Building Code Requirements for Reinforced Masonry

Handbook 74

United States Department of Commerce
National Bureau of Standards

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Building Code Requirements for Reinforced Masonry

By

Sectional Committee on Building Code Requirements and Good Practice Recommendations for Masonry—A41

Under the Sponsorship of the
National Bureau of Standards

Approved

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Foreword

This is the first edition of a standard on requirements for reinforced masonry. It is a complete code of minimum requirements for reinforced masonry construction, including definitions and requirements for materials, structural design, and allowable stresses. This document, prepared by American Standards Association Sectional Committee A41, under the sponsorship of the National Bureau of Standards, is one of a series of related standards being developed by various committees under the jurisdiction of the Construction Standards Board of the American Standards Association.

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The Sectional Committee on Building Code Requirements and Good Practice Recommendations for Masonry, A41, which developed this standard had the following personnel at the time of approval:

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Building Code Requirements for Reinforced Masonry

1. General

1.1. Scope. This standard covers requirements suitable for use in building codes, applying to the design and construetion of reinforced masonry in building construction. It does not include requirements for reinforced concrete, reinforced gypsum concrete, nor requirements concerning fire protection.

1.2. Administration.[1]

(a) Drawings and typical details of all reinforced masonry construction showing the sizes and position of all structural members, steel reinforcement, design strengths, live loads, and lateral forces used in the design shall be filed with the building department before a permit to construct such work shall be issued. Calculations pertaining to the design shall be submitted, if requested by the building official.

(b) The sponsors of any system of reinforced masonry which has been in successful use or the adequacy of which has been shown by test and the design of which is either in conflict with or not covered by these regulations shall have the right to present the data on which their design is based in accordance with the provisions of the building code regarding alternate materials and constructions.

(c) Satisfactory assurances shall be given the building offieial that sufficient supervision will be provided to obtain the required quality of workmanship. If the building official is not satisfied that the extent of supervision and inspection provided will assure such workmanship, he may require that the allowable stresses used in design be reduced.

1.3. Definitions. Unless otherwise expressly stated, the following terms shall, for the purpose of this standard, have the meanings indicated in this section. Where terms are not defined in this section, they shall have their ordinarily accepted meanings, or such as the context may imply.

1.3.1. ***Bonder* (*Header*).** A masonry unit which ties two or more wythes (leaves) of the wall together by overlapping, such as a header.

1.3.2. ***Column.*** A compression member, vertical or nearly vertical, whose width does not exceed four times its thickness and the height of which exceeds three times its least lateral dimension.

[1] Applicable only when the local building code does not have a similar requirement.

1.3.3. ***Concrete.*** A mixture of portland cement, aggregates and water.

1.3.4. ***Cross-sectional Area.*** Net cross-sectional area of a masonry unit shall be taken as the gross cross-sectional area minus the area of cores or cellular space. Gross cross-sectional area of scored units shall be determined to the outside of the scoring but the cross-sectional area of the grooves shall not be deducted from the gross cross-sectional area to obtain the net cross-sectional area.

1.3.5. ***Deformed Bar.*** A reinforcing bar conforming to the Standard Specifications for Minimum Requirements for Deformations of Deformed Steel Bars for Concrete Reinforcement (ASTM A305–56 T). Bars not conforming to these specifications are classed as plain bars.

1.3.6. ***Effective Area of Reinforcement.*** The area obtained by multiplying the right cross-sectional area of the metal reinforcement by the cosine of the angle between its direction and the direction for whieh the effectiveness of the reinforcement is to be determined.

1.3.7. ***Grout.*** Mixture of eementitious material and aggregate to which sufficient water is added to produce pouring consistency without segregation of the constituents.

1.3.8. ***Header*** (see Bonder).

1.3.9. ***Hollow Masonry Unit.*** A masonry unit whose net cross-sectional area in any panel parallel to the bearing surface is less than 75 percent of its gross cross-sectional area measured in the same plane. (See Cross-Sectional Area.)

1.3.10. ***Leaf* (*leaves*).** (See Wythe.)

1.3.11. ***Masonry Unit.*** Any brick, tile, or block conforming to the requirements of section 3.

1.3.12. ***Mortar.*** A plastic mixture of cementitious material, fine aggregate and water.

1.3.13. ***Partially Reinforced Masonry Walls.*** Walls designed as plain masonry except that reinforcement is provided in some portions to resist flexural tensile stresses.

1.3.14. ***Pea Gravel Grout.*** Grout to which pea gravel is added.

1.3.15. ***Pilaster.*** That portion of a wall which may serve as either a vertical beam or a column or both. In reinforced masonry the pilaster may or may not project beyond either face of the wall.

1.3.16. ***Reinforced Masonry.*** Unit masonry in which reinforcement is embedded as required in these regulations and in such a manner that the two materials act together in resisting forces.

1.3.17. ***Reinforced Grouted Masonry.*** Masonry construction made with solid masonry units in which interior joints of masonry are filled by pouring grout therein and in which reinforcement is embedded.

1.3.18. ***Reinforced Hollow Unit Masonry.*** Masonry construction made with hollow masonry units in which certain cells are continuously filled with concrete or grout and in which reinforcement is embedded.

1.3.19. ***Reinforcement,*** Structural steel shapes, steel bars, rods, wire fabric, or expanded metal embedded or incased in masonry in such a manner that it works with the masonry in resisting forces.

1.3.20. ***Solid Masonry Unit.*** A masonry unit whose net cross-sectional area in every plane parallel to the bearing surface is 75 percent or more of its gross cross-sectional area measured in the same plane. (See Cross-sectional Area.)

1.3.21. ***Stretcher.*** A unit laid with its length horizontal, and parallel with the face of the wall or other masonry member.

1.3.22. ***Unit Masonry.*** A built-up construction or combination of masonry units set in mortar or grout.

1.3.23. ***Wythe (Leaf).*** Each continuous vertical section of a wall one masonry unit in thickness and tied to its adjacent vertical section or sections (front or back) by bonders (headers), metal ties, or grout.

2. Tests

2.1. **When Required.** The building official, or his authorized representative, shall have the right to order the test of any material entering into reinforced masonry to determine its suitability for the purpose; to order reasonable tests of the reinforced masonry from time to time to determine whether the materials and methods in use are such as to produce reinforced masonry 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.

2.2. **Tests of Materials.** Tests of materials shall be made in accordance with the applicable standards of the American Society for Testing Materials. 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.

2.3. **Test of Existing Structure.**

(a) A load test of an existing structure to determine its adequacy (stiffness and strength) for the intended use shall not be made until the portion subjected to the load is at least 56 days old, unless the owner of the structure agrees to the test being made at an earlier age.

