CHAPTER 19
CONCRETE

Italics are used for text within Sections 1903 through 1908 of this code to indicate provisions that differ from ACI 318.

SECTION 1901
GENERAL

1901.1 Scope. The provisions of this chapter shall govern the materials, quality control, design and construction of concrete used in structures.

Exception: Buildings and structures located within the high-velocity hurricane zone shall comply with the provisions of Sections 1917 and 1919 through 1929.

1901.2 Plain and reinforced concrete. Structural concrete shall be designed and constructed in accordance with the requirements of this chapter and ACI 318 as amended in Section 1908 of this code. Except for the provisions of Sections 1904 and 1910, the design and construction of slabs on grade shall not be governed by this chapter unless they transmit vertical loads or lateral forces from other parts of the structure to the soil.

1901.3 Source and applicability. The format and subject matter of Sections 1902 through 1907 of this chapter are patterned after, and in general conformity with, the provisions for structural concrete in ACI 318.

1901.4 Construction documents. The *construction documents* for structural concrete construction shall include:

1. The specified compressive strength of concrete at the stated ages or stages of construction for which each concrete element is designed.
2. The specified strength or grade of reinforcement.
3. The size and location of structural elements, reinforcement and anchors.
4. Provision for dimensional changes resulting from creep, shrinkage and temperature.
5. The magnitude and location of prestressing forces.
6. Anchorage length of reinforcement and location and length of lap splices.
7. Type and location of mechanical and welded splices of reinforcement.
8. Details and location of contraction or isolation joints specified for plain concrete.
9. Minimum concrete compressive strength at time of posttensioning.
10. Stressing sequence for posttensioning tendons.
11. For structures assigned to *Seismic Design Category* D, E or F, a statement if slab on grade is designed as a structural diaphragm (see Section 21.12.3.4 of ACI 318).

1901.5 Special inspection. Reserved.

SECTION 1902
DEFINITIONS

1902.1 General. The words and terms defined in ACI 318 shall, for the purposes of this chapter and as used elsewhere in this code for concrete construction, have the meanings shown in ACI 318 as modified by Section 1908.1.1.

SECTION 1903
SPECIFICATIONS FOR TESTS AND MATERIALS

1903.1 General. Materials used to produce concrete, concrete itself and testing thereof shall comply with the applicable standards listed in ACI 318. *Where required, special inspections and tests shall be in accordance with Chapter 17.*

1903.2 Glass fiber reinforced concrete. *Glass fiber reinforced concrete (GFRC) and the materials used in such concrete shall be in accordance with the PCI MNL 128 standard.*

SECTION 1904
DURABILITY REQUIREMENTS

1904.1 Water-cementitious materials ratio. Where maximum water-cementitious materials ratios are specified in ACI 318, they shall be calculated in accordance with ACI 318, Section 4.1.

1904.2 Exposure categories and classes. Concrete shall be assigned to exposure classes in accordance with ACI 318, Section 4.2, based on:

1. Exposure to freezing and thawing in a moist condition or deicer chemicals;
2. Exposure to sulfates in water or soil;
3. Exposure to water where the concrete is intended to have low permeability; and
4. Exposure to chlorides from deicing chemicals, salt, saltwater, brackish water, seawater or spray from these sources, where the concrete has steel reinforcement.

1904.3 Concrete properties. Concrete mixtures shall conform to the most restrictive maximum water-cementitious materials ratios and minimum specified concrete compressive strength requirements of ACI 318, Section 4.3, based on the exposure classes assigned in Section 1904.2.

Exception: *For occupancies and appurtenances thereto in Group R occupancies that are in buildings less than four stories above grade plane, normal-weight aggregate concrete is permitted to comply with the requirements of Table*

TABLE 1904.3
MINIMUM SPECIFIED COMPRESSIVE STRENGTH (f'_c)

TYPE OR LOCATION OF CONCRETE CONSTRUCTION	MINIMUM SPECIFIED COMPRESSIVE STRENGTH (f'_c at 28 days, psi)		
	Negligible exposure	Moderate exposure	Severe exposure
Basement walls[c] and foundations not exposed to the weather	2,500	2,500	2,500[a]
Basement slabs and interior slabs on grade, except garage floor slabs	2,500	2,500	2,500[a]
Basement walls[c], foundation walls, exterior walls and other vertical concrete surfaces exposed to the weather	2,500	3,000[b]	3,000[b]
Driveways, curbs, walks, patios, porches, carport slabs, steps and other flatwork exposed to the weather, and garage floor slabs	2,500	3,000[b, d]	3,500[b, d]

For SI: 1 pound per square inch = 0.00689 MPa.

a. Concrete in these locations that can be subjected to freezing and thawing during construction shall be of air-entrained concrete in accordance with Section 1904.4.1.

b. Concrete shall be air entrained in accordance with Section 1904.4.1.

c. Structural plain concrete basement walls are exempt from the requirements for exposure conditions of Section 1904.3 (see Section 1909.6.1).

d. For garage floor slabs where a steel trowel finish is used, the total air content required by Section 1904.4.1 is permitted to be reduced to not less than 3 percent, provided the minimum specified compressive strength of the concrete is increased to 4,000 psi.

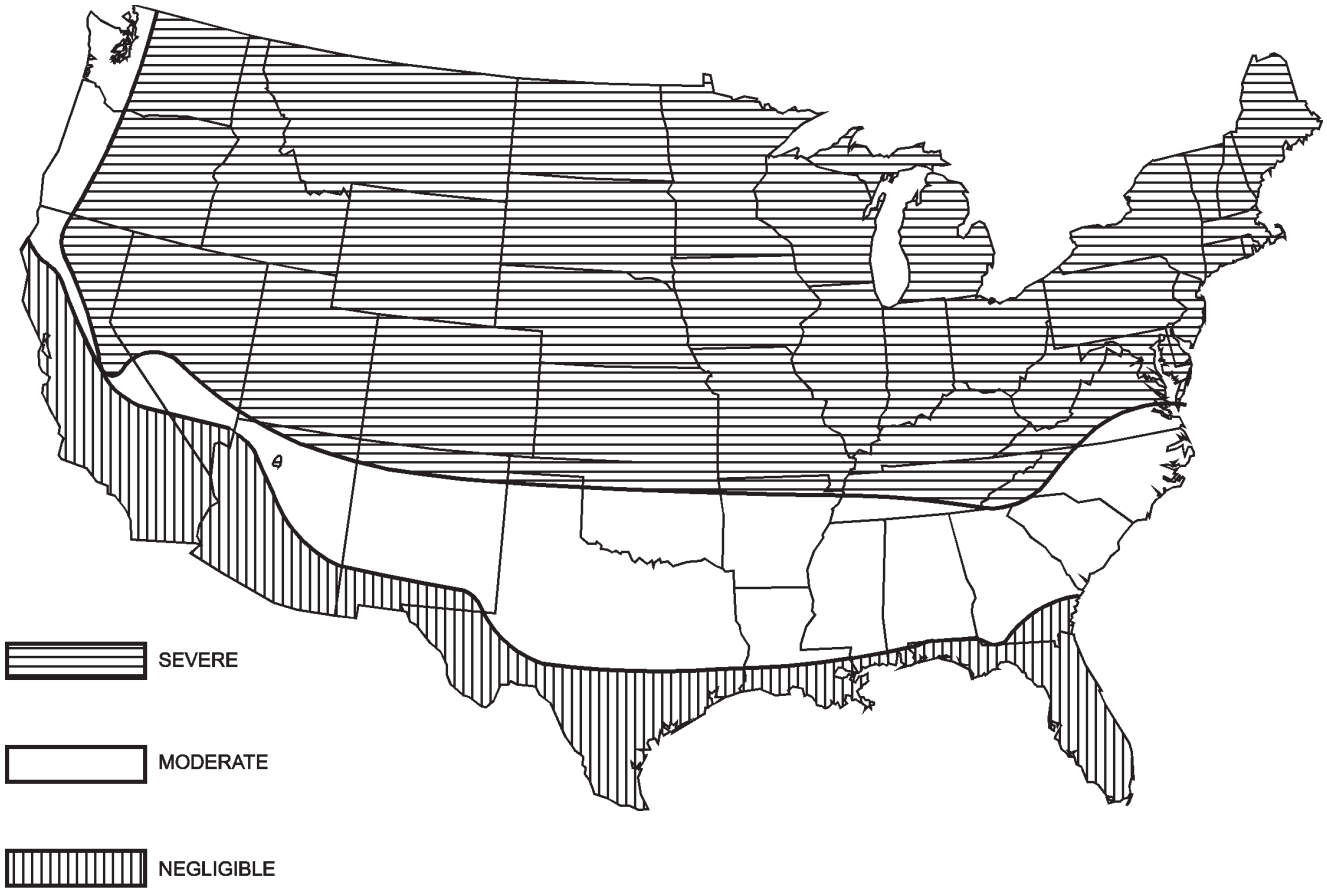

FIGURE 1904.3
WEATHERING PROBABILITY MAP FOR CONCRETE[a, b, c]

a. Lines defining areas are approximate only. Local areas can be more or less severe than indicated by the region classification.

b. A "severe" classification is where weather conditions encourage or require the use of deicing chemicals or where there is potential for a continuous presence of moisture during frequent cycles of freezing and thawing. A "moderate" classification is where weather conditions occasionally expose concrete in the presence of moisture to freezing and thawing, but where deicing chemicals are not generally used. A "negligible" classification is where weather conditions rarely expose concrete in the presence of moisture to freezing and thawing.

c. Alaska and Hawaii are classified as severe and negligible, respectively.

1904.3 based on the weathering classification (freezing and thawing) determined from Figure 1904.3 in lieu of the requirements of ACI 318, Table 4.3.1.

1904.4 Freezing and thawing exposures. Concrete that will be exposed to freezing and thawing, in the presence of moisture, with or without deicing chemicals being present, shall comply with Sections 1904.4.1 and 1904.4.2.

1904.4.1 Air entrainment. Concrete exposed to freezing and thawing while moist shall be air entrained in accordance with ACI 318, Section 4.4.1.

1904.4.2 Deicing chemicals. For concrete exposed to freezing and thawing in the presence of moisture and deicing chemicals, the maximum weight of fly ash, other pozzolans, silica fume or slag that is included in the concrete shall not exceed the percentages of the total weight of cementitious materials permitted by ACI 318, Section 4.4.2.

1904.5 Alternative cementitious materials for sulfate exposure. Alternative combinations of cementitious materials for use in sulfate-resistant concrete to those listed in ACI 318, Table 4.3.1 shall be permitted in accordance with ACI 318, Section 4.5.1.

SECTION 1905
CONCRETE QUALITY, MIXING AND PLACING

1905.1 General. The required strength and durability of concrete shall be determined by compliance with the proportioning, testing, mixing and placing provisions of Sections 1905.1.1 through 1905.13.

1905.1.1 Strength. Concrete shall be proportioned to provide an average compressive strength as prescribed in Section 1905.3 and shall satisfy the durability criteria of Section 1904. Concrete shall be produced to minimize the frequency of strengths below f'_c as prescribed in Section 1905.6.3. *For concrete designed and constructed in accordance with this chapter, f'_c shall not be less than 2,500 psi (17.22 MPa).* No maximum specified compressive strength shall apply unless restricted by a specific provision of this code or ACI 318.

1905.2 Selection of concrete proportions. Concrete proportions shall be determined in accordance with the provisions of ACI 318, Section 5.2.

