CHAPTER 2—NOTATION AND TERMINOLOGY

CODE

2.1—Scope

2.1.1 This chapter defines notation and terminology used in this Code.

2.2—Notation

a = depth of equivalent rectangular stress block, in.

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.

A_1 = loaded area for consideration of bearing, strut, and node strength, in.^{2}

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 its upper base equal to the loaded area. The sides of the pyramid, cone, or tapered wedge shall be sloped one vertical to two horizontal, in.^{2}

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

A_{bp} = area of the attachment base plate in contact with concrete or grout when loaded in compression, in.^{2}

A_{brg} = net bearing area of the head of stud, anchor bolt, or headed deformed bar, in.^{2}

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

$A_{c,eff}$ = concrete area containing reinforcement parallel to reinforcing bar group and enclosed within a distance $0.75h_{ef}$ from the perimeter of the reinforcing bar group, in.^{2}

A_{cf} = greater gross cross-sectional area of the two orthogonal slab-beam strips intersecting at a column of a two-way prestressed slab, in.^{2}

A_{ch} = cross-sectional area of a member measured to the outside edges of transverse reinforcement, in.^{2}

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

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}

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

A_{cv} = gross area of concrete section bounded by web thickness and length of section in the direction of shear force considered in the case of walls, and gross area of concrete section in the case of diaphragms. Gross area is total area of the defined section minus area of any openings, in.^{2}

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

$A_{ef,sl}$ = effective bearing area of shear lug, in.^{2}

A_f = area of reinforcement in bracket or corbel resisting design moment, in.^{2}

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)

COMMENTARY

R2.2—Notation

CODE

COMMENTARY

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

A_{hs} = total cross-sectional area of hooked or headed bars being developed at a critical section, in.^{2}

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

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

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

$A_{\ell d}$ = area of distributed reinforcement parallel to the longitudinal axis of the member within spacing $s_{\ell d}$, in.^{2}

A_n = area of reinforcement in bracket or corbel resisting factored restraint force N_{uc}, in.^{2}

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

A_{Na} = projected influence area of a single adhesive anchor or group of adhesive anchors, for calculation of bond strength in tension, in.^{2}

A_{Nao} = projected influence area of a single adhesive anchor, for calculation of bond strength in tension if not limited by edge distance or spacing, in.^{2}

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

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}

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

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

A_{pd} = total area occupied by duct, sheathing, and prestressing reinforcement, in.^{2}

A_{ps} = area of prestressed longitudinal tension reinforcement, in.^{2}

A_{pt} = total area of prestressing reinforcement, in.^{2}

A_s = area of nonprestressed longitudinal tension reinforcement, in.^{2}

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

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

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

$A_{se,N}$ = effective cross-sectional area of anchor in tension, in.^{2}

$A_{se,V}$ = effective cross-sectional area of anchor in shear, in.^{2}

A_{shear} = cross-sectional area used to calculate the shear stiffness, in.^{2}

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

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}

A_{st} = total area of nonprestressed longitudinal reinforce-

CODE

ment including bars and excluding prestressing reinforcement, in.^{2}

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

A_{td} = area of distributed reinforcement transverse to the longitudinal axis of the member within spacing s_{td}, in.^{2}

A_{tp} = area of prestressing reinforcement in a tie, in.^{2}

A_{tr} = total cross-sectional area of all transverse reinforcement satisfying 25.4.2.6 within spacing s that crosses the potential plane of splitting through the reinforcement being developed, in.^{2}

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

A_{tt} = total cross-sectional area of parallel tie reinforcement to be considered as confining headed bars, in.^{2}

A_v = area of shear reinforcement within spacing s, in.^{2}

$A_{v,min}$ = minimum area of shear reinforcement within spacing s, in.^{2}

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

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

$A_{vf,min}$ = minimum area of shear-friction reinforcement, in.^{2}

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

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

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}

b = width of compression face of member, in.

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

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

b_c = cross-sectional dimension of member core measured to the outside edges of the transverse reinforcement composing area A_{sh}, in.

b_{cf} = effective overhanging compression flange width, in.

b_f = effective flange width, in.

b_o = perimeter of critical section for two-way shear in slabs and footings, in.

b_s = width of strut, in.

b_{sl} = width of shear lug, in.

b_{slab} = effective slab width, in.

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

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

b_w = web width or diameter of circular section, in.

B = bias factor to adjust nominal strength to seismic target reliabilities (Appendix A)

B_n = nominal bearing strength, lb

B_u = factored bearing load, lb

COMMENTARY

CODE

c = distance from extreme compression fiber to neutal axis, in.

c_1 = dimension of rectangular or equivalent rectangular column, capital, or bracket measured in the direction of the span for which moments or joint shear forces are being determined, in.

