Preparation of Notation for Concrete (ACI 104-71)
(Revised 1982) (Reapproved 1997)

Reported by ACI Committee 104*

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Indicates how symbols shall be selected top represent quantities or terms Principle symbols are upper and lower case Roman letters and Greek lower case letters. Roman lower case letters are used as subscripts and Greek upper case letters are reserved for mathematics.

Keywords: coding; concretes; definitions; **nomenclature; notation;** prestressed concrete; reinforced concrete; structural analysis; structural design; **symbols; terminology.**

PREPARATION OF NOTATION

Scope

All symbols used in defining any aspect of concrete construction shall be prepared using the guide outlined in Table 1.

Construction of symbols

The preparation of a symbol to represent a given quantity shall be conducted in the following manner.

(a) The leading or main letter of the symbol shall be selected from Table 1 based on

TABLE 1—GUIDE FOR CONSTRUCTION OF SYMBOLS

(a) Roman capital letters (dimensions: force, force times length, area, area to a power, temperature)
1. Moments, shears, normal forces, concentrated loads, total loads
2. Area, first and second moments of area
3. Strain moduli (exception to dimensions)
4. Temperature

(b) Roman lower case letters (dimensions: length, length per time to a power, force per unit length, area, or volume, except where used as subscripts)
1. Unit moments, shears, normal forces, loads
2. Linear dimensions (length, width, thickness, etc.
3. Unit strengths, stresses[1]
4. Velocity acceleration, frequency
5. Descriptive letters (subscripts)

(c) Greek upper case letters
Reserved for mathematics

(d) Greek lower case letters (dimensionless)
1. Coefficients and dimensionless ratios
2. Strains
3. Angles
4. Specific gravity (ratio of densities)
5. Variable stresses (exception, CEB usage only)[1]

(e) Indices
′ = compression

(f) Subscripts
Roman lower case letters may be used following the main symbol as required. Definitions assigned to subscripts include but are not limited to those listed below

a = additional
b = bond
c = concrete
e = effective, elastic
i = initial
k = characteristic
l = longitudinal
m = average
p = prestress
r = tensile rupture
s = steel
u = ultimate
υ = shear
x, y, z = axial directions

[1]Compatibility between ACI and CEB symbology for stresses to be achieved in the future

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consideration of the dimensions of the quantity under consideration.

(b) An index representing compression shall be added to symbols representing geometrical quantities if required.

(c) Descriptive subscripts may be selected as desired. When subscripts other than those appearing in Table 1 are used, a clear written definition of their meaning shall be given.

(d) The sign of a computed stress is given by + (plus) for tension and – (minus) for compression.

COMMENTARY AND APPENDICES

Tne following commentary and appendices, while not a part of ACI 104-71, will assist the user in applying the standard and selecting notation which conforms to selections made by ACI committees, based on the standard.

Commentary on Application of Standard Notation

Need for standard notation

A "symbol" is here defined as a short grouping of letters and numerals to represent a written definition of some engineering concept. Thus, A_s is commonly used to define the cross-sectional area of reinforcing steel. The body of symbols used by an engineering discipline is further defined as the "notation" for that discipline. The sole function of a notation is to serve as a form of "shorthand" to aid in the communication of ideas among members of the discipline. A good notation then is one which best serves its masters. Hallmarks of a good notation are lack of ambiguity in determining the meaning of any given symbol, consistency of construction of symbols, and a common use of the notation by all members of the discipline.

Prior to the adoption of ACI Standard 104 in 1971, the notation for concrete in use in United States practice was the product of random evolution and not systematic planning. As a result, a single symbol was often used to represent a multiplicity of disparate concepts in a number of cases. For example, the symbol D was used to represent dead loads, bar diameter, column diameter, and wall length. Also a number of slightly different definitions of the same basic concept were represented by a single symbol, such as t to represent many kinds of thickness. With the rapid development of new knowledge and the corresponding continual need for new symbols, the need for a consistent method for the construction and definition of symbols was apparent.

In the 1977 Code, the subscript u has been reserved for load effects (shear force, bending moment) computed from factored loads. The subscript n is used for nominal strength which is the strength calculated using the nominal values of f_c', f_y, etc., and the standard calculation procedures.

Development of standard notation

Recognizing the need for a standard, the Technical Activities Committee of ACI organized Committee 104, Notation, in 1964. Initially, the committee examined the notation[1] prepared by Commission VII, Notation and Terminology, of the Comite Europeen du Beton (European Concrete Committee) to see if it could be adopted in toto since one of the goals was the attainment of a universal standard. However, the first version of the notation prepared by CEB VII was felt to be unacceptable since it involved the use of a large number of sub- and superscripts and Greek letters. Hence, it was necessary for ACI 104 to develop an independent notation which was, however, modeled as closely as possible on that of the CEB. The first version of the ACI 104 notation was published in the May 1968 ACI JOURNAL.[2]

Close liaison between ACI 104 and CEB VII was maintained by having several persons serve simultaneously as members of each committee. The possibility of arriving at a common ACI-CEB notation was continuously explored but appeared unlikely until about 1969, since the CEB notation had already been adopted by several countries for use in their national building codes. However, at the 13th biennial meeting of the CEB, held at Scheveningen, Netherlands, in September 1969, discussions of a common ACI-CEB Standard for notation were held. Extensive discussions were conducted jointly by ACI 104 and CEB VII and also the general assembly discussed notation during two meetings. The point was repeatedly made that several major codes, including the ACI, the CEB, the British, the Scandinavian, and others, were soon to appear in new editions and that the Scheveningen meeting represented the last chance to arrive at a common standard for perhaps decades. During the discussions numerous compromises were made and a proposed standard was developed. The standard was adopted by the CEB general assembly contingent upon its acceptance by the ACI. The standard was then presented to ACI membership vote and adopted as an ACI standard in 1971. The new standard for preparation of notation for concrete thus became the first universal standard in any profession.

The logic of the system described in Table 1 of the standard lies in the selection of the leading letter of a symbol based on a consideration of the units of the physical quantity involved. One exception occurs in the case of strain moduli. The symbols E and G are retained for Young's modulus and the shear modulus since these are now universally in use. One divergence between CEB and ACI usage is the retention by CEB of sigma and tau for normal and shear stresses.

A detailed description of the usage of each Roman and Greek letter based upon the standard is given in Appendix A. Definitions which are not italicized were jointly adopted. Italicized definitions have been adopted by ACI.

References

1. *International Recommendations for the Design and Construction of Concrete Structures,* Comite Europeen du Beton/Federation Internationale de la Precontrainte, Paris, 1970. (English translation, Cement and Concrete Association, London, 1970, 80 pp.)