(b) When a load test is required and 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 design 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 design dead load for at least 48 hr.

(c) Immediately prior to the application of the test load, the necessary initial readings shall be made for the measurements of deflections (and strains, if these are to be determined) caused by the application of the test load. The members selected for loading shall be subjected to a superimposed test load of two times the design live load, but not less than 80 psf for floor construction nor less than 60 psf for roof construction. The superimposed load shall be applied without shock to the structure and in a manner to avoid arching of the loading materials. Unless otherwise directed by the building official, the load shall be distributed to simulate the distribution of the load assumed in the design.

(d) The test load shall be left in position for 24 hr when readings of the deflections shall again be made. The test load shall be removed and additional readings of deflections shall then be made 24 hr after the removal of the partitions or other construction likely to be damaged by test load. The following criteria shall be used in determining conformity with the load test requirements:

(1) If the structure shows evident failure, the changes or modifications needed to make the structure adequate for the rated capacity shall be made; or a lower rating may be established.

(2) The maximum deflection, D, of a flexural member at the end of the 24-hr period shall not exceed the limit in table 1 considered by the building official to be appropriate for the construction. All terms are expressed in the same units; L being the span of the member, and t the thickness or depth.

The maximum deflection shall not exceed $L/200$ for a floor construction intended to support or to be attached to partitions or other construction likely to be damaged by large deflections of the floor.

TABLE 1. *Maximum allowable deflection*

Construction	Deflection
Cantilever beams and slabs	$L^2/1{,}800\,t$
Simple beams and slabs	$L^2/4{,}000\,t$
Beams continuous at one support and slabs continuous at one support for the direction of the principal reinforcement.	$L^2/9{,}000\,t$
Flat slabs (L=the shorter span)	$L^2/10{,}000t$
Beams and slabs continuous at the supports for the direction of the principal reinforcement.	$L^2/10{,}000t$

The recovery of deflection within 24 hr after the removal of the load shall be at least 75 percent of the maximum deflection. However, if the recovery of deflection is less than 75 percent, the member may be retested upon approval by the building official. A second test shall not be made until at least 72 hr after the removal of the first test load. The maximum deflection in a retest shall not exceed the limits given in table 1 and the recovery of deflection shall be at least 75 percent.

3. Materials

3.1. **Quality.** Materials used in reinforced masonry shall be of good quality, conforming to generally accepted good practice. Except as may be otherwise provided herein, the standards and requirements set forth in section 3.2, Standards of Quality, shall be deemed to represent generally accepted good practice in building construction.

NOTE: The nationally recognized standards noted in this section are adopted by reference and give title, name of sponsoring organization, and serial designation including the latest date of adoption. Instead of giving the latest date of adoption of such standards, some authorities favor the more general method of referring to a standard "as amended from time to time." This is not favored because of the possibility that courts will not uphold such a reference to a standard on the grounds that it might be improper delegation of legislative authority and that there is uncertainty of the edition of the standard. The constitutional provisions affecting adoption of standards vary from State to State, therefore it is suggested that code writers consult the appropriate law officer to ascertain the method which carries legal sanction.

3.1.1. ***Secondhand Materials.*** Secondhand materials shall not be used in reinforced masonry unless such materials conform to these requirements and have been thoroughly cleaned.

3.2. **Standards of Quality.**

3.2.1. ***Building Brick.***

3.2.1.1. BRICK AND SOLID CLAY OR SHALE MASONRY UNITS. Standard Specifications for Building Brick (Solid Masonry Units Made from Clay or Shale) (ASTM C62–58; ASA A98.1–1959).

3.2.1.2. SAND-LIME BRICK. Standard Specifications for Sand-Lime Building Brick (ASTM C73–51; ASA A78.1–1952).

3.2.1.3. CONCRETE BRICK. Standard Specifications for Concrete Building Brick (ASTM C55–55; ASA A75.1–1956).

3.2.1.4. GRADES. Clay, shale, or sand-lime brick subject to the action of weather or soil, but not subject to frost action when permeated with water, shall be Grade MW or Grade SW, and when subject to temperature below freezing while in contact with the soil shall be Grade SW; concrete brick subject to the action of weather or soil shall be Grade A.

NOTE: In localities where brick conforming in physical properties to the requirements of this specification are not readily obtainable, the use of other brick should be permitted, if suitable evidence of strength and resistance to weathering is presented to the building official.

3.2.2. ***Structural Clay Tile and Hollow Clay or Shale Masonry Units.***

3.2.2.1. LOAD-BEARING WALL TILE. Standard Specifications for Structural Clay Load-Bearing Wall Tile (ASTM C34–57; ASA A74.1–1958). Structural clay tile subject to the action of weather or soil shall be Grade LBX.

3.2.3. ***Concrete Masonry Units.***

3.2.3.1. HOLLOW LOAD-BEARING UNITS. Standard Specifications for Hollow Load-Bearing Concrete Masonry Units (ASTM C90–52; ASA A79.1–1953). Hollow load-bearing masonry units subject to the action of weather or soil shall be Grade A.

3.2.3.2. SOLID LOAD-BEARING UNITS. Standard Specifications for Solid Load-Bearing Concrete Masonry Units (ASTM C145–52; ASA A81.1–1953). Solid units subject to the action of weather or soil shall be Grade A.

3.2.4. ***Glazed Building Units.*** Units shall conform to the applicable requirements of the specifications for solid or hollow clay masonry units of section 3.2.1, Brick and Solid Clay or Shale Masonry Units and section 3.2.2, Structural Clay Tile and Hollow Clay or Shale Masonry units.

3.2.5. ***Reinforcement.*** Reinforcement for reinforced masonry shall conform to the following applicable standards; deformed reinforcing bars also shall conform to the requirements of Standard Specifications for Minimum Requirements for the Deformations of Deformed Steel bars for Concrete Reinforcement (ASTM A305–56T).

Standard Specifications for Billet-Steel Bars for Concrete Reinforcement (ASTM A15–58T; ASA A50.1–1959).

Standard Specifications for Rail-Steel Bars for Concrete Reinforcement (ASTM A16–57T; ASA A50.2–1958).

Standard Specifications for Cold-Drawn Steel Wire for Concrete Reinforcement (ASTM A82–58T; ASA A50.3–1959).

Standard Specifications for Axle-Steel Bars for Concrete Reinforcement (ASTM A160–57T; ASA G43.1–1958).

Standard Specifications for Welded Steel Wire Fabric for Concrete Reinforcement (ASTM A185–58T; ASA G45.1–1959).