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

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

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

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 tension is applied to the anchor, c_{a1} is the minimum edge distance. Where anchors subject to shear are located in narrow sections of limited thickness, see 17.7.2.1.2

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

c_{ac} = critical edge distance required to develop the basic strength as controlled by concrete breakout or bond of a post-installed anchor in tension in uncracked concrete without supplementary reinforcement to control splitting, in.

c_b = lesser 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.

c_c = clear cover of reinforcement, in.

c_{Na} = projected distance from center of an anchor shaft on one side of the anchor required to develop the full bond strength of a single adhesive anchor, in.

c_{sl} = distance from the centerline of the row of anchors in tension nearest the shear lug to the centerline of the shear lug measured in the direction of shear, in.

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.

C_m = factor relating actual moment diagram to an equivalent uniform moment diagram

d' = distance from extreme compression fiber to centroid of longitudinal compression reinforcement, in.

d = distance from extreme compression fiber to centroid of longitudinal tension reinforcement, in.

d_a' = value substituted for d_a if an oversized anchor is used, in.

d_a = outside diameter of anchor or shaft diameter of headed stud, headed bolt, or hooked bolt, in.

COMMENTARY

c'_{a1} = limiting value of c_{a1} where anchors are located less than $1.5c_{a1}$ from three or more edges, in.; see Fig R17.7.2.1.2

C = compressive force acting on a nodal zone, lb

CODE

d_{agg} = nominal maximum size of coarse aggregate, in.

d_b = nominal diameter of bar, wire, or prestressing strand, in.

d_p = distance from extreme compression fiber to centroid of prestressed reinforcement, in.

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

D = effect of service dead load

D_s = effect of superimposed dead load

D_u = ultimate deformation capacity; the largest deformation at which the hysteresis model is deemed valid given available laboratory data or other substantiating evidence (Appendix A)

D_w = effect of self-weight dead load of the concrete structural system

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.

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

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

E = effect of horizontal and vertical earthquake-induced forces

E_c = modulus of elasticity of concrete, psi

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

E_{ce} = expected modulus of elasticity of concrete, psi (Appendix B)

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

E_h = effect of horizontal earthquake-induced forces

EI = flexural stiffness of member, in.^{2}-lb

$(EI)_{eff}$ = effective flexural stiffness of member, in.^{2}-lb

E_{mh} = load effect due to the horizontal seismic force including overstrength, Ω_o, as defined in ASCE/SEI 7

E_p = modulus of elasticity of prestressing reinforcement, psi

E_s = modulus of elasticity of reinforcement and structural steel, excluding prestressing reinforcement, psi

f'_c = specified compressive strength of concrete, psi

$\sqrt{f'_c}$ = square root of specified compressive strength of concrete, psi

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

f'_{ce} = expected compressive strength of concrete, psi (Appendix A, B)

COMMENTARY

d_{burst} = distance from the anchorage device to the centroid of the bursting force, T_{burst}, in.

D_i = diagonal compression component of shear flow resistance in concrete, lb

e_{anc} = eccentricity of the anchorage device or group of devices with respect to the centroid of the cross section, in.

E_{ce} = expected modulus of elasticity of concrete is calculated using expected compressive strength of concrete. (Appendix B)

CODE

$\sqrt{f'_{ce}}$ = square root of expected compressive strength of concrete, psi

f'_{ci} = specified compressive strength of concrete at transfer of prestress, psi

$\sqrt{f'_{ci}}$ = square root of specified compressive strength of concrete at transfer of prestress, psi

f_{ct} = measured average splitting tensile strength of light-weightconcrete, psi

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

f_{dc} = decompression stress; stress in the prestressed reinforcement if stress is zero in the concrete at the same level as the centroid of the prestressed reinforcement, psi

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 where the centroid lies within the flange, psi. In a composite concrete member, f_{pc} is the resultant compressive stress at centroid of composite section, or at junction of web and flange where the centroid lies within the flange, due to both prestress and moments resisted by precast member acting alone

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

f_{ps} = stress in prestressed reinforcement at nominal flexural strength, psi

f_{pu} = specified tensile strength of prestressing reinforcement, psi

f_{py} = specified yield strength of prestressing reinforcement, psi

f_r = modulus of rupture of concrete, psi

f_s = tensile stress in reinforcement at service loads, excluding prestressed reinforcement, psi

f'_s = compressive stress in reinforcement under factored loads, excluding prestressed reinforcement, psi

f_{se} = effective stress in prestressed reinforcement, after allowance for all prestress losses, psi

f_t = extreme fiber stress in the precompressed tension zone calculated at service loads using gross section properties after allowance of all prestress losses, psi

f_u = specified tensile strength of nonprestressed reinforcement, psi

f_{ue} = expected tensile strength for nonprestressed reinforcement, psi (Appendix A, B)

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

f_y = specified yield strength for nonprestressed reinforcement, psi

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

COMMENTARY

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

CODE

f_{ye} = expected yield strength for nonprestressed reinforcement, psi (Appendix A, B)

f_{yt} = specified yield strength of transverse reinforcement, psi

F = effect of service load due to fluids with well-defined pressures and maximum heights

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

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

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

F_{un} = factored force on the face of a node, lb

F_{us} = factored compressive force in a strut, lb

F_{ut} = factored tensile force in a tie, lb

h = overall thickness, height, or depth of member, in.

