ARTICLE 19
REINFORCED CONCRETE AND PLAIN CONCRETE CONSTRUCTION

Sub-Article 1
General Provisions

§C26-1455.0 Reinforced concrete and plain concrete-general provisions.
The provisions of this title apply to the use of reinforced concrete and plain concrete. The provisions of sections C26-1455.0 through C26-1564.0 shall supplement the general provisions of this title in order to provide for the proper design and construction of structures of these materials. In all matters pertaining to design and construction where the provisions of this article are in conflict with other provisions of this title, the provisions of this article shall govern.

§C26-1456.0. Definitions.-

a. For the purposes of this title, the words and terms listed in this section shall have the meanings herein given, except as they are defined in any other law, section or regulation which may in particular cases apply.

b. The provisions of Article 2 of this code where not inconsistent with the definitions given in this article shall also apply to reinforced concrete and plain concrete construction.

§C26-1456.1. Aggregate.-

a. The term "aggregate" shall mean inert material which is mixed with cement and water to produce concrete, consisting in general of sand, pebbles, gravel, cinders, crushed stones, blast furnace slag, burnt shale or clay, or similar materials.

b. The term "coarse aggregate" shall mean aggregate consisting of particles more than one-quarter of an inch in size.

c. The term "fine aggregate" shall mean aggregate consisting of particles one-quarter of an inch or less in size, but not less than the minimum size as specified under C26-1467.0.

§C26-1456.2. Blast furnace slag.-The term "blast furnace slag" shall mean the non-metallic-product, consisting essentially of silicates and alumino-silicates of lime, which is developed simultaneously with iron in a blast furnace.

§C26-1456.3. Column.-The term "column" shall mean an upright compression member the length of which exceeds three times its least lateral dimension.

§C26-1456.4. Combination column.-The term "combination column" shall mean a column in which a structural steel section, designed to carry the principal part of the load, is wrapped with wire and encased in concrete of such quality that some additional load may be allowed.

§C26-1456.5. Composite column.-The term "composite column" shall mean a column in which a steel or cast-iron structural member is completely encased in concrete containing spiral and longitudinal reinforcement.

§C26-1456.6. Concrete.-

a. The term "concrete" shall mean a mixture of portland cement, fine aggregate, coarse aggregate and water. Admixtures may be used as approved by the board.

b. Average concrete.-The term "average concrete" shall mean concrete the working stresses of which are established in accordance with the provisions of Section C26-1477.0 and any other applicable sections of this article.

c. Controlled concrete.-The term "controlled concrete" shall mean concrete the working stresses of which are established in accordance with the provisions of Section C26-1478.0, and any other applicable sections of this article.

d. Grade I cement concrete.-The term “Grade I cement concrete” shall mean concrete in which the coarse aggregate consists of limestone, trap rock, blast furnace slag, cinders or calcareous gravel.

e. Grade II cement concrete.-The term “Grade II cement concrete” shall mean concrete in which the coarse aggregate consists of granite or silicious gravel.

§C26-1456.7. Concrete products.-The term “concrete products” shall mean bricks, blocks or other units made of cement, aggregates and water.

§C26-1456.8. Consistency.-The term “consistency” shall mean the relative plasticity of freshly mixed concrete or mortar.

§C26-1456.9. Core area.-The term “core area” shall mean the area within the outer circumference of the hooping in columns with spiral reinforcement.

§C26-1456.10. Crushed stone.-The term “crushed stone” shall mean bedded rocks or boulders, broken into fragments of varying shapes and sizes.

§C26-1456.11. Cyclopean or rubble concrete.-The term “cyclopean concrete” or “rubble concrete” shall mean concrete masonry in which the finer material form a matrix for large stone and boulders.

§C26-1456.12. Deformed bar.-The term “deformed bar” shall mean a reinforcing bar conforming to “Specifications for Minimum Requirements for the Deformations of Deformed Steel Bars for Concrete Reinforcement” (AS.T.M. A305-56T) and for No. 14S and No. 18S bars A.S.T.M. A408-62T. Wire mesh with welded intersections not farther apart than six inches in the direction of the principal reinforcement and with cross wires not smaller than 0.135 inch in diameter (No. 10 American Steel and Wire gage) may be rated as deformed bar.

§C26-1456.13. Effective area of concrete.-The term “effective area of concrete” shall mean the area of a section which lies between the centroid of the tensile reinforcement and the compression face of the flexural member.

§C26-1456.14. Effective area of reinforcement.-The term “effective area of reinforcement” shall mean the area obtained by multiplying the right cross-sectional area of the reinforcement by the cosine of the angle between its direction and the direction for which the effectiveness is to be determined.

§C26-1456.15. Gravel.-The term “gravel” shall mean rounded particles larger than sand grains, resulting from the natural disintegration or weathering or rocks.

§C26-1456-16. Panel length.-The term “panel length” shall mean the distance along a panel side from center to center of columns of a flat slab.

§C26-1456.17. Pedestal.-The term “pedestal” shall mean an upright compression member, the height of which does not exceed three times its least lateral dimensions.

§C26-1456.18. Plain bar.-Reinforcement which does not conform to the definition of deformed bar shall be classed as a plain bar.

§C26-1456.19. Plain concrete.-The term “plain concrete” shall mean concrete without reinforcement or reinforced only for shrinkage or temperature changes.

§C26-1456.20. Precast concrete.-The term “precast concrete” shall mean a plain or reinforced concrete building element cast in other than its final position in the structure.

§C26-1456.21. Prestressed concrete.-The term “prestressed concrete” is concrete in which there have been introduced internal stresses of such magnitude and distribution that the stresses resulting from loads are counteracted to a desired degree. In reinforced concrete the prestress is commonly introduced by tensioning the reinforcement.

§C26-1456.22. Reinforced concrete.-The term “reinforced concrete” shall mean concrete in which reinforcement other than that provided for shrinkage or temperature changes is embedded in such a manner that the two materials act together in resisting forces.

§C26-1456.23. Sand.-The term "sand" shall mean small grains one-quarter of an inch or less in size resulting from the natural disintegration of rocks.

§C26-1456.24. Surface water.-The term "surface water" shall mean the water carried by the aggregate except that held by absorption within aggregate particles themselves.

§C26-1456.25. Wall beam.-The term "wall beam" shall mean a reinforced concrete beam which extends from column to column along the outer edge of a wall panel.

§C26-1456.26. Water-cement ratio.-The term "water-cement ratio" shall mean the total quantity of water entering the mixture, including the surface water carried by the aggregate, expressed in terms of the quantity of cement. The water-cement ratio shall be expressed in United States gallons per ninety-four pound sack of cement.

§C26-1457.0. American Society for Testing and Materials (A.S.T.M.)

The following specifications of the American Society for Testing and Materials (A.S.T.M.) shall be considered as part of this article as if fully set forth elsewhere herein:

A7-61T	Tentative specifications for steel for bridges and buildings
A15-62T	Tentative specifications for billet-steel bars for concrete reinforcement
A16-62T	Tentative specifications for rail-steel bars for concrete reinforcement
A82-62T	Tentative specifications for cold-drawn steel wire for concrete reinforcement
A160-62T	Tentative specifications for axle-steel bars for concrete reinforcement
A184-37	Standard specifications for fabricated steel bar or rod mats for concrete reinforcement
A185-61T	Tentative specifications for welded steel wire fabric for concrete reinforcement
A305-56T	Tentative specifications for minimum requirements for the deformations of deformed steel bars for concrete reinforcement
A377-57	Specifications for cast iron pressure pipe
A408-62T	Tentative specifications for special large size deformed billet-steel bars for concrete reinforcement
A431-62T	Tentative specifications for high strength billet-steel bars for concrete reinforcement
A432-62T	Tentative specifications for reformed billet-steel bars for concrete reinforcement with 60,000 pounds per square inch minimum yield strength
C31-62T	Standard method of making and curing concrete compression and flexure test specimens in field
C33-61T	Specifications for concrete aggregates
C39-61	Standard method of test for compressive strength of molded concrete cylinders
C42-62	Standard methods of securing, preparing and testing specimens from hardened concrete for compressive and flexural strengths
C94-62	Specifications for ready-mixed concrete
C150-62	Standard specifications for Portland cement
C172-54	Standard method of sampling fresh concrete
C175-61	Standard specifications for air-entraining Portland cement
C192-62T	Standard method of making and curing concrete compression and flexure test specimens in the laboratory
C260-60T	Tentative specifications for air-entraining admixtures for concrete
C330-60T	Tentative specifications for lightweight aggregates for structural concrete
C138-44	Standard method of test for weight per cubic foot, yield and air content (gravimetric) of concrete

C173-58	Standard method of test for air content of freshly mixed concrete by the volumetric method
C231-60	Standard method of test for air content of freshly mixed concrete by the pressure method

Sub-Article 2
Tests, Inspections and Materials

§C26-1458.0. Notation relating to load test.

D = deflection, produced by a test load, of a member relative to the ends of the span

L=span of member under load test (the shorter span of flat slabs and of floors supported on four sides)

t = total thickness or depth of a member under load test

§C26-1459.0. Tests.-

a. The superintendent shall have the authority to order the test of any material entering 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.

b. Tests of materials shall be made in accordance with the requirements of the American Society for Testing and Materials as noted elsewhere in this article. The complete records of such tests shall be available for inspection during the progress of the work and for two years thereafter, and shall be preserved for that purpose by the engineer or architect.

c. Before any cement shall be used for concrete work, test reports shall be available to show that it meets the physical requirements of this title, and is approved by the board.

§C26-1460.0. Tests of controlled and/or average concrete.

a. Sampling. During the progress of the work, samples of concrete shall be taken directly from the mixer in accordance with "Method of Sampling Fresh Concrete A.S.T.M. C172-54." Each sample shall be tested for slump, air content, temperature and weight per cubic foot in accordance with A.S.T.M. C138-44. If the measured slump or air content falls outside the limits specified in C26-1477.0 and C26-1478.0, a check sampling shall be made immediately on another portion of the same sample. In the event of a second failure, the concrete shall be considered to have failed to meet the requirements.

If the time required to discharge the load being sampled is greater than 15 minutes, a separate set of test cylinders shall be made from each one-third portion of the load taken at a greater interval than 15 minutes.

b. Molding standard test acceptance cylinders. For each class of concrete placed on any one day, three standard acceptance cylinders shall be made from the sampling described in a above for each fifty cubic yards or fraction thereof placed. These specimens shall be molded, stored for 24 hours, carefully transported to an approved testing laboratory and cured for 27 days in accordance with A.S.T.M. C31-61T. When requested by the borough superintendent or the licensed professional engineer responsible for the job per C26-1463.0, a fourth specimen shall simultaneously be molded to be tested at 3, 7 or 14 days as may be requested.

Additional specimens for determining when forms may be stripped or a structure may be put to use may also be required. These field cylinders shall be removed from their molds after 24 hours, stored and cured on the work site as near to the sampled concrete in the structure as possible, and subject to the same exposure as the job concrete of which it is representative. These field cylinders shall be kept unmolested on the structure for at least three-fourths of the test period before being taken to the laboratory for testing.

The specimens shall be marked and identified with tags on which shall be noted the class of concrete, date and time of day when molded, the delivery receipt and truck number if ready-mixed, the results of the tests of slump, air content and temperature, and a clear description of where the concrete was placed in the structure. The date of arrival at the testing laboratory also shall be noted thereon.

c. Compression tests. Twenty-eight days after the specimens were molded the three acceptance cylinders shall be tested in compression in accordance with A.S.T.M. C39-61 by an approved testing laboratory. The test strength shall be the average of the breaking strengths of the three acceptance cylinders. If one of the molded specimens shall show manifest evidence of improper sampling, molding, handling or testing, it shall be discarded and the remaining two averaged. If more than one cylinder must be discarded, the entire test shall be discarded. In no case shall a given class of concrete be represented by less than three separate samplings and three compression test strengths.

d. When the average strength of the test cylinders falls consistently below the minimum ultimate strength required by the design, a change in the proportions or water content of the concrete shall be made, to secure the required strength for the remaining portion of the structure.

e. When the average strength of the test cylinders for any portion of the structure is less than that required by the design, the concrete represented by such cylinders may be considered to be of adequate strength if: (1) The designer of the structure submits a correct analysis of stresses to show that the stresses in the portion of the structure affected will not exceed the allowable stresses as specified in C26-1480.0, with the value of f'_c equal to the compressive strength of the concrete as determined by the tests; or (2) if the tests are performed in accordance with the specifications for the standard method of securing, preparing and testing specimens from hardened concrete for compressive and flexural strengths, A.S.T.M., C42, and the tests show that the strength of the concrete equals or exceeds the design strength, and provided test specimens are obtained from the structure in such manner that the strength of the structure is not impaired; or (3) the structure may be considered to meet the designated requirement if load tests are performed as specified in Section C26-1461.0 for that portion of the structure where the concrete of questionable strength has been placed and the results and interpretation of such tests and the resulting safe capacity of the structure are approved by the superintendent.

§C26-1461.0. Loading-

a. Notation

D =dead load

L =Live load

Δ = maximum deflection, produced by a test load, of a member relative to the ends of the span, or of the free end of a cantilever relative to its support.

l=span of member under load test (the shorter span of flat slabs and of floors supported on four sides). The span is the distance between the centers of the supports or the clear distance between supports plus the depth of the member, whichever is smaller.

t = total thickness or depth of member under load test.

b. Static load tests of structures

(a) The superintendent shall have the right to order the test under load of any portion of a structure when conditions are such as to cause doubt about the safety of the structure.

(b) When such load tests of a structure are required a qualified professional engineer acceptable to the superintendent shall conduct the tests.

(c) Load tests of structures shall not be made until the portion subjected to load is at least 56 days old, unless the owner of the structure agrees to the test being made at an earlier age.

(d) When the whole structure is not to be tested, the portion of the structure thought to provide the least margin of safety shall be selected for loading. Prior to the application of the test load, a load which simulates the effect of that portion of the dead load which is not already present shall be applied and shall remain in place until after a decision has been made regarding the acceptability of the structure. The test load shall not be applied until the structural members to be tested have borne the full service dead load for at least 48 hours.

(e) Immediately prior to the application of the test load to flexural members (including beams, slabs, and floor and roof construction), the necessary initial reading shall be made for the measurements of deflections (and strains, if these are considered necessary), caused by the application of the test load.

(f) The members selected for loading shall be subjected to a superimposed test load equivalent to 0.3 times the dead load plus 1.7 times the service live load (test load = 0.3D + 1.7L). The test load shall be applied without shock to the structure and in a manner to avoid arching of the loading materials.

(g) The test load shall be left in position for 24 hours whereupon readings of the deflections shall be taken. The test load shall be removed and additional readings of deflections shall be taken 24 hours after the removal of the test load.

§C26-1462.0. Criteria for evaluation of load tests of existing structures.

a. If the structure shows evident failure or fails to meet the following criteria, the changes needed to make the structure adequate for the rated capacity shall be made; or a lower rating may be established.

(a) If the maximum deflection, Δ, of a reinforced concrete beam, floor or roof exceeds $1^2/20{,}000t$, the recovery of deflection within 24 hours after the removal of the test load shall be at least 75 percent of the maximum deflection.