Standard Specifications for Steel for Bridges and Buildings (ASTM A7–58T; ASA G24.1–1959).

3.2.6. ***Cementitious Materials.*** Cementitious materials shall conform to one of the following specifications of the American Society for Testing Materials, as specified:

3.2.6.1. Portland Cement. Type I, II, or III of the Standard Specifications for Portland Cement (ASTM C150–56). Type IA, IIA, or IIIA of the Specifications for Air-Entraining Portland Cement (ASTM C175–56). Type IS or ISA of the Specifications for Portland Blast-Furnace Slag Cement (ASTM C205–58T).

3.2.6.2. Quicklime. Standard Specifications for Quicklime for Structural Purposes (ASTM C5–26).

3.2.6.3. Hydrated Lime. Standard Specifications for Hydrated Lime for Masonry Purposes (Type S) (ASTM C207–49).

3.2.7. ***Aggregates.*** Fine aggregates shall conform to the Specifications for Aggregate for Masonry Mortar (ASTM C144–52T); coarse aggregates shall conform to Coarse Aggregate Size No. 8 of Specifications for Aggregates for Masonry Grout (ASTM C404–57T).

3.2.8. ***Water.*** Water shall be clean and potable.

3.2.9. ***Admixtures.*** Integral waterproofing compounds, accelerators, or other admixtures not definitely mentioned in the specifications shall not be used in mortar or grout unless approved by the building official.

3.2.10. ***Mortar Colors.*** Only pure mineral mortar colors shall be used, and only when the quality and the amount to be used has been approved by the building official.

3.2.11. ***Anti-freeze Compounds.*** No anti-freeze liquid, salts or other substances shall be used in the mortar to lower the freezing point.

4. Mortar and Grout

4.1. **Materials.** Materials used as ingredients in the mortar and grout shall conform to the requirements specified in sections 3.2.6 to 3.2.11 above.

4.2. **Storage of Materials.** Cementitious materials and aggregates shall be stored in such a manner as to prevent deterioration or intrusion of foreign material.

4.3. **Mixing.** The mixing of all cementitious materials and aggregates shall be for a minimum period of 3 min, with the amount of water required to produce the desired workability, in a mechanical-type batch mixer. Handmixing of the mortar may be permitted on jobs involving the use of less than 50 ft ^{3} per day. Grout or mortar for embedment of structural reinforcement shall be mixed in a mechanical mixer.

4.4. **Mortar Proportions.** Mortar shall consist of a mixture of cementitious material and aggregate conforming to the requirements specified in sections 3.2.6 and 3.2.7, to which sufficient water has been added to bring the mixture to a plastic state. Mortar proportions are by volume and are based on damp, loose measure of sand. Mortar shall be composed of 1 part portland cement, ¼ to ½ parts hydrated lime or lime putty, and fine aggregate consisting of 2¼ to 3 times the sum of the separate volumes of the cement and the lime used.

4.5. **Grout Proportions.** Grout shall consist of a mixture of cementitious material and aggregate conforming to the requirements specified in sections 3.2.6 and 3.2.7, to which sufficient water has been added to cause the mixture to flow readily. Grout proportions are by volume and are based on damp, loose measure of sand and gravel. Grout shall be of type MG or PG, proportioned as follows:

(a) MG grout shall be composed of 1 part portland cement, not more than ¼ part hydrated lime or lime putty, and fine aggregate consisting of 2¼ to 3 times the sum of the separate volumes of the cement and the lime used.

(b) PG grout shall be composed of 1 part portland cement, not more than ¼ part hydrated lime or lime putty and 2 to 3 parts fine aggregate and 1 to 2 parts coarse aggregate. In no case shall the sum of the volumes of the fine and coarse aggregate exceed 4 times the sum of the separate volumes of the cement and the lime used.

4.6. **Method of Measuring Materials.** The method of measuring materials for the mortar used in construction shall be such that the specified proportions of the mortar materials can be controlled and accurately maintained.

NOTE: Weights of materials are considered to be as follows:

Material	Weight
Portland cement	94 lb/ft^3
Hydrated lime	40 lb/ft^3
Lime putty [a]	80 lb/ft^3
Sand	1 ft^3 of damp, loose sand contains 80 lb of dry sand

[a] All quicklime should be slaked according to the manufacturer's directions. All quicklime putty, except pulverized quicklime putty, should be sieved through a no. 20 (840-μ) sieve and allowed to cool until it has reached a temperature of 80° F.

5. Allowable Stresses

5.1. Notations

d=Depth from compression face of beam or slab to center of longitudinal tensile reinforcement; the least lateral dimension of column or prism, in.

h=Unsupported length of column or prism, in.

f_m=Compressive stress in extreme fiber of masonry in flexure, psi.

f'_m=Compressive strength of masonry at age of 28 days unless otherwise specified, psi. (Gross area for solid-unit masonry and net area for hollow-unit masonry.)

f_s=Tensile stress in main reinforcement; nominal allowable stress in vertical column reinforcement, psi.

f_v=Tensile stress in web reinforcement, psi.

n=Ratio of modulus of elasticity of the reinforcement to that of masonry.

u=Bond stress, psi.

v_m=Shearing stress permitted in masonry, psi.

v=Shearing stress, psi.

E_m=Modulus of elasticity of masonry, psi.

E_s=Modulus of elasticity of reinforcement, psi.

5.2. **Masonry Strength.** For the design of reinforced masonry structures, the value of f'_m used for determining the allowable stresses as stipulated in section 5.5 shall be based on the specified minimum 28-day compressive strength of the masonry or on the specified minimum compressive strength at the earlier age at which the masonry 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 masonry at a specified age for which all parts of the structure were designed.

5.3. Determination of Masonry Strength.

5.3.1. ***Solid Masonry.*** The determination of the compressive strength of solid masonry (f'_m) shall be made by one of the following methods:

Method No.1. When the compressive strength of the solid masonry is to be established by preliminary tests, the tests shall be made in advance of the operations using prisms built of similar materials under the same conditions and, insofar as possible, with the same bonding arrangement as for the structure. In building the prisms, the moisture content of the unit at time of laying, the consistency of the mortar and the workmanship shall be the same as will be used in the structure. The test prisms for beams and slabs shall be built of representative units, with their long dimension horizontal.

Unless permission is otherwise given, all specimens shall have a height-to-thickness ratio (h/d) of not less than 2 and shall be not less than 16 in. in height. If h/d differs from 2, the value of f'_m shall be taken as the compressive strength of the specimens multiplied by a correction factor as follows:

Ratio of height to thickness (h/d)	1.5	2.0	2.5	3.0
Correction factor	0.86	1.00	1.11	1.20

Factors between those listed shall be determined by direct interpolation.