1905.3 Proportioning on the basis of field experience and/or trial mixtures. Concrete proportioning determined on the basis of field experience and/or trial mixtures shall be done in accordance with ACI 318, Section 5.3.

1905.4 Proportioning without field experience or trial mixtures. Concrete proportioning determined without field experience or trial mixtures shall be done in accordance with ACI 318, Section 5.4.

1905.5 Average strength reduction. As data become available during construction, it is permissible to reduce the amount by which the average compressive strength (f'_c) is required to exceed the specified value of f'_c in accordance with ACI 318, Section 5.5.

1905.6 Evaluation and acceptance of concrete. The criteria for evaluation and acceptance of concrete shall be as specified in Sections 1905.6.2 through 1905.6.5.

1905.6.1 Qualified technicians. Concrete shall be tested in accordance with the requirements in Sections 1905.6.2 through 1905.6.5. Qualified field testing technicians shall perform tests on fresh concrete at the job site, prepare specimens required for curing under field conditions, prepare specimens required for testing in the laboratory and record the temperature of the fresh concrete when preparing specimens for strength tests. Qualified laboratory technicians shall perform all required laboratory tests.

1905.6.2 Frequency of testing. The frequency of conducting strength tests of concrete and the minimum number of tests shall be as specified in ACI 318, Section 5.6.2.

Exception: When the total volume of a given class of concrete is less than 50 cubic yards (38 m^3), strength tests are not required when evidence of satisfactory strength is submitted to and approved by the building official.

1905.6.3 Strength test specimens. Specimens prepared for acceptance testing of concrete in accordance with Section 1905.6.2 and strength test acceptance criteria shall comply with the provisions of ACI 318, Section 5.6.3.

1905.6.4 Field-cured specimens. Where required by the building official to determine adequacy of curing and protection of concrete in the structure, specimens shall be prepared, cured, tested and test results evaluated for acceptance in accordance with ACI 318, Section 5.6.4.

1905.6.5 Low-strength test results. Where any strength test (see ACI 318, Section 5.6.2.4) falls below the specified value of f'_c, the provisions of ACI 318, Section 5.6.5, shall apply.

1905.7 Preparation of equipment and place of deposit. Prior to concrete being placed, the space to receive the concrete and the equipment used to deposit it shall comply with ACI 318, Section 5.7.

1905.8 Mixing. Mixing of concrete shall be performed in accordance with ACI 318, Section 5.8.

1905.9 Conveying. The method and equipment for conveying concrete to the place of deposit shall comply with ACI 318, Section 5.9.

1905.10 Depositing. The depositing of concrete shall comply with the provisions of ACI 318, Section 5.10.

1905.11 Curing. The length of time, temperature and moisture conditions for curing of concrete shall be in accordance with ACI 318, Section 5.11.

1905.12 Cold weather requirements. Concrete to be placed during freezing or near-freezing weather shall comply with the requirements of ACI 318, Section 5.12.

1905.13 Hot weather requirements. Concrete to be placed during hot weather shall comply with the requirements of ACI 318, Section 5.13.

SECTION 1906
FORMWORK, EMBEDDED PIPES AND CONSTRUCTION JOINTS

1906.1 Formwork. The design, fabrication and erection of forms shall comply with ACI 318, Section 6.1.

1906.2 Removal of forms, shores and reshores. The removal of forms and shores, including from slabs and beams (except where cast on the ground), and the installation of reshores shall comply with ACI 318, Section 6.2.

1906.3 Conduits and pipes embedded in concrete. Conduits, pipes and sleeves of any material not harmful to concrete and within the limitations of ACI 318, Section 6.3, are permitted to be embedded in concrete with approval of the registered design professional.

1906.4 Construction joints. Construction joints, including their location, shall comply with the provisions of ACI 318, Section 6.4.

SECTION 1907
DETAILS OF REINFORCEMENT

1907.1 Hooks. Standard hooks on reinforcing bars used in concrete construction shall comply with ACI 318, Section 7.1.

1907.2 Minimum bend diameters. Minimum reinforcement bend diameters utilized in concrete construction shall comply with ACI 318, Section 7.2.

1907.3 Bending. The bending of reinforcement shall comply with ACI 318, Section 7.3.

1907.4 Surface conditions of reinforcement. The surface conditions of reinforcement shall comply with the provisions of ACI 318, Section 7.4.

1907.5 Placing reinforcement. The placement of reinforcement, including tolerances on depth and cover, shall comply with the provisions of ACI 318, Section 7.5. Reinforcement shall be accurately placed and adequately supported before concrete is placed.

1907.6 Spacing limits for reinforcement. The clear distance between reinforcing bars, bundled bars, tendons and ducts shall comply with ACI 318, Section 7.6.

1907.7 Concrete protection for reinforcement. The minimum specified concrete cover for reinforcement shall comply with Sections 1907.7.1 through 1907.7.8.

1907.7.1 Cast-in-place concrete (nonprestressed). Minimum specified concrete cover shall be provided for reinforcement in nonprestressed, cast-in-place concrete construction in accordance with ACI 318, Section 7.7.1.

1907.7.2 Cast-in-place concrete (prestressed). The minimum specified concrete cover for prestressed and nonprestressed reinforcement, ducts and end fittings in cast-in-place prestressed concrete shall comply with ACI 318, Section 7.7.2.

1907.7.3 Precast concrete (manufactured under plant control conditions). The minimum specified concrete cover for prestressed and nonprestressed reinforcement, ducts and end fittings in precast concrete manufactured under plant control conditions shall comply with ACI 318, Section 7.7.3.

1907.7.4 Bundled bars. The minimum specified concrete cover for bundled bars shall comply with ACI 318, Section 7.7.4.

1907.7.5 Headed shear stud reinforcement. For headed shear stud reinforcement, the minimum specified concrete cover shall comply with ACI 318, Section 7.7.5.

1907.7.6 Corrosive environments. In corrosive environments or other severe exposure conditions, prestressed and nonprestressed reinforcement shall be provided with additional protection in accordance with ACI 318, Section 7.7.6.

1907.7.7 Future extensions. Exposed reinforcement, inserts and plates intended for bonding with future extensions shall be protected from corrosion.

1907.7.8 Fire protection. When this code requires a thickness of cover for fire protection greater than the minimum concrete cover in Section 1907.7, such greater thickness shall be specified.

1907.8 Special reinforcement details for columns. Offset bent longitudinal bars in columns and load transfer in structural steel cores of composite compression members shall comply with the provisions of ACI 318, Section 7.8.

1907.9 Connections. Connections between concrete framing members shall comply with the provisions of ACI 318, Section 7.9.

1907.10 Lateral reinforcement for compression members. Lateral reinforcement for concrete compression members shall comply with the provisions of ACI 318, Section 7.10.

1907.11 Lateral reinforcement for flexural members. Lateral reinforcement for compression reinforcement in concrete flexural members shall comply with the provisions of ACI 318, Section 7.11.

1907.12 Shrinkage and temperature reinforcement. Reinforcement for shrinkage and temperature stresses in concrete members shall comply with the provisions of ACI 318, Section 7.12.

1907.13 Requirements for structural integrity. The detailing of reinforcement and connections between concrete members shall comply with the provisions of ACI 318, Section 7.13, to improve structural integrity.

SECTION 1908
MODIFICATIONS TO ACI 318
RESERVED

SECTION 1909
STRUCTURAL PLAIN CONCRETE

1909.1 Scope. The design and construction of structural plain concrete, both cast-in-place and precast, shall comply with the minimum requirements of Section 1909 and ACI 318, Chapter 22, as modified in Section 1908.

1909.1.1 Special structures. For special structures, such as arches, underground utility structures, gravity walls and shielding walls, the provisions of this section shall govern where applicable.

1909.2 Limitations. The use of structural plain concrete shall be limited to:

1. Members that are continuously supported by soil, such as walls and footings, or by other structural members capable of providing continuous vertical support.
2. Members for which arch action provides compression under all conditions of loading.
3. Walls and pedestals.

The use of structural plain concrete columns and structural plain concrete footings on piles is not permitted. See Section 1908.1.8 for additional limitations on the use of structural plain concrete.

1909.3 Joints. Contraction or isolation joints shall be provided to divide structural plain concrete members into flexurally discontinuous elements in accordance with ACI 318, Section 22.3.

1909.4 Design. Structural plain concrete walls, footings and pedestals shall be designed for adequate strength in accordance with ACI 318, Sections 22.4 through 22.8.

Exception: For Group R-3 occupancies and buildings of other occupancies less than two *stories above grade plane* of light-frame construction, the required edge thickness of ACI 318 is permitted to be reduced to 6 inches (152 mm), provided that the footing does not extend more than 4 inches (102 mm) on either side of the supported wall.

1909.5 Precast members. The design, fabrication, transportation and erection of precast, structural plain concrete elements shall be in accordance with ACI 318, Section 22.9.

1909.6 Walls. In addition to the requirements of this section, structural plain concrete walls shall comply with the applicable requirements of ACI 318, Chapter 22.

1909.6.1 Basement walls. The thickness of exterior basement walls and foundation walls shall be not less than $7^1/_2$ inches (191 mm).

1909.6.2 Other walls. Except as provided for in Section 1909.6.1, the thickness of bearing walls shall be not less than $^1/_{24}$ the unsupported height or length, whichever is shorter, but not less than $5^1/_2$ inches (140 mm).

1909.6.3 Openings in walls. Not less than one No. 5 bar shall be provided around window, door and similar sized openings. The bar shall be anchored to develop f_y in tension at the corners of openings.

SECTION 1910
MINIMUM SLAB PROVISIONS

1910.1 General. The thickness of concrete floor slabs supported directly on the ground shall not be less than $3^1/_2$ inches (89 mm). A 6-mil (0.006 inch; 0.15 mm) polyethylene vapor retarder with joints lapped not less than 6 inches (152 mm) shall be placed between the base course or subgrade and the concrete floor slab, or other *approved* equivalent methods or materials shall be used to retard vapor transmission through the floor slab.

Exception: A vapor retarder is not required:

1. For detached structures accessory to occupancies in Group R-3, such as garages, utility buildings or other unheated facilities.
2. For unheated storage rooms having an area of less than 70 square feet (6.5 m^2) and carports attached to occupancies in Group R-3.
3. For buildings of other occupancies where migration of moisture through the slab from below will not be detrimental to the intended occupancy of the building.
4. For driveways, walks, patios and other flatwork which will not be enclosed at a later date.
5. Where *approved* based on local site conditions.

1910.2 Joints. Concrete slabs on ground shall be provided with joints in accordance with ACI 224.3R or other approved methods. Joints shall be designed by an architect or engineer.

Exception: Joints are not required in unreinforced plain concrete slabs on ground or in slabs for one- and two-family dwellings complying with one of the following:

1. Concrete slabs on ground containing synthetic fiber reinforcement. Fiber lengths and dosage amounts shall comply with one of the following:
   (a) Fiber lengths shall be $^1/_2$ inch to 2 inches (13 to 51 mm) in length. Dosage amounts shall be from 0.75 to 1.5 pounds per cubic yard (0.45 to 0.89 kg/m^3) in accordance with the manufacturer's recommendations. Synthetic fibers shall comply with ASTM C 1116. The manufacturer or supplier shall provide certification of compliance with ASTM C 1116 when requested by the building official; or,
   (b) Fiber length shall be from $^1/_2$ inch to 2 inches (13 mm to 51 mm) in length, monofilament or fibrillated. Dosage amounts shall be from 0.5 to 1.5 pounds per cubic yard (0.30 to 0.89 kg/m^3) to achieve minimum 40 percent reduction of plastic shrinkage cracking of concrete versus a control mix in accordance with ICBO AC32. Independent test results using minimum six (6) test speci-

mens shall be provided to the building official showing compliance with ICBO A32. Synthetic fiber shall comply with ASTM C 1116, Paragraph 4.1.3, Type III. The manufacturer or supplier shall provide certification of compliance with ASTM C 1116 when requested by building official.

