ACI 343R-95

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Analysis and Design of Reinforced Concrete Bridge Structures

Reported by Joint ACI-ASCE Committee 343

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W. M. Davidge	Allan C. Harwood	John C. Payne	J. Jim Zhao

These recommendations, reported by Joint ACI-ASCE Committee 343 on Concrete Bridge Design, provide currently acceptable guidelines for the analysis and design of reinforced, prestressed, and partially prestressed concrete bridges based on the state of the art at the time of writing the report. The provisions recommended herein apply to pedestrian bridges, highway bridges, railroad bridges, airport taxiway bridges, and other special bridge structures. Recommendations for Transit Guideways are given in ACI 358R.

The subjects covered in these recommendations are: common terms; general considerations; materials; construction; loads and load combinations; preliminary design; ultimate load analysis and strength design; service load analysis and design; prestressed concrete; superstructure systems and elements; substructure systems and elements; precast concrete; and details of reinforcement.

The quality and testing of materials used in construction are covered by reference to the appropriate AASHTO and ASTM standard specifications. Welding of reinforcement is covered by reference to the appropriate AWS standard.

Keywords: admixtures; aggregates; anchorage (structural); beam-column frame; beams (supports); **bridges (structures)**; cements; cold weather construction; columns (supports); combined stress; composite construction (concrete and steel); composite construction (concrete to concrete); compressive strength; **concrete construction**; concretes; concrete slabs; construction joints; **construction materials**; continuity (structural); cover; curing; deep beams; deflection; earthquake-resistant structures; flexural strength; footings; **formwork (construction)**; frames; hot weather construction; **inspection**; lightweight concretes; **loads (forces)**; mixing; mixture proportioning; modulus of elasticity; moments; **placing**; **precast concrete**; prestressed concrete; prestressing steels; **quality control**; **reinforced concrete**; reinforcing steels; **serviceability**; shear strength; spans; **specifications**; splicing; strength; **structural analysis**; **structural design**; T-beams; torsion; ultimate strength method; water; welded-wire fabric.

Note: In the text, measurements in metric (SI) units in parentheses follow measurements in inch-pound units. Where applicable for equations, equations for metric (SI) units in parentheses follow equations in inch-pound units.

CONTENTS

ACI 343R-95 became effective March 1, 1995 and supersedes ACI 343R-88. For the 1995 revision, Chapters 6 and 12 were rewritten.

Complex highway interchange in California with 15 bridge structures

CHAPTER 1—DEFINITIONS, NOTATION, AND ORGANIZATIONS

1.1—Introduction

This chapter provides currently accepted definitions, notation, and abbreviations particular to concrete bridge design practice which have been used in the preparation of this document.

Concrete bridge types commonly in use are described separately in Chapter 2, Requirements for Bridges, in Chapter 6, Preliminary Design, and in Chapter 11, Superstructure Systems and Elements.

1.2—Definitions

For cement and concrete terminology already defined, reference is made to ACI 116R. Terms not defined in ACI 116R or defined differently from ACI 116R are defined for specific use in this document as follows:

aggregate, normal weight—aggregate with combined dry, loose weight, varying from 110 lb. to 130 lb/ft^3 (approximately 1760 to 2080 kg/m^3).

compressive strength of concrete (f_c')—specified compressive strength of concrete in pounds per square inch (psi) or (MPa).

Wherever this quantity is under a radical sign, the square root of the numerical value only is intended and the resultant is in pounds per square inch (psi) or (MPa).

concrete, heavyweight—a concrete having heavyweight aggregates and weighing after hardening over 160 lb/ft^3 (approximately 2560 kg/m^3).

concrete, shrinkage-compensating—an expansive cement concrete in which expansion, if restrained, induces compressive strains that are intended to approximately offset tensile strains in the concrete induced by drying shrinkage.