Method No. 2. When the compressive strength of the solid masonry is not determined by preliminary tests and the units, mortar, and workmanship conform to all applicable requirements of these regulations, the allowable stresses may be based upon an assumed value of f'_m interpolated from the values in table 2.

TABLE 2. *Compressive strength of masonry*

Gross area for masonry of solid units; net area for masonry of hollow units

Compressive strength of the units	Assumed compressive strength of masonry, f'_m
psi	*psi*
1,000 to 1,500	900 to 1,150
over 1,500 to 2,500	1,151 to 1,550
over 2,500 to 4,000	1,551 to 2,000
over 4,000 to 6,000	2,001 to 2,400
over 6,000 to 8,000	2,401 to 2,700
over 8,000 to 10,000	2,701 to 2,900
over 10,000 to 12,000	2,901 to 3,000
over 12,000	3,000

5.3.2. ***Hollow Masonry.*** The determination of the compressive strength of hollow masonry (f'_m) shall be made by one of the following methods:

Method No. 1. When the compressive strength of the hollow masonry is to be established by preliminary tests, the tests shall be made in advance of the operations, using prisms built of similar materials, under the same conditions and, insofar as possible, with the same bonding arrangement as for the structure.

Test prisms shall be built in the form of squares 8 in. by 8 in. in plan and 16 in. high or in the form of rectangles 8 in. by 16 in. in plan and 16 in. high. The hollow core shall not be filled with grout.

Masonry strength (f'_m) shall be computed by dividing the maximum load by the net area of the masonry units used in construction of the prisms.

Method No. 2. When the compressive strength of the hollow masonry is not determined by preliminary tests and the units, mortar, and workmanship conform to all applicable requirements of these regulations, the allowable stresses may be based upon an assumed value of f'_m given in section 5.3.1, Method No. 2.

5.4. Tests of Masonry Prisms.

(a) Test prisms shall be constructed as prescribed in section 5.3, and shall be stored in air at a temperature not less than 65° F. The ends of each prism shall be capped with a suitable material such as calcined gypsum to provide bearing surfaces plane within 0.003 in. and approximately perpendicular to the axis of the prism. The prism shall then be tested in accordance with the relevant provisions of the Standard Method of Test for Compressive Strength of Molded Concrete Cylinders, ASTM C39–56T.

(b) Not less than three specimens shall be made for each test.

(c) The standard age of test specimens shall be 28 days but 7-day tests may be used, provided the relation between the 7- and 28-day strengths of the masonry is established by test for the materials used.

5.5. Allowable Stresses in Reinforced Masonry.

(a) The allowable stresses in reinforced masonry shall not exceed the values shown in table 3.

TABLE 3. *Allowable stresses in masonry*

Description		Allowable stress
Compressive:		
Axial	f_m	See sections 9.4 and 9.9.
Flexural	f_m	$0.33f'_m$.
Shear:		
Beams with no web reinforcement	v_m	50 psi.[a]
Beams with web reinforcement	v	150 psi.
Bond:		
Plain bars	u	80 psi.
Deformed bars (ASTM A305)	u	160 psi.
Bearing	f_m	$0.25f'_m$.
Modulus of elasticity	E_m	$1,000f'_m$.
Modulus of rigidity	E_v	$400f'_m$.

[a] See section 8.7.1(c).

(b) In composite walls or other structural members composed of different kinds or grades of units the maximum stress shall not exceed the allowable stress for the weakest unit of the combination of which the member is composed.

5.6. **Allowable Stress in Reinforcement.** Unless otherwise provided in this standard, the stresses in reinforcement shall not exceed the following, where f_s=tensile stress in longitudinal reinforcement, and f_v=tensile stress in web reinforcement:

Tensile stress:
- 18,000 psi for structural grade steel bars,
- 18,000 psi for structural steel shapes,
- 20,000 psi for intermediate grade steel bars, and hard-grade bars (billet steel, rail steel, or axle steel).

Compressive stress in column verticals:
- 16,000 psi for intermediate grade steel bars,
- 20,000 psi for hard-grade steel bars (billet steel, rail steel, or axle steel).

6. Masonry Construction

6.1. **Preparation of Equipment and Place of Construction.** Before placing masonry, all forms and equipment shall be cleaned, all debris and ice shall be removed from the spaces to be occupied by the masonry, and the reinforcement shall be thoroughly cleaned of ice or other coatings.

6.2. **Preparation of Masonry Units.** At the time of laying, all units shall be sound and clean.

6.2.1. ***Brick Made from Clay or Shale.*** At the time of laying, all units shall have sufficient moisture content so that the amount of water absorbed by a bad face during the suction test, as described in Standard Methods of Sampling and Testing Brick (ASTM C67–57), is not more than 0.025 oz/min/in.^{2} of the surface immersed.

6.2.2. ***Concrete Masonry Units.*** Concrete masonry units shall not be wetted before laying in the wall, except in extremely dry desert areas where the bearing surfaces of the face shells may be slightly moistened immediately before laying to prevent excessive drying of mortar.

6.3. **Mortar and Grout**

6.3.1. ***Mortar.*** The consistency of mortar shall be adjusted to the satisfaction of the mason but as much water shall be added as is compatible with convenience in using the mortar. If the mortar begins to stiffen from evaporation or absorption of a part of the mixing water, the mortar shall be restored to workable consistency by adding water and remixing. Mortar or grout shall not be used after it has begun to set.

6.3.2. ***Grout.***

(a) MG grout shall consist of mortar to which sufficient water has been added to produce a pouring consistency and it shall be stirred or worked at frequent intervals before placing to prevent separation of the materials.

(b) PG grout or pea gravel grout: In grout spaces in reinforced grouted masonry 2 in. or more in both horizontal dimensions and in grout spaces in filled cell construction 4 in. or more in both horizontal dimensions, the grout shall be type PG grout. Brick pieces or chips may be embedded into grout in such spaces, provided each piece or chip is surrounded by ½ in. or more of grout.

6.4. **Reinforced Grouted Masonry.** All masonry units used in grouted masonry shall be laid plumb in full head and bed joints and all interior joints, cores, or spaces that are designed to receive grout shall be solidly filled. The grouted longitudinal joints shall be not less than ¾ in. wide. Mortar "fins" shall not protude into spaces to be filled with grout. When the least clear dimension of the longitudinal vertical joint or core is less than 2 in., the maximum height of grout pour shall be limited to 12 ins. When the least clear dimension of the longitudinal vertical joint or core is 2 in. or more, the maximum height of grout pour shall not exceed 48 times the least clear dimension of the longitudinal vertical joint or core for PG grout nor 64 for MG grout but not to exceed a height of 12 ft. Grout shall be agitated or puddled during placement to insure complete filling of the grout space. When grouting is stopped for 1 hr or longer the grout pour shall be stopped 1½ in. below the top of a masonry unit. Masonry bonders (headers) shall not be used, but metal wall ties may be used to prevent spreading of the wythes and to maintain vertical alinement of the wall. When such metal ties are used, they shall be protected as required in section 7.7.(g).