2. Concrete slabs on ground containing 6 × 6 W1.4 × W1.4 welded wire reinforcement fabric located in the middle to the upper one-third of the slab. Welded wire reinforcement fabric shall be supported with approved materials or supports at spacings not to exceed 3 feet (914 mm) or in accordance with the manufacturer's specifications. Welded plain wire reinforcement fabric for concrete shall conform to ASTM A 185, Standard Specification for Steel Welded Wire Reinforcement Fabric, Plain, for Concrete Reinforcement.

SECTION 1911
ANCHORAGE TO CONCRETE—
ALLOWABLE STRESS DESIGN

1911.1 Scope. The provisions of this section shall govern the *allowable stress design* of headed bolts and headed stud anchors cast in normal-weight concrete for purposes of transmitting structural loads from one connected element to the other. These provisions do not apply to anchors installed in hardened concrete. The bearing area of headed anchors shall be not less than one and one-half times the shank area. Where strength design is used, the design strength of anchors shall be determined in accordance with Section 1912. Bolts shall conform to ASTM A 307 or an *approved* equivalent.

1911.2 Allowable service load. The allowable service load for headed anchors in shear or tension shall be as indicated in Table 1911.2. Where anchors are subject to combined shear and tension, the following relationship shall be satisfied:

$$(P_s / P_t)^{5/3} + (V_s / V_t)^{5/3} \le 1 \qquad \textbf{(Equation 19-1)}$$

where:

P_s = Applied tension service load, pounds (N).

P_t = Allowable tension service load from Table 1911.2, pounds (N).

V_s = Applied shear service load, pounds (N).

V_t = Allowable shear service load from Table 1911.2, pounds (N).

1911.3 Required edge distance and spacing. The allowable service loads in tension and shear specified in Table 1911.2 are for the edge distance and spacing specified. The edge distance and spacing are permitted to be reduced to 50 percent of the values specified with an equal reduction in allowable service load. Where edge distance and spacing are reduced less than 50 percent, the allowable service load shall be determined by linear interpolation.

1911.4 Increase in allowable load. Increase of the values in Table 1911.2 by one-third is permitted where the provisions of Section 1605.3.2 permit an increase in allowable stress for wind loading.

1911.5 Increase for special inspection. Where *special inspection* is provided for the installation of anchors, a 100-percent increase in the allowable tension values of Table 1911.2 is permitted. No increase in shear value is permitted.

TABLE 1911.2
ALLOWABLE SERVICE LOAD ON EMBEDDED BOLTS (pounds)

BOLT DIAMETER (inches)	MINIMUM EMBEDMENT (inches)	EDGE DISTANCE (inches)	SPACING (inches)	MINIMUM CONCRETE STRENGTH (psi)					
				f'_c = 2,500		f'_c = 3,000		f'_c = 4,000	
				Tension	Shear	Tension	Shear	Tension	Shear
1/4	2 1/2	1 1/2	3	200	500	200	500	200	500
3/8	3	2 1/4	4 1/2	500	1,100	500	1,100	500	1,100
1/2	4 4	3 5	6 6	950 1,450	1,250 1,600	950 1,500	1,250 1,650	950 1,550	1,250 1,750
5/8	4 1/2 4 1/2	3 3/4 6 1/4	7 1/2 7 1/2	1,500 2,125	2,750 2,950	1,500 2,200	2,750 3,000	1,500 2,400	2,750 3,050
3/4	5 5	4 1/2 7 1/2	9 9	2,250 2,825	3,250 4,275	2,250 2,950	3,560 4,300	2,250 3,200	3,560 4,400
7/8	6	5 1/4	10 1/2	2,550	3,700	2,550	4,050	2,550	4,050
1	7	6	12	3,050	4,125	3,250	4,500	3,650	5,300
1 1/8	8	6 3/4	13 1/2	3,400	4,750	3,400	4,750	3,400	4,750
1 1/4	9	7 1/2	15	4,000	5,800	4,000	5,800	4,000	5,800

For SI: 1 inch = 25.4 mm, 1 pound per square inch = 0.00689 MPa, 1 pound = 4.45 N.

SECTION 1912
ANCHORAGE TO CONCRETE—
STRENGTH DESIGN

1912.1 Scope. The provisions of this section shall govern the strength design of anchors installed in concrete for purposes of transmitting structural loads from one connected element to the other. Headed bolts, headed studs and hooked (J- or L-) bolts cast in concrete and expansion anchors and undercut anchors installed in hardened concrete shall be designed in accordance with Appendix D of ACI 318, provided they are within the scope of Appendix D.

The strength design of anchors that are not within the scope of Appendix D of ACI 318, shall be in accordance with an *approved* procedure.

SECTION 1913
SHOTCRETE

1913.1 General. Shotcrete is mortar or concrete that is pneumatically projected at high velocity onto a surface. Except as specified in this section, shotcrete shall conform to the requirements of this chapter for plain or reinforced concrete.

1913.2 Proportions and materials. Shotcrete proportions shall be selected that allow suitable placement procedures using the delivery equipment selected and shall result in finished in-place hardened shotcrete meeting the strength requirements of this code.

1913.3 Aggregate. Coarse aggregate, if used, shall not exceed $^3/_4$ inch (19.1 mm).

1913.4 Reinforcement. Reinforcement used in shotcrete construction shall comply with the provisions of Sections 1913.4.1 through 1913.4.4.

1913.4.1 Size. The maximum size of reinforcement shall be No. 5 bars unless it is demonstrated by preconstruction tests that adequate encasement of larger bars will be achieved.

1913.4.2 Clearance. When No. 5 or smaller bars are used, there shall be a minimum clearance between parallel reinforcement bars of $2^1/_2$ inches (64 mm). When bars larger than No. 5 are permitted, there shall be a minimum clearance between parallel bars equal to six diameters of the bars used. When two curtains of steel are provided, the curtain nearer the nozzle shall have a minimum spacing equal to 12 bar diameters and the remaining curtain shall have a minimum spacing of six bar diameters.

Exception: Subject to the approval of the *building official*, required clearances shall be reduced where it is demonstrated by preconstruction tests that adequate encasement of the bars used in the design will be achieved.

1913.4.3 Splices. Lap splices of reinforcing bars shall utilize the noncontact lap splice method with a minimum clearance of 2 inches (51 mm) between bars. The use of contact lap splices necessary for support of the reinforcing is permitted when *approved* by the *building official*, based on satisfactory preconstruction tests that show that adequate encasement of the bars will be achieved, and provided that the splice is oriented so that a plane through the center of the spliced bars is perpendicular to the surface of the shotcrete.

1913.4.4 Spirally tied columns. Shotcrete shall not be applied to spirally tied columns.

1913.5 Preconstruction tests. When required by the *building official*, a test panel shall be shot, cured, cored or sawn, examined and tested prior to commencement of the project. The sample panel shall be representative of the project and simulate job conditions as closely as possible. The panel thickness and reinforcing shall reproduce the thickest and most congested area specified in the structural design. It shall be shot at the same angle, using the same nozzleman and with the same concrete mix design that will be used on the project. The equipment used in preconstruction testing shall be the same equipment used in the work requiring such testing, unless substitute equipment is *approved* by the *building official*.

1913.6 Rebound. Any rebound or accumulated loose aggregate shall be removed from the surfaces to be covered prior to placing the initial or any succeeding layers of shotcrete. Rebound shall not be used as aggregate.

1913.7 Joints. Except where permitted herein, unfinished work shall not be allowed to stand for more than 30 minutes unless edges are sloped to a thin edge. For structural elements that will be under compression and for construction joints shown on the *approved construction documents*, square joints are permitted. Before placing additional material adjacent to previously applied work, sloping and square edges shall be cleaned and wetted.

1913.8 Damage. In-place shotcrete that exhibits sags, sloughs, segregation, honeycombing, sand pockets or other obvious defects shall be removed and replaced. Shotcrete above sags and sloughs shall be removed and replaced while still plastic.

1913.9 Curing. During the curing periods specified herein, shotcrete shall be maintained above 40°F (4°C) and in moist condition.

1913.9.1 Initial curing. Shotcrete shall be kept continuously moist for 24 hours after shotcreting is complete or shall be sealed with an *approved* curing compound.

1913.9.2 Final curing. Final curing shall continue for seven days after shotcreting, or for three days if high-early-strength cement is used, or until the specified strength is obtained. Final curing shall consist of the initial curing process or the shotcrete shall be covered with an *approved* moisture-retaining cover.

1913.9.3 Natural curing. Natural curing shall not be used in lieu of that specified in this section unless the relative humidity remains at or above 85 percent, and is authorized by the *registered design professional* and *approved* by the *building official*.

1913.10 Strength tests. Strength tests for shotcrete shall be made by an *approved agency* on specimens that are representative of the work and which have been water soaked for at least 24 hours prior to testing. When the maximum-size aggregate is larger than $^3/_8$ inch (9.5 mm), specimens shall consist of not less than three 3-inch-diameter (76 mm) cores or 3-inch (76 mm) cubes. When the maximum-size aggregate is $^3/_8$ inch (9.5 mm)

or smaller, specimens shall consist of not less than 2-inch-diameter (51 mm) cores or 2-inch (51 mm) cubes.

1913.10.1 Sampling. Specimens shall be taken from the in-place work or from test panels, and shall be taken at least once each shift, but not less than one for each 50 cubic yards (38.2 m^3) of shotcrete.

1913.10.2 Panel criteria. When the maximum-size aggregate is larger than $^3/_8$ inch (9.5 mm), the test panels shall have minimum dimensions of 18 inches by 18 inches (457 mm by 457 mm). When the maximum size aggregate is $^3/_8$ inch (9.5 mm) or smaller, the test panels shall have minimum dimensions of 12 inches by 12 inches (305 mm by 305 mm). Panels shall be shot in the same position as the work, during the course of the work and by the nozzlemen doing the work. The conditions under which the panels are cured shall be the same as the work.

1913.10.3 Acceptance criteria. The average compressive strength of three cores from the in-place work or a single test panel shall equal or exceed 0.85 f'_c with no single core less than 0.75 f'_c. The average compressive strength of three cubes taken from the in-place work or a single test panel shall equal or exceed f'_c with no individual cube less than 0.88 f'_c. To check accuracy, locations represented by erratic core or cube strengths shall be retested.

SECTION 1914
REINFORCED GYPSUM CONCRETE

1914.1 General. Reinforced gypsum concrete shall comply with the requirements of ASTM C 317 and ASTM C 956.

1914.2 Minimum thickness. The minimum thickness of reinforced gypsum concrete shall be 2 inches (51 mm) except the minimum required thickness shall be reduced to $1^1/_2$ inches (38 mm), provided the following conditions are satisfied:

1. The overall thickness, including the formboard, is not less than 2 inches (51 mm).
2. The clear span of the gypsum concrete between supports does not exceed 33 inches (838 mm).
3. Diaphragm action is not required.
4. The design live load does not exceed 40 pounds per square foot (psf) (1915 Pa).