concrete, structural lightweight—concrete containing lightweight aggregate having unit weight ranging from 90 to 115 lb/ft^3 (1440 to 1850 kg/m^3). In this document, a lightweight concrete without natural sand is termed "all-lightweight concrete," and lightweight concrete in which all fine aggregate consists of normal weight sand is termed "sand-lightweight concrete."

design load—applicable loads and forces or their related internal moments and forces used to proportion members. For service load analysis and design, design load refers to loads without load factors. For ultimate load analysis and strength design, design load refers to loads multiplied by appropriate load factors.

effective prestress—the stress remaining in concrete due to prestressing after all losses have occurred, excluding the effect of superimposed loads and weight of member.

load, dead—the dead weight supported by a member (without load factors).

load, live—the live load specified by the applicable document governing design (without load factors).

load, service—live and dead loads (without load factors).

plain reinforcement—reinforcement without surface deformations, or one having deformations that do not conform to the applicable requirements for deformed reinforcement.

pretensioning—a method of prestressing in which the tendons are tensioned before the concrete is placed.

surface water—water carried by an aggregate except that held by absorption within the aggregate particles themselves.

1.3—Notation

Preparation of notation is based on ACI 104R. Where the same notation is used for more than one term, the uncommonly used terms are referred to the Chapter in which they are used. The following notations are listed for specific use in this report:

a = depth of equivalent rectangular stress block
a = constant used in estimating unit structure dead load (Chapter 5)
a = compression flange thickness (Chapter 7)
a_b = depth of equivalent rectangular stress block for balanced conditions
a_i = fraction of trucks with a specific gross weight
a_v = ratio of stiffness of shearhead arm to surrounding composite slab section
A = effective tension area of concrete surrounding the main tension reinforcing bars and having the same centroid as that reinforcement, divided by the number of bars, or wires. When the main reinforcement consists of several bar or wire sizes, the number of bars or wires should be computed as the total steel area divided by the area of the largest bar or wire used
A = axial load deformations and rib shortening used in connection with t-loads (Chapter 5)
A_b = area of an individual bar
A_c = area of core of spirally reinforced compression member measured to the outside diameter of the spiral
A_e = area of longitudinal bars required to resist torsion
A_e = effective tension area of concrete along side face of member surrounding the crack control reinforcement (Chapter 8)
A_f = area of reinforcement required to resist moment developed by shear on a bracket or corbel
A_g = gross area of section
A_h = area of shear reinforcement parallel to flexural tension reinforcement
A_l = total area of longitudinal reinforcement to resist torsion
A_n = area of reinforcement in bracket or corbel resisting tensile force N_{uc}
A_{ps} = area of prestressed reinforcement in tension zone
A_s = area of tension reinforcement
A_s' = area of compression reinforcement
A_{sa} = area of bonded reinforcement in tension zone
A_{se} = area of stirrups transverse to potential bursting crack and within a distance s_e
A_{sf} = area of reinforcement to develop compressive strength of overhanging flanges of I- and T-sections
A_{sh} = total area of hoop and supplementary cross ties in rectangular columns
A_{st} = total area of longitudinal reinforcement (in compression members)
A_t = area of one leg of a closed stirrup resisting torsion within a distance s
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
A_{vf} = area of shear-friction reinforcement
A_{vh} = area of shear reinforcement parallel to the flexural tension reinforcement within a distance s_2
A_w = area of an individual wire
A_1 = loaded area, bearing directly on concrete
A_2 = maximum area of the portion of the supporting surface that is geometrically similar to, and concentric with, the loaded area
b = width of compressive face of member
b = constant used in estimating unit structure dead load (Chapter 5)
b = width or diameter of pier at level of ice action (Chapter 5)
b = width of web (Chapter 6)
b = width of section under consideration (Chapter 7)
b_e = width of concrete section in plane of potential bursting crack
b_o = periphery of critical section for slabs and footings
b_v = width of the cross section being investigated for horizontal shear
b_w = web width, or diameter of circular section
B = buoyancy
c = distance from extreme compressive fiber to neutral axis
C = construction, handling, and erection loads (Chapter 5)
C = stiffness parameter used in connection with lateral distribution of wheel loads to multibeam precast concrete bridges (Chapter 10)
C = ultimate creep coefficient (Chapter 5)
C_a = indentation coefficient used in connection with ice forces
C_e = exposure coefficient used in connection with wind forces
C_i = coefficient for pier inclination from vertical
C_m = factor used in determining effect of bracing on columns (Chapter 7)
C_t = factor relating shear and torsional stress properties equal to b_w times d divided by the summation of x^2 times y
C_t = creep deformation with respect to time (Chapter 5)
C_u = ultimate creep deformation (Chapter 5)
C_u = ultimate creep coefficient
C_w = shape factor relating to configuration of structure and magnitude of wind force on structure
CF = centifugal force
d = distance from extreme compressive fiber to centroid of tension reinforcement
d = depth of section under consideration (Chapter 7)
d = depth of girder (Chapter 5)
d' = distance from extreme compressive fiber to