2. Vanderbilt, M. D., "Notation—The Case for a New System," ACI JOURNAL, *Proceedings* V. 65, No. 5, May 1968, pp. 357–361.

3. "Bases for Design of Structures: Notations, General Symbols," (ISO 3898-1976), International Standards Organization/American National Standards Institute, New York, 1976, 4 pp.

Appendices

APPENDIX A—DETAILED DESCRIPTION OF USAGE OF ROMAN AND GREEK LETTERS*

Typical notation for reinforced concrete cross sections is shown in Fig. 1.

Capital Roman letters

A = area
B =
C = torsional constant
D = *dead load*
E = modulus of elasticity; *earthquake load*
F = force; load; *liquid pressure*
G = modulus of shear
H = *lateral force; lateral earth pressure*
I = moment of inertia
J =
K = any coefficient with proper dimensions
L = *live load*
M = bending moment
N = normal force
O = (VOID)†
P = prestressing force; *axial load*
Q =
R =
S = first moment of an area; internal forces; load effects
T = torsional moment; temperature
U = *required strength*
V = shear force
W = wind load
X = reactions or forces in general, parallel to axis x
Y = reactions or forces in general, parallel to axis y
Z = reactions or forces in general, parallel to axis z

Lower case Roman letters

a = deflection; distance; *depth of rectangular stress block*
b = width
c = distance from compression fiber to neutral axis
d = effective depth; diameter (see also h)
e = eccentricity, base of Napierian logarithms (mathematical usage)
f = unit strength *or stress* (*f_c for concrete in compression, f_r* for concrete in tension, and f_s for steel)
g = acceleration due to gravity
h = total depth; thickness; diameter
i =
j =
k = any coefficient with proper dimensions
l = span; length of member or element
m = bending moment per unit length
n = unit normal force; number
o = (VOID)
p = (VOID)
q =
r = *radius of gyration*
s = standard deviation; spacing
t = time; unit torsional moment per unit length
u =
v = shear; *stress*
w = crack width; *total load per unit length or area*
x = coordinate
y = coordinate
z = coordinate; *reinforcement distribution factor*

*Italicized words indicate ACI usage.
All other definitions are common ACI-CEB-FIP usage.
A blank space indicates an unassigned letter.
†Void indicates the letter shall not be used.

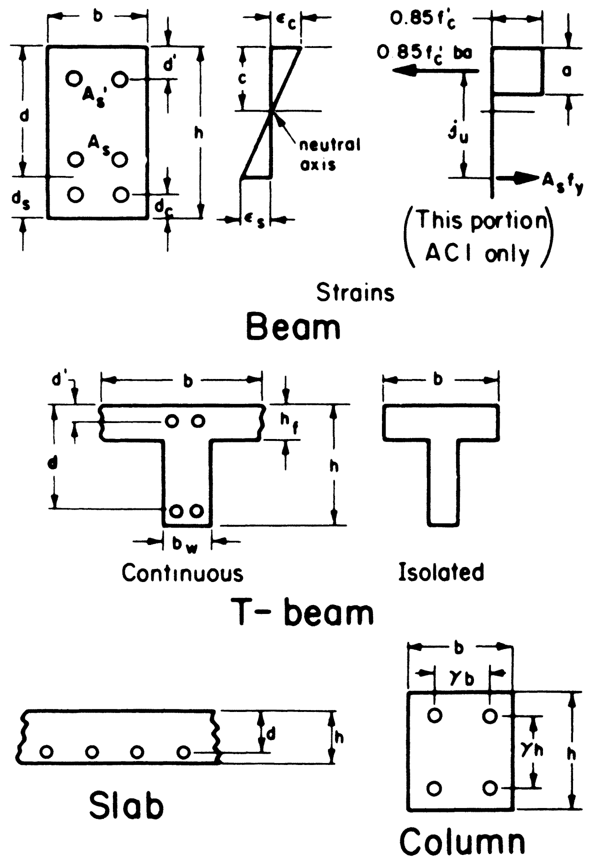

Fig. 1 — Typical notation for reinforced concrete cross sections

Lower case Greek letters

Alpha	α	= angle; ratio; coefficient
Beta	β	= angle; ratio; coefficient
Gamma	γ	= specific gravity; ratio
Delta	δ	= coefficient; coefficient of variation
Epsilon	ϵ	= strain
Zeta	ζ	= coefficient
Eta	η	= (VOID)
Theta	θ	= rotation
Iota	ι	= (VOID)
Kappa	κ	= (VOID)
Lambda	λ	= slenderness ratio; coefficient
Mu	μ	= coefficient of friction
Nu	ν	= Poisson's ratio
Xi	ξ	= coefficient
Omicron	o	= (VOID)
Pi	π	= reserved for mathematics, 3.14159
Rho	ρ	= geometrical ratio of reinforcement $\rho = \frac{A_s}{A_c}$, $\rho' = \frac{A_s'}{A_c}$
Sigma	σ	= normal stress (CEB only)
Tau	τ	= shear or transverse stress (CEB only)
Upsilon	υ	= (VOID)
Phi	ϕ	= *strength reduction factor; creep coefficient*

Chi χ = (VOID)
Psi ψ =
Omega ω = reinforcing strength index

Subscripts

a = additional
b = bond; bar; beam; *balanced*
c = concrete; column; compression; *critical*
d = design; *dead load*
e = effective; elastic
f = flange; flexure; friction; fatigue
g = *gross*
h = horizontal; hook; *hoop*
i = initial
j =
k = characteristic
l = longitudinal; *live load*
m = average values; *moment*
n = number; *net; nominal*
o = a particular value of a quantity
p = prestress; *pile*
q =
r = tensile rupture
s = steel; slab
t = transversal; torsion; tension; total; *tubing;* time
u = *unsupported;* factored load effect at ultimate
v = shear; vertical
w = wind; *wire; web; wall*
x = axial direction
y = axial direction; yield
z = axial direction
0, 1, 2 . . . = particular values of quantities

Subscripts formed from abbreviations

bal = *balanced*
cr = *cracked,* critical
max = maximum
min = minimum
sp = *spiral*
vert = *vertical*

Subscripts for loads

d = *dead load*
l = *live load*
eq = earthquake
h = *earth pressure*
te = temperature; creep; shrinkage; prestrain effects
wl = wind load

APPENDIX B—NOTATION FOR ACI 318-05

Reproduced in the following pages is the notation selected for "Building Code Requirements for Structural Concrete (ACI 318-05) and Commentary (318R-05)." These lists should be useful to committees and other authors in selecting notation for their use. Note that while ACI 318-05, and all preceeding discussion, is independent of any system of units such as SI, U.S. Customary, etc., many of the symbols given in the following contain U.S. Customary units because they appear in empirical equations.