(b) If the maximum deflection, Δ, is less than $1^2/20{,}000t$, the requirement on recovery of deflection in (a) above, may be waived.

(c) In determining the limiting deflection for a cantilever, l shall be taken as twice the distance from the support to the end, and the deflection shall be adjusted for movement of the support.

(d) Construction failing to show 75 percent recovery of the deflection may be re-tested. The second test loading shall not be made until at least 72 hours after removal of the test load for the first test. The structure shall show no evidence of failure in the re-test, and the recovery of deflection caused by the second test load shall be at least 75 percent.

§C26-1463.0. Supervision of the testing of the materials and the inspection of construction of concrete structures.

a. The owner of a proposed concrete structure, where controlled and/or average concrete is being used, shall engage a licensed professional engineer or registered architect approved by the engineer or architect of record responsible for the design to supervise the testing of the materials and the inspection of concrete construction, to check that all required tests are made and laboratory tests are submitted, to order such changes of the mix of concrete as required to produce concrete of the necessary strength, to report to the superintendent any deviation from the requirements of this article as indicated by records of inspection and reports of tests. The applicant for the building permit shall submit to the department a signed statement by the above mentioned licensed professional engineer or registered architect stating that he has assumed the responsibility for testing of the materials and inspection of the concrete work and will file all reports as required by the department.

b. Arrangements for tests of concrete, concrete materials and reinforced concrete structures where required by the provisions of this article or ordered by the superintendent shall be made by the owner or his representative. All such tests shall be made without expense to the department.

c. All such tests shall be made by competent persons, and when required by the superintendent, shall be made in the presence of his representative. The superintendent may reject any test upon the ground of technical insufficiency and may require further tests under the supervision of an approved testing laboratory.

d. The requirement set forth in subdivision “a” of this section; that the owner engage a licensed professional engineer or registered architect to supervise the testing and inspection of concrete construction may be waived by the superintendent when less than 50 cubic yards of average concrete is placed in anyone structure and the stresses do not exceed the following:

Designation	Description	Allowable working stresses in lbs. per sq. inch	
		2000	**2500**
Flexure: f_c			
Extreme fibre stress in compression		650	800
Shear: v			
Members with no web reinforcement		40	50
Members with longitudinal bars and with either stirrups or properly located bent bars		100	125
Members with longitudinal bars and a combination of stirrups and bent bars		150	190
Footings		40	50
Bond: u			
Deformed bars as defined in section C26-1456.12 Top bars (so placed that more than 12” of concrete is placed below the bar)		100	125
In two-way footings (except top bars)		75	95
All others		112	142
Bearing: f_c			
On full area		500	625

Tests of the average concrete shall be made and filed as required by section C26-1460.0 of the administrative code.

§C26-1464.0. Inspection of controlled concrete construction.-

a. All controlled concrete work, including concrete forms and reinforcement, shall be continuously inspected at the mixing plant and at the work site by qualified inspectors, under the supervision of the licensed professional engineer, employed for this purpose by the owner. A record shall be kept of such inspection which shall cover the type, quality and quantity of concrete materials, including water, the mixing and placing of the concrete, the slump, unit weight and air content of the concrete, the placing of the reinforcing steel, the size and dimensions of the concrete members, for compliance with the specifications and approved plans, and a complete record of all test samples and tests. The inspection record shall also include a complete record of the progress of the work and of the temperatures, including those of the concrete when placed, and of the protection given to the concrete while curing. Records of inspection required above and tests required by Section C26-1460.0 shall be filed with the department.

§C26-1465.0. Inspection of average concrete construction.-

a. All average concrete work, including concrete, forms and reinforcement, shall be continuously inspected at the work site by qualified inspectors, under the supervision of the licensed professional engineer, or registered architect, employed for this purpose by the owner. A record shall be kept of such inspection which shall cover the certification of the concrete required by section C26-1477.0, the placing of the concrete, the slump, unit weight and air content of the concrete, placing of the reinforcing steel, the size and dimension of the concrete members, and a complete record of all test samples and tests. The inspection record shall also include a complete record of the progress of the work and of the temperatures, including those of concrete when placed, and of the protection given to the concrete when placed, and of the protection given to the concrete while curing. Such records shall be kept on file by the architect or engineer of record during the progress of the work and for two years after completion of the structure and shall be available for inspection by the superintendent at all times during this period. Records of tests required by section C26-1460.0 shall be filed with the department.

b. The requirement that the inspection be under the supervision of a licensed professional engineer or registered architect may be waived by the superintendent if the conditions outlined in section C26-1463.0, subdivision “d” are complied with.

§C26-1466.0. Portland cement.-

a. Portland cement shall conform to “specifications for Portland cement” (ASTM C150-62) or “specifications for air-entraining Portland cement” (ASTM C175-61).

§C26-1467.0. Concrete aggregates.-

a. Concrete aggregates shall conform to “specifications for concrete aggregates” (A.S.T.M. C33-61T), or to “specifications for lightweight aggregates for structural concrete” (ASTM C330-60T). Lightweight aggregates shall be approved by the board.

b. The size of the aggregate shall be at most one-fifth of the narrowest dimension between forms of the member for which the concrete is to be used, or three-fourths of the minimum clear spacing between reinforcing bars.

§C26-1468.0. Water.-

a. Water used in fixing concrete shall be clean and free from injurious amounts of oils, acids, alkalis, organic materials, or other deleterious substances.

§C26-1469.0. Metal reinforcement.-

a. Reinforcing bars shall conform to the requirements of “specifications for billet-steel bars for concrete reinforcement” (ASTM A15-62T and A408-62T), “specifications for rail-steel bars for concrete reinforcement” (ASTM A16-62T), “specifications for axle-steel bars for concrete reinforcement” (ASTM A160-62T) or “specifications for fabricated steel bar or rod mats for concrete reinforcement” (ASTM A 184-37), “tentative specifications for high strength billet steel bars for concrete reinforcement” (ASTM A431-62T), “tentative specifications for deformed billet steel bars for concrete reinforcement with 60,000 pounds per square inch minimum yield point” (ASTM A432-62T). Deformations on deformed bars shall conform to “specifications for minimum requirements for the deformations of deformed bars for concrete reinforcement” (ASTM A305-56T and A408-62T).

b. Cold-drawn wire or welded wire fabric for concrete reinforcement shall conform to the requirements of “specifications for cold-drawn steel wire for concrete reinforcement” (ASTM A82-62T), or “specifications for welded steel wire fabric for concrete reinforcement” (ASTM A185-61T).

c. Structural steel shall conform to the requirements of “specifications for steel for bridges and buildings” (ASTM A7-61T) and tentative specification for structural steel (ASTM A36-62T).

d. Cast-iron sections for composite columns shall conform to “specifications for cast iron pressure pipe” (ASTM A377-57).

§C26-1470.0. Identification of metal reinforcement.-

a. All reinforcing bars shall be identifiable as to point of origin, grade of steel and the size.

b. All bundles or rolls of cold-drawn steel wire reinforcement shall be securely tagged, so as to identify the manufacturer, the grade of steel and the size.

§C26-1471.0. Storage of materials.-

a. Cement and aggregates shall be stored in such a manner as to prevent deterioration or intrusion of foreign matter. Any material which has deteriorated or which has been damaged shall not be used for concrete.

Sub-Article 3
Concrete Quality and Allowable Stresses

f_c = compressive unit stress in extreme fiber of concrete in flexure.

f'_c = compressive strength of concrete at age of twenty-eight days unless otherwise specified.

f_r = compressive unit stress in the metal core of a composite column.

f_s = tensile unit stress in longitudinal reinforcement; nominal allowable stress in vertical column reinforcement.

f_v = tensile unit stress in web reinforcement.

n = ratio of modulus of elasticity of steel to that of concrete.

u = bond stress per unit of surface area of bar.

v = shearing unit stress.

v_c = shearing unit stress permitted on the concrete.

psi = pounds per square inch.

§C26-1473.0. Concrete quality.-

a. For the design of reinforced concrete structures, the value of f'_c used for determining the allowable stresses as stipulated in section C26-1480.0 shall be based on the specified minimum twenty-eight day compressive strength of the concrete, or on the specified minimum compressive strength at the earlier age at which the concrete may be expected to receive its full load. All plans, submitted for approval or used on the job, shall clearly show the assumed strength of concrete at a specified age for which all parts of the structure were designed.

b. Concrete which in its final state will be exposed to the action of freezing weather and all concrete garage floors shall have a mix designed with entrained air to provide a concrete with maximum resistance to freezing, thawing and wear, for the aggregates and cement used.

§C26-1474.0. Concrete proportions and consistency.-

a. The proportions of aggregate to cement for any concrete shall be such as to produce a mixture which will work readily into the corners and angles of the forms and around reinforcement with the method of placing employed on the work, but without permitting the materials to segregate or excess free water to collect on the surface. The combined aggregates shall be of such composition of sizes that when separated on the No. 4 standard sieve, the weight passing the sieve (fine aggregate) shall not be less than thirty percent nor greater than fifty percent of the total, unless otherwise approved by the superintendent.

b. The methods of measuring concrete materials shall be such that the proportions can be accurately controlled and easily checked at any time during the work.

c. Plain concrete shall have a minimum cement factor of five bags per cubic yard of concrete, and a maximum of eight and one-half U.S. gallons of water per bag of cement including water contained in the aggregate. Such concrete shall develop a strength of at least two thousand pounds per square inch when tested in accordance with the standard methods of test (ASTM C39-61).

Reports of such tests shall be filed with the department. At least two test specimens shall be tested for each day's placing.

§C26-1475.0. Allowable working stresses for plain concrete.-

a. For plain concrete the allowable working stresses used for design shall not exceed the following values:

1. The compressive stress, due to combined live and dead loads shall not exceed four hundred pounds per square inch.

2. In footings, the tension stress due to bending away from the face of the supported wall or pier, at any section, on a depth four inches less than the footing thickness, shall not exceed fifty pounds per square inch.

§C26-1476.0. Method of establishing working stresses in reinforced concrete.-

a. The allowable working stresses used in the design of reinforced concrete structures shall be established by the methods described by sections C26-1477.0 or C26-1478.0 and by section C26-1479.0.

b. When concrete structures are designed to receive their full design loads at a period of less than twenty-eight days after being installed, all the requirements of section C26-1478.0 and section C26-1479.0b shall be complied with in establishing the allowable working stresses used is the design as well as in the conduct of the work.

c. When air-entraining cement, or any admixture or additive is to be used in the concrete, all of the requirement of section C26-1478.0 and section C26-1479.0b shall be complied with in establishing the allowable working stresses used in the design as well as in the conduct of the work.

§C26-1477.0. Average concrete; proportions and twenty-eight day strengths.-

a. The producer of average concrete shall use mix proportions and water cement ratios which have been shown by previous use to produce satisfactory concrete of the required strength at a slump of five inches with a tolerance of plus or minus one inch. Average concrete shall be limited to the concrete strengths shown in table "A" below, and the cement factor used shall not be less than the value given in the table for the corresponding concrete strengths.

TABLE A

Minimum compressive strength in twenty-eight days (f'_c) pounds per square inch	Minimum bags of cement per cubic yard of concrete	Maximum permissible water cement ratio, U.S. gallons per 94-pound sack of cement	
		Non air-entrained concrete	Air-entrained concrete
2000	5.5	8	7 1/4
2500	6.0	7 1/4	6 1/4

b. Each load of concrete shall be certified by the producer to the owner, whether produced at ready mix plant or site mixed, as to the concrete strength and actual quantities per cubic yard of each material; including water, contained therein. A copy of such certificate shall be available to the department during the progress of the work and for two years thereafter.

§C26-1478.0. Controlled concrete, proportions and twenty-eight day strengths.-The strength of all controlled concrete shall be established in accordance with the following provisions:

Preliminary tests of controlled concrete.-

a. Job site, weighed, batched and mixed concrete.-Preliminary tests of controlled concrete shall be made by an approved testing laboratory in advance of the beginning of operations, using the materials proposed and consistencies as hereinafter specified, and tested wet in accordance with the standard method of test for compressive strength of molded concrete cylinders, A.S.T.M. C39-61, including tests of fine and coarse aggregate and the provisions therein for curing in a moist room of seventy degrees Fahrenheit. A curve representing the relation between the average strength of the concrete at twenty-eight days, or at earlier periods, and the water cement ratio shall be established for a range of values including all of the strengths and ages called for in the plans. The tests shall include at least four different water cement ratios, and at least four specimens for each water cement ratio. The mixes used in the tests shall have a slump of five inches, with a tolerance of plus or minus one inch. The water cement ratio is to be used in the structure shall be that corresponding to a point on the curve established by these tests, representing a strength of concrete fifteen percent higher than the minimum ultimate strength called for on the plans. The cement factor used in the work shall have at least the value established by the tests, but shall not be less than the factor given in Table "B" below for the corresponding concrete strength.

TABLE B

Minimum compressive strength in twenty-eight days (f'_c) pounds per square inch	**Minimum bags of cement per cubic yard of concrete**
2000	5.00
2500	5.25
3000	5.75
3500	6.50
3750	6.75
4000	7.00
5000	7.50

Note:

1. If 4000 pound concrete is used in columns, the floor construction concrete shall be not less than 3000 pounds f'_c controlled concrete.

2. If 5000 pound concrete is used in columns, the floor construction concrete shall be not less than 3500 pounds f'_c controlled concrete.

b. Ready-mixed concrete.-Every owner or his representative shall have an approved testing laboratory submit a mix design based upon tests similar to a hereof.

c. The minimum bags of cement per cubic yard of concrete noted in the preceding Tables A and B may be reduced under the following conditions:

(a) The preliminary tests of the concrete shall be made under the supervision of a licensed professional engineer for the specific project.

(b) The cement, aggregate, admixtures, and other ingredients of the concrete shall be those used for the specific project.

(c) The licensed professional engineer who supervises the preliminary tests shall also inspect the concrete construction as required in C26-1463.0.

(d) The designing architect and engineer of record shall certify that the tests meet their requirements for the strength and durability of the structure.

Reports of tests required in C26-1478.0 shall be filed with the department prior to placement of any concrete covered by tests.

§C26-1479.0. Allowable working stresses for reinforced concrete.-

a. For average concrete the maximum allowable working stresses in pounds per square inch used for design shall be based on the values of f'_c as determined and limited by section C26-1477.0 and shall be as given in section C26-1480.0.

b. For controlled concrete the maximum allowable working stresses in pounds per square inch on which the design is based shall be as given in section C26-1480.0 where f'_c equals the values determined in accordance with section C26-1478.0 of this section, but not to exceed 5000 pounds per square inch.

§C26-1480.0. Allowable working stresses in concrete.-The allowable working stresses in concrete shall not be greater than the percentage of the strength nor greater than the values given in the following table; psi = pounds per square inch.