6.5. **Reinforced Hollow Masonry.**

(a) All units shall be laid plumb with full face shell mortar beds. All head (or end) joints shall be filled solidly with mortar for a distance in from the face of the unit or wall not less than the thickness of the longitudinal face shells. Cross webs adjacent to vertical cores which are to be filled with grout shall be fully bedded in mortar to prevent leakage of grout.

(b) Bond of masonry units in a single wythe shall be provided by lapping units in successive verticle courses. When partially reinforced walls are laid in stack bond, the reinforcing shall conform to section 9.10.

(c) All reinforced hollow masonry shall be built to preserve the unobstructed vertical continuity of the cores to be filled. Mortar "fins" protruding from joints shall be removed before pouring grout. The minimum continuous clear dimensions of vertical cores shall be 2 by 3 in. In filling vertical cores, the grout pour shall not exceed 4 ft in height unless cleanouts are left open at the bottom masonry course of each core to be reinforced and such cleanouts closed only after inspection of the core space and the setting of the vertical reinforcement in fixed position.

(d) Grout shall be rodded or puddled during placement to insure complete filling of the core. When grouting is stopped for 1 hr or longer, the grout pour shall be stopped 1½ in. below the top of a masonry unit.

(e) Horizontal beams may be built of reinforced hollow masonry, using channeled units to permit horizontal reinforcement to be placed in the desired position. The top of unfilled cores below such horizontal beams shall be covered to confine the grout fill to the beam section. No material shall be used which destroys the bond between courses. Grouting of beams over openings shall be done in a continuous operation. All grout shall be puddled in place to insure complete filling of cores and incasement of reinforcement.

6.6. **Joints.** Exterior joints shall be trowel-pointed or shall be tooled with a jointer, compacting the mortar into the joint and against the masonry units with firm pressure.

6.7. **Cold-Weather Requirements.**

(a) Adequate equipment shall be used for heating the masonry materials and protecting the masonry during freezing or near-freezing weather. No frozen material or materials containing ice shall be used.

(b) Sand shall be heated in such a manner as to remove frost or ice. Water or sand shall not be heated to a temperature above 160°F. When necessary to remove frost, the masonry units shall be heated.

(c) Whenever the temperature of the surrounding air is below 40°F, all newly constructed reinforced masonry laid in mortar, in which high-early-strength portland cement is used, shall be maintained at a temperature of at least 50°F for not less than 24 hr by means of enclosures, artificial heat, or by other protective methods as will meet the approval of the building official. When any cementing material other than high-early-strength portland cement is used, this temperature shall be maintained for at least 72 hr.

(d) All methods and materials for the protection of the fresh masonry work against freezing shall be subject to the approval of the building official. In general, the methods and materials now commonly accepted as suitable for the protection of reinforced concrete construction in freezing weather shall be used. Salt or other chemicals for lowering the freezing temperature of the mortar shall not be used.

7. Details of Construction

7.1. **Design of Forms.** Forms shall conform to the shape, lines, and dimensions of the members as shown on the plan, and shall be substantial and sufficiently tight to prevent leakage of mortar. They shall be properly braced or tied together so as to maintain position and shape.

7.2. **Removal of Shores and Forms.**

(a) In no case shall shores and forms be removed until it is certain that the masonry has hardened sufficiently to carry its own weight and all other reasonable temporary loads that may be placed on it during construction. The results of suitable control tests may be used as evidence that the masonry has attained such sufficient strength.

(b) For girders and beams, the minimum time which shall elapse before removal of shores or forms shall be 10 days after the completion of the member, providing that suitable curing conditions have been obtained during that period. The forms and shores under slabs shall not be removed in less than 7 days after completion of such slabs and then only when suitable curing conditions have existed throughout the entire curing period. At least 16 hr shall elapse after completing the construction of a masonry column or wall before the application of a uniformly distributed load and an additional 48 hr shall elapse before applying a concentrated load, such as one from a truss, girder, or beam.

7.3. **Pipe, Conduit, etc, Embedded in Masonry.** Pipes which will contain liquid, gas, or vapor at temperatures higher than room temperature shall not be embedded in masonry necessary for structural stability or fire protection. Drain pipes and pipes whose contents will be under pressure greater than atmospheric pressure by more than 5 psi shall not be embedded in structural masonry except in passing through from one side to the other of a floor, wall, or beam. Placement of pipe or conduits in unfilled cores of hollow unit masonry shall not be considered as embedment. Electric conduits and other pipes, with their fittings, whose embedment is allowed, shall not displace more than 4 percent of the cross-sectional area of the masonry of a column on which stress is calculated nor shall they displace any masonry of a column which is required for fire protection. Sleeves or other pipes passing through floors, walls, or beams shall not be of such size or in such location as unduly to impair the strength of the construction; such sleeves or pipes may be considered as replacing structurally the displaced masonry, provided they are not exposed to rusting or other deterioration, are of iron or steel not thinner than standard wrought-iron pipe, have a nominal inside diameter not over 2 in., and are spaced not less than 3 diam on center. Embedded pipes or conduits other than those merely passing through shall not be larger in outside diameter than 1/3 the thickness of the slab, wall, or beam in which they are embedded; shall not be spaced closer than 3 diam on centers, nor so located as unduly to impair the strength of the construction.

7.4. **Cleaning and Bonding Reinforcement.** Before being placed, all metal reinforcement shall be free from loose rust and other coatings that would destroy or reduce the bond. All reinforcement shall be accurately cut to length and bent by such methods as will prevent injury to the material. All kinks or bends in the bars caused by handling incident to delivery shall be straightened out without injury to the material before placing it in the masonry.

7.5. **Placing Reinforcement.**

7.5.1. ***Minimum Bar Spacing.*** The minimum clear distance between parallel bars except in columns shall be equal to the nominal diameter of the bar.

7.5.2. ***Reinforced Grouted Masonry.*** In reinforced grouted masonry, vertical reinforcement shall be accurately placed and held rigidly in position before work is started. Horizontal reinforcement may be placed as the work progresses.

