axial force in a *braced frame*.

*Diaphragm plate:* Plate possessing in-plane shear stiffness and strength, used to transfer forces to the supporting elements.

*Diaphragm:* Roof, floor or other membrane or bracing system that transfers in-plane forces to the lateral force resisting system.

*Displacement:* May be a translation, a rotation, or a combination of both.

*Distributed load:* An external force which acts over a length or an area.

*Double curvature:* Deformed shape of a beam with one or more inflection points within the span.

*Double-concentrated forces:* Two equal and opposite forces that form a couple on the same side of the loaded member.

*Drift:* Lateral deflection of structure due to lateral wind or seismic load.

*Ductility:* The capacity of a material to deform without breaking; it is measured as the ratio of total strain at failure, divided by the strain at the elastic limit.

*Durability:* Ability of a material, element or structure to perform its intended function for its required life without the need for replacement or significant repair, but subject to normal maintenance.

*Dynamic equilibrium:* Equilibrium of a moving object without change of motion.

*Dynamic load:* Cyclic load, such as gusty wind or seismic loads.

*Effective length factor,  $K$ :* Ratio between the *effective length* and the unbraced length of the member.

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

*Effective net area:* Net area modified to account for the effect of shear lag.

*Effective section modulus:* Section modulus reduced to account for buckling of slender compression elements.

*Effective width:* Reduced width of a plate or slab with an assumed uniform stress distribution which produces the same effect on the behavior of a structural member as the actual plate or slab with its nonuniform stress distribution.

*Elastic:* A material or structure is elastic if it returns to its original geometry upon unloading.

*Elastic/plastic:* Materials that have both an elastic zone and a plastic zone (i.e. steel).

*Elastic limit:* The point of a stress/strain graph beyond which deformation of a material is plastic, i.e. remains permanently deformed.

*Elastic modulus:* The linear slope value relating material stress to strain.

*End-bearing pile:* A pile supported on firm soil or rock.

*Energy:* The work to move a body a distance; energy is the product of forces times distance.

*Epicenter:* The point on the Earth's surface above the hypocenter where an earthquake originates.

*Equilibrium:* An object is in equilibrium if the resultant of all forces acting on it has zero magnitude.

*External force:* A force acting on an object; external forces are also called applied forces.

*Factored load:* Product of a *load factor* and the *nominal load*.

*Fatigue:* *Limit state* of crack initiation and growth resulting from repeated application of live loads, usually by reversing the loading direction.

*Fillet weld:* Weld of generally triangular cross section made between intersecting surfaces of elements.

*Fitted bearing stiffener:* *Stiffener* used at a support or concentrated *load* that fits tightly against one or both flanges of a *beam* so as to transmit load through bearing.

*Fixed connection:* A connection that resists axial and shear forces and bending moments.

*Flexure:* Bending deformation (of increasing curvature).

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

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

*Force:* Resultant of distribution of stress over a prescribed area, or an action that tends to change the shape of an object, move an object, or change the motion of an object.

*Foundations:* There are two basic types: ‘shallow,’ which includes pad footing, strip footings and rafts and ‘deep’ i.e. piles. The choice is a function of the strength and stiffness of the underlying strata and the load to be carried, the aim being to limit differential settlement on the structure and more importantly the finishes.

*Fully restrained moment connection:* Connection capable of transferring moment with negligible rotation between connected members.

*Funicular:* The shape of a chain or string suspended from two points under any load.

*Gravity:* An attractive force between objects; each object accelerates at the attractive force divided by its mass.

*Groove weld:* Weld in a groove between connection elements.

*Gusset plate:* Plate element connecting truss members of a strut or brace to a *beam* or *column*.

*Hertz:* Cycles per second.

*Horizontal diaphragm:* A floor or roof deck to resist lateral load.

*Horizontal shear:* Force at the interface between steel and concrete surfaces in a *composite beam*.

*Indeterminate structure:* A structure with more unknown reactions than static equations (3).

*Inelastic:* Inelastic (plastic) strain implies permanent deformation.

*Inertia:* Tendency of objects at rest to remain at rest and objects in motion to remain in motion.

*In-plane instability:* *Limit state* of a *beam-column* bent about its major axis while *lateral buckling* or *lateral-torsional buckling* is prevented by *lateral bracing*.

*Instability:* *Limit state* reached in the loading of a structural component, frame or structure in which a slight disturbance in the *loads* or geometry produces large displacements.

*Internal force:* The force within an object that resists external forces, also called resisting force.

*Joint:* Area where two or more ends, surfaces, or edges are attached. Categorized by type of *fastener* or weld used and method of force transfer.

*Joist:* A repetitive light beam.

*K-connection:* Connection in which forces in *branch members* or connecting elements transverse to the *main member* are primarily equilibrated by forces in other branch members or connecting elements on the same side of the main member.