The notation used in the code and commentary follows "Preparation of Notation for Concrete (ACI 104-71 (Revised 1982) (Reapproved 1997))" with very few exceptions and also follows the principles adopted by the Comite Euro-International du Beton.

Code notation

The terms in this list are used in the code and as needed in the commentary.

a = depth of equivalent rectangular stress block as defined in 10.2.7.1, in., Chapter 10

a_v = shear span, equal to distance from center of concentrated load to either (a) face of support for continuous or cantilevered members, or (b) center of support for simply supported members, in., Chapter 11, Appendix A

A_b = area of an individual bar or wire, in.^{2}, Chapters 10, 12

A_{brg} = bearing area of the head of stud or anchor bolt, in.^{2}, Appendix D

A_c = area of concrete section resisting shear transfer, in.^{2}, Chapter 11

A_{cf} = larger gross cross-sectional area of the slab-beam strips of the two orthogonal equivalent frames intersecting at a column of a two-way slab, in.^{2}, Chapter 18

A_{ch} = cross-sectional area of a structural member measured out-to-out of transverse reinforcement, in.^{2}, Chapters 10, 21

A_{cp} = area enclosed by outside perimeter of concrete cross section, in.^{2}, see 11.6.1, Chapter 11

A_{cs} = cross-sectional area at one end of a strut in a strut-and-tie model, taken perpendicular to the axis of the strut, in.^{2}, Appendix A

A_{ct} = area of that part of cross section between the flexural tension face and center of gravity of gross section, in.^{2}, Chapter 18

A_{cv} = gross area of concrete section bounded by web thickness and length of section in the direction of shear force considered, in.^{2}, Chapter 21

A_{cw} = area of concrete section of an individual pier, horizontal wall segment, or coupling beam resisting shear, in.^{2}, Chapter 21

A_f = area of reinforcement in bracket or corbel resisting factored moment, in.^{2}, see 11.9, Chapter 11

A_g = gross area of concrete section, in.^{2} For a hollow section, A_g is the area of the concrete only and does not include the area of the void(s), see 11.6.1, Chapters 9-11, 14-16, 21, 22, Appendixes B, C.

A_h = total area of shear reinforcement parallel to primary tension reinforcement in a corbel or bracket, in.^{2}, see 11.9, Chapter 11

A_j = effective cross-sectional area within a joint in a plane parallel to plane of reinforcement generating shear in the joint, in.^{2}, see 21.5.3.1, Chapter 21

A_ℓ = total area of longitudinal reinforcement to resist torsion, in.^{2}, Chapter 11

$A_{\ell,min}$ = minimum area of longitudinal reinforcement to resist torsion, in.^{2}, see 11.6.5.3, Chapter 11

A_n = area of reinforcement in bracket or corbel resisting tensile force N_{uc}, in.^{2}, see 11.9, Chapter 11

A_{nz} = area of a face of a nodal zone or a section through a nodal zone, in.^{2}, Appendix A

A_{Nc} = projected concrete failure area of a single anchor or group of anchors, for calculation of strength in tension, in.^{2}, see D.5.2.1, Appendix D

A_{Nco} = projected concrete failure area of a single anchor, for calculation of strength in tension if not limited by edge distance or spacing, in.^{2}, see D.5.2.1, Appendix D

A_o = gross area enclosed by shear flow path, in.^{2}, Chapter 11

A_{oh} = area enclosed by centerline of the outermost closed transverse torsional reinforcement, in.^{2}, Chapter 11

A_{ps} = area of prestressing steel in flexural tension zone, in.^{2}, Chapter 18, Appendix B

A_s = area of nonprestressed longitudinal tension reinforcement, in.^{2}, Chapters 10-12, 14, 15, 18, Appendix B

A_s' = area of longitudinal compression reinforcement, in.^{2}, Appendix A

A_{sc} = area of primary tension reinforcement in a corbel or bracket, in.^{2}, see 11.9.3.5, Chapter 11

A_{se} = effective cross-sectional area of anchor, in.^{2}, Appendix D

A_{sh} = total cross-sectional area of transverse reinforcement (including crossties) within spacing s and perpendicular to dimension b_c, in.^{2}, Chapter 21

A_{si} = total area of surface reinforcement at spacing s_i in the i-th layer crossing a strut, with reinforcement at an angle α_i to the axis of the strut, in.^{2}, Appendix A

$A_{s,min}$ = minimum area of flexural reinforcement, in.^{2}, see 10.5, Chapter 10

A_{st} = total area of nonprestressed longitudinal reinforcement, (bars or steel shapes), in.^{2}, Chapters 10, 21

A_{sx} = area of structural steel shape, pipe, or tubing in a composite section, in.^{2}, Chapter 10

A_t = area of one leg of a closed stirrup resisting torsion within spacing s, in.^{2}, Chapter 11

A_{tp} = area of prestressing steel in a tie, in.^{2}, Appendix A

A_{tr} = total cross-sectional area of all transverse reinforcement within spacing s that crosses the potential plane of splitting through the reinforcement being developed, in.^{2}, Chapter 12

A_{ts} = area of nonprestressed reinforcement in a tie, in.^{2}, Appendix A

A_v = area of shear reinforcement spacing s, in.^{2}, Chapters 11, 17

A_{Vc} = projected concrete failure area of a single anchor or group of anchors, for calculation of strength in shear, in.^{2}, see D.6.2.1, Appendix D

A_{Vco} = projected concrete failure area of a single anchor, for calculation of strength in shear, if not limited by corner influences, spacing, or member thickness, in.^{2}, see D.6.2.1, Appendix D

A_{vd} = total area of reinforcement in each group of diagonal bars in a diagonally reinforced coupling beam, in.^{2}, Chapter 21

A_{vf} = area of shear-friction reinforcement, in.^{2}, Chapter 11

A_{vh} = area of shear reinforcement parallel to flexural tension reinforcement within spacing s_2, in.^{2}, Chapter 11

$A_{v,min}$ = minimum area of shear reinforcement within spacing s, in.^{2}, see 11.5.6.3 and 11.5.6.4, Chapter 11