DESCRIPTION	Symbol	*Percentage of compressive strength	ALLOWABLE WORKING STRESSES						
			For strength of concrete shown below						
			Maximum value psi	f'_c=2000 psi n=15*	f'_c=2500 psi n=12*	f'_c=3000 psi n=10*	f'_c=3500 psi n=8.6*	f'_c=4000 psi n=7.5*	f'_c=5000 psi n=6*
Flexure: f_c									
Extreme fiber stress in compression	f_c	$.45f'_c$		900	1125	1350	1575	1800	2250
Extreme fiber stress in tension in plain concrete footings	f_c	$.03f'_c$		60	75	90	105	120	150
Shear: v (as a measure of diagonal tension)									
Members with no web reinforcement	v_c	$.03f'_c$	90	60	75	90	90	90	90
Members with longitudinal bars and with either stirrups or properly located bent bars	v	$.08f'_c$	240	160	200	240	240	240	240
Members with longitudinal bars and a combination of stirrups and bent bars (The latter bent up suitably to carry at least $0.04f'_c$)		$.12f'_c$	360	240	300	360	360	360	360
For flat slabs see sub-article 10.									
Footings	v_c	$.03f'_c$	75	60	75	75	75	75	75
Bond: u									
Deformed bars as defined in Section C26-1456.12									
Top bars (so placed that more than 12" of concrete is placed below the bar)	u	$.07f'_c$	245	140	175	210	245	245	245
In two-way footings (except top bars)	u	$.08f'_c$	280	160	200	240	280	280	280
All others	u	$.10f'_c$	350	200	250	300	350	350	350
Plain bars not conforming to ASTM A-305-56T as defined in Section C26-1456.18 (Must be hooked)									
Top bars	u	$.03f'_c$	105	60	75	90	105	105	105
In two-way footings (except top bars)	u	$.036f'_c$	126	72	90	108	126	126	126
All others	u	$.045f'_c$	158	90	113	135	158	158	158
Bearing: f_c									
On full area	f_c	$.25f'_c$		500	625	750	875	1000	1250
Concentric on one-third area of less#	f_c	$.375f'_c$		750	938	1125	1312	1500	1875

[c] When shear value exceeds .75 of .03 f'_c provide #3 stirrups on 12 inch centers

*For any strength of concrete in accordance with Section C26-1475.0 $n = \frac{30000}{f'_c}$

#This increase shall be permitted only when the least distance between the edges of the loaded and unloaded areas is a minimum of one-fourth of the parallel side dimension of the loaded area. The allowable bearing stress on a reasonably concentric area greater than one-third but less than the full area shall be interpolated between the values given.

§26-1481.0. Allowable unit stresses in reinforcement.-Unless otherwise provided in this article, steel for concrete reinforcement shall not be stressed in excess of the following limits:

a. Tension

(f_s = tensile unit stress in longitudinal reinforcement) and (f_v = tensile unit stress in web reinforcement) 20,000 psi for rail-steel concrete reinforcing bars, billet-steel concrete reinforcing bars of intermediate and hard grades, axle-steel concrete reinforcing bars of intermediate and hard grades, and cold-drawn steel wire for concrete reinforcement; 18,000 psi for billet-steel concrete reinforcing bars of structural grade, and axle-steel concrete reinforcing bars of structural grade.

b. Tension in one-way slabs of not more than 12-ft span (f_s = tensile unit stress in main reinforcement). For the main reinforcement, in one-way slabs, fifty percent of the minimum yield point specified in the specifications of the American Society for Testing and Materials for the particular kind and grade of reinforcement used, but in no case to exceed 30,000 psi.

c. Compression, vertical column reinforcement (f_s = nominal allowable stress in vertical column reinforcement) forty percent of the minimum yield point specified in the specifications of the American Society for Testing and Materials for the particular kind and grade of reinforcement used, but in no case to exceed 30,000 psi.

(f_r = allowable unit stress in the metal core of composite and combination columns)

Structural steel sections	16,000 psi
Cast iron sections	10,000 psi
Steel pipe	See limitations of section C26-1538.0

d. Compression, flexural members

For compression reinforcement in flexural members see section C26-1506.0.

Sub-Article 4
Mixing and Placing Concrete

§C26-1482.0. Preparation of equipment and place of deposit.-

a. Before concrete is placed, all equipment for mixing and transporting the concrete shall be cleaned, all debris and ice shall be removed from the spaces to be occupied by the concrete, forms shall be thoroughly wetted or oiled, masonry filler units that will be in contact with concrete shall be well drenched, and the reinforcement shall be thoroughly cleaned of ice or other coatings.

b. Water shall be removed from place of deposit before concrete is placed unless otherwise permitted by the superintendent.

§C26-1483.0. Mixing of concrete.-

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

b. For job-mixed concrete, mixing shall be done in a batch mixer of approved type. The mixer shall be rotated at a speed recommended by the manufacturer and mixing shall be continued for at least one and one-half minutes after all materials are in the drum. For batches larger than one cubic yard, mixing time shall be increased fifteen seconds for each additional cubic yard or fraction thereof.

c. Ready-mixed concrete shall be mixed and delivered in accordance with the requirements set forth in “specifications for ready-mixed concrete” (ASTM C94-62).

§C26-1484.0. Conveying.-

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

b. Equipment for chuting, pumping, and pneumatically conveying concrete shall be of such size and design as to insure a practically continuous flow of concrete at the delivery end without separation of materials.

§C26-1485.0. Depositing.-

a. Concrete shall be deposited as nearly ,as practicable in its final position to avoid segregation due to rehandling or flowing. The concreting shall be carried on at such a rate that the concrete is at all times plastic and flows readily into the spaces between the bars. No concrete that has partially hardened or been contaminated by foreign particles shall be deposited on the work, nor shall retempered concrete be used.

b. When concreting is once started, it shall be carried on as a continuous operation until the placing of the panel or section is completed. The top surface shall be generally level. When construction joints are necessary, they shall be made in accordance with section C26-1496.0.

c. All concrete shall be thoroughly compacted by suitable means during the operation of placing and shall be thoroughly worked around the reinforcement and embedded fixtures and into the corners of the forms.

d. Where conditions make compacting difficult, or where the reinforcement is congested, batches of mortar containing the same proportions of cement to sand as used in the concrete, shall first be deposited in the forms to a depth of at least one inch.

§C26-1486.0. Curing.-

a. In all concrete structures, a concrete made with normal portland cement shall be maintained above 50°F, in a moist condition for at least the first seven days after placing and high-early-strength concrete shall be so maintained for at least the first three days. Other approved curing methods may be used if the specified strengths are obtained.

§C26-1487.0. Cold weather requirements.-

a. Adequate equipment shall be provided for heating the concrete materials and protecting the concrete during freezing or near freezing weather. All concrete materials and all reinforcements, forms, fillers, and ground with which the concrete is to come in contact shall be free from frost. No frozen materials or materials containing ice shall be used.

§C26-1488.0. Protection of heating equipment.-

a. Where salamanders or other heating equipment are used, escape hatches and protection against fire, complying with the requirements of section C26-555.2, shall be provided.

Sub-Article 5
Forms and Details of Construction

§C26-1489.0. Design and construction of forms.-

a. The design and construction of forms shall conform to the following requirements:

1. Forms shall conform to the shapes, lines and dimensions of the member as called for on the plans. Forms shall be substantial and sufficiently tight to prevent leakage of mortar; and shall be properly placed or tied together so as to maintain position and shape and insure safety to workmen and passerby. Temporary openings shall be provided where necessary, to facilitate cleaning and inspection immediately before depositing concrete.

2. Where the height of the shores exceeds ten feet, adequate diagonal bracing shall be provided in both longitudinal and transverse directions. In addition, adequate diagonal

braces shall be provided at the ends of the framework. Diagonal bracing shall extend from the top to bottom of shores.

3. The unbraced length of wood shores supporting forms shall not exceed fifty times the least dimension. Metal shores or frames shall be type approved by the board of standards and appeals and shall be installed in accordance with the approval of the board. Shores shall be adequately secured at the top and shall be properly wedged at top or bottom, if required.

4. Where shores rest upon the ground, adequate mud sill, or other bases, shall be provided to support the shores adequately.

5. Qualified workmen shall be detailed constantly during the placing of concrete to insure that there is no movement of shores, braces or other supports. The name of the foreman in charge of the formwork shall be posted in the field office of the contractor.

6. The individual, firm or corporation who does the concrete work shall be responsible for the adequate design and construction of all forms used in the construction of the building. Whenever the shore height exceeds fourteen feet, or the load on the forms exceeds one hundred fifty pounds per square foot, or power buggies are used, or two stage shores are used, the individual firm or corporation who does the concrete work shall certify to the department that the form design has been checked and approved as adequate by a licensed professional engineer who has had at least five years of experience as a structural and the forms have been constructed in conformance with the design which was checked and approved by the said engineer.

§C26-1490.0. Removal of forms.-

a. Forms shall be removed in such a manner as to insure the complete safety of the structure. Where the structure as a whole is supported on shores, beam and girder sides, column and similar vertical forms may be removed after twenty-four hours or when the concrete is sufficiently hard not to be injured thereby. In no case shall the supporting forms or shoring be removed until the members have acquired sufficient strength to support safely their weight and the load thereon. The results of suitable control tests may be used as evidence that the concrete has attained such sufficient strength, as specified by the engineer, and filed with the department.

§C26-1491.0. Conduits, pipes, etc., embedded in concrete.-

a. Electric conduits, junction boxes and other pipes whose embedment is allowed shall not, with their fittings, displace that concrete of a column on which stress is calculated, or which is required for fire protection, to greater extent than four percent of the area of the cross section. Sleeves or other pipes passing through floors, walls, or beams shall not be of such size or in such location as to impair unduly the strength of the construction; such sleeves or pipes may be considered as replacing structurally the displaced concrete, provided they are not exposed to rusting or other deterioration, are of iron or steel not thinner than standard steel pipe, have a nominal inside diameter not over two inches, and are spaced not less than three diameters on centers. Except when plans of conduits and pipes are approved by the structural engineer and so certified to the department, embedded pipes or conduits, other than those merely passing through, shall not be larger in outside diameter than one-third the thickness of the slab, wall, or beam in which they are embedded, nor shall they be spaced closer than three diameters on center, nor so located as to impair unduly the strength of the construction.

One and three eighths outside diameter conduit in a four inch slab is permitted under the one-third of the slab thickness rule. The design of all slabs and beams shall be such that they shall have the required strength in shear when the area of the conduits, junction or outlet boxes are deducted from the section in shear. The depth of junction or outlet boxes shall not exceed three inches for a four inch slab, or three and one half inches for a five inch slab.

Junction or outlet boxes placed in the middle of the span of either a one-way or two-way slab shall be spaced not less than twenty inches on centers. Junction or outlet boxes located other than in the middle half of the spans shall be not less than eight feet on centers.

b. Pipes which will contain liquid, gas or vapor may be embedded in structural concrete under the following conditions:

1. The temperature of the liquid, gas, or vapor shall not exceed one hundred and fifty degrees Fahrenheit.

2. The maximum pressure to which any piping or fittings shall be subjected shall be two hundred pounds per square inch above atmospheric pressure.

3. All pipings and fittings shall be tested as a unit for leaks immediately prior to concreting. The testing pressure per square inch above atmospheric pressure shall be fifty percent in excess of the pressure to which the piping and fittings may be subjected but the minimum testing pressure shall be not less than one hundred and fifty pounds per square inch above atmospheric pressure. The pressure test shall be held for four hours with no drop in pressure except that which may be caused by air temperature.

4. Pipes carrying liquid, gas or vapor which is explosive or injurious to health shall again be tested as specified in paragraph 3 after the concrete has hardened.

5. No liquid, gas or vapor, except water not exceeding ninety degrees Fahrenheit nor twenty pounds per square inch pressure, is to be placed in the pipes until the concrete has thoroughly set.

6. In solid slabs the piping shall be placed between the top and bottom reinforcement.

7. The concrete covering of the pipes shall be not less than one inch.

8. Reinforcement with an area equal to at least two tenths percent of the area of the concrete section shall be provided normal to the piping.

9. The pipings and fittings shall be assembled by welding, brazing, solder-sweating, or other equally satisfactory method. Screw connections are prohibited. The piping shall be so fabricated and installed that it will not require any cutting, bending, or displacement of the reinforcement from its proper location.

10. No liquid, gas, or vapor which may be injurious or detrimental to the pipes shall be placed in them.

11. Drain pipes and other piping designed for pressures of not more than one pound per square inch above atmospheric pressure need not be tested as required in paragraph (3) above.

§C26-1492.0. Cleaning and bending reinforcement.-

a. Metal reinforcement, at the time concrete is placed, shall be free from loose rust scale or other coatings that will destroy or reduce the bond. Bends for stirrups and ties shall be made around a pin having a diameter not less than two times the minimum thickness of the bar. Hooks shall conform to the requirements of section C26-1526.0. Bends for other bars shall be made around a pin having a diameter not less than six times the minimum thickness of the bar, except that for bars larger than one inch, the pin shall not be less than eight times the minimum thickness of the bar. All bars shall be bent cold. Reinforcement shall be formed to the dimensions indicated on the plans before it is embedded in the concrete.

§C26-1493.0. Placing reinforcement.-

a. Metal reinforcement shall be accurately placed and adequately secured in position by concrete or metal chairs or spacers. The clear distance between parallel bars, except in columns, shall be not less than the nominal diameter of the bars, one and one-third times the maximum size of the coarse aggregate, nor one inch. Where reinforcement in beams or girders is placed in two or more layers, the clear distance between layers shall not be less than one inch, and the bars in the upper layers shall be placed directly above those in the bottom layer.

§C26-1494.0. Splices in reinforcement of slabs, beams and girders.-

a. In slabs, beams and girders, splices of 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 listed in section C26-1480.0. The minimum overlap for a lapped splice shall be twenty-four bar diameters, but not less than twelve inches for bars. The clear distance between bars shall also apply to the clear distance between a contact splice and adjacent splices or bars.

§C26-1495.0. Concrete protection for reinforcement.-

a. The reinforcement of footings and other principal structural members in which the concrete is deposited against the ground shall have not less than three inches of concrete between it and the ground contact surface. If 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 two inches of concrete for bars larger than No.5 and one and one-half inches for No.5 bars or smaller.

b. The concrete protective covering for reinforcement at surfaces not exposed directly to the ground or weather shall be not less than three-quarters of an inch for slabs and walls; and not less than one and one-half inches for beams and girders, and two inches for columns. In concrete joist floors in which the clear distance between joists is not more than thirty inches, the protection of reinforcement shall be at least three-quarters of an inch.

c. Concrete protection for reinforcement shall in all cases be at least equal to the diameter of the bars.

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

§C26-1496.0. Construction joints.-

a. Joints not indicated on the plans shall be so made and located as to least impair the strength of the structure. Where a joint is to be made, the surface of the concrete shall be thoroughly cleaned and all laitance removed. In addition to the foregoing, all joints shall be thoroughly wetted, and slushed with a coat of neat cement grout immediately before placing of new concrete.

b. At least two hours must elapse after depositing concrete in the columns or walls before depositing in beams, girders, or slabs supported thereon. Beams, girders, brackets, column capitals, and haunches shall be considered as part of the floor system and shall be placed monolithically therewith.

c. 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 such point, in which case the joints in the girders shall be offset a distance equal to twice the width of the beam. In this last case provision shall be made for shear by use of inclined reinforcement.