centroid of compression reinforcement
d_b = nominal diameter of bar, wire, or prestressing strand
d_c = thickness of concrete cover measured from the extreme tensile fiber to the center of the bar located closest thereto
d_p = effective depth of prestressing steel (Chapter 7)
d_s = effective depth for balanced strain conditions (Chapter 7)
d_u = effective depth used in connection with prestressed concrete members (Chapter 7)
D = dead load
D = diameter of lead plug in square or circular isolation bearing (Chapter 11)
D_f = depth of footing
DF = distribution factor used in connection with live loads
DR = derailment force
DS = displacement of supports
e = base of Napierian logarithms
e = span for simply supported bridge or distance between points of inflection under uniform load (Chapter 10)
e = eccentricity of design load parallel to axis measured from the centroid of the section (Chapter 7)
e_b = M_b/P_b = eccentricity of the balanced condition-load moment relationship
e_n = clear span length of slab (Chapter 10)
e_1 = length of short span of slab
e_2 = length of long span of slab
E = effective width of concrete slab resisting wheel or other concentrated load (Chapter 10)
E = earth pressure used in connection with loads (Chapter 5)
E_c = modulus of elasticity of concrete
E_{ci} = modulus of elasticity of concrete at transfer of stress
E_{ps} = modulus of elasticity of prestressing strand
E_s = modulus of elasticity of steel
EI = flexural stiffness of compression members
EQ = earthquake force
f = natural frequency of vibration of structure (Chapter 5)
f_a = axial stress
f_a = basic allowable stress (Chapter 5)
f_b = bending stress
f_b = average bearing stress in concrete on loaded area (Chapter 8)
f_c = extreme fiber compressive stress in concrete at service loads
f_c' = specified compressive strength of concrete
f_{cds} = change in concrete stress at center of gravity of prestressing steel due to all dead loads except the dead load acting at the time the prestressing force is applied
f_{ci}' = compressive strength of concrete at time of initial prestress
f_{cir} = concrete stress immediately after transfer at center of gravity of prestressing steel
f_{cp} = concrete bearing stress under anchor plate of post-tensioning tendon
f_{ct} = average splitting tensile strength of lightweight aggregate concrete
f_f = stress range
f_l = stress produced by ith loading (Chapter 5)
f_{lc} = loss in prestressing steel stress due to creep
f_{le} = loss in prestressing steel stress due to elastic shortening
f_{lf} = loss in prestressing steel stress due to friction
f_{lp} = total loss in prestressing steel stress
f_{lr} = loss in prestressing steel stress due to relaxation
f_{ls} = loss in prestressing steel stress due to shrinkage
f_{min} = algebraic minimum stress level where tension is positive and compression is negative
f_{pc} = compressive stress in the concrete, after all prestress losses have occurred, at the centroid of the cross section resisting the applied loads or at the junction of the web and flange when the centroid lies in the flange. (In a composite member, f_{pc} will be the resultant compressive stress at the centroid of the composite section, or at the junction of the web and flange when the centroid lies within the flange, due to both prestress and to bending moments resisted by the precast member acting alone)
f_{pe} = compressive stress in concrete due to prestress only, after all losses, at the extreme fiber of a section at which tensile stresses are caused by applied loads
f_{po} = steel stress at jacking end of post-tensioning tendon
f_{ps} = stress in prestressing steel at design loads
f_{pu} = ultimate strength of prestressing steel
f_{py} = specified yield strength of prestressing tendons
f_r = modulus of rupture of concrete
f_s = tensile stress in reinforcement at service loads
f_s' = stress in compressive reinforcement
f_{sb}' = stress in compressive reinforcement at balanced conditions
f_{se} = effective stress in prestressing steel, after losses
f_t = extreme fiber tensile stress in concrete at service loads
f_y = specified yield stress, or design yield stress of nonprestressed reinforcement
f_{ya} = design yield stress of steel of bearing plate
f_{yh} = design yield stress of steel for hoops and supplementary cross ties in columns
F = frictional force
F = horizontal ice force on pier (Chapter 5)
F_a = allowable compressive stress
F_b = allowable bending stress
g = acceleration due to gravity, 32.2 ft/sec^2 (9.81 m/sec^2)
G_A = ratio of stiffness of column to stiffness of members at A end resisting column bending