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

h_{ef} = effective embedment depth of anchor or reinforcing bar, in.

$h_{ef,sl}$ = effective embedment depth of shear lug, in.

h_n = structural height from the base to the highest level of the seismic-force-resisting system of the structure, ft, where the base is the level at which the horizontal earthquake ground motions are considered to be imparted to the structure

h_{sl} = embedment depth of shear lug, in.

h_{sx} = story height for story x, in. (Appendix A, B)

h_u = laterally unsupported height at extreme compression fiber of wall or wall pier, in., equivalent to ℓ_u for compression members

h_w = height of entire wall from base to top, or clear height of wall segment or wall pier considered, in.

h_{wcs} = height of entire structural wall above the critical section for flexural and axial loads, in.

h_x = maximum center-to-center spacing of longitudinal bars laterally supported by corners of crossties or hoop legs around the perimeter of a column or wall boundary element, in.

H = effect of service load due to lateral earth pressure, ground water pressure, or pressure of bulk materials, lb

I = moment of inertia of section about centroidal axis, $in.^4$

I_b = moment of inertia of gross section of beam about centroidal axis, $in.^4$

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

I_e = effective moment of inertia for calculation of deflection, $in.^4$

I_g = moment of inertia of gross concrete section about centroidal axis, neglecting reinforcement, $in.^4$

COMMENTARY

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

h'_{ef} = limiting value of h_{ef} where anchors are located less than $1.5h_{ef}$ from three or more edges, in.; refer to Fig. R17.6.2.1.2.

CODE

I_s = moment of inertia of gross section of slab about centroidal axis, in.^{4}

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

k = effective length factor for compression members

k_c = coefficient for basic concrete breakout strength in tension

k_{cp} = coefficient for pryout strength

k_f = concrete strength factor

k_n = confinement effectiveness factor

K_{tr} = transverse reinforcement index, in.

L = effect of service live load

L_r = effect of service roof live load

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

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

ℓ_2 = length of span in direction perpendicular to ℓ_1, measured center-to-center of supports, in.

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

ℓ_{be} = length of boundary element from compression face of member, in.

ℓ_c = length of compression member, measured center-to-center of the joints, in.

ℓ_d = development length in tension of deformed bar, deformed wire, plain and deformed welded wire reinforcement, or pretensioned strand, in.

ℓ_{db} = debonded length of prestressed reinforcement at end of member, in.

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

ℓ_{dh} = development length in tension of deformed bar or deformed wire with a standard hook, measured from outside end of hook, point of tangency, toward critical section, in.

ℓ_{dt} = development length in tension of headed deformed bar, measured from the bearing face of the head toward the critical section, in.

ℓ_e = load bearing length of anchor for shear, in.

ℓ_{ext} = straight extension at the end of a standard hook, in.

ℓ_n = length of clear span measured face-to-face of supports, in.

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

ℓ_p = plastic-hinge length for analysis purposes, in. (Appendix A)

COMMENTARY

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

K_t = torsional stiffness of member; moment per unit rotation

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

ℓ_b = width of bearing, in.

ℓ_{dm} = required development length if bar is not entirely embedded in confined concrete, in.

CODE

ℓ_{sc} = compression lap splice length, in.

ℓ_{st} = tension lap splice length, in.

ℓ_t = span of member under load test, taken as the shorter span for two-way slab systems, in. Span is the lesser 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

ℓ_{tr} = transfer length of prestressed reinforcement, in.

ℓ_u = unsupported length of column or wall, in.

ℓ_{vh} = distance between points of zero and maximum moment along which horizontal shear is transferred across the interface, in.

ℓ_w = length of entire wall, or length of wall segment or wall pier considered in direction of shear force, in.

M_1 = lesser factored end moment on a compression member, in.-lb

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

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

M_2 = greater factored end moment on a compression member. If transverse loading occurs between supports, M_2 is taken as the largest moment occurring in member. Value of M_2 is always positive, in.-lb

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

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

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 analysis, in.-lb

M_a = maximum moment in member due to service loads at stage deflection is calculated, in.-lb

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

M_{cr} = cracking moment, in.-lb

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

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

M_n = nominal flexural strength at section, in.-lb

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

COMMENTARY

M = moment acting on anchor or anchor group, in.-lb

M_d = moment due to unfactored dead load, in.-lb

CODE

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

M_{ne} = flexural strength at section, determined using expected material strengths, in.-lb (Appendix B)

M_{pr} = probable flexural strength of members, with or without axial load, determined using the properties of the member at 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

M_{sa} = maximum moment in wall due to service loads, excluding $P\Delta$ effects, in.-lb