*Kern:* The core of a post or other compression member which limits eccentric stresses being tensile.

*Lacing:* Plate, angle or other steel shape, in a lattice configuration, that connects two steel shapes together.

*Lap joint:* Joint between two overlapping connection elements in parallel planes.

*Lateral bracing:* *Diagonal bracing*, *shear walls* or equivalent means for providing in-plane lateral stability.

*Lateral load resisting system:* Structural system designed to resist lateral loads and provide stability for the structure as a whole.

*Lateral load:* *Load*, such as that produced by wind or earthquake effects, acting in a lateral direction.

*Lateral-torsional buckling:* 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.

*Length effects:* Consideration of the reduction in strength of a member based on its *unbraced length*.

*Limit state:* 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*).

*Linear:* A structural or material behavior is linear if its deformation is directly proportional to the loading.

*Line of action:* The line of action defines the location and incline of a vector.

*Linear elastic:* A force-displacement relationship which is both linear and elastic.

*Live load:* Any load not permanently attached to the structure.

*Load:* Force or other action that results from the weight of building materials, occupants and their possessions, environmental effects, differential movement, or restrained dimensional changes.

*Load effect:* Forces, stresses and deformations produced in a *structural component* by the applied *loads*.

*Load factor*: 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 bending*: *Limit state* of large deformation of a flange under a concentrated tensile force.

*Local buckling*: *Limit state* of buckling of a compression element within a cross section.

*Local crippling*: *Limit state* of local failure of web plate in the immediate vicinity of a concentrated *load* or reaction.

*Local yielding*: *Yielding* that occurs in a local area of an element.

*LRFD (Load and Resistance Factor Design)*: 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*: Load combination in the *applicable building code* intended for strength design (*load and resistance factor design*).

*Main member*: *Chord member* or column to which *branch members* or other connecting elements are attached.

*Mass*: Mass is the property of an object to resist acceleration.

*Magnitude*: a scalar value of physical units, such as force or displacement.

*Modulus of elasticity*: The proportional constant relating stress/strain of material in the linear elastic range: calculated as stress divided by strain. The modulus of elasticity is the slope of the stress-strain graph, usually denoted as E, also as Young's Modulus Y, or E-Modulus.

*Moment*: A force causing rotation without translation; defined as force times lever arm.

*Moment of inertia*: Moment of inertia is the capacity of an object to resist bending or buckling, defined as the sum of all parts of the object times the square of their distance from the centroid.

*Moment connection*: Connection that transmits bending moment between connected members.

*Moment frame*: Framing system that provides resistance to lateral loads and provides stability to the *structural system*, primarily by shear and flexure of the framing members and their connections.

*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) to resist *load effects*, as determined in accordance with this *Specification*.

*Normal stress*: Stress acting parallel to the axis of an object in compression and tension; normal stress is usually simply called stress.

*Out-of-plane buckling*: *Limit state* of a beam-column bent about its major axis while lateral buckling or *lateral-torsional buckling* is not prevented by lateral bracing.

*Overlap connection*: *Connection* in which intersecting *branch members* overlap.

*Overturn*: Topping, or tipping over under lateral load.

*Permanent load:* Load in which variations over time are rare or of small magnitude. All other loads are *variable loads*.

*Pin connection:* A pin connection transfers axial and shear forces but no bending moment.

*Pin support:* A pin support resists axial and shear forces but no bending moment.

*Pitch:* Longitudinal center-to-center spacing of fasteners. Center-to-center spacing bolt threads along axis of bolt.

*Plastic:* Material may be elastic or plastic. Plastic deformation of a structure or material under load remains after the load is removed.

*Plastic analysis:* *Structural analysis* based on the assumption of rigid-plastic behavior, in other words, that equilibrium is satisfied throughout the structure and the stress is at or below the yield stress.

*Plastic hinge:* Yielded zone that forms in a structural member when the *plastic moment* is attained. The member is assumed to rotate further as if hinged, except that such rotation is restrained by the *plastic moment*.

*Plastic moment:* Theoretical resisting moment developed within a fully yielded cross section.

*Plastic stress distribution method:* Method for determining the stresses in a composite member assuming that the steel section and the concrete in the cross section are fully plastic.

*Plate girder:* Built-up beam.

*Plug weld:* Weld made in a circular hole in one element of a joint fusing that element to another element.

*Post-buckling strength:* Load or force that can be carried by an element, member, or frame after initial buckling has occurred.

*Pressure:* Similar to stress, the force intensity at a point, except that pressure is acting on the surface of an object rather than within the object.

*Prying action:* Amplification of the tension force in a bolt caused by leverage between the point of applied load, the bolt and the reaction of the connected elements.

*Punching load:* Component of *branch member* force perpendicular to a *chord*.