7.5.3. ***Reinforced Hollow Masonry.*** In reinforced hollow masonry, vertical reinforcement may be placed after cleaning cores ready for inspection and before inspection occurs. Vertical reinforcement shall be accurately placed and shall be held in position at intervals not to exceed 160 times the minimum dimension of the reinforcement. Horizontal reinforcement may be placed as the work progresses.

7.6. **Splices in Reinforcement.** Splices may be made only at such points and in such manner that the structural strength of the member will not be reduced. Lapped splices shall provide sufficient lap to transfer the working stress of the reinforcement by bond and shear. Welded or mechanical connections shall develop the strength of the reinforcement.

7.7. **Protection for Reinforcement.** All bars shall be completely embedded in mortar or grout. All reinforcement shall have a coverage of masonry not less than the following:

(a) 3 in. for bottoms of footings;

(b) 2 in. on vertical members where masonry is exposed to action of weather or soil for bars larger than ⅝ in. and 1½ in. for bars ⅝ in. or less;

(c) 1½ in. for all reinforcement in columns;

(d) 1½ in. on the bottom and sides of beams or girders;

(e) ¾ in. from the faces of all walls not exposed to action of weather or soil;

(f) 1-bar diam over all bars, but not less than ¾ in. at the upper faces on any member, except where exposed to weather or soil in which cases the minimum coverage shall be 2 in. or 3 in., respectively;

(g) Reinforcement consisting of bars or wire ¼ in. or less in diameter embedded in the horizontal mortar joints shall have not less than ⅝-in. mortar coverage.

7.8. **Minimum Joint Thickness.** The thickness of grout or mortar between masonry units and reinforcement shall be not less than ¼ in. except that ¼-in. bars may be laid in ½-in. horizontal mortar joints, and No. 6 gage or smaller wires may be laid in ⅜-in. horizontal joints. Vertical joints containing both horizontal and vertical reinforcement shall be not less than ½ in. larger than the sum of the diameters of the horizontal and vertical reinforcement contained therein.

7.9. **Construction Joints.** Where fresh masonry joins masonry that is partially set or totally set, the exposed surface of the finished masonry shall be cleaned with a wire brush and dampened when necessary to obtain the best possible bond with the new work. All loose masonry units and mortar shall be removed.

7.10. **Chases and Recesses.** Chases and recesses in reinforced masonry walls shall not be constructed so as to reduce the required strength, thickness, or fire resistance of the wall.

7.11. **Arches and Lintels.** The support for masonry over openings shall be lintels of incombustible materials or masonry arches.

8. Design

8.1. Notations

A_v=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, sq in.

a=Angle between inclined web bars and axis of beam, deg.

b=Width of rectangular flexural member or width of flange for T and I sections, in.

b'=Width of web in T and I flexural members. For hollow masonry, width is equal to width of filled core area plus the thickness of adjacent webs, in.

d=Depth from compression face of beam to centroid of longitudinal tensile reinforcement, in.

f'_m=Compressive strength of masonry at age of 28 days unless otherwise specified, psi.

f_v=Tensile stress in web reinforcement, psi.

j=Ratio of distance between centriod of compression and centriod of tension to the depth d.

l=Clear span for positive moment and the average of the two adjacent clear spans for negative moment, ft.

n=Ratio of modulus of elasticity of reinforcement to that of masomry$=E_n/E_m$ assumed as equal to $30,000/f'_m$.

s=Spacing of stirrups or of bent bars in a direction parallel to that of the main reinforcement, in.

u=Bond stress, psi.

v=Shearing stress, psi.

v_m=Shearing stress permitted in masonry, psi.

V=Total shear, lb.

V'=Excess of the total shear over that permitted in the masonry, lb.

w=Uniformly distributed load per unit of length of beam, lb/ft, or uniformly distributed load per unit length of slab strip 12 in. wide, psf.

Σo=Sum of perimeters of bars in one set, in.

8.2. **Assumptions.** The design of reinforced masonry shall be in accordance with the following principal assumptions:

(a) A section that is plane before bending remains plane after bending.

(b) Moduli of elasticity of the masonry and of the reinforcement remain constant.

(c) Tensile forces are resisted only by the tensile reinforcement.

(d) Reinforcement is completely surrounded by and bonded to masonry material.

8.3. **Design Loads.** 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, with such reductions for structural members as are permitted.

8.4. Resistance to Wind, Blast, and Earthquake Forces.

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

(b) For stresses due to wind, blast, or earthquake combined with dead and live loads, the allowable stresses may be increased 33⅓ percent, provided the strength of the section thus formed is not less than that required for dead and live loads alone.

(c) Wind, blast, and earthquake stresses may be assumed never to occur simultaneously.

8.5. Flexural Computations.

(a) All members shall be designed to resist at all sections the maximum bending moment and shears produced by dead load, live load, and other forces, as determined by the principle of continuity and relative rigidity.

(b) Where the larger of the two adjacent spans does not exceed the shorter by more than 20 percent and loads are uniformly distributed and the live load does not exceed three times the dead load, the following moments and shears for beams and girders may be used:

Positive moment:	
End spans:	
If discontinuous end is unrestrained	$1/11\ wl^2$
If discontinuous end is integral with support	$1/14\ wl^2$
Interior spans	$1/16\ wl^2$
Negative moment at exterior face of first interior support:	
Two spans	$1/9\ wl^2$
More than two spans	$1/10\ wl^2$
Negative moment at face of other interior support	$1/11\ wl^2$
Shear in end members at first interior support	$1.15\ wl/2$
Shear at other supports	$wl/2$

(c) The span length of freely supported beams shall be the clear span plus the depth of beam, but shall not exceed the distance between centers of the supports.

(d) In the application of the principle of continuity, center-to-center distances may be used in the basic moment determination of all members. Moments actually prevailing at the faces of support shall be used for the design of beams and girders at such points.

(e) The depth of the beam or slab shall be taken as the distance from the centroid of the tensile reinforcement to the compression face.

(f) The clear distance between lateral supports of a beam shall not exceed 32 times the least width of compression flange.

(g) Compression steel in beams or girders shall be anchored by ties or stirrups not less than ¼ in. in diameter, spaced not farther apart than 16-bar diam or 48-tie diam. Such ties or stirrups shall be used throughout the distance where compression steel is required.

(h) In computing flexural stresses where reinforcement occurs, the effective width shall be not greater than four times the wall thickness in solid masonry, nor more than the width of the solidly filled section plus the length of the masonry unit but not to exceed four times the wall thickness in hollow masonry.

(i) Where the minimum continuous clear opening of a grout space in filled cell construction exceeds 6 in., it may be filled and the concrete portions may be designed like reinforced concrete.