SECTION 1915
CONCRETE-FILLED PIPE COLUMNS

1915.1 General. Concrete-filled pipe columns shall be manufactured from standard, extra-strong or double-extra-strong steel pipe or tubing that is filled with concrete so placed and manipulated as to secure maximum density and to ensure complete filling of the pipe without voids.

1915.2 Design. The safe supporting capacity of concrete-filled pipe columns shall be computed in accordance with the *approved* rules or as determined by a test.

1915.3 Connections. Caps, base plates and connections shall be of *approved* types and shall be positively attached to the shell and anchored to the concrete core. Welding of brackets without mechanical anchorage shall be prohibited. Where the pipe is slotted to accommodate webs of brackets or other connections, the integrity of the shell shall be restored by welding to ensure hooping action of the composite section.

1915.4 Reinforcement. To increase the safe load-supporting capacity of concrete-filled pipe columns, the steel reinforcement shall be in the form of rods, structural shapes or pipe embedded in the concrete core with sufficient clearance to ensure the composite action of the section, but not nearer than 1 inch (25 mm) to the exterior steel shell. Structural shapes used as reinforcement shall be milled to ensure bearing on cap and base plates.

1915.5 Fire-resistance-rating protection. Pipe columns shall be of such size or so protected as to develop the required fire-resistance ratings specified in Table 601. Where an outer steel shell is used to enclose the fire protective covering, the shell shall not be included in the calculations for strength of the column section. The minimum diameter of pipe columns shall be 4 inches (102 mm) except that in structures of Type V construction not exceeding three *stories above grade plane* or 40 feet (12 192 mm) in *building height*, pipe columns used in basements and as secondary steel members shall have a minimum diameter of 3 inches (76 mm).

1915.6 Approvals. Details of column connections and splices shall be shop fabricated by *approved* methods and shall be *approved* only after tests in accordance with the *approved* rules. Shop-fabricated concrete-filled pipe columns shall be inspected by the *building official* or by an *approved* representative of the manufacturer at the plant.

SECTION 1916
RESERVED

SECTION 1917
LIGHTWEIGHT INSULATING CONCRETE ROOF DECK

1917.1 Lightweight insulating concrete. Material produced with or without aggregate additions to portland cement, water and air to form a hardened material possessing insulating qualities, which, when oven dried shall have a unit weight no greater than 50 pcf (801 kg/m^3).

1917.1.1 Aggregate lightweight insulating concrete. Insulating concrete formulated predominantly with perlite or vermiculite aggregate having a minimum compressive strength of 125 psi (861.8 kPa) when tested in compliance with ASTM C 495.

1917.1.2 Cellular lightweight insulating concrete. Insulating concrete formulated by mixing a hydrated cementitious matrix around noninterconnecting air cells created by the addition of preformed foam formed from hydrolyzed proteins or synthetic surfactants. The cured cellular lightweight insulating concrete shall have minimum compressive strength of 160 psi (1103 kPa) when tested in compliance with ASTM C 495 and C 796.

1917.1.3 Cellular/aggregate (hybrid) lightweight insulating concrete. Insulated concrete formulated by combin-

ing preformed foam with low density aggregates to impart properties of both aggregate and cellular lightweight insulating concrete. It shall have a minimum compressive strength of 200 psi (1379 kPa) when tested in compliance with ASTM C 495 and C 796.

1917.1.4 Walkability. A term defining the ability of lightweight insulating concrete to withstand anticipated construction foot traffic during the roof membrane application without significant indentations in the lightweight insulating concrete surface.

1917.2 Inspection.

1917.2.1 Application of all lightweight insulating concrete roof decks shall be by applicators approved by the lightweight insulating concrete deck manufacturer. Product Approval shall be required for all lightweight insulating concrete systems.

1917.2.2 The permit holder shall notify the building official 48 hours prior to the pouring of lightweight insulating concrete.

1917.2.3 The permit holder shall make available to the building official a job log with the following minimum items.

1. Cast density recordings/hour.
2. Product evaluation for application.
3. Date and job locations identified.
4. Results of any field test conducted.

1917.2.4 Once the roof deck system can support foot traffic, the building official shall have clear access and clear path at his option for inspection of lightweight insulating concrete.

1917.3 Testing. The building official may require tests of the lightweight insulating concrete to confirm the fastener withdrawal resistance, compressive strength or drainage ability.

1917.3.1 Existing roof assemblies to receive lightweight insulating concrete other than galvanized G-90 steel deck or structural concrete deck shall be tested for uplift for adhesion to the substrate to confirm compliance with design pressure.

1917.4 Materials and limitations of use. Lightweight insulating concrete, in conjunction with galvanized formed steel sheets, shall not be used as a roof deck in areas where highly corrosive chemicals are used or stored.

1917.4.1 Lightweight insulating concrete shall be poured over bottom slotted galvanized (G-90) steel decking as follows; cellular, 0.5 percent open; hybrid, 0.75 percent open, aggregate 1.5 percent open. No lightweight insulating concrete shall be poured over a painted or non-galvanized steel deck.

1. Lightweight insulating concrete over structural concrete slabs, twin tees, precast units or other non-venting substrates shall be vented to allow the escape of excess moisture.

1917.4.2 Minimum thickness of lightweight insulating concrete shall be 2 inches (51 mm) over the top plane of the substrate unless otherwise specified in the Product Approval. Lightweight insulating concrete shall be of sufficient thickness to receive the specified base ply fastener length.

1917.4.3 Reserved.

1917.4.4 Galvanized coatings of formed steel sheets shall be in accordance with ASTM A 525 with a minimum coating designation of G-90. Base steel shall conform to ASTM A 446, Grade A, B, C, D or greater and ASTM A 611 C, D or E.

1917.4.5 Chemical admixtures shall be in compliance with ASTM C 494. Calcium chloride or any admixture containing chloride salts shall not be used in insulating concrete. Fiber reinforcement may be used to control cracking. Mineral admixtures shall conform to ASTM C 618.

1917.4.6 Vermiculite or perlite shall be in compliance with ASTM C 332, Group I. Foam concentrates shall be in compliance with ASTM C 796 and ASTM C 869.

1917.4.7 Mixing, placing and finishing shall be in compliance with the deck system Product Approval. Slurry coating, two-density casting and double casting shall be acceptable per the specific manufacturer's recommendations.

1917.4.8 If the lightweight insulating concrete deck is to receive Product Approval for a direct-adhered roofing system, the deck surface shall be prepared to the requirements set forth in the roof system Product Approval.

1917.4.9 All base ply fasteners for use in lightweight insulating concrete roof decks shall have a Product Approval for use with the specific lightweight insulating concrete roof system in compliance with manufacturer's recommendations and the design pressure of Section 1609.

1917.4.10 The lightweight insulating concrete fastener withdrawal shall have a minimum resistance for new pours of

1. 60 pounds (267 N) in 28 days when the fastener is installed and allowed to age in the concrete.
2. 40 pounds (178 N) at time of roofing.

1917.4.11 Lightweight insulating concrete system expansion joints shall be provided at the following locations:

1. Where expansion joints are provided in the structural assembly.
2. Where steel framing, structural steel or decking change direction.
3. Where separate wings of "L," "U," "T" or similar configurations exist.
4. Where the type of decking changes (for example, where a precast concrete deck and a steel deck abut).
5. Whenever additions are connected to existing buildings.
6. At junctions where interior heating conditions change.
7. Wherever differential movement between vertical walls and the roof deck may occur.

1917.4.12 Insulation board with lightweight insulating concrete shall conform to Type I expanded polystyrene insulation as defined in ASTM C 578.

1. Packaged insulation board delivered to the job site shall comply with the provisions of Section 2603.2 or Section 2613.1.3.
2. Installation of insulating board in conjunction with lightweight insulating concrete shall comply with uplift requirements set forth in Section 1609. Insulation panels shall be placed in a minimum $^1/_8$-inch (3.2 mm) slurry bed of insulating concrete while the material is still in a plastic state. The insulating concrete shall be cast over the insulation boards according to the insulating concrete manufacturer's Product Approval. Insulation panels shall be provided with holes and/or slots for keying and venting.

1917.4.13 Reinforcing mesh shall be provided as required to meet fire-rating and/or special structural design requirements. Refer to a specific Product Approval for the specific requirements applicable to the product being installed.

SECTION 1918
SPECIAL WIND PROVISIONS FOR CONCRETE

1918.1 Reinforced concrete components. The design and construction of reinforced concrete components for buildings sited in areas where the ultimate design wind speed, V_{ult}, is greater than 115 mph (45 m/s) in accordance with Figure 1609 shall conform to the requirements of ACI 318 or with Section 1609.1.1, Exception 1, as applicable, except as modified in this section.

1918.2 Insulated concrete form wall. Insulated concrete form (ICF) wall construction for buildings shall be in accordance with ACI 318 or with Section 1609.1.1, Exception 1, as applicable.

1918.3 Gable endwalls.

1918.3.1 General. Gable endwalls shall be structurally continuous between points of lateral support.

1918.3.2 Cathedral endwalls. Gable endwalls adjacent to cathedral ceilings shall be structurally continuous from the uppermost floor to ceiling diaphragm or to the roof diaphragm.

SECTION 1919
HIGH-VELOCITY HURRICANE ZONES—GENERAL

1919.1 Scope. This section prescribes requirements for reinforced concrete in construction regulated by this code.

1919.2 Application. Reinforced concrete shall be of the materials, proportions strength and consistency as set forth in this section and shall be designed by methods admitting of rational analysis according to established principles of mechanics.

1919.3 Requirements. All structures of reinforced concrete, including prestressed concrete, shall be designed and constructed in accordance with the provisions of ACI 318 as adopted herein.

1919.4 Workmanship. Concrete construction shall be in conformance with the tolerance, quality and methods of construction set forth in Section1920.

SECTION 1920
HIGH-VELOCITY HURRICANE ZONES—STANDARDS

1920.1 The following standards are hereby adopted as part of this code as set forth in Chapter 35 of this code.

1920.2 American Concrete Institute (ACI).

1. Standard Tolerances for Concrete Construction and Materials, ACI 117.
2. Specifications for Structural Concrete for Buildings, ACI 301.
3. Manual of Standard Practice for Detailing Reinforced Concrete Structures, ACI 315.
4. Building Code Requirements for Reinforced Concrete, ACI 318.
5. Recommended Practice for Concrete Formwork, ACI 347.
6. Recommended Practice for Shotcreting, ACI 506.
7. Specification for Materials, Proportioning, and Application of Shotcrete, ACI 506.2.
8. Deformed and Plain Billet Steel Bars for Concrete Reinforcement, ASTM A 615, including S1.

1920.3 American National Standards Institute (ANSI)/American Society of Civil Engineers (ASCE).

1. Specifications for the Design and Construction of Composite Slabs and Commentary on Specifications for the Design and Construction of Composite Slabs, ANSI/ASCE 3.
2. Guideline for Structural Assessment of Existing Buildings, ANSI/ASCE 11.

1920.4 American Society for Testing Materials (ASTM).

1. Deformed and Plain Billet Steel Bars for Concrete Reinforcement, ASTM A 615, including S1.
2. Testing Concrete Aggregates for Use in Construction and Criteria for Laboratory Evaluation, ASTM C 1077.

SECTION 1921
HIGH-VELOCITY HURRICANE ZONES—DEFINITIONS

1921.1 The following definitions apply to the provisions of Sections 1919 through 1929.

PLAIN CONCRETE. Concrete that is either unreinforced or contains less reinforcement than the minimum amount specified for reinforced concrete.