*P- $\delta$  effect:* Effect of loads acting on the deflected shape of a member between joints or nodes.

*P- $\Delta$  effect:* Effect of loads acting on the displaced location of joints or nodes in a structure. In tiered building structures, this is the effect of loads acting on the laterally displaced location of floors and roofs.

*Radius of gyration:* A mathematical property, determining the stability of a cross section, defined as:  $r = \sqrt{I/A}$ , where I = moment of inertia and A = cross section area.

*Reaction:* The response of a structure to resist applied load.

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

*Resilience:* The property of structures to absorb energy without permanent deformation of fracture.

*Resistance factor  $\phi$* : Factor that accounts for unavoidable deviations of the *nominal strength* from the actual strength and for the manner and consequences of failure.

*Resultant*: The resultant of a system of forces is a single force or moment whose magnitude, direction, and location make it statically equivalent to the system of forces.

*Retaining wall*: Wall used to hold back soil or other materials.

*Roller support*: In two dimensions, a roller support restrains one translation degree of freedom.

*Rupture strength*: In a *connection*, strength limited by tension or shear rupture.

*Safety factor*: 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 consequence of failure.

*Scalar*: A mathematical entity with a numeric value but no direction (in contrast to a vector).

*Section modulus*: The property of a cross section defined by its shape and orientation; section modulus is denoted  $S$ , and  $S = I/c$ , where  $I$  = moment of inertia about the centroid and  $c$  is the distance from the centroid to the edge of the section,

*Service load combination*: Load combination under which serviceability limit states are evaluated.

*Service load*: Load under which *serviceability limit states* are evaluated.

*Serviceability limit state*: Limiting condition affecting the ability of a structure to preserve its appearance, maintainability, durability or the comfort of its occupants or function of machinery, under normal usage.

*Shear*: A sliding force, pushing and pulling in opposite directions.

*Shear buckling*: *Buckling* mode in which a plate element, such as the web of a beam, deforms under pure shear applied in the plane of the plate.

*Shear connector*: Headed stud, cannel, plate or other shape welded to a steel member and embedded in concrete of a *composite member* to transmit shear forces at the interface between the two materials.

*Shear connector strength*: *Limit state* of reaching the strength of a *shear connector*, as governed by the connector bearing against the concrete in the slab or by the *tensile strength* of the connector.

*Shear modulus*: The ratio of shear stress divided by the shear strain in a linear elastic material.

*Shear rupture*: Limit state of *rupture (fracture) due to shear*.

*Shear strain*: Strain measuring the intensity of racking in a material. Shear strain is measured as the change in angle of a small square part of a material.

*Shear stress*: Stress acting parallel to an imaginary plane cut through an object.

*Shear wall*: Wall that provides resistance to lateral loads in the plane of the wall and provides stability for the structural system.

*Shear yielding*: *Yielding* that occurs due to shear.

*Shear yielding (punching)*: In a connection, *limit state* based on out-of-plane shear strength of the *chord wall* to which *branch members* are attached.

- Slip*: In a bolted connection, *limit state* of relative motion of connected parts prior to the attainment of the *available strength* of the connection.
- Slip-critical connection*: Bolted *connection* designed to resist movement by friction on the faying surface of the connection under the clamping forces of the bolts.
- Slot weld*: Weld made in an elongated hole fusing an element to another element.
- Splice*: *Connection* between two structural elements joined at their ends to form a single, longer element.
- Stability*: Condition reached in the loading of a structural component, frame or structure in which a slight disturbance in the *loads* or geometry does not produce large displacements.
- Static equilibrium*: Equilibrium of an object at rest.
- Stiffness*: The capacity of a material to resist deformation.
- Stiffened element*: Flat compression element with adjoining out-of-plane elements along both edges parallel to the direction of loading.
- Stiffener*: Structural element, usually an angle or plate, attached to a *member* to distribute *load*, transfer shear or prevent buckling.
- Stiffness*: Resistance to deformation of a member or structure, measured by the ratio of the applied force (or moment) to the corresponding displacement (or rotation).
- Strain*: Change of length along an axis, calculated as  $\epsilon = \Delta L/L$ , where L is the original length and  $\Delta L$  is the change of length.
- Strength*: The capacity of a material to resist breaking.
- Strength design*: A design method based on factored load and ultimate strength for concrete design.
- Strength limit state*: Limiting condition affecting the safety of the structure, in which the ultimate load-carrying capacity is reached.
- Stress*: Force per unit area caused by axial force, moment, shear or torsion.
- Stress concentration*: Localized stress considerably higher than average (even in uniformly loaded cross sections of uniform thickness) due to abrupt changes in geometry or localized loading.
- Stress resultant*: A system of forces which is statically equivalent to a stress distribution over an area.
- Stress*: The internal reaction to an applied force, measured in force per unit area.
- Structure*: Composition of elements that define form and resist applied loads.
- Structural Aluminum*: Elements manufactured of aluminum for structural purposes, generally 50% larger than comparable steel elements due to the lower *modulus of elasticity*.
- Structural Steel*: Elements manufactured of steel with properties designated by *ASTM standards*, including A36, A992 & A572.
- Strong axis*: Major principal centroidal axis of a cross section.
- Structural analysis*: Determination of *load effects* on members and *connections* based on principles of structural mechanics.