M_{sc} = factored slab moment that is resisted by the column at a joint, in.-lb

M_u = factored moment at section, in.-lb

M_{ua} = moment at midheight of wall due to factored lateral and eccentric vertical loads, not including $P\Delta$ effects, in.-lb

n = number of items, such as, bars, wires, monostrand anchorage devices, or anchors

n_ℓ = number of longitudinal bars around the perimeter of a column core with rectilinear hoops that are laterally supported by the corner of hoops or by seismic hooks. A bundle of bars is counted as a single bar

n_s = number of stories above the critical section

N_a = nominal bond strength in tension of a single adhesive anchor, lb

N_{ag} = nominal bond strength in tension of a group of adhesive anchors, lb

N_b = basic concrete breakout strength in tension of a single anchor in cracked concrete, lb

N_{ba} = basic bond strength in tension of a single adhesive anchor, lb

N_c = resultant tensile force acting on the portion of the concrete cross section that is subjected to tensile stresses due to the combined effects of service loads and effective prestress, lb

N_{cb} = nominal concrete breakout strength in tension of a single anchor, lb

N_{cbg} = nominal concrete breakout strength in tension of a group of anchors, lb

N_{cp} = basic concrete pryout strength of a single anchor, lb

N_{cpg} = basic concrete pryout strength of a group of anchors, lb

N_n = nominal strength in tension, lb

$N_{n,c}$ = nominal strength in tension of a single anchor governed by concrete breakout, pullout, or side-face blowout strength, lb

$N_{n,cg}$ = nominal strength in tension of an anchor group governed by concrete breakout, pullout, or side-face blowout strength, lb

COMMENTARY

n_t = number of threads per inch

N = tension force acting on anchor or anchor group, lb

N_i = axial tension component of shear flow resistance in longitudinal reinforcement, lb

$N_{n,c}$ = Nominal strength in tension of a single anchor is given in Table 17.5.2

$N_{n,cg}$ = Refer to the concrete failure modes given in Table 17.5.2

CODE

N_p = pullout strength in tension of a single anchor in cracked concrete, lb

N_{pn} = nominal pullout strength in tension of a single anchor, lb

N_{rg} = nominal concrete breakout strength of reinforcing bar group, lb

N_{sa} = nominal strength of a single anchor or individual anchor in a group of anchors in tension as governed by the steel strength, lb

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

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

N_{srg} = contribution of parallel reinforcement to the nominal breakout strength of a reinforcing bar group, lb

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

N_{ua} = factored tensile force applied to anchor or individual anchor in a group of anchors, lb

$N_{ua,g}$ = total factored tensile force applied to anchor group, lb

$N_{ua,i}$ = factored tensile force applied to most highly stressed anchor in a group of anchors, lb

$N_{ua,s}$ = factored sustained tension load, lb

N_{uc} = factored restraint force applied to a bearing connection acting perpendicular to and simultaneously with V_u, to be taken as positive for tension, lb

$N_{uc,max}$ = maximum restraint force that can be transmitted through the load path of a bearing connection multiplied by the load factor used for live loads in combinations with other factored load effects

p_{cp} = outside perimeter of concrete cross section, in.

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

P_a = maximum allowable compressive strength of a deep foundation member, lb

P_c = critical buckling load, lb

P_n = nominal axial compressive strength of member, lb

P_{ne} = axial compressive strength of member, determined using expected material strengths, lb (Appendix B)

$P_{n,bal}$ = nominal axial strength at the balanced strain condition, lb

$P_{n,max}$ = maximum nominal axial compressive strength of a member, lb

P_{nte} = axial tensile strength of member, determined using expected material strengths, lb (Appendix B)

P_{nt} = nominal axial tensile strength of member, lb

$P_{nt,max}$ = maximum nominal axial tensile strength of member, lb

P_o = nominal axial strength at zero eccentricity, lb

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

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

COMMENTARY

p_o = perimeter of area A_o, in.

CODE

P_u = factored axial force; to be taken as positive for compression and negative for tension, lb

$P\Delta$ = secondary moment due to lateral deflection, in.-lb

q_u = factored load per unit area, lb/ft^2

Q = stability index for a story

r = radius of gyration of cross section, in.

r_b = bend radius at the inside of a bar, in.

R = cumulative load effect of service rain load

R_n = nominal strength (Appendix B)

R_{ne} = expected yield strength (Appendix A)

$R_{ne,w}$ = expected strength of reinforced concrete member using f_{ce}' and f_{ye} (Appendix B)

s = center-to-center spacing of items, such as longitudinal reinforcement, transverse reinforcement, tendons, or anchors, in.

s_2 = center-to-center spacing of longitudinal shear or torsional reinforcement, in.

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

$s_{\ell d}$ = center-to-center spacing of longitudinal distributed reinforcement measured over the height of the member, in.

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

s_s = sample standard deviation, psi

s_{td} = center-to-center spacing of transverse distributed reinforcement measured in the longitudinal direction of the member, in.

s_w = clear distance between adjacent webs, in.

s_{wd} = center-to-center spacing of curtains or planes of longitudinal or transverse distributed reinforcement measured across the width or thickness of the member, in.

S = effect of service snow load

S_{DS} = 5% damped, spectral response acceleration parameter at short periods determined in accordance with the general building code

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 effects

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

S_n = nominal moment, shear, axial, torsion, or bearing strength

S_y = yield strength of connection, based on f_y of the connected part, for moment, shear, torsion, or axial force, psi

t = wall thickness of hollow section, in.

t_{cf} = effective compression flange thickness, in.

t_f = thickness of flange, in.