REINFORCED CONCRETE. Concrete reinforced with no less than the minimum amount required by ACI 318, pre-

stressed or non-prestressed, and designed on the assumption that the two materials act together in resisting forces.

PRESTRESSED CONCRETE. Reinforced concrete in which internal stresses have been introduced to reduce potential tensile stresses in concrete resulting from loads. The term prestressed concrete refers to pretensioned concrete in which the reinforcing is tensioned before hardening of the concrete, to postensioned concrete in which the reinforcing is tensioned after hardening of the concrete, or combinations of both pretensioning and posttensioning.

PRECAST CONCRETE. Plain or reinforced concrete elements cast elsewhere than their final position in a structure.

SHOTCRETE. Mortar or concrete pneumatically projected at high velocity onto a surface.

SECTION 1922
HIGH-VELOCITY HURRICANE ZONES—MATERIALS

1922.1 Cements. Cements shall conform to one of the following specifications for portland cement as set forth in Chapter 35.

1. Portland Cement, ASTM C 150.
2. Blended Hydraulic Cements, ASTM C 595, excluding Types S and SA, which are not intended as principal cementing constituents of structural concrete.

1922.2 Aggregates for concrete shall conform to one of the following specifications as set forth in Chapter 35 of this code or Section 1922.2.1.

1. Concrete Aggregates, ASTM C 33.
2. Lightweight Aggregates for Structural Concrete, ASTM C 330.

1922.2.1 Gradation of locally produced sand and crushed rock aggregate shall be as follows:

COARSE AGGREGATE

Percent Passing		
$1^1/_2$ inches	sieve	100
1 inches	sieve	95 - 100
$^1/_2$ inches	sieve	25 - 60
#4	sieve	0 - 10
#8	sieve	0 - 5

FINE AGGREGATE

Percent Passing		
$^3/_8$ inches	sieve	100
#4	sieve	90 - 100
#8	sieve	70 - 95
#16	sieve	50 - 85
#30	sieve	30 - 70
#50	sieve	10 - 45
#100	sieve	0 - 10

1922.2.2 Aggregates failing to meet ASTM C 33, ASTM C 330 or the above special gradation but which have been shown by special test or actual service to produce concrete of adequate strength and durability may be used when certified by the engineer.

1922.2.3 Aggregates shall be quarried or washed in fresh water and shall contain not more than $^1/_{20}$ of 1-percent salt by weight.

1922.3 Water used in mixing concrete shall be clean and free from injurious amounts of oils, acids, alkalis, salts, organic materials or other substances that may be deleterious to concrete or reinforcement.

1922.3.1 Mixing water for concrete, including that portion of mixing water contributed in the form of free moisture on aggregates, shall not contain deleterious amounts of chloride ion.

1922.4 Reinforcement.

1922.4.1 Deformed reinforcement shall conform to one of the specifications as set forth in Chapter 35, except as provided in Section 3.5 of ACI 318.

1922.4.2 Prestressing tendons shall conform to one of the specifications as set forth in Chapter 35.

Exception: Wire strands and bars not specifically listed in ASTM A 421, A 416, or A 722 may be used provided they conform to minimum requirements of these specifications and do not have properties that make them less satisfactory than those listed in ASTM A 416, A 421 or A 722.

1922.4.3 Reinforcement consisting of structural steel, steel pipe or steel tubing may be used as specified in ACI 318.

1922.4.4 All welding of reinforcement shall conform to the Structural Welding Code - Reinforcing Steel, AWS D1.4, as set forth in Chapter 35.

1922.4.5 Reinforcement to be welded shall be indicated on the drawings, and welding procedures to be used shall be specified. ASTM steel specifications, except ASTM A 706, shall be supplemented to require a report of material properties necessary to conform to welding procedures specified in AWS D1.4.

1922.4.6 Deformed reinforcement may be galvanized or epoxy-coated in accordance with the Specifications for Zinc-Coated (galvanized) Bars for Concrete reinforcement, ASTM A 767 or the Specification for Epoxy-Coated Bars, ASTM A 775. Zinc or epoxy-coated reinforcement shall conform to ASTM A 615, A 616 (S1), A 617 or A 706.

1922.5 Admixtures.

1922.5.1 Admixtures to be used in concrete shall conform to one of the specifications set forth in Chapter 35.

1922.5.2 An admixture shall be shown capable of maintaining essentially the same composition and performance throughout the work as the product used in establishing concrete proportions.

1922.5.3 Admixtures containing chloride ions shall not be used in concrete if their use will produce a deleterious concentration of chloride ion in the mixing water.

1922.6 Test of materials.

1922.6.1 The building official, or his or her authorized representative, shall have the right to order the test of any material entering into concrete or reinforced concrete to determine its suitability for the purpose; to order reasonable tests of the concrete from time to time to determine whether the materials and methods in use are such as to produce concrete of the necessary quality; and to order the test under load of any portion of a completed structure when conditions have been such as to leave doubt as to the adequacy of the structure to serve the purpose for which it is intended.

1922.6.2 Materials and of concrete shall be tested in accordance with applicable standards of ASTM International as listed in Chapter 35. Tests shall be made by an approved testing laboratory and results of such tests shall be submitted to the building official. Approved testing laboratories shall comply with ASTM C 1077.

1922.6.3 A complete record of tests of materials and of concrete shall be available to the building official for inspection during progress of work and for five years after completion of the project, and shall be preserved by the inspecting engineer or architect for that purpose.

1922.6.4 If doubt develops concerning the safety of a structure or member, the building official may order a structural strength investigation by analysis or by means of load tests, or by a combination of analyses and load test as set forth in Chapter 20 of ACI 318.

SECTION 1923
HIGH-VELOCITY HURRICANE ZONES—CONCRETE QUALITY

1923.1 General.

1923.1.1 Concrete shall be proportioned and produced to provide an average compressive strength sufficiently high to minimize the frequency of strength test below the specified compressive strength of concrete, $f'c$.

1923.1.2 Requirements for $f'c$ shall be based on tests of cylinders made and tested as prescribed in Section 1923.2.2.3.

1923.1.3 Unless otherwise specified, $f'c$ shall be based on 28-day tests. If other than 28-day tests are called for, $f'c$ shall be indicated in design drawings or specifications.

1923.1.4 Design drawings shall show the specified compressive strength of concrete, $f'c$ for which each part of the structure is designed.

1923.2 Evaluation and acceptance concrete.

1923.2.1 Frequency of testing.

1923.2.1.1 The building official may require a reasonable number of tests to be made during the progress of the work, or may promulgate and set forth in writing such reasonable rules for requiring tests to be made by an approved laboratory as he may consider necessary to insure compliance with this code.

1923.2.1.2 Not less than three specimens shall be made for each standard test.

1923.2.1.3 Samples for strength of each class of concrete placed each day shall be taken not less than once a day, nor less than once for each 150 cubic yard (4.3 m^3) of concrete, nor less than once for each 5,000 square feet (465 m^2) of surface area for slabs or walls.

1923.2.1.4 On a given project, if total volume of concrete is such that frequency of testing required by Section 1923.2.1.1 would provide less than five strength tests for a given class of concrete, tests shall be made from at least five randomly selected batches or from each batch if fewer than five batches are used.

1923.2.1.5 Test cylinders taken on truck-mixed concrete shall be taken at the approximate one-quarter point of the load.

1923.2.1.6 The age for strength tests shall be 28 days, or where specified, at the earlier age at which the concrete is to receive its full working load.

1923.2.2 Laboratory cured specimens.

1923.2.2.1 A strength test shall be the average of the strengths of two cylinders made from the same sample of concrete and tested at 28 days or at a test age designated for determination of $f'c$.

1923.2.2.2 Samples of strength tests shall be taken in accordance with the Method of Sampling Fresh Concrete, ASTM C 172, as set forth in Chapter 35.

1923.2.2.3 Cylinders for strength tests shall be molded and laboratory-cured in accordance with the Method of Making and Curing Concrete Test Specimens in the Field, ASTM C 31, as set forth in Chapter 35 of this code, and tested in accordance with the Method of Test for Compressive Strength of Cylindrical Concrete Specimens, ASTM C 39, as set forth in Chapter 35.

1923.2.2.4 The strength level of an individual class of concrete shall be considered satisfactory if both of the following requirements are met:

1. Average of all sets of three consecutive strength tests equal or exceed $f'c$.
2. No individual strength test (average of 2 cylinders) falls below $f'c$ by more than 500 psi (3448 kPa).

1923.2.2.5 If any of the requirements of Section 1923.2 are not met, steps shall be taken to increase the average of subsequent strength test results. Requirements of Section 1923.2.4 shall be observed if any individual strength test falls below $f'c$ by more than 500 psi (3448 kPa).

1923.2.3 Field cured specimens.

1923.2.3.1 The building official may require strength tests of cylinders cured under field conditions to check adequacy of curing and protection of concrete in the structure.

1923.2.3.2 Field-cured cylinders shall be cured under field conditions in accordance with Section 7.4 of the Method of Making and Curing Concrete Test specimens in the Field, ASTM C 31.

1923.2.3.3 Field-cured test cylinders shall be molded at the same time and from the same samples as laboratory-cured test cylinders.

1923.2.3.4 Procedures for protecting and curing concrete shall be improved when the strength of field-cured cylinders at test age designated for determination of $f'c$ is less than 85 percent of that of companion laboratory cured cylinders. The 85 percent may be waived if field cured strength exceeds $f'c$ by more than 500 psi (3448 Pa).

1923.2.4 Investigation of low strength test results.

1923.2.4.1 When there is a question as to the quality of the concrete in the structure, the building official may require core tests in accordance with the Standard Method of Obtaining and Testing Drilled Cores and Sawed Beams of Concrete, ASTM C 42, as set forth in Chapter 35 of this code, or order load tests on that portion of the structure where the questionable concrete has been placed.

1923.2.4.2 When concrete in structures has failed to meet the minimum standard, the building official shall order analysis and reports by a registered engineer to determine the adequacy of the structure.

1923.2.4.3 If the likelihood of low-strength concrete is confirmed and computations indicate that load-carrying capacity may have been significantly reduced, tests of cores drilled from the area in question may be required in accordance with the Method of Obtaining and Testing Drilled Cores and Sawed Beams of Concrete, ASTM C 42, as set forth in Chapter 35 of this code. In such case, three cores shall be taken for each strength test more than 500 psi (3448 kPa) below specified value of $f'c$.

1923.2.4.4 If concrete in the structure will be dry under service conditions, cores shall be air dried at a temperature between 60°F (15ºC) and 80ºF (27°) and a relative humidity less than 60 percent for 7 days before testing and shall be tested dry. If concrete in the structure will be more than superficially wet under service conditions, cores shall be immersed in water for at least 40 hours and be tested wet.

1923.2.4.5 Concrete in an area represented by core tests shall be considered structurally adequate if the average of three cores is equals to at least 85 percent of f ¢c and if no single core is less than 75 percent of $f'c$. To check testing accuracy, locations represented by erratic core strengths may be retested.

1923.2.4.6 Slump considerations. The maximum allowable slump of concrete shall be 6 inches (152 mm). On jobs controlled and supervised by a professional engineer, this maximum may be exceeded, but no concrete shall exceed the slump as indicated on the approved plans for proposed work.