Sub-Article 6
Design-General Considerations

§C26-1497.0. Design methods.-

a. The design of reinforced concrete members shall be made with reference to allowable stresses, working loads, and the accepted straightline theory of flexure. In determining the ratio n for design purposes, the modulus of elasticity for the concrete shall be assumed at $1000f'_c$ and that the steel as 30,000,000 pounds per square inch. For concrete weighing less than 145 pounds per cubic foot, the value for "n" shall be determined by the board. It is assumed that the steel takes all the tension stresses in flexural computations.

§C26-1498.0. Design loads.-

a. The provisions for design herein specified are based on the assumption that all structures shall be designed for all dead and live loads coming upon them, the live loads to be in accordance with the general requirements of the building code of which this forms a part, with such reductions for girders and lower story columns as are permitted therein.

§C26-1499.0. Resistance to wind forces.-

a. The resisting elements in structures required to resist wind shall be limited to the integral structural parts.

b. The moments, shears, and direct stresses resulting from wind forces determined in accordance with recognized methods shall be added to the maximum stresses which exist at any section for dead and live loads.

c. Members subject to stresses produced by wind combined with other loads may be proportioned for unit stresses thirty-three and one-third percent greater than those specified in sections C26-1480.0 and C26-1481.0, provided that the section thus required is not less than that required for the combination of dead and live loads.

Sub-Article 7
Flexural Computations

§C26-1500.0. Notation relating to flexural computations.

b	= width of rectangular flexural member or width of flanges for T and I sections
b'	= width of web in T and I flexural members
d	= depth from compression face of beam or slab to centroid of longitudinal tensile reinforcement; the diameter of a round bar
E	= modulus of elasticity
I	= moment of inertia of a section about the neutral axis for bending
h	= story height
l	=span length of slab or beam
l'	= clear span for positive moment and shear and the average of the two adjacent clear spans for negative moment (see section C26-1501.0)
t	= minimum total thickness of slab.
w	= uniformly distributed load per unit of length of beam or per unit area of slab

§C26-1501.0. General requirements.-

(a) All members of frames or continuous construction shall be designed to resist at all sections the maximum moments and shears produced by dead load, live load, and wind load, as determined by the theory of elastic frames in which the simplified assumptions of section C26-1502.0 may be used.

(b) Approximate methods of frame analysis are satisfactory for buildings of usual types of construction, spans, and story heights.

(c) In the case of two or more approximately equal spans (the larger of two adjacent spans not exceeding the shorter by more than twenty percent) with loads uniformly distributed, where the unit live load does not exceed three times the unit dead load, design for the following moments and shears is satisfactory:

Positive moment

End spans

If discontinuous end is unrestrained………………………… $\frac{1}{11}wl'^2$

If discontinuous end is integral with the support………….. $\frac{1}{14}wl'^2$

Interior Spans………………………………………………… $\frac{1}{16}wl'^2$

Negative moment at exterior face of first interior support two-spans……………………………………………………… $\frac{1}{9}wl'^2$

More than two spans………………………………………… $\frac{1}{10}wl'^2$

Negative moment at other faces of interior supports……….. $\frac{1}{11}wl'^2$

Negative moment at face of all supports for, (a) slabs with spans not exceeding ten feet and (b) beams and girders where ratio of sum of column stiffnesses to beam stiffnesses exceeds eight at each end of the span……………………… $\frac{1}{12}wl'^2$

Negative moment at interior faces of exterior supports for members built integrally with their supports.

Where the support is a spandrel beam or girder………….. $\frac{1}{24}wl'^2$

Where the support is a column……………………………… $\frac{1}{16}wl'^2$

Shear in end members at first interior support……………… $1.15\frac{wl'}{2}$

Shear at all other supports…………………………………… $\frac{wl'}{2}$

(d) Reinforced concrete floors and roofs for loads and spans specified in section C26-620.0 may be designed as prescribed by said section.

(e) A cellar floor or any floor resting directly on the ground shall be built in accordance with section C26-620.1.

(f) Beams supporting reinforced slabs shall be provided with tie rods where required by section C26-629.0.

§C26-1502.0. Conditions of design.-

(a) Arrangement of live load

1. The live load may be considered to be applied only to the floor under consideration, and the far ends of the columns may be assumed as fixed.

2. Consideration may be limited to combinations of dead load on all spans with full live load on two adjacent spans and with full live load on alternate spans.

(b) Span length

1. The span length, *l*, of members that are not built integrally with their supports shall be the clear span plus the depth of the slab or beam but shall not exceed the distance between centers of supports.

2. In analysis of continuous frames, center to center distances, *l* and h, may be used in the determination of moments. Moments at faces of supports may be used for design of beams and girders.

3. Solid or ribbed slabs with clear spans of not more than ten feet that are built integrally with their supports may be designed as continuous slabs on knife edge supports with spans equal to the clear spans of the slab and the width of beams otherwise neglected.

(c) Stiffness

1. Any reasonable assumption may be adopted for computing the relative stiffness of columns and of floor systems. The assumption made shall be consistent throughout the analysis.

2. In computing the value of I for relative stiffness of slabs, beams, girders, and columns, the reinforcement may be neglected. In T-shaped sections allowance shall be made for the effect of flange.

(d) Haunched floor members

1. The effect of haunches shall be considered both in determining bending moments and in computing unit stresses.

(e) Limitations

1. Wherever at any section positive reinforcement is indicated by analysis, the amount provided shall be not less than 0.005 b'd except in slabs of uniform thickness. (Use b instead of b' for rectangular flexural members.)

2. In structural slabs of uniform thickness the minimum amount of reinforcement in the direction of the spall shall be:

For structural, intermediate, and hard grades and rail steel..........	0.0025 bd
For steel having a minimum yield point of 56,000 pounds per square inch…………………………………………………………..	0.0020 bd

3. In slabs other than concrete joist construction or flat slabs, the principal reinforcement shall be centered not farther apart than three times the slab thickness nor more than eighteen inches.

(f) Moments in columns

For moments in columns see sections C26-1540.0 and C26-1541.0.

§C26-1503.0. Depth of beam or slab.-

(a) The depth of the beam or slab shall be taken as the distance from the centroid of the tensile reinforcement to the compression face of the structural members. Any floor finish not placed monolithically with the floor slab shall not be included as a part of the structural member. When the finish is placed monolithically with the structural slab in buildings of the warehouse or industrial class, there shall be placed an additional depth of one-half inch over that required by the design of the member.

(b) The following minimum thickness of Flexural Members shall be used:

Member	Simply Supported	Minimum Thickness, t		
		One End Continuous	Both Ends Continuous	Cantilever
One way slab	*l*/25	*l*/30	*l*/35	*l*/12
Beams	*l*/20	*l*/23	*l*/26	*l*/10

§C26-1504.0. Distance between lateral supports.-

(a) The clear distance between lateral supports of a beam shall not exceed thirty-two times the least width of compression flange.

§C26-1505.0. Requirements for T -beams.-

(a) In T-beam construction the slab and beam shall be built integrally or otherwise effectively bonded together. The effective flange width to be used in the design of symmetrical T-beams shall not exceed one-fourth of the span length of the beam, and its overhanging width on either side of the web shall not exceed eight times the thickness of the slab nor one-half the dear distance to the next beam.

(b) For beams having a flange on one side only, the effective overhanging flange width shall not exceed one-twelfth of the span length of the beam, nor six times the thickness of the slab, nor one-half the clear distance to the next beam.

(c) Where the principal reinforcement in a slab which is considered as the flange of a T-beam (not a joist in concrete joist floors) is parallel to the beam, transverse reinforcement shall be provided in the top of the slab. This reinforcement shall be designed to carry the load on the portion of the slab required for the flange of the T-beam. The flange shall be assumed to act as a cantilever. The spacing of the bars shall not exceed five times the thickness of the flange, nor in any case eighteen inches.

(d) Provision shall be made for the compressive stress at the support in continuous T-beam construction, care being taken that the provisions of section C26-1493.0 relating to the spacing of bars, and section C26-1485.0 (d) relating to the placing of concrete shall be fully met.

(e) The overhanging portion of the flange of the beam shall not be considered as effective in computing the shear and diagonal tension resistance of T-beams.

(f) Isolated beams in which the T-form is used only for the purpose of providing additional compression area, shall have a flange thickness not less than one-half the width of the web and a total flange with not more than four times the web thickness.

§C26-1506.0. Compression steel in flexural members.-

(a) Compression steel in beams or girders shall be anchored by ties or stirrups not less than one-quarter inch in diameter spaced not farther apart than sixteen bar diameters, or forty-eight tie diameters. Such stirrups or ties shall be used throughout the distance where the compression steel is required.

(b) To approximate the effect of creep, the stress in compression reinforcement resisting bending may be taken at twice the value indicated by using the straight-line relation between stress and strain and the modular ratio given in section C26-1497.0 (a), but not of greater value than the allowable stress in tension.

§C26-1507.0. Shrinkage and temperature reinforcement.-

(a) Reinforcement for shrinkage and temperature stresses normal to the principal reinforcement shall be provided in structural floor and roof slabs where the principal reinforcement extends in one direction only. Such reinforcement shall provide for the following minimum ratios of reinforcement area to concrete area bt, but in no case shall such reinforcing bars be placed farther apart than five times the slab thickness or more than eighteen inches.

Slabs where plain bars are used……………………………..……	0.0025
Slabs where deformed bars with specified yield points less than 60,000 pounds per square inch are used………………………….	0.0020
Slabs where deformed bars with 60,000 pounds per square inch specified yield point or wire fabric having welded intersections not farther apart in the direction of stress than twelve inches are used………………………………………………………………	0.0018

§C26-1508.0. Concrete joist floor construction.-

(a) In concrete joist floor construction consisting of concrete joists and slabs placed monolithically with or without burnt clay or concrete tile fillers, the joists shall not be farther apart than thirty inches face to face. The ribs shall be straight, not less than four inches wide, and of a depth not more than three times the width.

(b) When burned clay or concrete tile fillers of material having a unit compressive strength at least equal to that of the designed strength of the concrete in the joists are used, the vertical shells of the fillers in contact with the joists may be included in the calculations involving shear or negative bending moment. No other portion of the fillers may be included in the design calculations.

(c) The concrete slab over the fillers shall not be less than one and one-half inches in thickness, nor less in thickness than one-twelfth of the clear distance between joists. Shrinkage reinforcement shall be provided in the slab at right angles to the joists as required in section C26-1507.0.

(d) Where removable forms or fillers not complying with section C26-1508.0(b) are used, the thickness of the concrete slab shall not be less than one-twelfth of the clear distance between joists and in no case less than two inches. Such slab shall be reinforced at right angles to the joists with at least the amount of reinforcement required for flexure, giving due consideration to concentrations, if any, but in no case shall the reinforcement be less than that required by section C26-1507.0.

(e) When the finish used as a wearing surface is placed monolithically with the structural slab in buildings of the warehouse or industrial class, the thickness of the concrete over the fillers shall be one-half inch greater than the thickness used for design purposes.

(f) Where the slab contains conduits or pipes as allowed in section C26-1491.0, the thickness shall not be less than one inch plus the total over-all depth of such conduits or pipes at any point. Such conduits or pipes shall be so located as not to impair the strength of the construction.

(g) Shrinkage reinforcement shall·not be required in the slab parallel to the joists.

§C26-1509.0. Two-way systems with supports on four sides.-

(a) This construction, reinforced in two directions, includes solid reinforced concrete slabs; concrete joists with fillers of hollow concrete units or clay tile, with or without concrete top slabs; and concrete joists with top slabs placed monolithically with the joists. The slab shall be supported by walls or beams on all sides and if not securely attached to supports, shall be reinforced as specified C26-1509.0(b).

(b) Where the slab is not securely attached to the supporting beams or walls, special reinforcement shall be provided at exterior corners in both the bottom and top of the slab. This reinforcement shall be provided for a distance in each direction from the corner equal to one-fifth the longest span. The reinforcement in the top of the slab shall be parallel to the diagonal from the corner. The reinforcement in the bottom of the slab shall be at right angles to the diagonal or may be of bars in two directions parallel to the sides of the slab. The reinforcement in each band shall be of equivalent size and spacing to that required for the maximum positive moment in the slab.

(c) The slab and its supports shall be designed by approved methods which shall take into account the effect of continuity at supports, the ratio of length to width of slab and the effect of two-way action.

(d) In no case shall the slab thickness be less than four inches nor less than the perimeter of the slab divided by one hundred and eighty. The spacing of reinforcement shall not be more than three times the slab thickness and the ratio of reinforcement shall be at least 0.0025.

(e) The requirements of this section are satisfied by either of the methods of design covered in ACI 318-56.

Sub-Article 8
Shear and Diagonal Tension

§C26-1510.0. Notation relating to shear and diagonal tension.

Av	= total area of web reinforcement in tension within a distance of s (measured in a direction parallel to that of the main reinforcement) or the total area of all bars bent up in any one plane
α	= angle between inclined web bars and axis of beam
b	= width of rectangular flexural member of width of flange for T- and I- sections
b'	= width of web in T and I flexural members
d	= depth from compression face of beam or slab to centroid of longitudinal tensile reinforcement
f'_c	= compressive strength of concrete at age of twenty-eight days unless otherwise specified
f_v	= tensile unit stress in web reinforcement
j	= ratio of distance between centroid of compression and centroid of tension to the depth of d
s	= spacing of stirrups or of bent bars in a direction parallel to that of the main reinforcement
v	= shearing unit stress
V	= total shear
V'	= total shear carried by the web reinforcement

§C26-1511.0. Shearing unit stress.-

a. The shearing unit stress v, as a measure of diagonal tension, in reinforced concrete flexural members shall be computed by formula (2):

$$v = \frac{V}{bjd}$$

(2)

b. For beams of I- or T- section, b' shall be substituted for b in formula (2)

c. In concrete joist floor construction, where burned clay or concrete tile are used, b' may be taken as a width equal to thickness of the concrete web plus the thickness of the vertical shells of the concrete or burned clay tile in contact with the joist as in section C26-1508.0(b).

d. Wherever the value of the shearing unit stress computed by formula (2) exceeds the shearing unit stress v_c permitted on the concrete of an unreinforced web (see section C26-1480.0), web reinforcement shall be provided to carry the excess. Such reinforcement shall also be provided for a distance equal to the depth, d, of the member beyond the point theoretically required.

e. Where continuous or restrained beams or frames do not have a slab so cast as to provide T-beam action, the following provisions shall apply. Web reinforcement shall be provided from the support to a point beyond the extreme position of the point of inflection a distance equal to either one-sixteenth of the clear span or depth of the member, whichever is greater even though the shearing unit stress does not exceed v_c. Such reinforcement shall be designed to carry at least two-thirds of the total shear at the section. Web reinforcement shall be provided sufficient to carry at least two-thirds of the total shear at a section in which there is negative reinforcement.