A_1 = loaded area, in.^{2}, Chapters 10, 22

A_2 = area of the lower base of the largest frustum of a pyramid, cone, or tapered wedge contained wholly within the support and having for its upper base the loaded area, and having side slopes of 1 vertical to 2 horizontal, in.^{2}, Chapters 10, 22

b = width of compression face of member, in., Chapter 10, Appendix B

b_c = cross-sectional dimension of column core measured center-to-center of outer legs of the transverse reinforcement comprising area A_{sh}, in., Chapter 21

b_o = perimeter of critical section for shear in slabs and footings, in., see 11.12.1.2, Chapters 11, 22

b_s = width of strut, in., Appendix A

b_t = width of that part of cross section containing the closed stirrups resisting torsion, in., Chapter 11

b_v = width of cross section at contact surface being investigated for horizontal shear, in., Chapter 17

b_w = web width, or diameter of circular section, in., Chapters 10-12, 21, 22, Appendix B

b_1 = dimension of the critical section b_o measured in the direction of the span for which moments are determined, in., Chapter 13

b_2 = dimension of the critical section b_o measured in the direction perpendicular to b_1, in., Chapter 13

B_n = nominal bearing strength, lb, Chapter 22

B_u = factored bearing load, lb, Chapter 22

c = distance from extreme compression fiber to neutral axis, in., Chapters 9, 10, 14, 21

c_{ac} = critical edge distance required to develop the basic concrete breakout strength of a post-installed anchor in uncracked concrete without supplementary reinforcement to control splitting, in., see D.8.6, Appendix D

$c_{a,max}$ = maximum distance from center of an anchor shaft to the edge of concrete, in., Appendix D

$c_{a,min}$ = minimum distance from center of an anchor shaft to the edge of concrete, in., Appendix D

c_{a1} = distance from the center of an anchor shaft to the edge of concrete in one direction, in. If shear is applied to anchor, c_{a1} is taken in the direction of the applied shear. If the tension is applied to the anchor, c_{a1} is the minimum edge distance, Appendix D

c_{a2} = distance from center of an anchor shaft to the edge of concrete in the direction perpendicular to c_{a1}, in., Appendix D

c_b = smaller of (a) the distance from center of a bar or wire to nearest concrete surface, and (b) one-half the center-to-center spacing of bars or wires being developed, in., Chapter 12

c_c = clear cover of reinforcement, in., see 10.6.4, Chapter 10

c_t = distance from the interior face of the column to the slab edge measured parallel to c_1, but not exceeding c_1, in., Chapter 21

c_1 = dimension of rectangular or equivalent rectangular column, capital, or bracket measured in the direction of the span for which moments are being determined, in., Chapters 11, 13, 21

c_2 = dimension of rectangular or equivalent rectangular column, capital, or bracket measured in the direction perpendicular to c_1, in., Chapter 13

C = cross-sectional constant to define torsional properties of slab and beam, see 13.6.4.2, Chapter 13

C_m = factor relating actual moment diagram to an equivalent uniform moment diagram, Chapter 10

d = distance from extreme compression fiber to centroid of longitudinal tension reinforcement, in., Chapters 7, 9-12, 14, 17, 18, 21, Appendixes B, C

d' = distance from extreme compression fiber to centroid of longitudinal compression reinforcement, in., Chapters 9, 18, Appendix C

d_b = nominal diameter of bar, wire, or prestressing strand, in., Chapters 7, 12, 21

d_o = outside diameter of anchor or shaft diameter of headed stud, headed bolt, or hooked bolt, in., see D.8.4, Appendix D

d_o' = value substituted for d_o when an oversized anchor is used, in., see D.8.4, Appendix D

d_p = distance from extreme compression fiber to centroid of prestressing steel, in., Chapters 11,18, Appendix B

d_{pile} = diameter of pile at footing base, in., Chapter 15

d_t = distance from extreme compression fiber to centroid of extreme layer of longitudinal tension steel, in., Chapters 9, 10, Appendix C

D = dead loads, or related internal moments and forces, Chapters 8, 9, 20, 21, Appendix C

e = base of Napierian logarithms, Chapter 18

e_h = distance from the inner surface of the shaft of a J- or L-bolt to the outer tip of the J- or L-bolt, in., Appendix D

e_N' = distance between resultant tension load on a group of anchors loaded in tension and the centroid of the group of anchors loaded in tension, in.; e_N' is always positive, Appendix D

e_V' = distance between resultant shear load on a group of anchors loaded in shear in the same direction, and the centroid of the group of anchors loaded in shear in the same direction, in., e_V' is always positive, Appendix D

E = load effects of earthquake, or related internal moments and forces, Chapters 9, 21, Appendix C

E_c = modulus of elasticity of concrete, psi, see 8.5.1, Chapters 8-10, 14, 19

E_{cb} = modulus of elasticity of beam concrete, psi, Chapter 13

E_{cs} = modulus of elasticity of slab concrete, psi, Chapter 13

EI = flexural stiffness of compression member, in.^{2}-lb, see 10.12.3, Chapter 10

E_p = modulus of elasticity of prestressing steel, psi, see 8.5.3, Chapter 8

E_s = modulus of elasticity of reinforcement and structural steel, psi, see 8.5.2, Chapters 8, 10, 14

f_c' = specified compressive strength of concrete, psi, Chapters 4, 5, 8-12, 14, 18, 19, 21, 22, Appendixes A-D

$\sqrt{f_c'}$ = square root of specified compressive strength of concrete, psi, Chapters 8, 9, 11, 12, 18, 19, 21, 22, Appendix D

f_{ce} = effective compressive strength of the concrete in a strut or a nodal zone, psi, Chapter 15, Appendix A

f_{ci}' = specified compressive strength of concrete at time of initial prestress, psi, Chapters 7, 18

$\sqrt{f_{ci}'}$ = square root of specified compressive strength of concrete at time of initial prestress, psi, Chapter 18

f_{cr}' = required average compressive strength of concrete used as the basis for selection of concrete proportions, psi, Chapter 5

f_{ct} = average splitting tensile strength of lightweight concrete, psi, Chapters 5, 9, 11, 12, 22

f_d = stress due to unfactored dead load, at extreme fiber of section where tensile stress is caused by externally applied loads, psi, Chapter 11

f_{dc} = decompression stress; stress in the prestressing steel when stress is zero in the concrete at the same level as the centroid of the prestressing steel, psi, Chapter 18

f_{pc} = compressive stress in concrete (after allowance for all prestress losses) at centroid of cross section resisting externally applied loads or at junction of web and flange when the centroid lies within the flange, psi. (In a composite member, f_{pc} is the resultant compressive stress at centroid of composite section, or at junction of web and flange when the centroid lies within the flange, due to both prestress and moments resisted by precast member acting alone), Chapter 11