SECTION 1924
HIGH-VELOCITY HURRICANE ZONES—
MIXING AND PLACING CONCRETE

1924.1 Preparation of equipment and place of deposit.

1924.1.1 Preparation before concrete placement shall include the following:

1. All equipment for mixing and transporting concrete shall be clean.
2. All debris shall be removed from the spaces to be occupied by the concrete.
3. Forms shall be properly coated.
4. Masonry filler units that will be in contact with concrete shall be well drenched.
5. Reinforcement shall be thoroughly cleaned of deleterious coatings.
6. Water shall be removed from place of deposit before concrete is placed unless a tremie is to be used or unless otherwise permitted by the professional engineer.
7. All laitance and other unsound material shall be removed before additional concrete is placed against hardened concrete.

1924.2 Mixing.

1924.2.1 All concrete shall be mixed until there is uniform distribution of materials and shall be discharged completely before the mixer is recharged.

1924.2.2 Ready-mixed concrete shall be mixed and delivered in accordance with requirements of the Specifications for Ready-Mixed Concrete, ASTM C 94, or the Specifications for Concrete Made by Volumetric Batching and Continuous Mixing, ASTM C 685, as set forth in Chapter 35 of this code.

1924.2.3 Job-mixed concrete shall be mixed in accordance with the following:

1. Mixing shall be done in a batch mixer of approved type.
2. Mixer shall be rotated at a speed recommended by the manufacturer.
3. Mixing shall be continued for at least $1^1/_2$ minutes after all materials are in the drum, unless a shorter time is shown to be satisfactory by the mixing uniformity test of Specification for Ready-Mixed Concrete, ASTM C 94.
4. Materials handling, batching, and mixing shall conform to applicable provisions of the Specifications for Ready-Mixed Concrete, ASTM C 94.
5. A detailed record shall be kept to identify:
   - 5.1. Number of batches produced.
   - 5.2. Proportions of materials used.
   - 5.3. Approximate location of final deposit in structure.
   - 5.4. Time and date of mixing and placing.

1924.3 Conveying.

1924.3.1 Concrete shall be conveyed from mixer to the place of final deposit by methods that will prevent separation or loss of the materials.

1924.3.2 Conveying equipment shall be capable of providing a supply of concrete at the site of placement without separation of ingredients and without interruptions sufficient to permit loss of plasticity between successive increments.

1924.4 Depositing.

1924.4.1 Concrete shall be deposited as nearly as practicable in its final position to avoid segregation caused by rehandling or flowing.

1924.4.2 Concreting shall be carried on at such a rate that concrete is at all times plastic and flows readily into the spaces between reinforcement.

1924.4.3 Concrete that has partially hardened or been contaminated by foreign materials shall not be deposited in the structure.

1924.4.4 Retempered concrete or concrete that has been remixed after initial set shall not be used unless approved by the building official.

1924.4.5 After concreting is started, it shall be carried on as a continuous operation until placing of the panel or section, as defined by its boundaries or predetermined joints is completed except as permitted or prohibited by Section 1925.4.

1924.4.6 Top surfaces of vertically formed lifts shall be generally level.

1924.4.7 When construction joints are required, joints shall be made in accordance with Section 1925.4.

1924.4.8 All concrete shall be thoroughly consolidated by suitable means during placement and shall be thoroughly worked around the reinforcement and embedded fixtures and into corners of forms.

1924.5 Curing.

1924.5.1 Concrete, other than high-early-strength, shall be maintained in a moist condition for as least the first seven days after placement, except when cured in accordance with Section 1924.5.3.

1924.5.2 High-early-strength concrete shall be maintained in a moist condition for at least the first three days, except when cured in accordance with Section 1924.5.3.

1924.5.3 Accelerated curing.

1. Curing by high-pressure steam, steam at atmospheric pressure, heat and moisture, or other accepted processes, may be employed to accelerate strength gain and reduce time of curing.
2. Accelerated curing shall provide a compressive strength of the concrete at the load stage considered at least equal to required design strength at that load stage.
3. The curing process shall produce concrete with a durability at least equivalent to the curing method of Section 1924.5.3, Items 1 or 2.
4. Supplementary strength tests in accordance with Section 1923.2.3 may be required to ensure that curing is satisfactory.

1924.6 Bonding.

1924.6.1 Before fresh concrete is deposited or placed on or against concrete which has hardened for 8 hours or longer, the forms shall be retightened, the surface of the hardened concrete shall be cleaned of all foreign matter and laitance, and dampened, but not saturated. Fresh concrete shall not be deposited or placed on or against hardened concrete so dampened before the surface is completely free of shiny spots indicating free moisture. When the concrete against which fresh concrete will be placed is less than 8 hours old, all laitance, loose particles and dirt shall be removed.

1924.6.2 Where bonding of fresh to hardened concrete is necessary, construction joints and joints between footings and walls or columns, between walls or columns and beams or floors they support, and joints in unexposed walls shall be accomplished by reinforcement, dowels, adhesives, mechanical connectors or other approved methods. Hardened concrete at joints shall be dampened, but not saturated, immediately prior to the placement of fresh concrete.

SECTION 1925
HIGH-VELOCITY HURRICANE ZONES—FORMWORK, EMBEDDED PIPES AND CONSTRUCTION JOINTS

1925.1 Design of formwork.

1925.1.1 Forms shall be designed in accordance with ACI 347, Recommended Practice for Concrete Formwork.

1925.1.2 Forms shall result in a final structure that conforms to shapes, lines and dimensions of the members as required by the design drawings and specifications.

1925.1.3 Forms shall be substantial and sufficiently tight to prevent leakage of mortar.

1925.1.4 Forms shall be properly braced or tied together to maintain position and shape.

1925.1.5 Forms and their supports shall be designed so as not to damage previously placed structures.

1925.1.6 Design of formwork shall include consideration of the rate and method of placing concrete; construction loads, including vertical, horizontal and impact loads; and special form requirements for construction of shells, folded plates, domes, architectural concrete or similar types of elements.

1925.1.7 Forms for prestressed concrete members shall be designed and constructed to permit movement of the member without damage during application of prestressing force.

1925.2 Removal of forms and shores.

1925.2.1 No construction loads shall be supported on, nor any shoring removed from, any part of the structure under construction except when that portion of the structure in combination with the remaining forming and shoring sys-

tem has sufficient strength to safely support its weight and loads placed thereon.

1925.2.2 Sufficient strength shall be demonstrated by structural analysis considering proposed loads, strength of the forming and shoring system and concrete strength data. Concrete strength data may be based on tests of field-cured cylinders or, when approved by the building official, on other procedures to evaluate concrete strength. Structural analysis and concrete strength test data shall be furnished to the building official when so required.

1925.2.3 No construction loads exceeding the combination of superimposed dead load plus specified live load shall be supported on any unshored portion of the structure under construction, unless analysis indicated adequate strength to support such additional loads.

1925.2.4 Forms shall be removed in a manner that does not impair the safety and serviceability of the structure. All concrete to be exposed by form removal shall have sufficient strength not to be damaged thereby.

1925.2.5 Form supports for prestressed concrete members may be removed when sufficient prestressing has been applied to enable prestressed members to carry their dead load and anticipated construction loads.

1925.3 Conduits and pipes embedded in concrete.

1925.3.1 Conduits, pipes and sleeves of any material not harmful to concrete, and with limitations of this section, may be embedded in concrete with approval of the professional engineer provided they are not considered to structurally replace the displaced concrete.

1925.3.2 Conduits or pipes of aluminum shall not be embedded in structural concrete unless effectively coated or covered to prevent aluminum-concrete reaction or electrolytic action between aluminum and steel.

1925.3.3 Conduits, pipes and sleeves passing through a slab, wall or beam shall not impair the strength of the construction.

1925.3.4 Conduits and pipes, with their fittings, embedded within a column shall not displace more than 4 percent of the area of cross section on which strength is calculated or which is required for fire protection.

1925.3.5 Except when plans for conduits and pipes are approved by the professional engineer and other than those merely passing through, conduits and pipes embedded within a slab, wall or beam shall satisfy the following:

1. They shall not be larger in outside dimension than three-eights of the overall thickness of slab, wall or beam in which they are embedded.
2. They shall not be spaced closer than three diameters or widths on center.
3. They shall not impair the strength of the construction.

1925.3.6 Conduits, pipes and sleeves may be considered as replacing structurally in compression the displaced concrete, provided:

1. They are not exposed to rusting or other deterioration.
2. They are of uncoated or galvanized iron or steel not thinner than standard Schedule 40 steel pipe, and
3. They have a nominal inside diameter not over 2 inches (51 mm) and are spaced not less than three diameters on centers.

1925.3.7 In addition to other requirements of Section 1925.3 pipes that will contain liquid, gas or vapor may be embedded in structural concrete under the following conditions:

1. Pipes and fittings shall be designed to resist effects of the material, pressure and temperature to which they will be subjected.
2. Temperature of liquid, gas or vapor shall not exceed 150ºF (66ºC).
3. Maximum pressure to which any piping or fittings shall be subjected shall not exceed 200 psi (1379 kPa) above atmospheric pressure.
4. All piping and fittings except as provided in Section 1925.3.5 shall be tested as a unit for leaks before concrete placement. Testing pressure above atmospheric pressure shall be 50 percent in excess of pressure to which piping and fittings may be subjected, but minimum testing pressure shall not be less than 150 psi (1034 kPa) above atmospheric pressure. Pressure test shall be held for 4 hours with no drop in pressure except that which may be caused by air temperature.
5. Drain pipes and other piping designed for pressures of not more than 1 psi (7 kPa) above atmospheric pressure need not be tested as required in Section 1925.3.7(4).
6. Pipes carrying liquid, gas or vapor that is explosive or injurious to health shall be tested again as specified in Section 1925.3.7(4) after concrete has hardened.
7. No liquid, gas or vapor, except water not exceeding 90ºF (32ºC) nor 50 psi (350 kPa) pressure, shall be placed in the pipes until the concrete has attained its design strength.
8. Unless piping in solid slabs is for radiant heating, it shall be placed between top and bottom reinforcement.
9. Concrete cover for pipes and fittings shall not be less than $1^1/_2$ inches (38 mm) for concrete exposed to earth or weather, nor $^3/_4$ inch (19 mm) for concrete not exposed to weather or in contact with ground.
10. Reinforcement with an area not less than 0.002 times the area of concrete section shall be provided normal to the piping.
11. Piping and fittings shall be assembled by welding, brazing, solder sweating or other equally satisfactory methods. Screw connections shall not be permitted. Piping shall be so fabricated and installed that cutting, bending or displacement of reinforcement from its proper location will not be required.

1925.4 Construction joints.

1925.4.1 Surfaces of the concrete construction joints shall be cleaned and laitance removed.

1925.4.2 Immediately before new concrete is placed, all construction joints shall be wetted and standing water removed.

1925.4.3 Construction joints shall be so made and located as not to impair the strength of the structure. Provision shall be made for transfer of shear and other forces through construction joints.

1925.4.4 Construction joints in floors shall be located near the middle of the spans of slabs, beams or girders, unless a beam intersects a girder at the middle location, in which case, joints in the girders shall be offset a distance approximately twice the width of the beam.

1925.4.5 Beams, girders or slabs supported by columns or walls shall not be cast or erected until concrete in the vertical support members is no longer plastic.

1925.4.6 Beams, girders, haunches, drop panels and capitals shall be placed monolithically as part of a slab system, unless otherwise shown on design drawing.