G_A = degree of fixity in the foundation (Chapter 11)
G_B = ratio of stiffness of column to stiffness of members at *B* end resisting column bending
G_{avg} = average ratio of stiffness of column to stiffness of members resisting column bending
G_{min} = minimum ratio of stiffness of column to stiffness of members resisting column bending
h = overall thickness of member
h = slab thickness (Chapter 6)
h = height of rolled on transverse deformation of deformed bar (Chapter 8)
h = height of fill (Chapter 5)
h = thickness of ice in contact with pier (Chapter 5)
h = asphalt wearing surface thickness (Chapter 5)
h_a = thickness of bearing plate
h_c = core dimension of column in direction under consideration
h_f = compression flange thickness of I- and T-sections
h_o = thickness of standard slab used in computing shrinkage
h_2 = thickness of bottom slab of box girder (Chapter 6)
H = average height of columns supporting bridge deck
H = curvature coefficient (Chapter 9)
I = impact due to live load (Chapter 5)
I = impact coefficient
I = moment of inertia (Chapter 7)
ICE = ice pressure
I_{cr} = moment of inertia of cracked section with reinforcement transformed to concrete
I_e = effective moment of inertia for computation of deflection (Chapter 8)
I_g = moment of inertia of gross concrete section about the centroidal axis, neglecting the reinforcement
I_s = moment of inertia of reinforcement about the centroidal axis of the member cross section
k = effective length factor for compression member (Chapters 7 and 11)
k = dimensionless coefficient for lateral distribution of live load for T- and I-girder bridge (Chapter 10)
k = coefficient for different supports in determining earthquake force (Chapter 5)
k_e = dimensionless coefficient for lateral distribution of live load for spread box-beam bridges (Chapter 10)
K = wobble friction coefficient of prestressing steel (Chapter 9)
K = constant used in connection with stream flow (Chapters 5 and 11)
K = value used for beam type and deck material (Chapter 10)
K = pier stiffness (Chapter 11)
l = length
l_a = additional embedment length at support or at point of inflection
l_a = distance from face of support to load for brackets and corbels (Chapter 7)
l_{bd} = basic development length for deformed bar in compression
l_d = development length
l_{dh} = development length for deformed bars in tension terminating in a standard hook
l_{hb} = basic development length of hooked bar
l_n = clear span measured face-to-face of supports
l_n = length of tendon (Chapter 3)
l_u = unsupported length of compression member
L = live load
L = span length used in estimating unit structure dead load (Chapter 5)
L = bridge length contributing to seismic forces (Chapter 5)
L = length of compression member used in computing pier stiffness (Chapter 11)
LF = longitudinal force from live load
M = number of individual loads in the load combination considered
M = live load moment per unit width of concrete deck slab (Chapter 10)
M_a = maximum moment in member at stage for which deflection is being computed
M_b = nominal moment strength of a section at simultaneous assumed ultimate strain of concrete and yielding of tension reinforcement (balanced conditions)
M_c = factored moment to be used for design of compression member
M_{cr} = moment causing flexural cracking at sections due to externally applied loads
M_m = modified moment (Chapter 7)
M_{max} = maximum factored moment due to externally applied loads, dead load excluded
M_n = nominal moment strength of section
M_{nx} = nominal moment strength of section about x-axis
M_{ny} = nominal moment strength of section about y-axis
M_u = factored moment at section, $M_u = \phi M_n$
M_{ux} = factored moment at section about x-axis, $M_{ux} = \phi M_{nx}$
M_{uy} = factored moment at section about y-axis, $M_{uy} = \phi M_{ny}$
M_x = applied design moment component about x-axis
M_y = applied design moment component about y-axis
M_1 = value of smaller factored end moment on compression member calculated from a conventional or elastic analysis, positive if member is bent in single curvature, negative if bent in double curvature
M_2 = value of larger factored end moment on compression member calculated by elastic analysis, always positive
n = modular ratio E_s/E_c