COMMENTARY

$P\delta$ = secondary moment due to individual member slenderness, in.-lb

q = shear flow, lb/in.

R = reaction, lb

CODE

t_{sl} = thickness of shear lug, in.

T = cumulative effects of service temperature, creep, shrinkage, differential settlement, and shrinkage compensating concrete

T_{cr} = cracking torsional moment, in.-lb

T_n = nominal torsional moment strength, in.-lb

T_t = total test load, lb

T_{th} = threshold torsional moment, in.-lb

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

U = strength of a member or cross section required to resist factored loads or related internal moments and forces in such combinations as stipulated in this Code

v_c = stress corresponding to nominal two-way shear strength provided by concrete, psi

v_n = equivalent concrete stress corresponding to nominal two-way shear strength of slab or footing, psi

v_s = equivalent concrete stress corresponding to nominal two-way shear strength provided by reinforcement, psi

v_u = maximum factored two-way shear stress calculated around the perimeter of a given critical section, psi

v_{ug} = factored shear stress on the slab critical section for two-way action due to gravity loads without moment transfer, psi

v_{uv} = factored shear stress on the slab critical section for two-way action, from the controlling load combination, without moment transfer, psi

V_b = basic concrete breakout strength in shear of a single anchor in cracked concrete, lb

$V_{brg,sl}$ = nominal bearing strength of a shear lug in direction of shear, lb

V_c = nominal shear strength provided by concrete, lb

V_{cb} = nominal concrete breakout strength in shear of a single anchor, lb

$V_{cb,sl}$ = nominal concrete breakout strength in shear of attachment with shear lugs, lb

V_{cbg} = nominal concrete breakout strength in shear of a group of anchors, lb

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

V_{cp} = nominal concrete pryout strength of a single anchor, lb

COMMENTARY

T = tension force acting on a nodal zone in a strut-and-tie model, lb (T is also used to define the cumulative effects of service temperature, creep, shrinkage, differential settlement, and shrinkage-compensating concrete in the load combinations defined in 5.3.6)

T_{burst} = tensile force in general zone acting ahead of the anchorage device caused by spreading of the anchorage force, lb

V = shear force acting on anchor or anchor group, lb

$V_{||}$ = maximum shear force that can be applied parallel to the edge, lb

$V_{\perp}$ = maximum shear force that can be applied perpendicular to the edge, lb

CODE

V_{cpg} = nominal concrete pryout strength of a group of anchors, lb

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

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

V_e = design shear force for load combinations including earthquake effects, lb

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

V_n = nominal shear strength, lb

$V_{n,c}$ = nominal strength in shear of a single anchor governed by concrete breakout or pryout strength, lb

$V_{n,cg}$ = nominal strength in shear of an anchor group governed by concrete breakout or pryout strength, lb

$V_{n,x}$ = shear strength in the x-direction

$V_{n,y}$ = shear strength in the y-direction

V_{ne} = expected shear strength, lb (Appendix A)

V_{nh} = nominal horizontal shear strength, lb

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

V_s = nominal shear strength provided by shear reinforcement, lb

V_{sa} = nominal shear strength of a single anchor or individual anchor in a group of anchors as governed by the steel strength, lb

V_u = factored shear force at section, lb

$V_{u,x}$ = factored shear force at section in the x-direction, lb

$V_{u,y}$ = factored shear force at section in the y-direction, lb

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

$V_{ua,g}$ = total factored shear force applied to anchor group, lb

$V_{ua,i}$ = factored shear force applied to most highly stressed anchor in a group of anchors, lb

V_{uEh} = factored shear force from load combinations including primary load E, considering only horizontal earthquake load effect E_h

V_{uh} = factored shear force along contact surface in composite concrete flexural member, lb

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

w/cm = water-cementitious material ratio

w_c = density, unit weight, of normalweight concrete or equilibrium density of lightweight concrete, lb/ft^3

w_t = effective height or width of concrete concentric with a tie, used to dimension the nodal zone in a strut-and-tie model, in.

w_u = factored load per unit length of beam or one-way slab, lb/in.

W = effect of wind load

COMMENTARY

$V_{n,c}$ = Refer to the concrete failure modes given in Table 17.5.2

$V_{n,cg}$ = Refer to the concrete failure modes given in Table 17.5.2

V_{uEh} = Refer to 5.3.1(e) and (g)

w_n = length of the side of a nodal zone, in.

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

$w_{t,max}$ = maximum effective height or width of concrete concentric with a tie, in.