f_{pe} = compressive stress in concrete due to effective prestress forces only (after allowance for all prestress losses) at extreme fiber of section where tensile stress is caused by externally applied loads, psi, Chapter 11

f_{ps} = stress in prestressing steel at nominal flexural strength, psi, Chapters 12, 18

f_{pu} = specified tensile strength of prestressing steel, psi, Chapters 11, 18

f_{py} = specified yield strength of prestressing steel, psi, Chapter 18

f_r = modulus of rupture of concrete, psi, see 9.5.2.3, Chapters 9, 14, 18, Appendix B

f_s = calculated tensile stress in reinforcement at service loads, psi, Chapters 10, 18

f_s' = stress in compression reinforcement under factored loads, psi, Appendix A

f_{se} = effective stress in prestressing steel (after allowance for all prestress losses), psi, Chapters 12, 18, Appendix A

f_t = extreme fiber stress in tension in the precompressed tensile zone calculated at service loads using gross section properties, psi, see 18.3.3, Chapter 18

f_{uta} = specified tensile strength of anchor steel, psi, Appendix D

f_y = specified yield strength of reinforcement, psi, Chapters 3, 7, 9-12, 14, 17-19, 21, Appendixes A-C

f_{ya} = specified yield strength of anchor steel, psi, Appendix D

f_{yt} = specified yield strength f_y of transverse reinforcement, psi, Chapters 10-12, 21

F = loads due to weight and pressures of fluids with well-defined densities and controllable maximum heights, or related internal moments and forces, Chapter 9, Appendix C

F_n = nominal strength of a strut, tie, or nodal zone, lb, Appendix A

F_{nn} = nominal strength at face of a nodal zone, lb, Appendix A

F_{ns} = nominal strength of a strut, lb, Appendix A

F_{nt} = nominal strength of a tie, lb, Appendix A

F_u = factored force acting in a strut, tie, bearing area, or nodal zone in a strut-and-tie model, lb, Appendix A

h = overall thickness or height of member, in., Chapters 9-12, 14, 17, 18, 20-22, Appendixes A, C

h_a = thickness of member in which an anchor is located, measured parallel to anchor axis, in., Appendix D

h_{ef} = effective embedment depth of anchor, in., see D.8.5, Appendix D

h_v = depth of shearhead cross section, in., Chapter 11

h_w = height of entire wall from base to top or height of the segment of wall considered, in., Chapters 11, 21

h_x = maximum center-to-center horizontal spacing of crossties or hoop legs on all faces of the column, in., Chapter 21

H = loads due to weight and pressure of soil, water in soil, or other materials, or related internal moments and forces, Chapter 9, Appendix C

I = moment of inertia of section about centroidal axis, in.^{4}, Chapters 10, 11

I_b = moment of inertia of gross section of beam about centroidal axis, in.^{4}, see 13.2.4, Chapter 13

I_{cr} = moment of inertia of cracked section transformed to concrete, in.^{4}, Chapters 9, 14

I_e = effective moment of inertia for computation of deflection, in.^{4}, see 9.5.2.3, Chapters 9, 14

I_g = moment of inertia of gross concrete section about centroidal axis, neglecting reinforcement, in.^{4},Chapters 9, 10

I_s = moment of inertia of gross section of slab about centroidal axis defined for calculating α_f and β_t, in.^{4}, Chapter 13

I_{se} = moment of inertia of reinforcement about centroidal axis of member cross section, in.^{4}, Chapter 10

I_{sx} = moment of inertia of structural steel shape, pipe, or tubing about centroidal axis of composite member cross section, in.^{4}, Chapter 10

k = effective length factor for compression members, Chapters 10, 14

k_c = coefficient for basic concrete breakout strength in tension, Appendix D

k_{cp} = coefficient for pryout strength, Appendix D

K = wobble friction coefficient per foot of tendon, Chapter 18

K_{tr} = transverse reinforcement index, see 12.2.3, Chapter 12

ℓ = span length of beam or one-way slab; clear projection of cantilever, in., see 8.7, Chapter 9

ℓ_a = additional embedment length beyond centerline of support or point of inflection, in., Chapter 12

ℓ_c = length of compression member in a frame, measured center-to-center of the joints in the frame, in., Chapters 10, 14, 22

ℓ_d = development length in tension of deformed bar, deformed wire, plain and deformed welded wire reinforcement, or pretensioned strand, in., Chapters 7, 12, 19, 21

ℓ_{dc} = development length in compression of deformed bars and deformed wire, in., Chapter 12

ℓ_{dh} = development length in tension of deformed bar or deformed wire with a standard hook, measured from critical section to outside end of hook (straight embedment length between critical section and start of hook [point of tangency] plus inside radius of bend and one bar diameter), in., see 12.5 and 21.5.4, Chapters 12, 21

ℓ_e = load bearing length of anchor for shear, in., see D.6.2.2, Appendix D

ℓ_n = length of clear span measured face-to-face of of supports, in., Chapters 8-11, 13, 16, 18, 21

ℓ_o = length, measured from joint face along axis of structural member, over which special transverse reinforcement must be provided, in., Chapter 21

ℓ_{px} = distance from jacking end of prestressing steel element to point under consideration, ft, see 18.6.2, Chapter 18

ℓ_t = span of member under load test, taken as the shorter span for two-way slab systems, in. Span is the smaller of (a) distance between centers of supports, and (b) clear distance between supports plus thickness h of member. Span for a cantilever shall be taken as twice the distance from face of support to cantilever end, Chapter 20

ℓ_u = unsupported length of compression member, in., see 10.11.3.1, Chapter 10

ℓ_v = length of shearhead arm from centroid of concentrated load or reaction, in., Chapter 11

ℓ_w = length of entire wall or length of segment of wall considered in direction of shear force, in., Chapters 11, 14, 21

ℓ_1 = length of span in direction that moments are being determined, measured center-to-center of supports, in., Chapter 13

ℓ_2 = length of span in direction perpendicular to ℓ_1, measured center-to-center of supports, in., see 13.6.2.3 and 13.6.2.4, Chapter 13

L = live loads, or related internal moments and forces, Chapters 8, 9, 20, 21, Appendix C

L_r = roof live load, or related internal moments and forces, Chapter 9

M = maximum unfactored moment due to service loads, including $P\Delta$ effects, in.-lb, Chapter 14

M_a = maximum unfactored moment in member at stage deflection is computed, in.-lb, Chapters 9, 14

M_c = factored moment amplified for the effects of member curvature used for design of compression member, in.-lb, see 10.12.3, Chapter 10