n = number of individual loads in the load combination considered (Chapter 5)
n_b = number of girders (Chapter 10)
n_e = number of design traffic lanes (Chapter 10)
N = nosing and lurching force
N = minimum support length (Chapter 5)
NB = number of beams
NL = number of design traffic lanes
N_u = design axial load normal to the cross section occurring simultaneously with V_u, to be taken as positive for compression, negative for tension, and to include the effects of tension due to shrinkage and creep
N_{uc} = factored tensile force applied at top of bracket or corbel acting simultaneously with V_u, taken as positive for tension
o = overhang of bridge deck beyond supporting member (Chapter 6)
o = effective ice strength (Chapter 5)
OL = overload
p = allowable bearing
p = minimum ratio of bonded reinforcement in tension zone to gross area of concrete section (Chapter 9)
p = unit weight of air (Chapter 5)
p = proportion of load carried by short span of two-way slab (Chapter 10)
P = load on one rear wheel of truck equal to 12,000 lb (53.4 kN) for HS15 loading and 16,000 lb (71.1 kN) for HS20 loading (Chapter 10)
P = load above ground (Chapter 11)
P_b = design axial load strength of a section at simultaneous assumed ultimate strain of concrete and yielding of tension reinforcement (balanced conditions)
P_{cr} = critical buckling load
P_n = nominal axial load at given eccentricity
P_{nx} = nominal axial load at given eccentricity about x-axis
P_{ny} = nominal axial load at given eccentricity about y-axis
P_{nxy} = nominal axial load strength with biaxial loading
P_o = nominal load strength at zero eccentricity
P_o = at rest earth pressures (Chapter 5)
P_s = ratio of spiral reinforcement
P_u = moment, shear, or axial load from the ith loading (Chapter 5)
P_u = factored axial load at given eccentricity, $P_u = \phi P_n$
P_{ux} = factored axial load strength corresponding to M_{ux} with bending considered about the x-axis only
P_{uy} = factored axial load strength corresponding to M_{uy} with bending considered about the y-axis only
P_{uxy} = factored axial load strength with biaxial loading
q = dynamic wind pressure
r = radius of gyration of the cross section of compression member
r = base radius of rolled on transverse deformation of deformed bar (Chapter 8)
R = average annual ambient relative humidity, percent
R_n = characteristic strength (moment, shear, axial load)
RH = mean annual relative humidity, percent (Chapter 5)
s = shear or torsion reinforcement spacing in direction parallel to longitudinal reinforcement
s = beam spacing (Chapter 6)
s_e = spacing of bursting stirrups
s_2 = shear or torsion reinforcement spacing in direction perpendicular to the longitudinal reinforcement or spacing of horizontal reinforcement in wall
s_w = spacing of wires
S = span length
S = average beam spacing for distribution of live loads (Chapter 10)
S = shrinkage and other volume changes used in connection with loads or forces to be considered in analysis and design (Chapter 5)
S_h = vertical spacing of hoops (stirrups) with a maximum of 4 in. (Chapter 11)
S_h = spacing of hoops and supplementary cross ties
SF = stream flow pressure = KV^2
SN = snow load
t = actual time in days used in connection with shrinkage and creep (Chapter 5)
t = age of concrete in days from loading (Chapter 5)
t^* = equivalent time in days used in connection with shrinkage (Chapter 5)
t_w = thickness of web in rectangular box section
t_y = temperature at distance y above depth of temperature variation of webs
t_y' = temperature reduction for asphalt concrete
T = temperature
T = maximum temperature at upper surface of concrete (Chapter 5)
T = fundamental period of vibration of the structure (Chapter 5)
T^* = minimum temperature of top slab over closed interior cells (Chapter 5)
T_c = nominal torsional moment strength provided by concrete
T_n = nominal torsional moment strength
T_s = nominal torsional moment strength provided by torsional reinforcement
T_u = factored torsional moment at section
v = total applied design shear stress at section
v_c = permissible shear stress carried by concrete
v_{dh} = design horizontal shear stress at any cross section
v_h = permissible horizontal shear stress
v_u = factored shear stress at section
V = total applied design shear force at section

