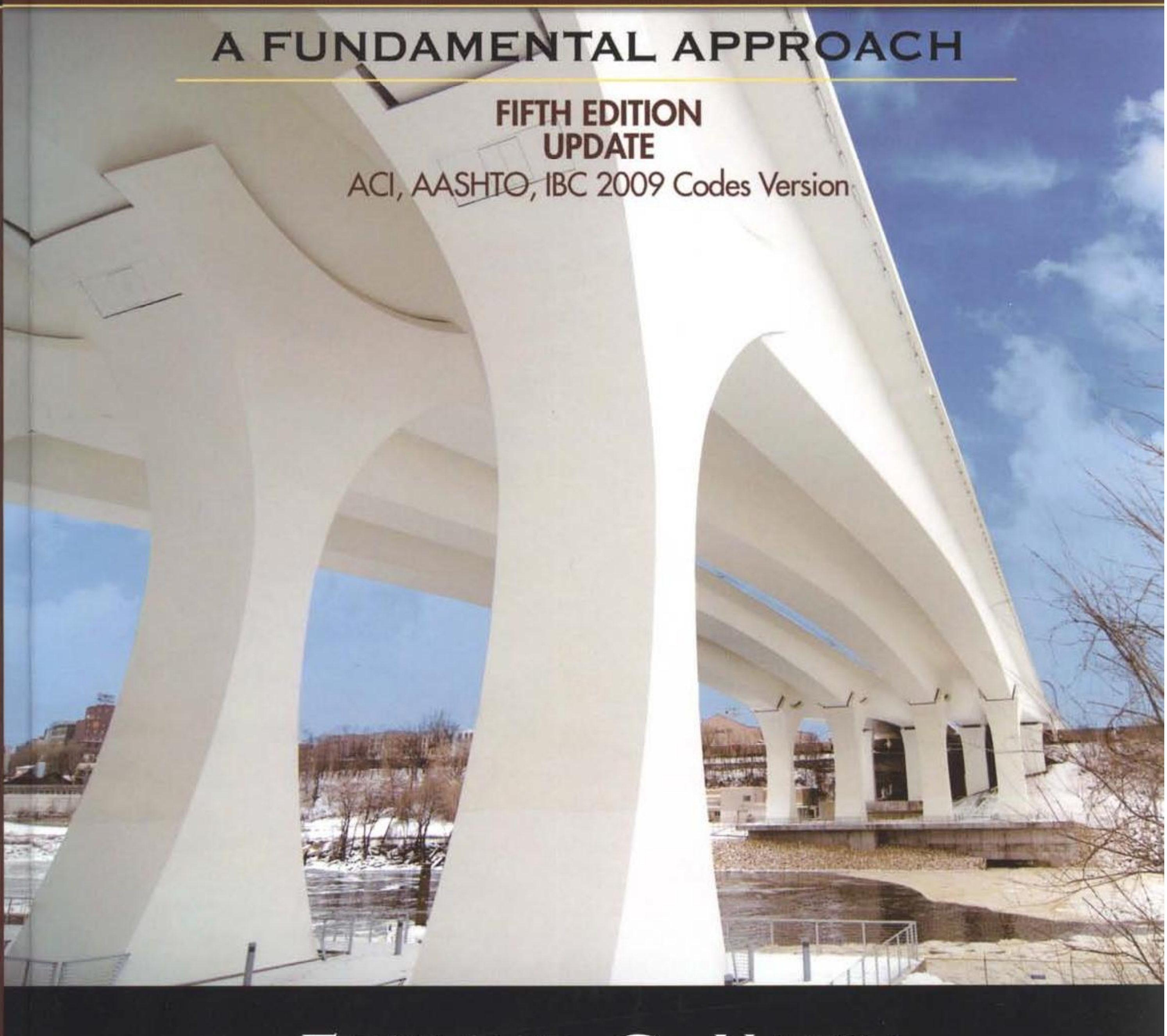
PRESTRESSED CONCRETE

A FUNDAMENTAL APPROACH

FIFTH EDITION UPDATE

ACI, AASHTO, IBC 2009 Codes Version



EDWARD G. NAWY

a = depth of equivalent rectangular stress block.

A_{cp} = area enclosed by outside perimeter of concrete cross section.

A_g = gross area of section, in.^{2}

A_h = area of shear reinforcement parallel to flexural tension reinforcement, in.^{2}

A_j = Effective cross-sectional area within a joint, in.^{2} in a plane parallel to plane of reinforcement generating shear in the joint. The joint depth shall be the overall depth of the column. Where a beam frames into a support of larger width, the effective width of the joint shall not exceed the smaller of:
(a) beam width plus the joint depth
(b) twice the smaller perpendicular distance from the longitudinal axis of the beam to the column side.

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

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

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

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

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

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

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

A_{sh} = total cross-sectional area of transverse reinforcement (including cross-ties) within spacing s and perpendicular to dimension h_c.