§C26-1512.0. Types of web reinforcement.-

a. Web reinforcement may consist of:

1. Stirrups or web reinforcing bars perpendicular to the longitudinal steel.
2. Stirrups or web reinforcing bars welded or otherwise rigidly attached to the longitudinal steel and making an angle of thirty degrees or more thereto.
3. Longitudinal bars bent so that the axis of the inclined portion of the bar makes an angle of fifteen degrees or more with the axis of the longitudinal portion of the bar.
4. Special arrangements of bars with adequate provisions to prevent slip of bars or splitting of the concrete by the reinforcement (see section C26-1514.0-f).

b. Stirrups or other bars to be considered effective as web reinforcement shall be anchored at both ends, according to the provisions of section C26-1524.0.

§C26-1513.0. Stirrups.-

a. The area of steel required in stirrups placed perpendicular to the longitudinal reinforcement shall be computed by formula (3).

$$A_v = \frac{V's}{f_v jd}$$

(3)

b. Inclined stirrups shall be proportioned by formula (5) (section C26-1514.0d).

c. Stirrups placed perpendicular to the longitudinal reinforcement shall not be used alone as web reinforcement when the shearing unit stress, v, exceeds $0.08f'_c$ or two-hundred-forty pounds per square inch.

§C26-1514.0. Bent bars.-

a. Only the center three-fourths of the inclined portion of any longitudinal bar that is bent up for web reinforcement shall be considered effective for that purpose, and such bars shall be bent around a pin having a diameter not less than six times the bar size.

b. When the web reinforcement consists of a single bent bar or of a single group of parallel bars all bent up at the same distance from the support, the required area of such bars shall be computed by formula (4).

$$A_v = \frac{V'}{f_v \sin \alpha}$$

(4)

c. In formula (4), V' shall not exceed $0.04\ f'_c$ bjd, or 120 bjd.

d. Where there is a series of parallel bars or groups of bars bent up at different distances from the support, the required area shall be determined by formula (5).

$$A_v = \frac{V's}{f_v jd(\sin\alpha + \cos\alpha)}$$

(5)

e. When bent bars, having a radius of bend of at least six bar diameters are used alone as web reinforcement, they shall be so spaced that the effective inclined portion described in section C26-1514.0a meets the requirements of section C26-1516.0, and the allowable shearing unit stress shall not exceed $0.08f'_c$ nor two-hundred-forty pounds per square inch.

f. The shearing unit stress permitted when special arrangements of bars are employed shall be that determined by making comparative tests, to destruction, of specimens of the proposed system and of similar specimens reinforced in conformity with the provisions of this code, the same factor of safety being applied in both cases.

§C26-1515.0. Combined web reinforcement.-

a. Where more than one type of reinforcement is used to reinforce the same portion of the web, the total shearing resistance of this portion of the web shall be assumed as the sum of the shearing resistances computed for the various types separately. In such computations the shearing resistance of the concrete shall be included only once, and no one type of reinforcement shall be assumed to resist more than $2V^1/3$.

§C26-1516.0. Maximum spacing of web reinforcement.-

a. Where web reinforcement is required it shall be so spaced that every forty-five degree line (representing a potential crack) extending from the mid-depth of the beam to the longitudinal tension bars shall be crossed by at least one line of web reinforcement. If a shearing unit stress in excess of $0.06f'_c$ is used, every such line shall be crossed by at least two such lines of web reinforcement.

§C26-1517.0. Minimum web reinforcement.-Where web reinforcement is required, the amount used shall be not less than 0.15 percent of the area computed as the product of the width of the member at mid-depth and the horizontal spacing of the web reinforcement.

§C26-1518.0. Shearing stresses in flat slabs. (see Section C26-1529.0).

§C26-1519.0. Shear and diagonal tension in footings.-

a. In isolated footings the shearing unit stress computed by formula (2) on the critical section (see section C26-1551.0a) shall not exceed $0.03f'_c$ nor in any case shall it exceed seventy-five pounds per square inch.

Sub-Article 9
Bond and Anchorage

§C26-1520.0. Notation relating to bond and anchorage.

d	= depth from compression face of beam or slab to centroid of longitudinal tensile reinforcement.
f'_c	= compressive strength of concrete at age of twenty-eight days unless otherwise specified.
j	= ratio of distance between centroid of compression and centroid of tension to the depth d.
Σo	= sum of perimeters of bars in one set.
u	= bond stress per unit of surface area of bar.

V =total shear.

§C26-1521.0. Computation of bond stress in beams.-

a. In flexural members in which the tensile reinforcement is parallel to the compression face, the bond stress at any cross section shall be computed by formula (6).

$$u = \frac{V}{\Sigma ojd}$$

(6)

in which V is the shear at that section and Σo is taken as the perimeter of all effective bars crossing the section on the tension side. Bent-up bars that are not more than d/3 from the level of the main longitudinal reinforcement may be included. Critical sections occur at the face of the support, at each point where tension bars terminate within a span, and at the point of inflection.

b. Bond shall be similarly computed on compressive reinforcement, but the shear used in computing the bond shall be reduced in the ratio of the compressive force assumed in the bars to the total compressive force at the section. Anchorage shall be provided by embedment past the section to develop the assumed compressive force in the bars at the bond stress in section C26-1480.0.

c. Adequate end anchorage shall be provided for the tensile reinforcement in all flexural members to which formula (6) does not apply, such as sloped, stepped or tapered footings, brackets or beams in which the tensile reinforcement is not parallel to the compression face.

§C26-1522.0. Anchorage requirements.-

a. Tensile negative reinforcement in any span of a continuous, restrained or cantilever beam, or in any member of a rigid frame shall be adequately anchored by bond, hooks, or mechanical anchors in or through the supporting member. Within any such span every reinforcing bar, except in a lapped splice, whether required for positive or negative reinforcement, shall be extended at least twelve diameters beyond the point at which it is no longer needed to resist stress. At least one-third of the total reinforcements provided for negative moment at the support shall be extended beyond the extreme position of the point of inflection a distance sufficient to develop by bond one-half the allowable stress in such bars, not less than one-sixteenth of the clear span length, or not less than the depth of the member, whichever is greater. The tension in any bar at any section must be properly developed on each side of the section by hook, lap, or embedment (sec section C26-1526.0). If preferred, the bar may be bent across the web at any angle of not less than fifteen degrees with the longitudinal portion of the bar and be made continuous with the reinforcement which resists moment of opposite sign.

b. Of the positive reinforcement in continuous beams not less than one-fourth the area shall extend along the same face of the beam into the support a distance of six inches.

c. In simple beams, or at the freely supported end of continuous beams, at least one-third the required positive reinforcement shall extend along the same face of the beam into the support a distance of six inches.

§C26-1523.0. Plain bars in tension.-Plain bars in tension, shall terminate in standard hooks except that hooks shall not be required on the positive reinforcement at interior supports of continuous members.

§C26.1524.0. Anchorage of web reinforcement.-

a. The ends of bars forming simple U- or multiple stirrups shall be anchored by one of the following methods:

1. By a standard hook, considered as developing ten thousand pounds per square inch, plus embedment sufficient to develop by bond the remaining stress in the bar at the unit stress specified in section C26-1480.0. The effective embedded length of a stirrup leg shall be taken as the distance between the mid-depth of the beam and the tangent of the hook.

2. Welding to longitudinal reinforcement.

3. Bending tightly around the longitudinal reinforcement through at least one hundred and eighty degrees.

4. Embedment above or below the mid-depth of the beam on the compression side, a distance sufficient to develop the stress to which the bar will be subjected at a bond stress of not to exceed $0.045f'_c$ on plain bars nor $0.10f'_c$ on deformed bars, but, in any case, a minimum of twenty-four bar diameters.

b. Between the anchored ends, each bend in the continuous portion of a U- or multiple U-stirrup shall be made around a longitudinal bar.

c. Hooking or bending stirrups around the longitudinal reinforcement shall be considered effective only when these bars are perpendicular to the longitudinal reinforcement.

d. Longitudinal bars bent to act as web reinforcement shall, in a region of tension, be continuous with the longitudinal reinforcement. The tensile stress in each bar shall be fully developed in both the upper and the lower half of the beam as specified in section C26-1524.0a1 and C26-1524.0a4.

e. In all cases web reinforcement shall be carried as close to the compression surface of the beam as fireproofing regulations and the proximity of other steel will permit.

§C26-1525.0. Anchorage of bars in footing slabs.-

a. Plain bars in footing slabs shall be anchored by means of standard hooks. The outer faces of these hooks and the ends of deformed bars shall be not less than three inches nor more than six inches from the face of the footing.

§C26-1526.0. Hooks.-

a. The term “hook” or “standard hook” as used herein shall mean either:

1. A complete semicircular turn with a radius of bend on the axis of the bar of not less than three and not more than six bar diameters, plus an extension of at least four bar diameters at the free end of the bar, or

2. A ninety-degree bend having a radius of not less than four bar diameters plus an extension of twelve bar diameters, or

3. For stirrup anchorage only, a one hundred and thirty-five degree turn with a radius on the axis of the bar of three diameters plus an extension of at least six bar diameters at the free end of the bar.

Hooks having a radius of bend of more than six bar diameters shall be considered merely as extensions to the bars.

b. No hook shall be assumed to carry a load which would produce a tensile stress in the bar greater than ten thousand pounds per square inch.

c. Hooks shall not be considered effective in adding to the compressive resistance of bars.

d. Any mechanical device capable of developing the strength of the bar without damage to the concrete may be used in lieu of a hook. Tests must be presented to the board to show the adequacy of such devices.

Sub-Article 10
Flat Slabs with Square or Rectangular Panels

§C26-1527.0. Notation relating to flat slabs.

A = distance in the direction of span from center of support to the intersection of the centerline of the slab thickness with the extreme forty-five degree diagonal line lying wholly within the concrete section of the slab and column or other support, including drop panel, capital and bracket.

b = width of section.

c = effective support size (see section C26-1531.0c).

d = depth from compression face of beam or slab to centroid of tensile reinforcement.

f'_c = compressive strength of concrete at age of twenty-eight days unless otherwise specified.

H =story height in feet of the column or support of a flat slab center to center of slabs.

j = ratio of distance between centroids of compression and tension to depth d.

L = span length of a flat slab panel center to center of supports.

M_c = numerical sum of assumed positive and average negative moments at the critical design sections of a flat slab panel (see section C26-1531.0f1).

t = thickness of slab in inches at center of panel.

t_1 = thickness in inches of slabs without drop panels, or through drop panel, if any.

t_2 =thickness in inches of slabs with drop panels at points beyond the drop panel.

v = shearing unit stress.

V = total shear.

w' = uniformly distributed unit dead and live load.

W = total dead and live load on panel.

W_D =total dead load on panel.

W_L =total live load on panel, uniformly distributed.

§C26-1528.0. Definitions and scope.-

a. Flat slab-A concrete slab reinforced in two or more directions, generally without beams or girders to transfer the loads to supporting members. Slabs with recesses or pockets made by permanent or removable fillers between reinforcing bars may be considered flat slabs. Slabs with panel ceilings may be considered as flat slabs provided the panel of reduced thickness lies entirely within the area of intersecting middle strips, and is at least two-thirds the thickness of the remainder of the slab, exclusive of the drop panel, and is not less than four inches thick.

b. Column capital-An enlargement of the end of a column designed and built to act as an integral unit with the column and flat slab. No portion of the column capital shall be considered for structural purposes which lies outside of the largest right circular cone with ninety-degrees vertex angle than can be included within the outlines of the column capital. Where no capital is used, the face of the column shall be considered as the edge of the capital.

c. Drop panel-The structural portion of a flat slab which is thickened throughout an area surrounding the column, column capital, or bracket.

d. Panel strips-A flat slab shall be considered as consisting of strips in each direction, as follows:

A middle strip one-half panel in width, symmetrical about panel centerline.

A column strip consisting of the two adjacent quarter-panels either side of the column centerline.

§C26-1529.0. Design procedures.-

a. Methods of analysis-All flat slab structures shall be designed in accordance with a recognized elastic analysis subject to the limitations of sections C26-1529.0 and C26-1530.0, except that the empirical method of design given in section C26-1531.0 may be used for the design of flat slabs conforming with the limitations given therein. Flat slabs within the limitations of section C26-1531.0 when designed by elastic analysis, may have resulting analytical moments reduced in such proportion that the numerical sum of the positive and average negative bending moments used in design procedure need not exceed M_o as specified under section C26-1531.0(f).

b. Critical sections-The slab shall be proportioned for the bending moments prevailing at every section except that the slab need not be proportioned for a greater negative moment than that prevailing at a distance A from the support centerline.

c. Size and thickness of slabs and drop panels.

1. Subject to limitations of section C26-1529.0(c)3, the thickness of a flat slab and the size and thickness of the drop panel, where used, shall be such that the compressive stress due to bending at any section, and the shear about the column, column capital, and drop panel shall not exceed the unit stresses allowed in concrete of the quality used. When designed under section C26-1531.0, three-fourths of the width of the strip shall be used as the width of the section in computing compression due to bending, except that on a section through a drop panel, three-fourths of the width of the drop panel shall be used. Account shall be taken of any recesses which reduce the compressive area.

2. The shearing unit stress on vertical sections which follow a periphery, b, at distance, d, beyond the edges of the column or column capital and parallel or concentric with it, shall not exceed the following values for the concrete when computed by the formula.

$$v = \frac{V}{bjd}$$

(a) $0.03f'_c$ but not more than one hundred pounds per square inch when at least fifty percent of the total negative reinforcement required for bending in the column strip passes through the periphery.

(b) $0.025f'_c$ but not more than eighty-five pounds per square inch when twenty-five percent, which is the least value permitted, of the total negative reinforcement required or bending in the column strip passes through the periphery.

(c) Proportionate values of the shearing unit stress for intermediate percentages of reinforcement.

3. Where drop panels are used, the shearing unit stress on vertical sections which lie at a distance, d, beyond the edges of the drop panel, and parallel with them, shall not exceed $0.03f'_c$ nor one hundred pounds per square inch. At least fifty percent of the total negative reinforcement required for bending in the column strip shall be within the width of strip directly above the drop panel.

4. Slabs with drop panels whose length is at least one-third the parallel span length and whose projection below the slab is at least one-fourth the slab thickness shall be not less than L/40 nor four inches in thickness.

Slabs without drop panels as described above shall be not less than L/36 nor five inches in thickness.

5. For determining reinforcement, the thickness of the drop panel below the slab shall not be assumed to be more than one-fourth of the distance from the edge of the drop panel to the edge of the column capital.

d. Arrangement of slab reinforcement.

1. The spacing of the bars at critical sections shall not exceed two times the slab thickness, except for those portions of the slab area which may be of cellular or ribbed construction. In the slab over the cellular spaces, reinforcement shall be provided as required by section C26-1507.0.

2. In exterior panels, except for bottom bars adequately anchored in the drop panel, all positive reinforcement perpendicular to the discontinuous edge shall extend to the edge of the slab and have embedment, straight or hooked, of at least six inches in spandrel beams, walls, or columns where provided. All negative reinforcement perpendicular to the discontinuous edge shall be bent, hooked, or otherwise anchored in spandrel beams, walls, or columns.

3. The area of reinforcement shall be determined from the bending moments at the critical sections but shall not be less than 0.0025 bd at any section.