V = horizontal earthquake force (Chapter 5)
V = velocity of water used in connection with stream flow (Chapter 5)
V = maximum probable wind velocity (Chapter 5)
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_i = factored shear force at section due to externally applied loads occurring simultaneously with M_{max}
V_n = nominal shear strength provided by concrete and shear reinforcement
V_{nh} = nominal horizontal shear strength provided by concrete and shear reinforcement
V_p = vertical component of effective prestress force at section considered
V_s = nominal shear strength provided by shear reinforcement
V_u = factored shear force at section
w = unit structure dead load
w_c = unit weight of concrete
w_c = roadway width between curbs (Chapters 10 and 11)
w_e = road slab width from edge of slab to midway between exterior beam and first interior beam
W = wind load used in connection with application of wind loads to different types of bridges
W = total weight of structure (Chapter 5)
W = crack width (Chapter 11)
W_f = gross weight of fatigue design truck
W_i = gross weight of specific trucks used in determining fatigue design truck
W_h = wind load applied in horizontal plane
W_p = weight of pier and footing below ground
W_s = weight of soil directly above footing
W_v = wind load applied in vertical plane
WL = wind load applied on live load (Chapter 5)
WL = wind load on live load
x = shorter overall dimension of rectangular part of cross section
x = tandem spacing used in connection with aircraft loads (Chapter 5)
x = width of box girder (Chapter 6)
x_1 = shorter center-to-center dimension of closed rectangular stirrup
x_1 = distance from load to point of support (Chapter 10)
x_2 = distance from center of post to point under investigation (Chapter 10)
y = longer overall dimension of rectangular part of cross section
y = dual spacing used in connection with aircraft loads (Chapter 5)
y = height of box girder (Chapter 6)
y_1 = longer center-to-center dimension of closed rectangular stirrup
y_d = mean thickness of deck between webs
y_t = distance from the centroidal axis of cross section, neglecting the reinforcement, to the extreme fiber in tension
Y_o = depth of temperature variation of webs
Y_s = height of temperature variation in soffit slab
z = quantity limiting distribution of flexural reinforcement
z = height of top of superstructure above ground (Chapter 5)
α = angle between inclined shear reinforcement and longitudinal axis of member
α = angle of pier inclination from vertical (Chapters 5 and 11)
α = load factor used in connection with group loadings (Chapter 5)
α = total angular change of prestressing steel profile (Chapter 9)
α_v = total vertical angular change of prestressing steel profile (Chapter 9)
α_h = total horizontal angular change of prestressing steel profile (Chapter 9)
α_f = angle between shear friction reinforcement and shear plane
α_i = load factor for the ith loading (Chapter 5)
α_t = factor used in connection with torsion reinforcement
β = percent of basic allowable stress (Chapter 5)
β_b = ratio of area of bars cut off to total area of bars at section
β_c = ratio of long side to short side of concentrated load or reaction area
β_d = ratio of maximum factored dead load moment to maximum factored total load moment, always positive
β_1 = factor used to determine the stress block in ultimate load analysis and design
γ = unit weight of soil
δ_b = moment magnification factor for braced frames
δ_s = moment magnification factor for frames not braced against sidesway
λ = correction factor related to unit weight of concrete
μ = coefficient of friction
μ = curvature friction coefficient (Chapter 9)
μ = ductility factor (Chapter 11)
ξ = time-dependent factor for sustained loads (Chapter 8)
$(\xi_{cr})_t$ = time-dependent factor for estimating creep under sustained loads (Chapter 5)
ξ_i = instantaneous strain at application of load (Chapter 5)
$(\xi_{sh})_t$ = shrinkage at time t (Chapter 5)
$(\xi_{sh})_u$ = ultimate shrinkage (Chapter 5)
ρ = ratio of tension reinforcement = A_s/bd
ρ' = ratio of compression reinforcement = A_s'/bd