M_{cr} = cracking moment, in.-lb, see 9.5.2.3, Chapters 9, 14

M_{cre}= moment causing flexural cracking at section due to externally applied loads, in.-lb, Chapter 11

M_m = factored moment modified to account for effect of axial compression, in.-lb, see 11.3.2.2, Chapter 11

M_{max}= maximum factored moment at section due to externally applied loads, in.-lb, Chapter 11

M_n = nominal flexural strength at section, in.-lb, Chapters 11, 12, 14, 18, 21, 22

M_{nb}= nominal flexural strength of beam including slab where in tension, framing into joint, in.-lb, see 21.4.2.2, Chapter 21

M_{nc}= nominal flexural strength of column framing into joint, calculated for factored axial force, consistent with the direction of lateral forces considered, resulting in lowest flexural strength, in.-lb, see 21.4.2.2, Chapter 21

M_o = total factored static moment, in.-lb, Chapter 13

M_p = required plastic moment strength of shearhead cross section, in.-lb, Chapter 11

M_{pr} = probable flexural strength of members, with or without axial load, determined using the properties of the member at the joint faces assuming a tensile stress in the longitudinal bars of at least $1.25f_y$ and a strength reduction factor, ϕ, of 1.0, in.-lb, Chapter 21

M_s = factored moment due to loads causing appreciable sway, in.-lb, Chapter 10

M_{sa} = maximum unfactored applied moment due to service loads, not including $P\Delta$ effects, in.-lb, Chapter 14

M_{slab}= portion of slab factored moment balanced by support moment, in.-lb, Chapter 21

M_u = factored moment at section, in.-lb, Chapters 10, 11, 13, 14, 21, 22

M_{ua}= moment at the midheight section of the wall due to factored lateral and eccentric vertical loads, in.-lb, Chapter 14

M_v = moment resistance contributed by shearhead reinforcement, in.-lb, Chapter 11

M_1 = smaller factored end moment on a compression member, to be taken as positive if member is bent in single curvature, and negative if bent in double curvature, in.-lb, Chapter 10

M_{1ns}= factored end moment on a compression member at the end at which M_1 acts, due to loads that cause no appreciable sidesway, calculated using a first-order elastic frame analysis, in.-lb, Chapter 10

M_{1s}= factored end moment on compression member at the end at which M_1 acts, due to loads that cause appreciable sidesway, calculated using a first-order elastic frame analysis, in.-lb, Chapter 10

M_2 = larger factored end moment on compression member, always positive, in.-lb, Chapter 10

$M_{2,min}$ =minimum value of M_2, in.-lb, Chapter 10

M_{2ns}= factored end moment on compression member at the end at which M_2 acts, due to loads that cause no appreciable sidesway, calculated using a first-order elastic frame analysis, in.-lb, Chapter 10

M_{2s}= factored end moment on compression member at the end at which M_2 acts, due to loads that cause appreciable sidesway, calculated using a first-order elastic frame, in.-lb, Chapter 10

n = number of items, such as strength tests, bars, wires, monostrand anchorage devices, anchors, or shearhead arms, Chapters 5, 11, 12, 18, Appendix D

N_b = basic concrete breakout strength in tension of a single anchor in cracked concrete, lb, see D.5.2.2, Appendix D

N_c = tension force in concrete due to unfactored dead load plus live load, lb, Chapter 18

N_{cb} = nominal concrete breakout strength in tension of a single anchor, lb, see D.5.2.1, Appendix D

N_{cbg}= nominal concrete breakout strength in tension of a group of anchors, lb, see D.5.2.1, Appendix D

N_n = nominal strength in tension, lb, Appendix D

N_p = pullout strength in tension of a single anchor in cracked concrete, lb, see D.5.3.4 and D.5.3.5, Appendix D

N_{pn}= nominal pullout strength in tension of a single anchor, lb, see D.5.3.1, Appendix D

N_{sa} = nominal strength of a single anchor or group of anchors in tension as governed by the steel strength, lb, see D.5.1.1 and D.5.1.2, Appendix D

N_{sb}= side-face blowout strength of a single anchor, lb, Appendix D

N_{sbg}= side-face blowout strength of a group of anchors, lb, Appendix D

N_u = factored axial force normal to cross section occurring simultaneously with V_u *or* T_u; to be taken as positive for compression and negative for tension, lb, Chapter 11

N_{ua}= factored tensile force applied to anchor or group of anchors, lb, Appendix D

N_{uc} = factored horizontal tensile force applied at top of bracket or corbel acting simultaneously with V_u, to be taken as positive for tension, lb, Chapter 11

p_{cp} = outside perimeter of concrete cross section, in., see 11.6.1, Chapter 11

p_h = perimeter of centerline of outermost closed transverse torsional reinforcement, in., Chapter 11

P_b = nominal axial strength at balanced strain conditions, lb, see 10.3.2, Chapters 9, 10, Appendixes B, C

P_c = critical buckling load, lb, see 10.12.3, Chapter 10

P_n = nominal axial strength of cross section, lb, Chapters 9, 10, 14, 22, Appendixes B, C

$P_{n,max}$ = maximum allowable value of P_n, lb, see 10.3.6, Chapter 10

P_o = nominal axial strength at zero eccentricity, lb, Chapter 10

P_{pj} = prestressing force at jacking end, lb, Chapter 18

P_{pu} = factored prestressing force at anchorage device, lb, Chapter 18

P_{px} = prestressing force evaluated at distance ℓ_{px} from the jacking end, lb, Chapter 18

P_s = unfactored axial load at the design (midheight) section including effects of self-weight, lb, Chapter 14

P_u = factored axial force; to be taken as positive for compression and negative for tension, lb, Chapters 10, 14, 21, 22

q_{Du} = factored dead load per unit area, Chapter 13

q_{Lu} = factored live load per unit area, Chapter 13

q_u = factored load per unit area, Chapter 13

Q = stability index for a story, see 10.11.4, Chapter 10

r = radius of gyration of cross section of a compression member, in., Chapter 10

R = rain load, or related internal moments and forces, Chapter 9

s = center-to-center spacing of items, such as longitudinal reinforcement, transverse reinforcement, prestressing tendons, wires, or anchors, in., Chapters 10-12, 17-21, Appendix D

s_i = center-to-center spacing of reinforcement in the i-th layer adjacent to the surface of the member, in., Appendix A

s_o = center-to-center spacing of transverse reinforcement within the length ℓ_o, in., Chapter 21

s_s = sample standard deviation, psi, Chapter 5, Appendix D

s_2 = center-to-center spacing of longitudinal shear or torsion reinforcement, in., Chapter 11