4. Required splices in bars may be made wherever convenient, but preferably away from points of maximum stress. The length of any such splice shall be at least thirty-six bar diameters.

e. Openings in flat slabs-Openings of any size may be provided in flat slabs if provision is made for the total positive and negative moments and for shear without exceeding the allowable stresses except that when design is based on section C26-1531.0, the limitations given therein shall not be exceeded.

f. Design of columns.

1. All columns supporting flat slabs shall be designed as provided in sub-article eleven with the additional requirements of this sub-article.

§C26-1530.0 Design by elastic analysis.-

a. Assumptions-In design by elastic analysis the following assumptions may be used and all sections shall be proportioned for the moments and shears thus obtained.

1. The structure may be considered divided into a number of bents, each consisting of a row of columns or supports and strips of supported slabs, each strip bounded laterally by the centerline of the panel on either side of the centerline of columns or supports. The bents shall be taken longitudinally and transversely of the building.

2. Each such bent may be analyzed in its entirety; or each floor thereof and the roof may be analyzed separately with its adjacent columns as they occur above and below, the columns being assumed fixed at their remote ends. Where slabs are thus analyzed separately, it may be assumed in determining the bending at a given support that the slab is fixed at any support two panels distant therefrom beyond which the slab continues.

3. The joints between columns and slabs may be considered rigid, and this rigidity (infinite moment of inertia) may be assumed to extend in the slabs from the center of the column to the edge of the capital, and in the column from the top of slab to the bottom of the capital. The change in length of columns and slabs due to direct stress, and deflections due to shear, may be neglected.

4. Where metal column capitals are used, account may be taken of their contributions to stiffness and resistance to bending and shear.

5. The moment of inertia of the slab or column at any cross section may be assumed to be that of the cross section of the concrete. Variation in the moments of inertia of the slabs and columns along their axis shall be taken into account.

6. Where the load to be supported is definitely known, the structure shall be analyzed for that load. Where the live load is variable but does not exceed three-quarters of the dead load, or the nature of the live load is such that all panels will be loaded simultaneously, the maximum bending may be assumed to occur at all sections under full live load. For other conditions, maximum positive bending near midspan of a panel may be assumed to occur under full live load in the panel and in alternate panels; and maximum negative bending in the slab at a support may be assumed to occur under full live load in the adjacent panels only.

b. Critical sections-The critical section for negative bending, in both the column strip and middle strip, may be assumed as not more than the distance A from the center of the column or support and the critical negative moment shall be considered as extending over this distance.

c. Distribution of panel moments-Bending at critical sections across the slabs of each bent may be apportioned between the column strip and middle strip, as given in the table 4. For design purposes, any of these percentages may be varied not more than ten percent of its value, but their sum for the full panel width shall not be reduced.

TABLE 4: DISTRIBUTION BETWEEN COLUMN STRIPS AND MIDDLE STRIPS IN PERCENT OF TOTAL MOMENTS AT CRITICAL SECTIONS OF A PANEL.

Strip		**Moment section**			
				Negative moment at exterior support	
		Negative moment at interior support	Positive moment	Slab supported on columns and on beams of total depth equal to the slab thickness*	Slab supported on reinforced concrete bearing wall or columns with beams of total depth equal or greater than 3 times the slab thickness*
Column Strip		76	60	80	60
Middle strip		24	40	20	40
Half column strip adjacent and parallel to marginal beam or wall	Total depth of beam equal to slab thickness*	38	30	40	30
	Total depth of beam or wall equal to greater than 3 times slab thickness*	19	15	20	15

*Interpolate for intermediate ratios of beam depth to slab thickness.

Note: The total dead and live load reaction of a panel adjacent to a marginal beam or wall may be divided between the beam or wall and the parallel half column strip in proportion to their stiffnesses, but the moment provided in the slab shall not be less than given in Table 4.

§C26-1531.0. Design by empirical method.-

a. General limitations-Flat slab construction may be designed by the empirical provisions of this section when they conform to all of the limitations on continuity and dimensions given herein.

1. The construction shall consist of at least three continuous panels in each direction.
2. The ratio of length to width of panels shall not exceed 1.33.
3. The grid pattern shall consist of approximately rectangular panels. The successive span lengths in each direction shall differ by not more than twenty percent of the longer span. Within these limitations, columns may be offset a maximum of ten percent of the span, in direction of the offset, from either axis between center lines of successive columns.
4. The calculated lateral force moments from wind may be combined with the critical moments as determined by the empirical method, and the lateral force moments shall be

distributed between the column and middle strips in the same proportions as specified for the negative moments.

b. Columns.

1. The minimum dimensions of any column shall be ten inches. For columns or other supports of a flab slab, the required minimum average moment of inertia, I_c, of the gross concrete section of the columns above and below the slab shall be determined from the following formula, and shall not be less than one thousand inches.[4] If there is not column above the slab, the I_c of the column below shall be twice that given by the formula with a minimum of one thousand inches.[4]

$$I_c = \frac{t^3 H}{0.5 + \frac{W_D}{W_L}}$$

(7)

where t need not be taken greater than t_1 or t_2 as determined in section C26-1531.0 d, H is the average story height of the columns above and below the slab, and W_L is the greater value of any two adjacent spans under consideration.

2. Columns supporting flat slabs designed by the empirical method shall be proportioned for the bending moments developed by unequally loaded panels, or uneven spacing of columns. Such bending moment shall be the maximum value derived from

$$(WL_1 - W_D L_2)\frac{l}{f}$$

L_1 and L_2 being lengths of the adjacent spans ($L_2 = 0$ when considering an exterior column) and f is 30 for exterior and 40 for interior columns.

This moment shall be divided between the columns immediately above and below the floor or roof line under consideration in direct proportion to their stiffness and shall be applied without further reduction to the critical sections of the columns.

c. Determination of “c” (effective support size).

1. Where column capitals are used, the value of c shall be taken as the diameter of the cone described in section C26-1528.0b measured at the bottom of the slab or drop panel.

2. Where a column is without a concrete capital, the dimension c shall be taken as that of the column in the direction considered.

3. Brackets capable of transmitting the negative bending and the shear in the column strips to the columns without excessive unit stress may be substituted for column capitals at exterior columns. The value of c for the span where a bracket is used shall be taken as twice the distance from the center of the column to a point where the bracket is one and one-half inches thick, but not more than the thickness of the column plus twice the depth of the bracket.

4. Where a reinforced concrete beam frames into a column without capital or bracket on the same side with the beam, for computing bending for strips parallel to the beam, the value of c for the span considered may be taken as the width of the column plus twice the projection of the beam above or below the slab or drop panel.

5. The average of the values of c at the two supports at the ends of a column strip shall be used to evaluate the slab thickness t_1 or t_2 as prescribed in section C26-1531.0d.

d. Slab thickness.

1. The slab thickness, span L being the longest side of the panel, shall be at least:

L/36 for slab without drop panels conforming with section C26-1531.0e, or when a drop panel is omitted at any corner of the panel, but not less than five inches nor t_1 as given below.

L/40 for slabs with drop panels conforming to section C26-1531.0(e) at all supports, but not less than four inches nor t_2 as given below.

2. The total thickness, t_1 in inches, of slabs without drop panels, or through the drop panel if any, shall be at least.

$$t_1 = 0.028L \quad \left(1 - \frac{2c}{3L}\right) \sqrt{\frac{w'}{f'_c/2000}} + 1\frac{1}{2} *$$

(8)

3. The total thickness, t_2, in inches, of slabs with drop panels, at points beyond the drop panel if any, shall be at least

$$t_2 = 0.024L \quad \left(1 - \frac{2c}{3L}\right) \sqrt{\frac{w'}{f'_c/2000}} + 1\frac{1}{2} *$$

(9)

4. Where the exterior supports provide only negligible restraint to the slab, the value of t_1 and t_2 for the exterior panel shall be increased by at least fifteen percent. Note: *In the above formula, t_1 and t_2 are in inches and L and c are in feet.

e. Drop panels.

1. The maximum total thickness at the drop panel used in computing the negative steel area for the column strip shall be $1.5t_2$.

2. The side or diameter of the drop panel shall be at least 0.33 times the span in the parallel direction.

3. The minimum thickness of slabs where drop panels at wall columns are omitted shall equal $(t_1 + t_2)/2$ provided the value of c used in the computations complies with section C26-1531.0 (c).

f. Bending moment coefficients.

1. The numerical sum of the positive and negative bending moments in the direction of either side of a rectangular panel shall be assumed as not less than

$$M_o = 0.09WLF \quad \left(1 - \frac{2c}{3L}\right)^2$$

(10)

in which F = 1.15-c/L but not less than 1.

2. Unless otherwise provided, the bending moments at the critical sections of the columns and middle strips shall be at least those given in table 1004 (f) ACI 318.56.

3. The average of the values of c at the two supports at the ends of a column strip shall be used to evaluate M_o, as determining bending in the strip. The average of the values of M_o, as determined for the two parallel half column strips in a panel, shall be used in determining bending in the middle strip.

4. Bending in the middle strips parallel to a discontinuous edge shall be assumed the same as in an interior panel.

5. For design purposes, any of the moments determined from table 1004(f)-ACI 318-56 may be varied by not more than 10 percent, but the numerical sum of the positive and negative moments in a panel shall be not less than the amount specified.

g. Length of reinforcement-In addition to the requirements of section C26-1529.0(d), reinforcement shall have the minimum lengths given in tables 1004(g)1 ACI 318-56 and 1004(g)2 ACI 318-56. Where adjacent spans are unequal, the extension of negative reinforcement on each side of the column centerline, as prescribed in table 1004(g)1 ACI 318-56, shall be based on the requirements of the longer span.

h. Openings in flat slabs.

1. Openings of any size may be provided in a flat slab in the area common to two intersecting middle strips provided the total positive and negative steel areas required in section C26-1531.0(f) are maintained.

2. In the area common to two column strips, but not more than one-eighth of the width of strip in any span shall be interrupted by openings. The equivalent of all bars interrupted shall be provided by extra steel on all sides of the openings. The shearing unit stresses given in section C26-1529.0(c)2 shall not be exceeded.

3. In any area common to one column strip, and one middle strip, openings may interrupt one-quarter of the bars in either strip. The equivalent of the bars so interrupted shall be provided by extra steel on all sides of the opening.

4. Any opening larger than described above shall be analyzed by accepted engineering principles and shall be completely framed as required to carry the loads to the columns.

Sub-Article 11
Reinforced Concrete Columns and Walls

§C26-1532.0. Notation relating to reinforced concrete columns and walls.

A_c = area of core of a spirally reinforced column measured to the outside diameter of the spiral; net area of concrete section of a composite column.

A_g =over-all or gross area of spirally reinforced or tied columns; the total area of the concrete encasement of combination columns.

A_r =area of the steel or cast-iron core of a composite column; the area of the steel core in a combination column.

A_s = effective cross-sectional area of reinforcement in compression in columns.

B = trial factor (see section C26-1541.0-c).

e = eccentricity of the resultant load on a column measured from the gravity axis.

F_a =nominal allowable axial unit stress (0.225 $f'_c + f_s p_g$) for spiral columns and 0.8 of this value for tied columns.

F_b =allowable bending unit stress that would be permitted if bending stress only existed.

f_a = nominal axial unit stress = axial load divided by area of member, A_g.

f_b = bending unit stress (actual = bending moment divided by section modulus of member.

f_c = computed concrete fiber stress in an eccentrically loaded column where the ratio of e/t is greater than 2/3.

f'_c = compressive strength of concrete at age of twenty-eight days, unless otherwise specified.

f_r = allowable unit stress in the metal core of a composite column.

f'_r =allowable unit stress on unencased steel columns and pipe columns.

f_s = nominal allowable stress in vertical column reinforcement.

f'_s =useful limit stress of spiral reinforcement.

h = unsupported length of column.

K_c =radius of gyration of concrete in pipe columns.

K_s =radius of gyration of a metal pipe section (in pipe columns.)

N = axial load applied to reinforced concrete column.

p' = ratio of volume of spiral reinforcement of the volume of the concrete core (out to out of spirals) of a spirally reinforced concrete column.

p_g = ratio of the effective cross-sectional area of vertical reinforcement to the gross area A_g.

P = total allowable axial load on a column whose length does not exceed ten times its least cross-sectional dimension.

P' = total allowable axial load on a long column.

t = over-all depth of rectangular column section, or the diameter of a round column.

§C26-1533.0. Limiting dimensions.-

a. The following sections on reinforced concrete and composite columns, except section C26-1539.0a apply to a short column for which the unsupported length is not greater than ten times the least dimension. When the unsupported length exceeds this value, the design shall be modified as shown in section C26-1539.0(a). Principal columns in buildings shall have a minimum diameter of twelve inches, or in the case of rectangular columns, a minimum thickness of eight inches, and a minimum gross area of one hundred and twenty square inches. Posts that are not continuous from story to story shall have a minimum diameter or thickness of six inches.

§C26-1534.0. Unsupported length of columns.-

a. For purposes of determining the limiting dimensions of columns, the unsupported length of reinforced concrete columns, shall be taken as the clear distance between floor slabs, except that

1. In flat slab construction, it shall be the clear distance between the floor and the lower extremity of the capital, the drop panel or the slab, whichever is least.
2. In beam and slab construction, it shall be the clear distance between the floor and the under side of the deeper beam framing into the column in each direction at the next higher floor level.
3. In columns restrained laterally by struts, it shall be the clear distance between consecutive struts in each vertical plane; provided that to be an adequate support, two such struts shall meet the column at approximately the same level, and the angle between vertical planes through the struts shall not vary more than fifteen degrees from a right angle. Such struts shall be of adequate dimensions and anchorage to restrain the column against lateral deflection.
4. In columns restrained laterally by struts or beams, with brackets used at the junction, it shall be the clear distance between the floor and the lower edge of the bracket, provided that the bracket width equals that of the beam or strut and is at least half that of the column.

b. For rectangular columns, that length shall be considered which produces the greatest ratio of length to depth of section.

§C26-1535.0. Spirally reinforced columns.-

a. Allowable load-The maximum allowable axial load, P, on columns, with closely spaced spirals enclosing a circular concrete core reinforced with vertical bars shall be given by formula (11).

$$P = A_g(0.225f'_c) + f_s p_g$$

(11)

Wherein f_s = nominal allowable stress in vertical column reinforcement, to be taken at forty percent of the minimum specification value of the yield point; viz., sixteen thousand pounds per square inch for intermediate grade steel and twenty thousand pounds per square inch for rail or hard grade steel. Nominal allowable stresses for reinforcement of higher yield point may be established at forty percent of the yield point stress, but not more than thirty thousand pounds per square inch when the properties of such reinforcing steels have been definitely specified by standards of ASTM designation. If this is done, the length of splice required by section C26-1535.0c shall be increased accordingly.

b. Vertical reinforcement-The ratio p_g shall not be less than 0.01 nor more than 0.08. The minimum number of bars shall be six, and the minimum bar size shall be Number 5. The center to center spacing of bars within the periphery of the column core shall not be less than two and one-half times the diameter for round bars or three times the side dimension for square bars. The clear spacing between individual bars or between pairs of bars at lapped splices shall not be less than one and one-half inches or one and one-half times the maximum size of the coarse aggregate used. These spacing rules also apply to adjacent pairs of bars at a lapped splice; each pair of lapped bars forming a splice may be in contact, but the minimum clear spacing between one splice and the adjacent splice should be that specified for adjacent single bars.

c. Splices in vertical reinforcement-Where lapped splices in the column verticals are used, the minimum amount of the lap shall be as follows:

1. For deformed bars with concrete having a strength of three thousand pounds per square inch or more, twenty diameters of bar of intermediate or hard grade steel. For bars of higher yield point, the amount of lap shall be increased one diameter for each one thousand pounds per square inch by which the allowable stress exceeds twenty thousand pounds per square inch. When the concrete strengths are less than three thousand pounds per square inch, the amount of lap shall be one third greater than the values given above.