CODE

W_{MRI} = wind effect with specified mean recurrence interval (MRI) (Appendix B)

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

z = distance between the tension resultant of anchors loaded in tension and compression resultant acting on the concrete in contact with baseplate

α = angle defining the orientation of reinforcement

α_1 = minimum angle between unidirectional distributed reinforcement and a strut

α_c = coefficient defining the relative contribution of concrete strength to nominal wall shear strength

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

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

α_s = constant used to calculate V_c in slabs and footings

α_{sh} = shape factor to define the shear stress limit for walls

β = ratio of long to short dimensions: clear spans for two-way slabs, sides of column, concentrated load or reaction area; or sides of a footing

β_1 = factor relating depth of equivalent rectangular compressive stress block to depth of neutral axis

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

β_c = confinement modification factor for struts and nodes in a strut-and-tie model

β_{dns} = ratio used to account for reduction of stiffness of columns due to sustained axial loads

β_{ds} = the ratio of maximum factored sustained shear within a story to the maximum factored shear in that story associated with the same load combination

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

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

γ_f = factor used to determine the fraction of M_{sc} transferred by slab flexure at slab-column connections

γ_p = factor used for type of prestressing reinforcement

γ_s = factor used to determine the portion of reinforcement located in center band of footing

γ_v = factor used to determine the fraction of M_{sc} transferred by eccentricity of shear at slab-column connections

δ = moment magnification factor used to reflect effects of member curvature between ends of a compression member

δ_c = wall displacement capacity at top of wall, in.

COMMENTARY

W_a = service-level wind load, lb

W_{MRI} = Wind effect with specified mean recurrence interval (MRI) depends on the risk category of the building and is provided in ASCE/SEI Prestandard for Performance-Based Wind Design. (Appendix B)

α_f = $E_{cb}I_b/E_{cs}I_s$

CODE

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

δ_u = design displacement, in.

$\delta_{x,w}$ = maximum story drift ratio expected in story x, according to analyses for wind demands. Drift ratio is calculated as relative difference of lateral displacement between the top and bottom of a story, divided by the story height. (Appendix B)

Δ_1 = maximum deflection, during first load test, measured 24 hours after application of the full test load, in.

Δ_2 = maximum deflection, during second load test, measured 24 hours after application of the full test load. Deflection is measured relative to the position of the structure at the beginning of the second load test, in.

Δ_{cr} = calculated out-of-plane deflection at midheight of wall corresponding to cracking moment M_{cr}, in.

Δ_L = deformation limit (strain, rotation, displacement) (Appendix B)

Δ_n = calculated out-of-plane deflection at midheight of wall corresponding to nominal flexural strength M_n, in.

Δ_o = relative lateral deflection between the top and bottom of a story due to V_{us}, in.

Δ_r = residual deflection measured 24 hours after removal of the test load. For the first load test, residual deflection is measured relative to the position of the structure at the beginning of the first load test. For the second load test, residual deflection is measured relative to the position of the structure at the beginning of the second load test, in.

Δ_s = out-of-plane deflection due to service loads, in.

Δ_u = calculated out-of-plane deflection at midheight of wall due to factored loads, in.

Δ_x = design story drift of story x, in.

Δf_p = increase in stress in prestressed reinforcement due to factored loads, psi

Δf_{ps} = stress in prestressed reinforcement at service loads less decompression stress, psi

ε_t = net tensile strain in extreme layer of longitudinal tension reinforcement at nominal strength, excluding strains due to effective prestress, creep, shrinkage, and temperature

ε_{ty} = value of net tensile strain in the extreme layer of longitudinal tension reinforcement used to define a compression-controlled section

COMMENTARY

Δf_{pt} = difference between the stress that can be developed in the prestressed reinforcement at the section under consideration and the stress required to resist factored bending moment at section, M_u/ϕ, psi

ε_{cu} = maximum usable strain at extreme concrete compression fiber

ε_s = strain in steel

CODE

ε_{ye} = expected yield strain of reinforcement (Appendix B)

θ = angle between axis of strut, compression diagonal, or compression field and the tension chord of the members

θ_y = yield rotation, radians (Appendix A)

θ_{ye} = expected yield rotation of member determined using expected material strengths, radians (Appendix B)

λ = modification factor to reflect the reduced mechanical properties of lightweight concrete relative to normalweight concrete of the same compressive strength

λ_a = modification factor to reflect the reduced mechanical properties of lightweight concrete in certain concrete anchorage applications

λ_s = factor used to modify shear strength based on the effects of member depth, commonly referred to as the size effect factor

λ_Δ = multiplier used for additional deflection due to long-term effects

μ = coefficient of friction

ξ = time-dependent factor for sustained load

ρ' = ratio of A_s' to bd

ρ = ratio of A_s to bd

ρ_ℓ = ratio of area of distributed longitudinal reinforcement to gross concrete area perpendicular to that reinforcement

ρ_p = ratio of A_{ps} to bd_p

ρ_s = ratio of volume of spiral reinforcement to total volume of core confined by the spiral, measured out-to-out of spirals

ρ_t = ratio of area of distributed transverse reinforcement to gross concrete area perpendicular to that reinforcement

ρ_v = ratio of tie reinforcement area to area of contact surface

ρ_w = ratio of A_s to $b_w d$

τ_{cr} = characteristic bond stress of adhesive anchor in cracked concrete, psi

τ_{uncr} = characteristic bond stress of adhesive anchor in uncracked concrete, psi

ϕ = strength reduction factor

ϕ_{cc} = strength reduction factor for compression-controlled sections

COMMENTARY

ε_y = yield strain of steel

λ = in most cases, the reduction in mechanical properties is caused by the reduced ratio of tensile-to-compressive strength of lightweight concrete compared to normalweight concrete. There are instances in the Code where λ is used as a modifier to reduce expected performance of lightweight concrete where the reduction is not related directly to tensile strength.

