DEPARTMENT OF COMMERCE
WASHINGTON

ELIMINATION OF WASTE SERIES

RECOMMENDED MINIMUM REQUIREMENTS FOR MASONRY WALL CONSTRUCTION

REPORT
OF
BUILDING CODE COMMITTEE

BUREAU OF STANDARDS

WASHINGTON
GOVERNMENT PRINTING OFFICE
1925

UNITED STATES DEPARTMENT OF COMMERCE
HERBERT HOOVER, SECRETARY

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REPORT OF BUILDING CODE COMMITTEE JUNE 26, 1924

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Frank P. Cartwright, technical secretary.

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LETTER OF SUBMITTAL

WASHINGTON, *October 1, 1924.*

Hon. HERBERT HOOVER,

Secretary of Commerce, Washington, D. C.

DEAR SIR: Under instruction from the Building Code Committee, appointed by you for the purpose of standardizing and simplifying building laws, I have the honor to submit herewith a report covering Recommended Minimum Requirements for Masonry Wall Construction. If this report meets with your approval, the committee recommends that it be printed for public distribution.

The same plan followed in preparing the committee's report on small dwelling construction was employed in drafting this report, namely, to collect data, prepare a tentative report, solicit cooperative criticism from every available source, and then draft a final report based upon the weight of accumulated opinion, balanced by the committee's best judgment. The details of this procedure are described in the introduction. The committee believes that an application of its recommendations in building code practice will result in material reduction in building costs without impairment of safety or permanency.

In this report, as in our first report, the Appendix forms a major portion of the publication. It contains a digest of data used as a basis for the requirements of Part II and considerable other matter of an educational character. The committee is confident that, although this material is not adapted for inclusion in a building ordinance, except in an appendix, it is nevertheless a very important part of the report and should be recognized as such.

Yours very truly,

IRA H. WOOLSON,
Chairman Building Code Committee,
Department of Commerce.

LETTER OF ACCEPTANCE

Department of Commerce,
Office of the Secretary,
Washington, October 23, 1924.

Mr. Ira H. Woolson,
Chairman Building Code Committee,
Department of Commerce, Washington, D. C.

Dear Mr. Woolson: I have received with great satisfaction the Recommended Minimum Requirements for Masonry Wall Construction, prepared by the Building Code Committee.

This report I know represents a great deal of painstaking labor on the part of yourself and the other members of the committee. Your work has been especially valuable, since it was on problems that would otherwise have remained without comprehensive, systematic efforts at solution. This has been accomplished by further cooperation between the Government and the public. The recommendations are of great importance from the point of view of elimination of waste, and should result in greater returns to the public for money spent on construction.

I have no hesitation in thanking you all in behalf of the American public, and I hope that the advantages of your recommendations will be quickly availed of by our municipalities, and the construction industries generally.

Yours faithfully,

Herbert Hoover.

RECOMMENDED MINIMUM REQUIREMENTS FOR MASONRY WALL CONSTRUCTION

Report of the Building Code Committee of the Department of Commerce

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This report is divided into three general headings, as follows:

PART I.—*Introduction:*

Describes briefly the organization of the committee and its method in preparing and presenting the recommendations.

PART II.—*Minimum requirements for safe and economical construction of masonry walls:*

These are briefly stated in the form of recommendations suitable for State or municipal adoption.

PART III.—*Appendix:*

Contains material not suited for incorporation in a building law, but which is explanatory of the requirements recommended in Part II and descriptive of good practice.

PART I.—INTRODUCTION

Several independent analyses have indicated forcefully that present municipal code requirements for masonry wall construction are, in general, unnecessarily restrictive of building enterprise, often require uneconomical construction, and are lacking in the uniformity desirable for convenience of designers and builders. The following report summarizes some of these analyses, describes investigations of the factors affecting masonry wall essentials, and presents recommendations for uniform code practice.