2. For plain bars, the minimum amount of lap shall be twice that specified for deformed bars.

3. Welded splices or other positive connections may be used instead of lapped splices. Welded splices shall preferably be used in cases where the bar size exceeds No. 11. An approved welded splice shall be defined as one in which the bars are butted and welded and that will develop in tension at least the yield point stress of the reinforcing steel used. Welded splices may be either thermite or arc-welded, if the steel analyses indicates its suitability for welding. All welding shall be in accord with the Board rules and conform to AWS Bulletin D12.1-61.

4. Where longitudinal bars are offset at a splice, the slope of the inclined portion of the bar with the axis of the column shall not exceed one in six, and the portions of the bar above and below the offset shall be parallel to the axis of the column. Adequate horizontal support at the offset bends shall be treated as a matter of design, and may be provided by metal ties, spirals or parts of the floor construction. Metal ties or spirals so

designed shall be placed near (never more than eight bar diameters from) the point of bend. The horizontal thrust to be resisted may be assumed as one and one-half times the horizontal component of the nominal stress in the inclined portion of the bar.

Offset bars shall be bent before they are placed in the forms. No field bending of bars partially embedded in concrete shall be permitted.

d. Spiral reinforcement-The ratio of spiral reinforcement, p' shall not be less than the value given by formula (12).

$$p' = 0.45 \quad \left(\frac{A_g}{A_c} - 1\right)^{f'_c}$$

(12)

Wherein f'_s = useful limit stress of spiral reinforcement, to be taken as forty-thousand pounds per square inch for hot rolled rods of intermediate grade, fifty-thousand pounds per square inch for rods of hard grade, and sixty-thousand pounds per square inch for cold drawn wire.

The spiral reinforcement shall consist of evenly spaced continuous spirals held firmly in place and true to line by vertical spacers, using at least two for spirals twenty inches or less in diameter, three for spirals twenty to thirty inches in diameters, and four for spirals more than thirty inches in diameter or composed of spiral rods five-eighths of an inch or larger in size. The spirals shall be of such size and so assembled as to permit handling and placing without being distorted from the designed dimensions. The material used in spirals shall have a minimum diameter of one-quarter of an inch for rolled bars or No. 4 AS&W gage for drawn wire. Anchorage for spiral reinforcement shall be provided by one and one-half extra turns for spiral rod or wire at each end of the spiral unit. Splices when necessary shall be made in spiral rod or wire by welding or by a lap of one and one-half turns. The center to center placing of the spirals shall not exceed one-sixth of the core diameter. The clear spacing between spirals shall not exceed three inches nor less than one and three-eighths inches or one and one-half times the maximum size of coarse aggregate used. The reinforcing spiral shall extend from the floor level in any story or from the top of the footing in the basement, to the level of the lowest horizontal reinforcement in the slab, drop panel or beam above. In a column with a capital, it shall extend to a plane at which the diameter or width of the capital is twice that of the column.

e. Protection of reinforcement-The column spiral reinforcement shall be protected everywhere by a covering of concrete cast monolithically with the core, for which the thickness shall not be less than two inches nor less than one and one-half times the maximum size of the coarse aggregate, nor shall it be less than required by the fire protection and weathering provisions of C26-1495.0.

f. Isolated column with multiple spirals-In case two or more interlocking spirals are used in a column, the outer boundary of the column shall be taken as a rectangle the sides of which are outside the extreme limits of the spiral at a distance equal to the requirements of section C26-1535.0e.

g. Limits of section of column built monolithically with wall-For a spiral column built monolithically with a concrete wall or pier, the outer boundary of the column section shall be taken either as a circle at least one and one-half inches outside the column spiral or a square or rectangle of which the sides are at least one and one-half inches outside the spiral of spirals.

h. Equivalent circular columns-As an exception to the general procedure of utilizing the full gross area of the column section, it shall be permissible to design a circular column and to build it with a square, octagonal, or other shaped section of the same least lateral dimension. In such case, the allowable load, the gross area considered, and the required percentages of reinforcement shall be taken as those of the circular column.

§C26-1536.0. Tied columns.-

a. Allowable load-The maximum allowable axial load on columns reinforced with longitudinal hard and separate lateral ties shall be eighty percent of that given by formula (11). The ratio, P_g, to be considered in tied columns, shall not be less than 0.01 nor more than 0.04. The longitudinal reinforcement shall consist of at least four bars, of minimum bar size of No.5. Splices in reinforcing bars shall be made as described in section C26-1535.0c. The spacing requirements for vertical reinforcement in section C26-1535.0b shall also apply for all tied columns.

b. Combined axial and bending load-For tied columns which are designed to withstand combined axial and bending stresses, the limiting steel ratio of 0.04 may be increased to 0.08. The amount of steel spliced by lapping shall not exceed a steel ratio of 0.04 in any three-foot length of column. The size of the column designed under this provision shall in no case be less than that required to withstand the axial load alone with a steel ratio of 0.04.

c. Lateral ties-Lateral ties shall be at least one-quarter inch in diameter and shall be spaced apart not over sixteen bar diameters, forty-eight tie diameters, or the least dimension of the column. When there are more than four vertical bars, additional ties shall be provided so that every longitudinal bar is held firmly in its designed position and has lateral support equivalent to that provided by a ninety-degree corner of a tie.

d. Limits of column section-In a tied column which for architectural reasons has a larger cross section than required by considerations of loading, a reduced effective area, A_g, not less than one-half of the total area, may be used in applying the provisions of section C26-1536.0a.

§C26-1537.0. Composite columns.-

a. Allowable load-The allowable load on a composite column, consisting of a structural steel or cast iron column thoroughly encased in concrete reinforced with both longitudinal and spiral reinforcement, shall not exceed that given by formula (13).

$$P = 0.225\, A_c f'_c + f_s A_s + f_r A_r$$

(13)

Wherein f_r = allowable unit stress in metal core, not to exceed sixteen thousand pounds per square inch for a steel core; or ten thousand pounds per square inch for a cast-iron core.

b. Details of metal core and reinforcement-The cross-sectional area of the metal core shall not exceed twenty percent of the gross area of the column. If a hollow metal core is used it shall be filled with concrete. The amounts of longitudinal and spiral reinforcement and the requirements as to spacing of bars, details of splices and thickness of protective shell outside the spiral shall conform to the limiting values specified in section C26-1535.0b, c, d, and e. A clearance of at least three inches shall be maintained between the spiral and the metal core at all points except that when the core consists of a structural H-column, the minimum clearance may be reduced to two inches.

c. Splices and connections of metal cores-Metal cores in composite columns shall be accurately milled at splices and positive provision shall be made for alignment of one core above another. At the column base, provision shall not be made to transfer the load to the footing at safe unit stresses in accordance with section C26-1480.0a. The base of the metal shall be designed to transfer the load from the entire metal section only, provided it is so placed in the pier or pedestal as to leave ample section of concrete above the base for the transfer of load from reinforced concrete section of the column by means of bond on the vertical reinforcement and by direct compression on the concrete. Transfer of loads to the metal core shall be provided for by the use of bearing members such as billets, brackets or other positive connections. These shall be provided at the top of the metal core and at intermediate floor levels where required. The column as a whole shall satisfy the requirements of formula (13) at any point; in addition to this, the reinforced concrete portion shall be designed to carry, in accordance with formula (11), all floor loads brought onto the column at levels between the metal brackets or connections. In applying formula (11), the value of A_g, shall be interpreted as the area of the concrete section outsides the metal core, and the allowable load on the reinforced concrete section shall be further limited to $0.35f'_cA_g$. Ample section of concrete and continuity of reinforcement shall be provided at the junction with beams or girders.

d. Allowable load on metal core only-The metal core of composite columns shall be designed to carry safely any construction or other loads to be placed upon them prior to their encasement in concrete.

§C26.1538.0. Combination columns.-

a. Steel columns encased in concrete-The allowable load on a structural steel column which is encased in concrete at least two and one-half inches thick over all metal (except rivet heads) reinforced as hereinafter specified, shall be computed by formula (14).

$$P = A_r f'_r \left[+ \frac{A_g}{100A_r} \right]$$

(14)

The concrete used shall develop a compressive strength, f'_c, of at least 2,000 pounds per square inch at twenty-eight days. The concrete shall be reinforced by the equivalent of welded wire mesh having wires of Number ten AS&W gage, the wires encircling the column being spaced not more than four inches apart and those parallel to the column axis not more than eight inches apart. This mesh shall extend entirely around the column at a distance of one inch inside the outer concrete surface and shall be lap-spliced at least forty wire diameters and wired at the splice. Special brackets shall be used to receive the entire floor load at each floor level. The steel column shall be designed to carry safely any construction or other loads to be placed upon it prior to its encasement in concrete.

b. Pipe columns-The allowable load on columns consisting of steel pipe filled with concrete shall be determined by formula (15).

$$P = 0.25f'_c \left(1 - 0.000025\frac{h^2}{K_s^2}\right) A_c + f'_r A_s$$

(15)

The value of f'_r shall be given by formula (16) when the pipe has a yield strength of at least thirty-three thousand pounds per square inch, and an h/K_s ratio equal to or less than one hundred and twenty.

$$f'_r = 17{,}000 - 0.485\frac{h^2}{K_s^2}$$

(16)

§C26-1539.0. Long columns.-

a. The maximum allowable load, P', on axially loaded reinforced concrete or composite columns having an unsupported length, h, greater than ten times the least lateral dimension, t, shall be given by formula (17).

$$P' = P\,(1.3 - 0.03\,h/t$$

(17)

where P is the allowable axial load on a short column as given by sections C26-1535.0, C26-1536.0 and C26-1537.0.

The maximum allowable, P', on eccentrically loaded columns in which h/t exceeds ten shall also be given by formula (17), in which P is the allowable eccentrically applied load on a short column as determined by the provisions of section C26-1451.0. In long columns subjected to definite bending stresses, as determined in section C26-1540.0, the ratio h/t shall not exceed twenty.

§C26-1540.0. Bending moment in columns.-

a. The bending moments in the columns of all reinforced concrete structures shall be determined on the basis of loading conditions and restraint and shall be provided for in the design. When the stiffness and strength of the columns are utilized to reduce moments in beams, girders, or slabs, as in the case of rigid frames, or in other forms of continuous construction wherein column moments are unavoidable, they shall be provided for in the design. In building frames, particular attention shall be given to the effect of unbalanced floor loads on both exterior and interior columns and of eccentric loading due to other causes. In computing moments in columns, the far ends may be considered fixed. Columns shall be designed to resist the axial forces from loads on all floors, plus the maximum bending due to loads on a single adjacent span of the floor under consideration.

Resistance to bending moments at any floor level shall be provided by distributing the moment between the columns immediately above and below the given floor in proportion to their relative stiffness and conditions of restraint.

§C26-1541.0. Columns subjected to axial load and bending.-

a. Members subject to an axial load and bending in one principal plane, but with the ratio of eccentricity to depth e/t no greater than 2/3, shall be so proportioned that

$$\frac{f_a}{F_a} + \frac{f_b}{F_b} \text{ does not exceed unity}$$

(18)

b. When bending exists on both of the principal axes, formula (18) becomes

$$\frac{f_a}{F_a} + \frac{f_{bx}}{F_b} + \frac{f_{by}}{F_b} \text{ does not exceed unity}$$

(19)

where f_{bx} and f_{by} are the bending moment components that the x and y principal axes divided by the section modulus of the transformed section relative to the respective axes, provided that the ratio e/t is no greater than 2/3 in either direction.

c. In designing a column subject to both axial load and bending, the preliminary selection of the column may be made by use of an equivalent axial load given by formula (20).

$$P = N\left(1 + \frac{Be}{t}\right)$$

(20)

When bending exists on both of the principal axes, the quantity Be/t is the numerical sum of the Be/t quantities in the two directions.

For trial computations B and may be taken from three to three and one-half for rectangular tied columns, the lower value being used for columns with the minimum amount of reinforcement. Similarly for circular spiral columns, the value of B from five to six may be used.

d. For columns in which the load N, has an eccentricity, e, greater than 2/3 the column depth, t, the determination of the fiber stress f_c shall be made by use of recognized theory for cracked sections, based on the assumption that the concrete does not resist tension. In such cases the modular ratio for the compressive reinforcement shall be assumed as double the value given in section C26-1497.0; however the stress in the compressive reinforcement when calculated on this basis, shall not be greater than the allowable stress in tension. The maximum combined compressive stress in the concrete shall not exceed $0.45f'_c$. For such cases the tensile steel stress shall also be investigated.

§C26-1542.0. Wind stress.-

a. When the allowable stress in columns is modified to provide for combined axial load and bending, and the stress due to wind loads is also added, the total shall still come within the allowable values specified for wind loads in section C26-1499.0 (c).

§C26-1543.0. Reinforced concrete walls.-

a. The allowable stresses in reinforced concrete bearing walls with a minimum reinforcement as required by section C26-1543.0h shall be $0.25f_c$ for walls having a ratio of height to thickness of ten or less, and shall be reduced proportionately to $0.15f'_c$ for wall having a ratio of height to thickness of twenty-five. When the reinforcement in bearing walls is designed, placed, and anchored in position as for tied columns, the allowable stresses shall be on the basis of section C26-1536.0, as for columns. In the case of concentrated loads, the length of the wall to be considered as effective for each shall not exceed the center to center distance between loads, nor shall it exceed the width of the bearing plus four times the wall thickness. The ratio p_g shall not exceed 0.04.

b. Walls shall be designed for any lateral or other pressure to which they are subjected: Proper provision shall be made for eccentric loads and wind stresses. In such designs the allowable stresses shall be given in section C26-1480.0 and section C26-1499.0c.

c. Panel and enclosure walls of reinforced concrete shall have thickness of not less than four inches and not less than one-thirtieth the distance between the supporting or enclosing members.

d. Reinforced concrete bearing walls of buildings shall not be less than six inches thick for the upper most fifteen feet of their height; and for each successive twenty-five feet downward, or fraction thereof, the minimum thickness shall be increased one inch. Reinforced concrete bearing walls of two-story dwellings may be six inches thick throughout their height.

e. Exterior basement walls, foundation walls, and party walls shall not be less than eight inches thick whether reinforced or not.

f. Reinforced concrete bearing walls shall have a thickness of at least one-twenty-fifth of the unsupported height or width, whichever is the shorter.

g. Reinforced concrete walls shall be anchored to the floors, or to the columns, pilasters, buttresses, and intersecting walls with reinforcement at least equivalent to No. 3 bars twelve inches on center, for each layer of wall reinforcement.

h. The area of the horizontal reinforcement of reinforced concrete walls shall be not less than 0.0025 and that of the vertical reinforcement not less than 0.0015 times the area of the reinforced section of the wall if of bars, and not less than three-fourths as much if welded wire fabric or A.S.T.M. A432-62T and A16-62T special grade bars. The wire of the welded fabric shall be of not less than No. 10 AS&W gage. Walls more than ten inches thick, except for basement walls, shall have the reinforcement for each direction placed in two layers parallel with the faces of the wall. One layer consisting of not less than one-half and not more than two-thirds the total required shall be placed not less than two inches nor more than one-third the thickness of the wall from the exterior surface. The other layer, comprising the balance of the required reinforcement, shall be placed not less than three-quarters of an inch and not more than one-third the thickness of the wall from the interior surface. Bars, if used, shall not be less than No. 3 bars, nor shall they be spaced more than eighteen inches on centers. Welded wire reinforcement for walls shall be in flat sheet form.

i. In addition to the minimum as prescribed in section C26-1543.0h there shall be not less than two No. 5 bars around all windows or door openings. Such bars shall extend at least 24 inches beyond the corner of the opening.

j. Where reinforced concrete bearing walls consist of studs or ribs tied together by reinforced concrete members at each floor level, the studs may be considered as columns, but the restrictions as to minimum diameter or thickness of columns shall not apply.

k. The limits of thickness and quantity or reinforcement may be waived where structural analysis shows adequate strength and stability.