σ = wall boundary extreme fiber concrete nominal compressive stress, psi

ς = exponent symbol in tensile/shear force interaction equation

τ = shear stress, psi

ϕ_K = stiffness reduction factor

CODE

ϕ_p = strength reduction factor for moment in pretensioned member at cross section closest to the end of the member where all strands are fully developed

ϕ_s = seismic resistance factor for force-controlled actions (Appendix A)

ψ_a = factor used to modify post-installed anchor strength based on assessment in accordance with ACI CODE-355.2 or ACI CODE-355.4

$\psi_{brg,sl}$ = shear lug bearing factor used to modify bearing strength of shear lugs based on the influence of axial load

ψ_c = factor used to modify development length based on concrete strength

ψ_{cc} = factor used to modify development length based on cover

$\psi_{c,N}$ = breakout cracking factor used to modify tensile strength of anchors based on the influence of cracks in concrete

$\psi_{c,P}$ = pullout cracking factor used to modify pullout strength of anchors based on the influence of cracks in concrete

$\psi_{c,V}$ = breakout cracking factor used to modify shear strength of anchors based on the influence of cracks in concrete and presence or absence of supplementary reinforcement

$\psi_{cm,N}$ = breakout compression field factor used to increase breakout strength for cases where a compression field inhibits concrete fracture development

$\psi_{cp,N}$ = breakout splitting factor used to modify tensile strength of post-installed anchors intended for use in uncracked concrete without supplementary reinforcement to account for the splitting tensile stresses

$\psi_{cp,Na}$ = bond splitting factor used to modify tensile strength of adhesive anchors intended for use in uncracked concrete without supplementary reinforcement to account for the splitting tensile stresses due to installation

ψ_e = factor used to modify development length based on reinforcement coating

$\psi_{ec,N}$ = breakout eccentricity factor used to modify tensile strength of anchors based on eccentricity of applied loads

$\psi_{ec,Na}$ = breakout eccentricity factor used to modify tensile strength of adhesive anchors based on eccentricity of applied loads

$\psi_{ec,V}$ = breakout eccentricity factor used to modify shear strength of anchors based on eccentricity of applied loads

$\psi_{ed,N}$ = breakout edge effect factor used to modify tensile strength of anchors based on proximity to edges of concrete member

$\psi_{ed,Na}$ = breakout edge effect factor used to modify tensile strength of adhesive anchors based on proximity to edges of concrete member

$\psi_{ed,V}$ = breakout edge effect factor used to modify shear strength of anchors based on proximity to edges of concrete member

COMMENTARY

CODE

ψ_g = factor used to modify development length based on grade of reinforcement

$\psi_{h,V}$ = breakout thickness factor used to modify shear strength of anchors located in concrete members with $h_a < 1.5c_{a1}$

ψ_o = factor used to modify development length of hooked and headed bars based on side cover and confinement

ψ_p = factor used to modify development length for headed reinforcement based on parallel tie reinforcement

ψ_r = factor used to modify development length based on confining reinforcement

ψ_s = factor used to modify development length based on reinforcement size

ψ_t = factor used to modify development length for casting location in tension

ψ_w = factor used to modify development length for welded deformed wire reinforcement in tension

ω_v = factor to account for dynamic shear amplification

Ω_o = amplification factor to account for overstrength of the seismic-force-resisting system determined in accordance with the general building code

Ω_v = overstrength factor to account for wall flexural overstrength at the wall critical section

2.3—Terminology

action, deformation-controlled—action allowed to exceed the expected yield deformation of the element being evaluated. (Appendix B)

action, force-controlled—action not allowed to exceed the design strength of the element being evaluated. (Appendix B)

adhesive—chemical components formulated from organic polymers, or a combination of organic polymers and inorganic materials that cure if blended together.

admixture—material other than water, aggregate, cementitious materials, and fiber reinforcement used as an ingredient, which is added to grout, mortar, or concrete, either before or during its mixing, to modify the freshly mixed, setting, or hardened properties of the mixture.

aggregate—granular material such as sand, gravel, crushed stone, iron blast-furnace slag, or recycled aggregates including crushed hydraulic cement concrete, used with a cementing medium to form concrete or mortar.

aggregate, lightweight—aggregate meeting the requirements of ASTM C330 and having a loose bulk density of 70 lb/ft^3 or less, determined in accordance with ASTM C29.