S = snow load, or related internal moments and forces, Chapters 9, 21

S_e = moment, shear, or axial force at connection corresponding to development of probable strength at intended yield locations, based on the governing mechanism of inelastic lateral deformation, considering both gravity and earthquake load effects, Chapter 21

S_m = elastic section modulus, in.^{3}, Chapter 22

S_n nominal flexural, shear, or axial strength of connection, Chapter 21

S_y = yield strength of connection, based on f_y, for moment, shear, or axial force, Chapter 21

t = wall thickness of hollow section, in., Chapter 11

T = cumulative effect of temperature, creep, shrinkage, differential settlement, and shrinkage-compensating concrete, Chapter 9, Appendix C

T_n = nominal torsional moment strength, in.-lb, Chapter 11

T_u = factored torsional moment at section, in.-lb, Chapter 11

U = required strength to resist factored loads or related internal moments and forces, Chapter 9, Appendix C

v_n = nominal shear stress, psi, see 11.12.6.2, Chapters 11, 21

V_b = basic concrete breakout strength in shear of a single anchor in cracked concrete, lb, see D.6.2.2 and D.6.2.3, Appendix D

V_c = nominal shear strength provided by concrete, lb, Chapters 8, 11, 13, 21

V_{cb} = nominal concrete breakout strength in shear of a single anchor, lb, see D.6.2.1, Appendix D

V_{cbg} = nominal concrete breakout strength in shear of a group of anchors, lb, see D.6.2.1, Appendix D

V_{ci} = nominal shear strength provided by concrete when diagonal cracking results from combined shear and moment, lb, Chapter 11

V_{cp} = nominal concrete pryout strength of a single anchor, lb, see D.6.3, Appendix D

V_{cpg} = nominal concrete pryout strength of a group of anchors, lb, see D.6.3, Appendix D

V_{cw} = nominal shear strength provided by concrete when diagonal cracking results from high principal tensile stress in web, lb, Chapter 11

V_d = shear force at section due to unfactored dead load, lb, Chapter 11

V_e = design shear force corresponding to the development of the probable moment strength of the member, lb, see 21.3.4.1 and 21.4.5.1 Chapter 21

V_i = factored shear force at section due to externally applied loads occurring simultaneously with M_{max}, lb, Chapter 11

V_n = nominal shear strength, lb, Chapters 8, 10, 11, 21, 22, Appendix D

V_{nh} = nominal horizontal shear strength, lb, Chapter 17

V_p = vertical component of effective prestress force at section, lb, Chapter 11

V_s = nominal shear strength provided by shear reinforcement, lb, Chapter 11

V_{sa} = nominal strength in shear of a single anchor or group of anchors as governed by the steel strength, lb, see D.6.1.1 and D.6.1.2, Appendix D

V_u = factored shear force at section, lb, Chapters 11-13, 17, 21, 22

V_{ua} = factored shear force applied to a single anchor or group of anchors, lb, Appendix D

V_{us} = factored horizontal shear in a story, lb, Chapter 10

w_c = unit weight of concrete, lb/ft^3, Chapters 8, 9

w_u = factored load per unit length of beam or one-way slab, Chapter 8

W = wind load, or related internal moments and forces, Chapter 9, Appendix C

x = shorter overall dimension of rectangular part of cross section, in., Chapter 13

y = longer overall dimension of rectangular part of cross section, in., Chapter 13

y_t = distance from centroidal axis of gross section, neglecting reinforcement, to tension face, in., Chapters 9, 11

α = angle defining the orientation of reinforcement, Chapters 11, 21, Appendix A

α_c = coefficient defining the relative contribution of concrete strength to nominal wall shear strength, see 21.7.4.1, Chapter 21

α_f = ratio of flexural stiffness of beam section to flexural stiffness of a width of slab bounded laterally by centerlines of adjacent panels (if any) on each side of the beam, see 13.6.1.6, Chapters 9, 13

α_{fm} = average value of α_f for all beams on edges of a panel, Chapter 9

α_{f1} = α_f in direction of ℓ_1, Chapter 13

α_{f2} = α_f in direction of ℓ_2, Chapter 13

α_i = angle between the axis of a strut and the bars in the ***i***-th layer of reinforcement crossing that strut, Appendix A

α_{px} = total angular change of tendon profile from tendon jacking end to point under consideration, radians, Chapter 18

α_s = constant used to compute V_c in slabs and footings, Chapter 11

α_v = ratio of flexural stiffness of shearhead arm to that of the surrounding composite slab section, see 11.12.4.5, Chapter 11

β = ratio of long to short dimensions: clear spans for two-way slabs, see 9.5.3.3 and 22.5.4; sides of column, concentrated load or reaction area, see 11.12.2.1; or sides of a footing, see 15.4.4.2, Chapters 9, 11, 15, 22

β_b = ratio of area of reinforcement cut off to total area of tension reinforcement at section, Chapter 12

β_d = ratio used to compute magnified moments in columns due to sustained loads, see 10.11.1 and 10.13.6, Chapter 10

β_n = factor to account for the effect of the anchorage of ties on the effective compressive strength of a nodal zone, Appendix A

β_p = factor used to compute V_c in prestressed slabs, Chapter 11

β_s = factor to account for the effect of cracking and confining reinforcement on the effective compressive strength of the concrete in a strut, Appendix A

β_t = ratio of torsional stiffness of edge beam section to flexural stiffness of a width of slab equal to span length of beam, center-to-center of supports, see 13.6.4.2, Chapter 13

β_1 = factor relating depth of equivalent rectangular compressive stress block to neutral axis depth, see 10.2.7.3, Chapters 10, 18, Appendix B

γ_f = factor used to determine the unbalanced moment transferred by flexure at slab-column connections, see 13.5.3.2, Chapters 11, 13, 21

γ_p = factor for type of prestressing steel, see 18.7.2, Chapter 18

γ_s = factor used to determine the portion of reinforcement located in center band of footing, see 15.4.4.2, Chapter 15

γ_v = factor used to determine the unbalanced moment transferred by eccentricity of shear at slab-column connections, see 11.12.6.1, Chapter 11

δ_{ns} = moment magnification factor for frames braced against sidesway, to reflect effects of member curvature between ends of compression member, Chapter 10

δ_s = moment magnification factor for frames not braced against sidesway, to reflect lateral drift resulting from lateral and gravity loads, Chapter 10

δ_u = design displacement, in., Chapter 21

Δf_p = increase in stress in prestressing steel due to factored loads, psi, Appendix A