§C26-1544.0. Fire resistance of concrete walls and partitions.-

a. Reinforced concrete walls built in conformity with section C26-1543.0 may be used for the purposes described in the following sections of this code:

1. Six inch thick wall as a fire wall under section C26-631.0.
2. Five inch thick wall as a fire partition under section C26-633.0.
3. Four inch thick wall as a fire resistive stairway enclosure where a two-hour fire-resistive rating is acceptable under Section C26-635.0.

b. A solid three inch thick cinder concrete partition (poured or block) may be used as a fireproof partition under section C26-636.0 of this code.

c. Poured in place concrete used for fireproofing of steel shall be tied with wire mesh weighing at least one and one-half pounds per square yard which shall be of a type approved by the board.

§C26-1545.0. Plain concrete.-The general requirements governing plain concrete masonry poured in place, as to workmanship, bond, anchors, forms, tests, construction details and miscellaneous provisions shall be the same as the requirements prescribed in sections C26-1455.0 through C26-1556.0 except that the thickness shall comply with section C26-432.0 of this code.

§C26-1546.0. Concrete chimneys.-Concrete chimneys shall comply with the requirements of subdivisions (a) and (c) of section C26-710.0 of this code.

Sub-Article 12
Footings

§C26-1547.0. Scope.-

a. The requirements prescribed in section C26-1548.0 to C26-1555 apply only to isolated footings.

§C26-1548.0. Loads and reactions.-

a. Footings shall be proportioned to sustain the applied loads and induced reactions without exceeding the allowable stresses as prescribed in sections C26-1480.0 and C26-1481.0, and as further provided in sections C26-1551.0, C26-1552.0 and C26-1553.0.

b. In cases where the footing is concentrically loaded and the member being supported does not transmit any moment to the footing, computations for moments and shears shall be based on an upward reaction assumed to be uniformly distributed per unit area or per pile and a downward applied load assumed to be uniformly distributed over the area of the footing covered by the column, pedestal, wall, or metallic column base.

c. In cases where the footing is eccentrically loaded and/or the member being supported transmits a moment to the footing, proper allowance shall be made for any variation that may exist in the intensifies of reaction and applied load consistent with the magnitude of the applied load and the amount of its actual or virtual eccentricity.

d. In the case of footings on piles, computations for moments and shears may be based on the assumption that the reaction from any pile is concentrated at the center of the pile.

§C26-1549.0. Sloped or stepped footings.-

a. In sloped or stepped footings, the angle of slope or depth and location of steps shall be such that the allowable stresses are not exceeded at any section.

b. In sloped or stepped footings, the effective cross section in compression shall be limited by the area above the neutral plane.

c. Sloped or stepped footings shall be cast as a unit.

§C26-1550.0. Bending moment.-

a. The external moment on any section shall be determined by passing through the section a vertical plane which extends completely across the footing, and computing the moment of the forces acting over the entire area of the footing on one side of said plane.

b. The greatest bending moment to be used in the design of all isolated footing shall be the moment computed in the manner prescribed in section C26-1550.0a at sections located as follow:

1. At the face of the column, pedestal or wall, for footings supporting a concrete column, pedestal or wall.
2. Halfway between the middle and the edge of the wall, for footings under masonry walls.
3. Halfway between the face of the column or pedestal and the edge of the metallic base, for footings under metallic bases.

c. The width resisting compression at any section shall be assumed as the entire width of the top of the footing at the section under consideration.

d. In one-way reinforced footings, the total tensile reinforcement at any section shall provide a moment of resistance at least equal to the moment computed in the manner prescribed in section C26-1550.0a; and in reinforcement thus determined shall be distributed uniformly across the full width of the section.

e. In two-way reinforced footings, the total tensile reinforcement at any section shall provide a moment of resistance at least equal to eighty-five percent of the moment computed in the manner prescribed in section C26-1550.0a; and the total reinforcement thus determined shall be distributed across the corresponding resisting section in the manner prescribed for the square footings in section C26-1550.0f, and for rectangular footings in section C26-1550.0g.

f. In two-way square footings, the reinforcement extending in each direction shall be distributed uniformly across the full width of the footing.

g. In two-way rectangular footings, the reinforcement in the long direction shall be distributed uniformly across the full width of the footing. In the case of the reinforcement in the short direction, that portion determined by formula (21) shall be uniformly distributed across a band-width (B) centered with respect to the centerline of the column or pedestal and having a width equal to the length of the short side of the footing. The remainder of the reinforcement shall be uniformly distributed in the outer portion of the footing.

$$\frac{\text{Reinforcement in band} - \text{width (B)}}{\text{Total reinforcement in short direction}} = \frac{2}{(S+1)}$$

(21)

In formula (21), S is the ratio of the long side to the short side of the footing.

§C26-1551.0. Shear and bond.-

a. The critical section for shear to be used as a measure of diagonal tension shall be assumed as a vertical section obtained by passing a series of vertical planes through the footing, each of which is parallel to a corresponding face of the column, pedestal, or wall and located a distance therefrom equal to the depth d for footings on soil, and one-half the depth d for footings on piles.

b. Each face of the critical section as defined in Section C26-1551.0(a) shall be considered as resisting an external shear equal to the load on an area bounded by said face of the critical section for shear, two diagonal lines drawn from the column or pedestal corners and making forty-five degrees angles with the principal axes of the footing, and that portion of the corresponding edge or edges of the footing intercepted between the two diagonals.

c. Critical sections for bond shall be assumed at the same planes as those prescribed for bending moment in section C26-1550.0(b); also at all other vertical planes where changes of section or of reinforcement occur.

d. Computation for shear to be used as a measure of bond shall be based on the same section and loading as prescribed for bending moment in section C26-1550.0(a).

e. The total tensile reinforcement at any section shall provide a bond resistance at least equal to the bond requirement as computed from the following percentages of the external shear at the section:

1. in one-way reinforced footings one-hundred percent.
2. in two-way reinforced footings, eighty-five percent.

f. In computing the external shear on any section through a footing supported on piles, the entire reaction from any pile whose center is located six inches or more outside the section shall be assumed as producing shear on the section; the reaction from any pile whose center is located six inches or more inside the section shall be assumed as producing no shear on the section. For intermediate positions of the pile center, the portion of the pile reaction to be assumed as producing shear on the section shall be based on straight-line interpolation between full value at six inches outside the section and zero value at six inches inside the section.

g. For allowable shearing stress, see sections C26-1480.0 and C26-1519.0.

h. For allowable bond stresses, see sections C26-1480.0 and C26-1521.0 through C26-1552.0.

§C26-1552.0. Transfer of stress at base of column.-

a. The stress in the longitudinal reinforcement of a column or pedestal shall be transferred to its supporting pedestal or footing either by extending the longitudinal bars into the supporting member, or by dowels.

b. In case the transfer of stress in the reinforcement is accomplished by extension of the longitudinal bars, they shall extend into the supporting member the distance required to transfer to the concrete, by allowable bond stress, their full working value.

c. In cases where dowels are used, their total sectional area shall be not less than the sectional area of the longitudinal reinforcement in the member from which the stress is being transferred. In no case shall the number of dowels per member be less than four and the diameter of the dowels shall not exceed the diameter of the column bars by more than one-eighth inch.

d. Dowels shall extend up to the column or pedestal a distance at least equal to that required for lap of longitudinal column bars (see section C26-1535.0) and down into the supporting pedestal or footing the distance required to transfer to the concrete, by allowable bond stress, the full working value of the dowel (see section C26-1526.60c).

e. The compressive stress in the concrete at the base of the column or pedestal shall be considered as being transferred by bearing to the top of the supporting pedestal or footing. The unit compressive stress on the loaded area shall not exceed the bearing stress allowable for the quality of concrete in the supporting member as limited by the ratio of the loaded area to the supporting area.

f. For allowable bearing stresses (see section C26-1480.0).

g. In sloped or stepped footings, the supporting area for bearing may be taken as the top horizontal surface of the footing, or assumed as the area on the lower base of the largest frustum of a pyramid or cone contained wholly within the footing and having for its upper base the area actually loaded, and having side slopes of one vertical to two horizontal.

§C26-1553.0. Pedestals and footings (plain concrete).-

a. The allowable compressive unit stress on the gross area of a concentrically loaded pedestal shall not exceed $0.25f'_c$. Where this stress is exceeded, reinforcement shall be provided and the member designed as a reinforced concrete column.

b. The depth and width of a pedestal or footing of plain concrete shall be such that the tension in the concrete shall not exceed $0.03f'_c$ or shall not exceed fifty pounds per square inch, and the average shearing stresses shall not exceed $0.02f'_c$ taken on sections as prescribed in section C26-1550.0 and C26-1551.0 for reinforced concrete footings.

§C26-1554.0. Footings supporting round columns.-

a. In computing the stresses, footings which support a round or octagonal concrete column or pedestal, the face of the column or pedestal shall be taken as the side of a square having an area equal to the area enclosed within the perimeter of the column or pedestal.

§C26-1555.0. Minimum edge-thickness.-

a. In reinforced concrete footings, the thickness above the reinforcement at the edge shall be not less than six inches for footings on soil, nor less than twelve inches for footings on piles.

b. In plain concrete footings, the thickness at the edge shall be not less than eight inches for footings on soil, nor less than fourteen inches above the tops of the piles for footings on piles.

§C26-1556.0. Foundation piers.-

a. The minimum diameter of foundation piers shall be two feet and the method of their installation and construction shall be such as to provide for accurate preparation and inspection of their bottoms, and to insure sound concrete.

b. The design of foundation piers built of concrete shall be governed by the requirements of Sections C26-1455.0 through C26·1554.0, provided that for a foundation pier, constructed of plain concrete, the height of which pier exceeds six times its least horizontal dimension, except where the least horizontal dimension is six feet or greater, the maximum allowable working stress shall be determined by the following formula:

$$f' \text{equals } f_c \left(1.3 \text{ minus } \frac{H}{20D}\right)$$

in which f' is the reduced allowable working stress in pounds per square inch.

f^c is the allowable bearing working stress in pounds per square inch given in section C26-1480.0.

H is the height of the pier in feet.

D is the least horizontal dimension in feet.

c. The height shall in all cases be at most twelve times the least horizontal dimension, and the compressive stress shall be at most eight hundred fifty pounds per square inch.

d. If piers are constructed of reinforced concrete, such piers may be constructed with spiral or vertical reinforcement as prescribed in section C26-1455.0 through C26-1554.0 except that when all other conditions of such sections are fulfilled the provisions of section C26-1539.0 shall be applicable. Such construction shall be subject to the following modifications:

1. The maximum allowance for spiral reinforcement shall be limited to one percent and the maximum stress permitted on the gross section, including vertical reinforcement, shall be limited to one thousand pounds per square inch.
2. When such piers are spirally reinforced, and are six feet or greater in diameter, or where the ratio of height to diameter of such piers is twelve to one or less, vertical reinforcement may be omitted, the factor "p_g" in the formula for columns with spiral reinforcement, prescribed in subdivision a of Section C26-1535.0 becoming zero. $P=A_c f_c (1 + 15p_g + 50 P')$
3. A minimum of three-quarters of one percent of vertical reinforcement uniformly spaced around the perimeter shall be used in all other cases.

e. Where a pier is circular and entirely encased by a steel shell having a minimum thickness of three-eighths of an inch, such percentage of the shell thickness as corresponds with the efficiency of the vertical joint may be considered as the equivalent of an equal volume of the spiral reinforcement required by subdivision d of section C26-1535.0. If horizontal joints are spliced, the shell may be considered as the vertical as well as the spiral reinforcement up to the efficiency of the horizontal joints in tension.

f. It shall be unlawful to design the bases of foundation piers so that the presumptive capacity of the bearing material is exceeded. The presumptive capacity of hard rock may, however, be increased above that stated in section C26-377.0 to equal the unit compression in the pier itself, provided all of the following conditions are satisfied:

1. Such pier bears on hard sound bed rock which is substantially level and the bearing surface of which is prepared by hand in level or benched areas.
2. Such loaded areas are ten feet or more from the lot line or forty feet or more from the curb level.

3. Forty-five degree slopes extending downward from the periphery of the bearing areas fall outside of and below any adjoining excavation.

Sub-Article 13
Precast Concrete

§C26-1557.0. Scope.-

a. All provisions of this code shall apply to precast concrete except for the specific variations given in this sub article.

§C26-1558.0. Aggregates.-

a. The maximum size of aggregate shall not be larger than one-third of the least dimension of the member.

§C26-1559.0. Concrete protection for reinforcement.-

a. At surfaces not exposed to weather, all reinforcement shall be protected by concrete equal to the nominal diameter of bars but not less than five-eighths inch.

§C26-1560.0. Details.-

a. All details of jointing, inserts, and anchors shall be shown on the drawings.

§C26-1561.0. Curing.-

a. 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 required by section C26-1480.0 provided that the compressive strength of the concrete at the time of use be at least equal to the specified design strength.

§C26-1562.0. Identification and marking.-

a. All precast concrete members shall be plainly marked to indicate the top of the member and its location and orientation in the structure. Identification marks shall be duplicated on the placing plans.

§C26-1563.0. Transportation, storage, and erection.-

a. Units shall be so stored, transported, and placed that they will not be over-stressed or damaged.

b. Precast concrete units shall be adequately braced and supported during erection to insure proper alignment and safety and such bracing or support shall be maintained until there are adequate permanent connections.

§C26-1564.0. Inspections and reports.-The inspection of precast concrete shall also include the inspection of the manufacture of the precast members and of the methods of placing and securing same in the structure. The records of inspection shall include reports of every step taken in the manufacture of the members and the erection of the structure.