The building code committee of the Department of Commerce was organized early in 1921, in response to a generally expressed public demand for greater uniformity and economy in building code requirements. Its first work concerned regulations affecting construction of small dwellings and the final report on that subject was published in January, 1923.[1]

[1] Recommended Minimum Requirements for Small Dwelling Construction; a 100-page report obtainable from the Superintendent of Documents, Government Printing Office, Washington, D. C., at 15 cents per copy.

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Following its organization the committee made an extensive canvass of professional opinion as to what parts of building codes most urgently needed revision and standardization. This showed that masonry wall regulations differ widely in various cities; that allowable masonry stresses and fire resistance requirements are based on inadequate knowledge of service under loading and fire exposure; and that as a result there is lack of safety in some localities and unnecessary use of materials and labor in others.

It was decided to collect all reliable data available for guidance of those drafting masonry wall provisions and to prepare recommendations representing the best information obtainable on the subject. An investigation of fire resistance of masonry walls had been instituted at the Bureau of Standards and has since been completed, and the results made available for this committee. Tests were made upon solid and hollow brick walls 11 by 16 feet in area and built with different varieties of brick and mortar. In the meantime all available data on the compressive strength of masonry were correlated, with especial care to evaluate the effects of differing conditions on strength and stability. These include results from an elaborate investigation of the compressive strength of brick walls in the largest units adapted to the 10,000,000-pound testing machine at the Bureau of Standards' former Pittsburgh laboratory. The advice of many experienced masonry builders was also obtained.

With this information in hand the committee prepared a tentative draft of code requirements regulating masonry wall construction in all types of buildings, together with an appendix explanatory of these requirements and including certain valuable material which had resulted from the investigations mentioned. Over 800 copies of this draft in mimeographed form, were submitted to architects, engineers, building officials, contractors, insurance adjusters, and others whose experience and interest qualified them to discuss the subject with authority.

The tentative draft was thoroughly reviewed. Over 150 letters were received presenting the well-considered opinions of about 200 experienced observers. These were summarized in form for ready reference and several meetings of the committee held for their consideration in connection with preparation of this report.

SCOPE OF REPORT

This report deals with exterior and interior masonry walls for all buildings. Walls for small dwellings are included, but are treated more specifically in the report on Recommended Minimum Requirements for Small Dwelling Construction, previously mentioned.

NOTE.—For reasons given in the Appendix, paragraph 8-3, reinforced concrete walls have been omitted.

ACKNOWLEDGMENT OF ASSISTANCE

The committee desires to express its appreciation of the cooperation extended by Bureau of Standards officials. S. H. Ingberg, of the bureau staff, rendered valuable assistance by compiling data, making available results of fire tests, by working with the committee at several meetings, and by supplying a discussion of bending stresses in walls due to wind loads and floor reactions. The unequaled research facilities of the bureau have been freely employed, and the results of numerous investigations made by the bureau in the field of masonry construction have been most helpful.

The committee also acknowledges the invaluable cooperation received from the great number of architects, engineers, building inspectors, fire chiefs, and others with whom it has been in contact. Their prompt and well-considered response to requests for information has greatly facilitated the work and has been much appreciated. It has been impracticable to report to each commentator the disposition of his suggestions. Many of the more important questions raised have been discussed in the Appendix.

PART II.—RECOMMENDED MINIMUM REQUIREMENTS FOR MASONRY WALL CONSTRUCTION

ARTICLE I.—DEFINITIONS

SECTION 1. DEFINITIONS.—For the purposes of this code the terms here defined shall have the following meanings.

1. *Bearing wall.*—A wall which supports any vertical load in addition to its own weight.

2. *Nonbearing wall.*—A wall which supports no load other than its own weight.

3. *Panel wall.*—A nonbearing wall in skeleton construction, built between columns or piers and wholly supported at each story. (See Appendix, par. 6-1.)

4. *Inclosure wall.*—An exterior nonbearing wall in skeleton construction anchored to columns, piers, or floors, but not necessarily built between columns or piers. (See Appendix, par. 6-2.)