8.6. **Combined Axial and Flexural Stresses.** Members subject to combined axial and flexural stresses shall be so proportioned that the quantity

$$\frac{f_a}{F_a}+\frac{f_m}{F_m} \text{ shall not exceed } 1$$

where f_a=computed axial stress=total axial load/area.

F_a=Axial stress permitted by this standard at point under consideration if member were carrying axial load only, including any increase in stress allowed by section 8.4.

f_m=Computed flexural stress.

F_m=Flexural stress permitted by this standard, if member were carrying bending load only, including any increase in stress allowed by section 8.4.

8.7. Shear and Diagonal Tension.

8.7.1. ***Shearing Stress.***

(a) The shearing stress, v, as a measure of diagonal tension in reinforced masonry flexural members, shall be computed by the following formula:

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

except for members of I or T section, where b' shall be substituted for b.

(*b*) When the value of the computed shearing stress exceeds the shearing stress, v_m, permitted on the masonry of an unreinforced web, web reinforcement shall be provided to carry the excess. Such reinforcement shall be provided for a distance equal to the depth, d, of the member, beyond the point theoretically required.

(c) Where continuous or restrained members are so constructed as not to provide T-beam or equivalent action, the following provisions shall apply. Web reinforcement shall be provided sufficient to carry the shearing stress in excess of 20 psi at any section from the support to a point beyond the point of inflection for a distance equal to $\frac{1}{16}$ the clear span or the depth of the member, whichever is greater. Web reinforcement shall be provided sufficient to carry the shearing stress in excess of 20 psi at any section in which there is negative reinforcement.

8.7.2. ***Types of Web Reinforcement.*** Web reinforcement may consist of:

(a) Bars (stirrups) perpendicular to the longitudinal reinforcement.

(b) Bars (stirrups) welded or otherwise rigidly attached to the longitudinal reinforcement and making an angle of 30° or more thereto.

(c) Longitudinal bars bent so that the axis of the inclined portion of the bar makes an angle of 15° or more with the axis of the longitudinal portion of the bar.

(d) Special arrangements of bars with adequate provisions to prevent slip of bars or splitting of the masonry by the reinforcement.

8.7.3. ***Stirrups.***

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

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

(b) Inclined stirrups shall be proportioned by the formula in section 8.7.4(c).

8.7.4. ***Bent Bars.***

(a) Only the center three-fourths of the inclined portion of bent bars shall be considered effective as web reinforcement.

(b) When the web reinforcement consists of a single bent bar or of a single group of bent bars, the required area of such bar or bars shall be computed by the following formula, provided V' shall not exceed $0.040 f'_m bjd$:

$$A_v=\frac{V'}{f_v \sin a}.$$

(c) Where there is a series of parallel bent bars, the required area shall be determined by the following formula:

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

8.7.5. ***Spacing of Web Reinforcement.*** Where web reinforcement is required, it shall be so spaced that every 45° line (representing a potential crack) extending from the middepth of the beam to the longitudinal tension bars shall be crossed by at least one line of web reinforcement.

8.8. Bond and Anchorage.

8.8.1. ***Computation of Bond Stress in Beams.*** In flexural members in which tensile reinforcement is parallel to the compressive face, the bond stress, u, shall be computed by the following formula:

$$u = \frac{V}{\Sigma o j d}$$

in which V=total external shear at the section.

8.8.2. ***Anchorage Requirements.***

(a) Tensile reinforcement for negative moment in any span of a continuous restrained beam or centilever 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 moment, shall be extended at least 12 diam beyond the point at which it is no longer needed to resist stress. At least one-third of the total reinforcement 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. If preferred, the bar may be bent across the web at an angle of not less than 15° with the longitudinal portion of the bar and be made continuous with the reinforcement which resists moment of opposite sign.

(b) At the continuous end of continuous beams, not less than one-quarter of the area of reinforcement for positive moment shall extend along the same face of the beam into the support a distance of 6 in. or more.

(c) In simple beams, or at the freely supported end of continuous beams, at least one-third of the required positive reinforcement shall extend along the same face of the beam into the support a distance of 6 in.

(d) 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.

8.8.3. ***Anchorage of Web Reinforcement.***

(a) Single separate bars used as web reinforcement shall be anchored at each end by one of the following methods:

(1) Welding to longitudinal reinforcement;

(2) Hooking tightly around the longitudinal reinforcement through 180°;

(3) Embedment above or below the middepth of the beam on compression side a distance sufficient to develop the stress to which the bar will be subject at a bond stress of, not to exceed the bond stresses permitted in section 5.5 for plain and deformed bars;

(4) Standard hook (see section 8.8.4(a)), considered as developing 7,500 psi, plus embedment sufficient to develop by bond the remainder of the stress to which the bar is subjected. The bond stress shall not exceed that specified in table 3, section 5.5(a). The effective embedded length shall not be assumed to exceed the distance between the middepth of the beam and the tangent of the hook.

(b) The extreme ends of bars forming a simple U or multiple stirrups shall be anchored by one of the methods of section 8.8.3(a) or shall be bent through an angle of at least 90° tightly around a longitudinal reinforcing bar not less in diameter than the stirrup bar, and shall project beyond the bend at least 12 diam of the stirrup bar.

(c) The loops or closed ends of such stirrups shall be anchored by bending around the longitudinal reinforcement through an angle of at least 90°, or by being welded or otherwise rigidly attached thereto.

(d) Hooking or bending stirrups or separate web reinforcement bars around the longitudinal reinforcement shall be considered effective only when these bars are perpendicular to the longitudinal reinforcement.

(e) 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 lower half of the beam by adequate anchorage through bond or hooks.

8.8.4. ***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 3 and not more than 6-bar diam, plus an extension of at least 4-bar diam at the free end of the bar, or

(2) A 90° bend having a radius of not less than 4-bar diam plus an extension of 12-bar diam.

(3) For stirrup anchorage only, a 135° turn with radius on the axis of the bar of 3 diam, plus an extension of at least 6-bar diam at the free end of the bar.

(b) Hooks having a radius of bend of more than 6-bar diam shall be considered merely as extensions to the bars.

(c) In general, hooks shall not be permitted in the tension portion of any beam except at the ends of simple or cantilever beams or at the freely supported ends of continuous or restrained beams.

(d) No hook shall be assumed to carry a load which would produce a tensile stress in the bar greater than 7,500 psi.

(e) Hooks shall not be considered effective in adding to the compressive resistance of bars.

(f) Any mechanical device capable of developing the strength of the bar without damage to the masonry may be used in lieu of a hook. Tests must be presented to show the adequacy of such devices.