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

A_{tr} = total cross-sectional area of transverse reinforcement (stirrup or tie) within a spacing s and perpendicular to plane of bars being spliced or developed, in.^{2}

A_v = area of shear reinforcement within a distance s, or area of shear reinforcement perpendicular to flexural tension reinforcement within a distance s for deep flexural members, in.^{2}

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

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

b = width of compression face of member, in.

b_o = perimeter of critical section for slabs and footings, in.

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

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

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

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

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

c_2 = size of rectangular or equivalent rectangular column, capital, or bracket measured transverse to the direction of the span for which moments are being determined, in.

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

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

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

d_c = thickness of concrete cover measured from extreme tension fiber to center of bar or wire located closest thereto, in.

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

e = eccentricity of load parallel to axis of member measured from centroid of cross section.

E_c = modulus of elasticity of concrete, psi.

E_s = modulus of elasticity of bar reinforcement, psi.

E_{ps} = modulus of elasticity of prestressing reinforcement.

f'_c = specified 28-day compressive strength of concrete, psi.

f_{cr} = average strength to be used as basis for selecting concrete proportions, psi.

f'_{cr} = required average compressive strength of concrete used as the basis for selection of concrete proportions, psi.

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

f'_{ci} = compressive strength of concrete at time of initial prestress, psi.

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

f_{ct} = average splitting tensile strength of lightweight aggregate concrete, psi.

[redacted]

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

f_{pc} = 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.

f_{ps} = stress in prestressed reinforcement at nominal strength.

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

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

f_r = modulus of rupture of concrete, psi.

f'_t = tensile strength of concrete, psi.

f_y = specified yield strength of nonprestressed reinforcement, psi.

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

h = overall thickness of member, in.

I = moment of inertia of section resisting externally applied factored loads, $in.^4$

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

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

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

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

k = effective length factor for compression members.

K_b = flexural stiffness of beam; moment per unit rotation.

K_c = flexural stiffness of column; moment per unit rotation.

K_{ec} = flexural stiffness of equivalent column; moment per unit rotation.

K_s = flexural stiffness of slab; moment per unit rotation.

K_t = torsional stiffness of torsional member; moment per unit rotation.

l_{dh} = development length of standard hook in tension, measured from critical section to outside end of hook (straight embedment length between critical section and start of hook [point of tangency] plus radius of bend and one bar diameter). in.

= l_{hb} × applicable modification factors.

M_a = maximum moment in member at stage deflection is computed.

M_c = factored moment to be used for design of compression member.

M_d = moment due to dead load.

M_{cr} = cracking moment.

M_n = nominal moment strength.

M_{m}- = maximum factored moment at section due to externally applied loads.

M_u = factored moment at section.

n = modular ratio of elasticity.

= E_s/E_c or E_{ps}/E_c.

N_u = factored axial load normal to cross section occurring simultaneously with V_u; to be taken as positive for compression, negative for tension, and to include effects of tension due to creep and shrinkage.

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

P_b = nominal axial load strength at balanced strain conditions.

P_c = critical buckling load.

P_n = nominal axial load strength at given eccentricity.

p_{cp} = outside perimeter of the concrete cross-section A_{cp}; in.

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

r = radius of gyration of cross section of a compression member.

s = spacing of shear or torsion reinforcement in direct parallel to longitudinal reinforcement, in.

t = thickness of a wall of a hollow section, in.

T_u = factored torsional moment at section.

V_c = nominal shear strength provided by concrete.

V_{ci} = nominal shear strength provided by concrete when diagonal cracking results from combined shear and moment.

V_{cw} = nominal shear strength provided by concrete when diagonal cracking results from excessive principal tensile stress in web.

V_d = shear force at section due to unfactored dead load.

V_p = vertical component of effective prestress force at section.

V_s = nominal shear strength provided by shear reinforcement.

V_u = factored shear force at section.

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A Fundamental Approach

Fifth Edition Update
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About the Cover: The new I-35W bridge, Minneapolis, Minnesota. Designed for the Minnesota Department of Transportation by FIGG, this new bridge incorporates aesthetics selected by the community using a theme of "Arches–Water–Reflection" to complement the site across the Mississipi River. Curved, 70′ tall concrete piers meet the sweeping parabolic arch of the 504′ precast, prestressed concrete main span over the river to create a modern bridge. The new 10-lane interstate bridge was constructed by Flatiron-Manson, JV and opened to traffic on September 18, 2008. The bridge was designed and built in 11 months. The bridge incorporates the first use of LED highway lighting, the first major use in the United States of nanotechnology cement that cleans the air (gateway sculptures) and "smart bridge" technology with 323 sensors embedded throughout the concrete to provide valuable data for the future. The photograph of the new I-35W bridge is courtesy of FIGG.

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To
Rachel E. Nawy

*For her high-limit state of stress endurance over the years,
which made the writing of this book in its several editions a reality.*

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