SECTION 1926
HIGH-VELOCITY HURRICANE ZONES—DETAILS OF REINFORCEMENT

1926.1 Bending reinforcement.

1926.1.1 All reinforcement shall be bent cold, unless otherwise permitted by the professional engineer.

1926.1.2 Reinforcement partially embedded in concrete shall not be field bent, except as shown on the design drawings or permitted by the professional engineer.

1926.2 Surface conditions of reinforcement.

1926.2.1 At the time concrete is placed, reinforcement shall be free from mud, oil or other nonmetallic coatings that adversely affect bonding capacity.

1926.2.2 Steel reinforcement, except prestressing tendons, with rust, mill scale or a combination of both shall be considered satisfactory, provided the minimum dimensions, including the height of deformations and weight of a hand-wire-brushed test specimen, are not less than applicable ASTM specification requirements.

1926.2.3 Prestressing tendons shall be clean and free of oil, dirt, scale, pitting and excessive ruts. A light oxide is permissible.

1926.3 Placing reinforcement.

1926.3.1 Steel reinforcement shall be accurately placed and adequately secured in position by concrete or metal chairs, spacers or other acceptable methods. The minimum clear distance between parallel bars, except in columns, shall be equal to the nominal diameter of the bars. In no case shall the clear distance between bars be less than 1 inch (25 mm), or less than one and one-third times the maximum size of the coarse aggregate. When reinforcement in beams or girders is placed in two or more layers, the clear distance between layers shall not be less than 1 inch (25 mm) nor less than the diameter of the bars, and the bars in the upper layers shall be placed directly above those in the bottom layer.

1926.3.2 Unless otherwise permitted by the building official and professional engineer, reinforcement, prestressing tendons and prestressing ducts shall be placed within the following tolerances:

1. Tolerance for depth, d, and minimum concrete cover in flexural members, walls and compression members shall be as follows, where d represents the distance from the extreme compression fiber to the centroid of the tension reinforcement:

	Tolerance on d	Tolerance on minimum concrete cover
d < 8 in.	+/- $^3/_8$ in.	- $^3/_8$ in.
d > 8 in.	+/- $^1/_2$ in.	- $^1/_2$ in.

Exceptions:

a. Tolerance for the clear distance to formed soffits shall be minus $^1/_4$ inch (6.3 mm).

b. Tolerance for cover shall not exceed minus one-third the minimum concrete cover required in the contract drawings nor less than 1 inch (25 mm) when exposed to weather.

2. Tolerance for longitudinal location of bends and ends of reinforcement shall be + 2 inches (+ 51 mm) except at discontinuous ends of members where tolerance shall be + $^1/_2$ inch (+ 12.7 mm).

1926.3.3 Welded wire fabric with a wire size not greater than W5 or D5 used in slabs not exceeding 10 feet (3 m) in span may be curved from a point near the top of the slab over the support to a point near the bottom of the slab at midspan, provided such reinforcement is either continuous over, or securely anchored at, the support.

1926.3.4 Welding of crossing bars shall not be permitted for assembly of reinforcement unless approved by the professional engineer of record.

1926.3.5 Spacing limits and concrete cover for reinforcement shall be shown on the design drawings.

1926.4 Splices in reinforcement.

1926.4.1 In slabs, beams and girders, splices in reinforcement at points of maximum stress shall be avoided wherever possible. Such splices, where used, shall be welded, lapped or otherwise fully developed, but, in any case, shall transfer the entire stress from bar to bar without exceeding the allowable bond and shear stresses. The minimum overlap for a lapped splice shall be 24 bar diameters, but not less than 12 inches (25 mm) for bars and in accordance with Section 12.15 and 12.16 of ACI 318. The clear distance between bars shall also apply to the clear distance from a contact splice and adjacent splices or bars.

1926.4.2 Reinforcement shall be spliced only as required or permitted on design drawings, or in specifications or as authorized by the professional engineer of record.

1926.4.3 Lap splices shall not be used for bars larger than #11 except as provided in ACI 318.

1926.4.4 Lap splices of bundled bars shall be based on the lap splice length required for individual bars within a bundle, increased 20 percent for a 3-bar bundle and 33 percent for a 4-bar bundle. Individual bar splices within a bundle shall not overlap.

1926.4.5 Bars spliced by noncontact lap splices in flexural members shall not be spaced transversely farther apart than one-fifth the required lap splice length, nor 6 inches (152 mm).

1926.4.6 Welded splices may be used, provided the metallurgical properties of the bars are suitable as determined by the professional engineer of record in accordance with AWS D1.4.

1926.4.7 End bearing splices.

1926.4.7.1 In bars required for compression only, compressive stress may be transmitted by bearing of square cut ends held in concentric contact by a suitable device.

1926.4.7.2 Bar ends shall terminate in flat surfaces within $1^1/_2$ degrees of a right angle to the axis of the bars and shall be fitted within 3 degrees of full bearing after assembly.

1926.4.7.3 End bearing splices shall be used only in members containing closed ties, closed stirrups or spirals.

1926.4.8 Welded splices in reinforcing bars shall be made by certified welders and shall comply with the Standard Structural Welding Code-Reinforcing Steel, AWS D1.4, as set forth in Chapter 35 of this code.

1926.5 Concrete protection for reinforcement (nonprestressed).

1926.5.1 The reinforcement of footings and other principal structural members in which the concrete is deposited against the ground shall have not less than 3 inches (76 mm) of concrete between it and the ground contact surface. If the concrete surfaces after removal of the forms are to be exposed to the weather or be in contact with the ground, the reinforcement shall be protected with not less than 2 inches (51 mm) of concrete for bars larger than No. 5 and $1^1/_2$ inches (38 mm) for No. 5 bars or smaller except as set forth in Section 1926.5.5.

1926.5.2 The concrete protective covering for reinforcement at surfaces not exposed directly to the ground or weather shall be not less than $^3/_4$ inch (19 mm) for slabs and wall; and not less than $1^1/_2$ inches (38 mm) for beams, girders and columns. In concrete ribbed floors in which the clear distance between ribs is not more than 30 inches (762 mm), the protection of reinforcement shall be at least $^3/_4$ inch (19 mm).

1926.5.3 Concrete protection for reinforcement shall in all cases be as least equal to the diameter of bars except for concrete slabs and joists as set forth herein.

1926.5.4 Exposed reinforcement bars intended for bonding with future extensions shall be protected from corrosion by concrete or other adequate covering.

1926.5.5 For exterior balcony slabs, slab surface shall be sloped $^1/_8$ unit in 12 units or greater to safeguard against ponding of water and slabs shall be designed and constructed in accordance with the provisions of ACI 318.

1926.5.6 Concrete cover for cast-in-place, precast and prestressed concrete shall be in accordance with ACI 318 if not otherwise specified in this section. When this code requires a thickness of cover for fire protection greater than the minimum concrete specified in ACI 318, the greater thickness shall be used.

1926.5.7 Exposed reinforcement, inserts and plates intended for bonding with future extensions shall be protected from corrosion.

SECTION 1927
HIGH-VELOCITY HURRICANE ZONES—PRECAST CONCRETE UNITS

1927.1 General.

1927.1.1 Precast concrete units shall comply with the minimum requirements set forth in this section, and the standard set forth in Section 1920.3.

1927.1.2 All precast concrete elements and their attachments (including imbedments) to the main structural frame shall be designed by, and bear the seal of a Florida-registered architect or a Florida-registered engineer, which architect or engineer shall be proficient in structural design. The design shall be based on rational analysis for loads set forth in Chapter 16 (High-Velocity Hurricane Zones). The architect/engineer of record may delegate this responsibility to a Florida-registered delegated engineer. In that case, shop drawings and design calculations prepared by such delegated engineer shall be reviewed and approved by the architect and the engineer of record.

1927.1.3 Only the material cast monolithically with the units at the time of manufacture shall be used in computing stresses unless adequate and approved shear transfer is provided.

1927.1.4 The building official may promulgate and set forth in writing such reasonable rules for requiring tests to be made by an approved laboratory as he may consider necessary to insure compliance with this code or uniformity of the products produced. The quantity of tests shall be based on consideration of safety or volume of output.

1927.1.5 The building official or his or her representative shall have free access to the plant of any producer at all hours of normal operation, and failure to permit such access shall be cause for revocation of approval.

1927.1.6 Failure of any product to satisfy in every respect the quality prescribed, or failure to conform with plans and specifications, shall be cause for rejection of the products.

1927.2 Statements of responsibilities of architects and professional engineers on design of structures using precast concrete components.

1927.2.1 The structural construction documents shall indicate the configuration of precast components and shall include details of supports, anchors and connections for those components. Permit documents shall include sufficient details describing the attachment of precast units (including imbedments) to the main structure.

1927.2.2 The precast permit documents shall bear the signature and seal of the professional architect or engineer charged with the responsibility of the design of the precast units. The architect or engineer of record may delegate this responsibility to a Florida-registered delegated engineer. In that case, shop drawings and design calculations prepared by such delegated engineer shall be reviewed and approved by the architect and/or the engineer of record as an indication that his or her intent has been understood and that the specified criteria have been used.

1927.2.3 The structural submittals shall include component details, calculations and fabrication and erection drawings. All such submittals shall identify the specific project.

1927.3 Aggregate. The maximum size of the aggregate for precast units shall be not larger than one-third of the narrowest dimension between sides of the forms of the member in which the unit is cast nor larger than three-fourths of the minimum clear spacing between reinforcing bars and sides of the forms, except that where concrete is placed by means of high frequency vibration, the maximum size of the aggregate shall not be larger than one-half of the narrowest dimension between sides of the form.

1927.4 Strength of concrete.

1927.4.1 Concrete for precast structural units made of crushed stone or other heavy aggregate shall have a compressive strength of not less than 2,500 psi (17 238 kPa) at 28 days.

1927.4.2 Concrete for precast units made of lightweight aggregate concrete shall follow the general provisions of Section 1923.1.2 with consideration of the nature and limitations of the aggregate and the strength of the product.

1927.5 Workmanship.

1927.5.1 The mix, the gradation of the aggregate and the workability shall be such as to insure complete filling of the form and continuous intimate bond between the concrete and all steel.

1927.5.2 Handling and conveying before curing shall be reduced to a minimum. Machinery for this purpose should be so designed that the unit will not be subject to bending or shock which would produce incipient cracks or broken edges or corners. Precast units shall not be freely transported or placed until the concrete is at least 14 days old, if made with regular cement, or at least seven days old, if made with Type III cement, or until its strength, as established by definite tests, is at least 60 percent of the required 28-day strength.

1927.5.3 The use of precast structural units not complying with ACI requirements or having visible cracks, honeycomb, exposed reinforcing except at ends or, with a compressive section dimension more than $^1/_8$ inch (3.1 mm) less than specified dimension shall not be permitted.

1927.6 Curing.

1927.6.1 No precast structural unit shall be removed from the form until the concrete has attained a compressive strength of 50 percent of the 28-day design strength but not less than 1,250 psi (8619 kPa) as verified by representative tests.

1927.6.2 Curing by high pressure steam, steam vapor or other accepted processes may be employed to accelerate the hardening of the concrete and to reduce the time of curing.

1927.6.3 To ensure the eventual placement of the units in the structure without damage, the handling shall be done in such a manner that bending shall be reduced to a minimum or prevented.

1927.7 Identification and marking. All joists, beams, girders and other units shall show some mark plainly indicating the top of the unit. This mark or symbol shall indicate the manufacturer, the date of manufacture and the length, size and type of reinforcing.