9. Reinforced Masonry Columns and Walls

9.1. **Notations.**

A_g=The overall or gross area of a reinforced masonry column of solid masonry units or solidly filled hollow masonry units. In walls of reinforced hollow masonry construction, A_g equals the net cross-sectional area in bearing (area bedded in mortar plus area of cavities filled with grout or mortar), sq in.

A_s=Effective cross-sectional area of reinforcement in compression in columns, sq in.

d=The least lateral dimension of a column, in.

e=Eccentricity of the resultant load on a column measured from the gravity axis, in.

f'_m=Compressive strength of masonry at 28 days unless otherwise specified, psi.

f_s=Nominal allowable stress in vertical column reinforcement, psi.

h=Unsupported length of column or wall, in.

p_v=Ratio of volume of lateral reinforcement to the volume of the masonry core (out-to-out of ties).

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, h/d 10 or less, lb.

P'=Total allowable axial load on a column, h/d greater than 10, lb.

t=Overall depth of a column section , in.

9.2. **Minimum Dimensions of Columns.** Reinforced masonry columns shall be not less than 12 in. in thickness. Exception: For minor columns not supporting floor or concentrated roof loads, columns may have a minimum thickness of 8 in.

9.3. **Unsupported Height of Columns.**

(a) The maximumun supported height, h, of reinforced masonry columns shall be not more than 20 times the least lateral dimension of the column d.

(b) The unsupported height, h, of reinforced masonry columns shall be taken as not less than the clear distance between the floor surface and the under side of the deeper beam framing into the column in each direction at the next higher floor level.

(c) For rectangular columns that combination of vertical and horizontal dimensions shall be used which gives the greatest ratio of h/d.

9.4. **Permissible Load on Columns.**

(a) The allowable axial load on columns having the ratio p_v less than 0.006 shall be computed by the following formula:

$$P=A_g[0.16f'_m+0.52p_gf_s]$$

(b) The maximum load P' on axially loaded columns having an unsupported length greater than 10 times the least lateral dimension d, shall not exceed:

$$P'=P\,[1.3-0.03h/d]$$

(c) The allowable axial load on columns having the ratio p_v 0.006 or more shall be one and one-quarter times that computed by the above formulas.

9.5. **Vertical Reinforcement of Columns and Pilasters.**

(a) The ratio (p_g) of vertical reinforcement shall be not less than 0.005 nor more than 0.04. The reinforcement shall consist of at least 4 bars each at least ½-in. diam.

(b) Where lapped splices are used the amount of lap shall be sufficient to transfer the allowable stress by bond but in no case shall the length of lapped splice be less than 24-bar diam.

(c) Welded splices shall develop the full strength of the bar.

(d) The column reinforcement shall be held firmly in its designed position.

9.6. **Lateral Reinforcement of Columns.**

(a) Lateral reinforcement shall be ties at least ¼ in. in diam. The spacing shall not exceed any one of the following: 16 vertical bar diam, 48 tie diam, the least column dimension or 16 in.

(b) In columns where the ratio p_v of lateral reinforcement is more than 0.006, the maximum center-to-center spacing of the lateral reinforcement shall be 4 in. Lateral reinforcement shall be not less than ¼-in. bars, shaped as a circle or rectangle. Splices shall be made by welding or lapping 50 diam. Two concentric ties may be placed in one joint.

9.7. **Bending Moments in Columns.**

(a) Bending moments resulting from eccentric loads and conditions of restraint, as in rigid frames or other forms of continous construction, shall be considered in the design.

(b) 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.

(c) The resistance to bending 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.

9.8. **Combined Stresses.** Stresses due to combined axial load and bending shall be determined in accordance with section 8.6, except that, where e/t is less than one-third, design may be based on the uncracked section.

9.9. **Reinforced Masonry Walls.**

(a) The allowable stresses in reinforced masonry bearing walls with minimum reinforcement as required by section 9.9(e), shall be $0.20f'_m$ for walls having a ratio of height to thickness of 10 or less, and shall be reduced proportionally to $0.15f'_m$ for walls having a ratio of height to thickness of 25. When the reinforcement in bearing walls is designed, placed, and anchored in position as for columns, the allowable stresses shall be on the basis of section 9.4, as for columns. 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. Concentrated loads shall not be considered as distributed by metal ties, nor distributed across continuous vertical joints.

(b) Walls shall be designed for eccentric loads and for any lateral forces, pressures or shears to which they are subjected. The design shall conform to the requirements of section 9.8.

(c) Reinforced masonry bearing walls shall have a nominal thickness of at least one-twenty-fifth of the unsupported height or width, whichever is the shorter but not less than 6 in. Panel and enclosing walls of reinforced masonry shall have a thickness of not less than one-thirtieth the distance between the supporting or enclosing members. Limits on height-to-thickness ratios of this section may be waived when written evidence is submitted by a qualified person showing that the walls meet all the other requirements of this standard.

(d) Reinforced masonry walls shall be securely anchored to adjacent structural members, such as roofs, floors, columns, pilasters, buttresses, and intersecting walls.

(e) Reinforced masonry walls shall be reinforced with an area of steel not less than 0.002 times the cross-sectional area of the wall, not more than two-thirds of which may be used in either direction. The maximum spacing of principal reinforcement shall be not more than six times the wall thickness nor more than 48 in.

(f) Horizontal reinforcement shall be provided in the top of footings, at the bottom and top of wall openings, at roof and floor levels, and at the top of parapet walls. Only reinforcement which is continuous in the wall shall be considered in computing the minimum area of reinforcement. In addition to the minimum reinforcement, there shall be not less than one ½-in. diam bar around all window and door openings, which shall extend at least 24 in. beyond the corner of the openings.

9.10. Partially Reinforced Masonry Walls.

(a) Partially reinforced masonry shall be designed as for plain masonry, except that reinforcement may be considered as resisting flexural tensile stresses.

(b) The minimum area of reinforcement required in section 9.9(e) shall not apply to partially reinforced masonry walls. Maximum spacing of vertical reinforcement in exterior partially reinforced masonry walls shall be 8 ft. Reinforcement shall be provided each side of each opening and at each corner of all walls. Horizontal reinforcement shall be provided at the top of footings, at the bottom and top of wall openings, at roof and floor levels, and at the top of parapet walls. When masonry units are laid in stacked bond, horizontal reinforcement consisting of ¼-in. diam bars placed 16 in. on center or their equivalent shall be provided.

(c) The effective width used in computing flexural stresses where reinforcement occurs in partially reinforced masonry shall be not greater than four times the wall thickness for solid masonry nor more than the width of the solidly filled section plus the unit length but not to exceed four times the wall thickness in hollow masonry.

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