Δf_{ps} = stress in prestressing steel at service loads less decompression stress, psi, Chapter 18

Δ_o = relative lateral deflection between the top and bottom of a story due to lateral forces computed using a first-order elastic frame analysis and stiffness values satisfying 10.11.1, in., Chapter 10

Δ_r = difference between initial and final (after load removal) deflections for load test or repeat load test, in., Chapter 20

Δ_s = maximum deflection at or near midheight due to service loads, in., Chapter 14

Δ_u = deflection at midheight of wall due to factored loads, in., Chapter 14

Δ_1 = measured maximum deflection during first load test, in., see 20.5.2, Chapter 20

Δ_2 = maximum deflection measured during second load test relative to the position of the structure at the beginning of second load test, in., see 20.5.2, Chapter 20

ε_t = net tensile strain in extreme layer of longitudinal tension steel at nominal strength, excluding strains due to effective prestress, creep, shrinkage, and temperature, Chapters 8-10, Appendix C

θ = angle between axis of strut, compression diagonal, or compression field and the tension chord of the member, Chapter 11,Appendix A

λ = modification factor related to unit weight of concrete, Chapters 11, 12, 17-19, Appendix A

λ_Δ = multiplier for additional deflection due to long-term effects, see 9.5.2.5, Chapter 9

μ = coefficient of friction, see 11.7.4.3, Chapter 11

μ_p = post-tensioning curvature friction coefficient, Chapter 18

ξ = time-dependent factor for sustained load, see 9.5.2.5, Chapter 9

ρ = ratio of A_s to bd, Chapters 11, 13, 21, Appendix B

ρ' = ratio of A_s' to bd, Chapter 9, Appendix B

ρ_b = ratio of A_s to bd producing balanced strain conditions, see 10.3.2, Chapters 10, 13, 14, Appendix B

ρ_ℓ = ratio of area of distributed longitudinal reinforcement to gross concrete area perpendicular to that reinforcement, Chapters 11,14, 21

ρ_p = ratio of A_{ps} to bd_p, Chapter 18

ρ_s = ratio of volume of spiral reinforcement to total volume of core confined by the spiral (measured out-to-out of spirals), Chapters 10, 21

ρ_t = ratio of area distributed transverse reinforcement to gross concrete area perpendicular to that reinforcement, Chapters 11, 14, 21

ρ_v = ratio of tie reinforcement area to area of contact surface, see 17.5.3.3, Chapter 17

ρ_w = ratio of A_s to b_wd, Chapter 11

ϕ = strength reduction factor, see 9.3, Chapters 8-11, 13, 14, 17-22, Appendixes A-D

$\psi_{c,N}$ = factor used to modify tensile strength of anchors based on presence or absence of cracks in concrete, see D.5.2.6, Appendix D

$\psi_{c,P}$ = factor used to modify pullout strength of anchors based on presence or absence of cracks in concrete, see D.5.3.6, Appendix D

$\psi_{c,V}$ = factor used to modify shear strength of anchors based on presence or absence of cracks in concrete and presence or absence of supplementary reinforcement, see D.6.2.7 for anchors in shear, Appendix D

$\psi_{cp,N}$ = factor used to modify tensile strength of post-installed anchors intended for use in uncracked concrete without supplementary reinforcement, see D.5.2.7, Appendix D

ψ_e = factor used to modify development length based on reinforcement coating, see 12.2.4, Chapter 12

$\psi_{ec,N}$ = factor used to modify tensile strength of anchors based on eccentricity of applied loads, see D.5.2.4, Appendix D

$\psi_{ec,V}$ = factor used to modify shear strength of anchors based on eccentricity of applied loads, see D.6.2.5, Appendix D

$\psi_{ed,N}$ = factor used to modify tensile strength of anchors based on proximity to edges of concrete member, see D.5.2.5, Appendix D

$\psi_{ed,V}$ = factor used to modify shear strength of anchors based on proximity to edges of concrete member, see D.6.2.6, Appendix D

ψ_s = factor used to modify development length based on reinforcement size, see 12.2.4, Chapter 12

ψ_t = factor used to modify development length based on reinforcement location, see 12.2.4, Chapter 12

ω = tension reinforcement index, see 18.7.2, Chapter 18, Appendix B

ω' = compression reinforcement index, see 18.7.2, Chapter 18, Appendix B

ω_p = prestressing steel index, see B.18.8.1, Appendix B

ω_{pw} = prestressing steel index for flanged sections, see B.18.8.1, Appendix B

ω_w = tensions reinforcement index for flanged sections, see B.18.8.1, Appendix B

ω_w' = compression reinforcement index for flanged sections, see B.18.8.1, Appendix B

R2.1 — Commentary notation

The terms used in this list are used in the commentary, but not in the code.

Units of measurement are given in the Notation to assist the user and are not intended to preclude the use of other correctly applied units for the same symbol, such as ft or kip.

c_{a1}' = limiting value of c_{a1} when anchors are located less than $1.5h_{ef}$ from three or more edges (see Fig. RD.6.2.4), Appendix D

C = compression force acting on a nodal zone, lb, Appendix A

f_{si} = stress in the i-th layer of surface reinforcement, psi, Appendix A

h_{anc} = dimension of anchorage device or single group of closely spaced devices in the direction of bursting being considered, in., Chapter 18

h_{ef}' = limiting value of h_{ef} when anchors are located less than $1.5h_{ef}$ from three or more edges (see Fig. RD.5.2.3), Appendix D

K_t = torsional stiffness of torsional member; moment per unit rotation, see R13.7.5, Chapter 13

K_{05} = coefficient associated with the 5 percent fractile, Appendix D

ℓ_{anc} = length along which anchorage of a tie must occur, in., Appendix A

ℓ_b = width of bearing, in., Appendix A

R = reaction, lb, Appendix A

T = tension force acting on a nodal zone, lb, Appendix A

w_s = width of a strut perpendicular to the axis of the strut, in., Appendix A

w_t = effective height of concrete concentric with a tie, used to dimension nodal zone, in., Appendix A

w_{tmax} = maximum effective height of concrete concentric with a tie, in., Appendix A

Δf_{pt} = f_{ps} at the section of maximum moment minus the stress in the prestressing steel due to prestressing and factored bending moments at the section under consideration, psi, see R11.6.3.10, Chapter 11

ϕ_K = stiffness reduction factor, see R10.12.3, Chapter 10

Ω_o = amplification factor to account for overstrength of the seismic-force-resisting system, specified in documents such as NEHRP,[21.1] SEI/ASCE,[21.48] IBC,[21.5] and UBC,[21.2] Chapter 21