1927.8 Cutting of holes. No openings or channels not provided for in the structural design shall be made on the job without the specific approval of the professional engineer in accordance with his or her written, detailed instructions covering such work.

1927.9 Anchorage. Anchorage of all precast concrete units shall be designed, based on rational analysis, to transmit loads and other forces to the structural frame.

1927.10 Bridging. Joists shall be secured against lateral displacement by cast-in-place bridging, and such bridging shall be spaced not to exceed 32 times the width of the compression flange of the joist except that for roof systems, cast-in-place portland-concrete slabs embedding the top flanges not less than $^1/_2$ inch (12.7 mm), or steel inserts cast in the joist heads to which bulb-tees supporting gypsum decks are welded, shall be accepted in lieu of bridging.

1927.11 Connections. All joints and connections will perform their function at all stages of loading without overstress and with proper safety factors against failure caused by overload. Loading conditions to be considered in the design of joints and connections are service loads, including wind forces, volume changes resulting from shrinkage, creep, and temperature change, reaction loads, and loading encountered in stripping forms, shoring and removal of shores, storage and transportation of members.

1927.12 Inspections.

1927.12.1 All structural precast units shall be inspected for quality control by an architect or professional engineer qualified to perform these inspections prior to the concrete placement at the casting yard.

1927.12.2 All structural precast units and their attachments to the main structure shall be inspected after erection, but before concealment. Such inspections shall be performed by a Florida registered architect or professional engineer.

SECTION 1928
HIGH-VELOCITY HURRICANE ZONES — PRESTRESSED CONCRETE

1928.1 Prestressed concrete, as defined in Section 1921, shall comply with this section.

1928.1.1 All prestressed structural items shall be designed by a registered professional engineer. Openings or channels not provided for in the structural design shall not be made on the job without the specific approval of the design professional engineer.

1928.1.2 The building official may promulgate and set forth in writing such reasonable rules for requiring tests to be made by an approved laboratory as he or she may consider necessary to insure compliance with this code or uniformity of the products produced.

1928.1.3 The building official or his or her representative shall have free access to the plant of any producer at all hours of normal operation. Failure to permit such access shall be cause for revocation of approval.

1928.1.4 Failure of any product to satisfy the quality prescribed or failure to conform to plans and specifications shall be cause for rejection of the product.

1928.2 Statements of responsibilities of architects and professional engineers on design of cast-in-place post-tensioned concrete structural systems.

1928.2.1 The structural construction documents shall show the magnitude and location of all prestressing forces and all design assumptions.

1928.2.2 The structural engineer of record and/or the architect of record shall require the submission of calculations and installation drawings from a specialty engineer for post-tensioning systems for review by the structural engineer of record and/or the architect of record. Review is an indication that his or her intent has been understood and that the specified criteria have been used. The installation drawings shall provide full details of materials to be used including necessary accessories and instructions for construction and shall identify the specific project and shall bear the impressed seal, signature and date of the specialty engineer who prepared them.

1928.2.3 It is the responsibility of the structural engineer of record and/or the architect of record to review the post-tensioning system installation drawings so that the drawings are coordinated with the reinforcing steel shop drawings.

1928.2.4 Determining the effect of post-tensioning on other parts of the building is the responsibility of the structural engineer of record and/or the architect of record.

1928.3 Design and construction.

1928.3.1 Design and construction shall be in accordance with Chapter 18 of ACI 318.

1928.3.2 Calcium chloride shall not be used in concrete for prestressed members.

1928.4 Tendon and anchorage zones.

1928.4.1 Reinforcement shall be provided where required in tendon anchorage zones to resist bursting, splitting, and spalling forces induced by tendon anchorage. Regions of abrupt change in section shall be adequately reinforced.

1928.4.2 End blocks shall be provided where required for support bearing or for distribution of concentrated prestressing forces.

1928.4.3 Post-tensioning anchorage and supporting concrete shall be designed to resist maximum jacking force for strength of concrete at time of prestressing.

1928.4.4 Post-tensioning anchorage zones shall be designed to develop the guaranteed ultimate tensile strength of prestressing tendons using a strength reduction factor of 0.90 for concrete.

1928.5 Corrosion protection for unbonded prestressing tendons.

1928.5.1 Unbonded tendons shall be completely coated with suitable material to ensure corrosion protection.

1928.5.2 Tendon wrapping shall be continuous over the entire length to be unbonded, and shall prevent intrusion of cement paste or loss of coating materials during concrete placement.

1928.6 Post-tensioning ducts.

1928.6.1 Ducts for grouted or unbonded tendons shall be mortar-tight and nonreactive with concrete, tendons or filler material.

1928.6.2 Ducts for grouted single wire, strand or bar tendons shall have an inside diameter at least $^1/_4$ inch (6.3 mm) larger than tendon diameter.

1928.6.3 Ducts for grouted multiple wire, strand or bar tendons shall have an inside cross-sectional area at least two times the net area of the tendons.

1928.7 Grout for prestressing tendons.

1928.7.1 Grout shall consist of portland cement and water; or Portland cement, sand and water.

1928.7.2 Materials for grout shall conform as specified in ACI 318 and be as follows:

1. Portland cement.
2. Water content shall be minimum necessary for proper pumping of grout; however, water-cement ratio shall not exceed 0.45 by weight.
3. Sand, if used, shall conform to Standard Specifications for Aggregate for Masonry Mortar, ASTM C 144, except that gradation may be modified as necessary to obtain satisfactory workability.

4. Admixtures conforming to ACI 318 and known to have no injurious effects on grout, steel or concrete may be used. Calcium chloride shall not be used.
5. Water shall not be added to increase grout flowability that has been decreased by delayed use of grout.
6. Grout temperatures shall not be above 90ºF (32ºC) during mixing and pumping.

1928.8 Protection for prestressing tendons. Burning or welding operations in the vicinity of prestressing tendons shall be carefully performed, so that tendons are not subject to excessive temperatures, welding sparks or ground currents.

1928.9 Application and measurement of prestressing force.

1928.9.1 Prestressing force shall be determined by both of the following methods and the cause of any difference in force determination that exceeds 5 percent shall be ascertained and corrected.

1. Measurement of tendon elongation. Required elongation shall be determined from average load-elongation curves for prestressing tendons used.
2. Observation of jacking force on a calibrated gauge or load cell or by use of a calibrated dynamometer.

1928.9.2 Where transfer of force from bulkheads or pretensioning bed to concrete is accomplished by flame cutting prestressing tendons, cutting points and cutting sequence shall be predetermined to avoid undesired temporary stresses.

1928.9.3 Long lengths of exposed pretensioned strand shall be cut near the member to minimize shock to concrete.

1928.9.4 Total loss of prestress as a result of unreplaced broken tendons shall not exceed 2 percent of total prestress.

1928.10 Post-tensioning anchorages and couplers.

1928.10.1 Couplers shall be placed in areas approved by the professional engineer and enclosed in housing long enough to permit necessary movements.

1928.10.2 In unbonded construction subject to repetitive loads, special attention shall be given to the possibility of fatigue in anchorages and couplers.

1928.10.3 Anchorage and end fittings shall be permanently protected against corrosion.

SECTION 1929
HIGH-VELOCITY HURRICANE ZONES—PNEUMATICALLY PLACED CONCRETE (SHOTCRETE)

1929.1 General.

1929.1.1 Pneumatically placed concrete is a proportioned combination of fine aggregate portland cement and water which, after mixing, is pneumatically projected by air directly onto the surface to which it is to be applied.

1929.1.2 Pneumatically placed concrete shall conform to all requirements of Specifications for Materials, Proportioning and Application of Shotcrete, ACI 506.2 published by the American Concrete Institute, except as modified herein.

1929.1.3 Pneumatically placed concrete shall be composed of Portland cement, aggregate and water proportioned to produce a concrete suitable for pneumatic application.

1929.1.4 Concrete ingredients shall be selected and proportioned in a manner that will produce concrete which will be extremely strong, dense and resistant to weathering and abrasion.

1929.2 Sampling and testing cement and aggregate. The contractor shall determine the source, kind and quality of the cement and aggregates to be used in the work well in advance of the time scheduled for starting the work and when so directed by the building official shall submit such information for approval before starting shotcrete operation.

1929.3 Surface preparation. To insure adequate bond, the newly chipped and sandblasted surface shall be thoroughly moistened with water prior to application of shotcrete. In no instance shall shotcrete be applied in an area where free running water exists.

1929.4 Proportioning. Prior to the start of shotcreting, the contractor shall submit to the professional engineer the recommended mix as a ratio of cement to aggregate. The recommended mix shall be on the basis of test data from prior experience.

1929.5 Mixing.

1929.5.1 Shotcrete shall be thoroughly mixed by machine and then passed through a sieve to remove all large particles before placing in the hopper of the cement gun. The mixture shall not be permitted to become damp. Each batch should be entirely discharged before recharging is begun. The mixer should be cleaned thoroughly enough to remove all adherent materials from the mixing vanes and from the drum at regular intervals.

1929.5.2 Water in any amount shall not be added to the mix before it enters the cement gun. Quantities of water shall be controlled by a valve at the nozzle of the gun. Water content shall be adjusted as required for proper placement, but shall in no case exceed 4 gallons (15 L) of water per sack of cement, including the water contained in the aggregate.

1929.5.3 Remixing or tempering shall not be permitted. Mixed material that has stood 45 minutes without being used shall be discarded. Rebound materials shall not be reused.

1929.6 Application.

1929.6.1 In shooting walls and columns, application shall begin at the bottom and the first coat shall completely embed the reinforcement to the form.

1929.6.2 In shooting beams, application shall begin at the bottom and a surface at right angles to the nozzle shall be maintained.

1929.6.3 In shooting slabs, the nozzle shall be held at a slight angle to the work so that rebound is blown on to the finished portion where it shall be removed.

1929.6.4 Corners shall be filled first. "Shooting" shall be from an angle as near perpendicular to the surface as practicable, with the nozzle held approximately 3 feet (915 mm)

from the work, except in confined control. If the flow of material at the nozzle is not uniform and slugs, sand spots or wet sloughs result, the nozzle person shall direct the nozzle away from the work until the faulty conditions are corrected. Such defects shall be replaced as the work progresses.

1929.6.5 Shotcreting shall be suspended if:

1. Air velocity separates the cement from the sand at the nozzle.
2. Temperature approaches freezing and the newly placed shotcrete cannot be protected.

1929.6.6 The time interval between successive layers in sloping, vertical or overhanging work must be sufficient to allow initial but not final set to develop. At the time the initial set is developing, the surface shall be cleaned to remove the thin film of laitance in order to provide a good bond with succeeding applications.

1929.7 Construction joints. Construction joints or day's work joints shall be sloped off to a thin, clean, regular edge, preferably at a 45 degree (0.78 rad) slope. Before placing the adjoining work, the slope portion and adjacent shotcrete shall be thoroughly cleaned as necessary, then moistened and scoured with an air jet.

1929.8 Curing and protection.

1929.8.1 Curing shall be in accordance with ACI 506.2 depending upon atmospheric condition.

1929.8.2 Immediately after placement, shotcrete shall be maintained in a moist condition for at least the first 24 hours.

1929.8.3 Final curing shall continue for seven days after placement if Type I Portland cement is used, or for three days if high-early-strength Type III Portland cement is used, or until the specified strength is attained. Final curing may consist of the initial curing process or an approved moisture-retaining covering.

1929.8.4 Natural curing may be used when relative humidity remains above 85 percent when approved by the professional engineer of record.