*Structural component*: Member, connector, connecting element or assemblage.

*Structural system*: An assemblage of load-carrying components that are joined together to provide interaction or interdependence.

*T-connection*: *Connection* in which the *branch member* or connecting element is perpendicular to the *main member* and in which forces transverse to the main member are primarily equilibrated by shear in the main member.

*Tensile rupture*: *Limit state* of rupture (fracture) due to tension.

*Tensile strength (of material)*: Maximum tensile stress that a material is capable of sustaining as defined by ASTM.

*Tensile strength (of member)*: Maximum tension force that a member is capable of sustaining.

*Tensile yielding*: *Yielding that occurs due to tension*.

*Tension*: A force that tends to elongate or enlarge an object.

*Tension and shear rupture*: In a bolt, *limit state* of rupture (fracture) due to simultaneous tension and shear force.

*Tie plate*: Plate element used to join parallel components of a *built-up column*, girder or strut rigidly connected to the parallel components and designed to transmit shear between them.

*Torsion*: A twisting moment.

*Torsional bracing*: Bracing resisting twist of a *beam* or *column*.

*Torsional buckling*: *Buckling mode* in which a compression member twists about its shear center axis.

*Torsional yielding*: *Yielding that occurs due to torsion*.

*Translation*: Motion of an object along a straight line path without rotation.

*Transverse reinforcement*: Steel reinforcement in the form of closed ties or welded wire fabric providing confinement for the concrete surrounding the steel shape core in an *encased concrete composite column*.

*Transverse stiffener*: *Web stiffener* oriented perpendicular to the flanges, attached to the web.

*Truss*: A linear support system consisting of triangular panels usually with pin joints.

*Ultimate strength*: The utmost strength reached by a material before breaking.

*Unbraced length*: Distance between braced points of a member, measured between the centers of gravity of the bracing members.

*Uneven load distribution*: In a *connection*, condition in which the load is not distributed through the cross section of connected elements in a manner that can be readily determined.

*Unframed end*: The end of a member not restrained against rotation by stiffeners of connection elements.

*Unstiffened elements*: Flat compression element with an adjoining out-of-plane element along one edge parallel to the direction of loading.

*Uplift*: Upward force, usually wind uplift.

*Variable load*: Load not classified as *permanent load*.

*Vector*: A mathematical entity having a magnitude, line of action, and a direction in space.

*Vertical bracing system*: System of *shear walls*, *braced frames* or both, extending through one or more floors of a building.

*Vertical diaphragm*: A wall to resist lateral load.

*Vibration*: The cyclic motion of an object.

*Wall*: A vertical element to resist load and define space; shear walls also resist lateral loads.

*Weak axis*: Minor principal centroidal axis of a cross section.

*Web buckling*: *Limit state* of lateral instability of a web.

*Web compression buckling*: *Limit state* of out-of-plane compression buckling of the web due to a concentrated compression force.

*Web sideways buckling*: *Limit state* of lateral buckling of the tension flange opposite the location of a concentrated compression force.

*Weld metal*: Portion of a fusion weld that has been completely melted during welding. Weld metal has elements of filler metal and base metal melted in the weld thermal cycle.

*Working stress*: The same as allowable stress.

*Yield moment*: In a member subjected to bending, the moment at which the extreme outer fiber first attains the *yield stress*.

*Yield point*: First stress in a material at which an increase in strain occurs without an increase in stress as defined by ASTM.

*Yield strength*: *Stress* at which a material exhibits a specified limiting deviation from the proportionality of stress to strain as defined by ASTM.

*Yield strain*: The strain of a material which occurs at the level of yield stress.

*Yield stress*: Generic term to denote either *yield point* or *yield strength*, as appropriate for the material.

*Yielding*: *Limit state* of inelastic deformation that occurs after the *yield stress* is reached.

*Yielding (plastic moment)*: *Yielding* throughout the cross section of a member as the bending moment reaches the *plastic moment*.

*Yielding (yield moment)*: *Yielding* at the extreme fiber on the cross section of a member when the bending moment reached the *yield moment*.

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References:

AISC, *Specifications for Structural Steel Buildings*, 13<sup>th</sup> ed. (2005)

Jacqueline Glass, *Encyclopaedia of Architectural Technology*, Wiley, Cornwall (2002)