COMMENTARY

R2.3—Terminology

action, deformation-controlled—Deformation-controlled actions are those under which elements exhibit acceptable degree of inelastic response and are deemed to have failed upon exceedance of a predefined deformation level or number of cycles. (Appendix B)

action, force-controlled—Force-controlled actions are those under which elements exhibit limited ductility and are deemed to have failed upon exceedance of design strength. (Appendix B)

aggregate—The use of recycled aggregate is addressed in the Code in 2019. The definition of recycled materials in ASTM C33 is very broad and is likely to include materials that would not be expected to meet the intent of the provisions of the Code for use in structural concrete. Use of recycled aggregates including crushed hydraulic-cement concrete in structural concrete requires additional precautions. See 26.4.1.2.1(c).

aggregate, lightweight—In some standards, the term “lightweight aggregate” is being replaced by the term “low-density aggregate.”

CODE

alternative cement—an inorganic cement that can be used as a complete replacement for portland cement or blended hydraulic cement, and that is not covered by applicable specifications for portland or blended hydraulic cements.

anchor—a steel element either cast into concrete or post-installed into a hardened concrete member and used to transmit applied loads to the concrete.

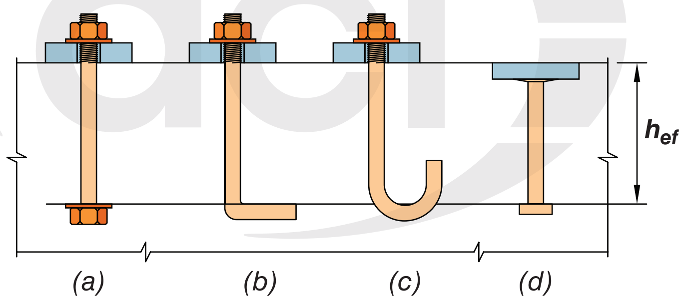
anchor, adhesive—a post-installed anchor, inserted into hardened concrete with an anchor hole diameter not greater than 1.5 times the anchor diameter, that transfers loads to the concrete by bond between the anchor and the adhesive, and bond between the adhesive and the concrete.

COMMENTARY

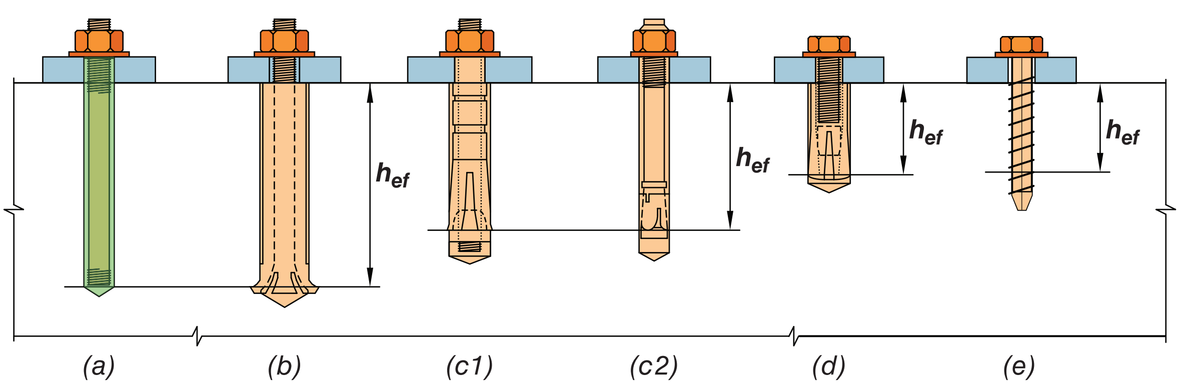
alternative cement—Alternative cements are described in the references listed in R26.4.1.1.1(b). Refer to 26.4.1.1.1(b) for precautions when using these materials in concrete covered by the Code.

anchor—Cast-in anchors include headed bolts, hooked bolts (J- or L-bolt), and headed studs. Post-installed anchors include expansion anchors, undercut anchors, and adhesive anchors; steel elements for adhesive anchors include threaded rods, deformed reinforcing bars, or internally threaded steel sleeves with external deformations. Anchor types are shown in Fig. R2.1.

anchor, adhesive—The design model included in Chapter 17 for adhesive anchors is based on the behavior of anchors with hole diameters not exceeding 1.5 times the anchor diameter. Anchors with hole diameters exceeding 1.5 times the anchor diameter behave differently and are therefore excluded from the scope of Chapter 17 and ACI CODE-355.4. To limit shrinkage and reduce displacement under load, most adhesive anchor systems require the annular gap to be as narrow as practical while still maintaining sufficient clearance for insertion of the anchor element in the adhesive filled hole and ensuring complete coverage of the bonded area over the embedded length. The annular gap for rein-



(A) Cast-in anchors: (a) hex head bolt with washer;
(b) L-bolt; (c) J-bolt; and (d) welded headed stud.



(B) Post-installed anchors: (a) adhesive anchor; (b) undercut anchor;
(c) torque-controlled expansion anchors [(c1) sleeve-type and (c2) stud-type];
(d) drop-in type displacement-controlled expansion anchor; and (e) screw anchor.

Fig. R2.1—Types of anchors.