ρ_b = reinforcement ratio producing balanced condition
ρ_{min} = minimum tension reinforcement ratio = A_s/bd
ρ_p = ratio of prestressed reinforcement = A_{ps}/bd
ρ_s = ratio of volume of spiral reinforcement to total volume of core (out-to-out of spirals) of a spirally reinforced compression member
ρ_v = $(A_s + A_h)/bd$
ρ_w = reinforcement ratio = A_s/b_wd
σ = moment magnification factor for compression members
σ = effective ice strength (Chapter 5)
τ_f = factor used in connection with prestressed concrete member design (Chapter 7)
ϕ = strength-reduction factor
ϕ = angle of internal friction (Chapter 5)

1.4—Referenced organizations

This report refers to many organizations which are responsible for developing standards and recommendations for concrete bridges. These organizations are commonly referred to by acronyms. Following is a listing of these organizations, their acronyms, full titles, and mailing addresses:

AASHTO
American Association of State Highway and Transportation Officials
444 N. Capital Street, NW, Suite 225
Washington, DC 20001

ACI
American Concrete Institute
PO Box 9094
Farmington Hills, MI 48333-9094

ANSI
American National Standards Institute
1439 Broadway
New York, NY 10018

AREA
American Railway Engineering Association
50 F Street, NW
Washington, DC 20001

ARTBA
American Road and Transportation Builders Association
525 School Street, SW
Washington, DC 20024

ASCE
American Society of Civil Engineers
345 E. 47th Street
New York, NY 10017

ASTM
ASTM International
100 Barr Harbor Dr.
West Conshohocken, PA 19428

AWS
American Welding Society
550 NW LeJeune Road
PO Box 351040
Miami, FL 33135

BPR
Bureau of Public Roads
This agency has been succeeded by the Federal Highway Administration

CEB
Comite European du Beton
(European Concrete Committee)
EPFL, Case Postale 88
CH 1015 Lausanne
Switzerland

CRSI
Concrete Reinforcing Steel Institute
933 N. Plum Grove Road
Schaumburg, IL 60195

CSA
Canadian Standards Association
178 Rexdale Boulevard
Rexdale (Toronto), Ontario
Canada M9W 1R3

FAA
Federal Aviation Administration
800 Independence Avenue, SW
Washington, DC 20591

FHWA
Federal Highway Administration
400 Seventh Street, SW
Washington, DC 20590

GSA
General Services Administration
18 F Street
Washington, DC 20405

HRB
Highway Research Board
This board has been succeeded by the Transportation Research Board

PCA
Portland Cement Association
5420 Old Orchard Road
Skokie, IL 60077

PCI
Precast/Prestressed Concrete Institute
209 W. Jackson Blvd.
Chicago, IL 60606-6938