5. *Curtain wall.*—A nonbearing wall between columns or piers and which is not supported by girders or beams.

6. *Party wall.*—A wall used or adapted for joint service between two buildings.

7. *Fire wall.*—A wall which subdivides a building to restrict the spread of fire, by starting at the foundation and extending continuously through all stories to and above the roof. (See Appendix, par. 7.)

8. *Fire division wall.*—A wall which subdivides a fire resistive building to restrict the spread of fire, but is not necessarily continuous through all stories nor extended through the roof. (See Appendix, pars. 7 and 17.)

9. *Veneered wall.*—A wall having a masonry facing which is not attached and bonded to the backing so as to form an integral part of the wall for purposes of load bearing and stability.

10. *Faced wall.*—A wall in which the masonry facing and backing are so bonded as to exert common action under load.

11. *Masonry.*—Stone, brick, concrete, hollow tile, concrete block or tile, gypsum block, or other similar building units or materials or a combination of same, bonded together with mortar to form a wall, pier, or buttress. (See Appendix, par. 8.)

12. *Piers.*—All bearing walls having a horizontal cross section of 4 square feet or less and not bonded at the sides into associated masonry shall be considered as piers.

13. *Portland cement mortar.*—A mortar composed of 1 part Portland cement to not more than 3 parts of sand, proportioned by volume, with an allowable addition of hydrated lime not to exceed

15 per cent of the cement by volume. (See Appendix, par. 10-4; and 13-2.)

14. *Cement-lime mortar.*—A mortar composed of 1 part Portland cement, 1 part hydrated lime, and not more than 6 parts of sand, proportioned by volume.

15. *Lime mortar.*—A mortar composed of 1 part slaked lime (lime putty) or dry hydrated lime and not more than 4 parts of sand, proportioned by volume. (See Appendix, par. 13-2.)

16. *Natural cement mortar.*—A mortar composed of 1 part natural cement to not more than 3 parts of sand, proportioned by volume.

17. *Ashlar masonry.*—Masonry of sawed, dressed, tooled, or quarry-faced stone with proper bond.

18. *Ashlar facing.*—Sawed or dressed squared stones used in facing masonry walls.

19. *Random ashlar facing.*—Sawed or dressed squared stone of various sizes properly bonded or fitted with close joints used for the facing of masonry walls.

20. *Coursed rubble.*—Masonry composed of roughly shaped stones fitting approximately on level beds and well bonded.

21. *Random rubble.*—Masonry composed of roughly shaped stone laid without regularity of coursing, but fitting together to form well-defined joints.

22. *Rough or ordinary rubble.*—Masonry composed of unsquared or field stones laid without regularity of coursing.

23. *Rubble concrete.*—Portland cement concrete in which the finer materials form a matrix for large stones and bowlders, sometimes termed cyclopean concrete.

NOTES.—1. Unless otherwise stated the word "concrete" for the purposes of this code is understood to mean Portland cement concrete.

2. Unless otherwise stated units of materials other than burned clay, having the same general shape and size of brick, are for the purposes of this code considered as brick. (See Appendix, par. 9-1.)

3. Unless otherwise stated the term "hollow tile" used without a qualifying adjective, is understood to mean clay hollow tile.

ARTICLE II.—SOLID BRICK WALLS

SEC. 2. QUALITY OF MATERIALS.—Brick, and sand-lime brick, used for bearing walls or piers shall be of quality at least equal to the "medium brick" described by the Standard Specifications for Building Brick of the American Society for Testing Materials, except that when the average compressive strength of brick grading "soft" by the absorption test, is more than 2,500 pounds per square inch, the requirements as to absorption may be waived. When used for non-bearing purposes and not exposed to the weather, brick may be of quality not inferior in any respect to the "soft" brick described in the above specifications. (See Appendix, pars. 9-2 and -3.)

The average compressive strength of concrete brick 28 days after being manufactured or when delivered on the job, shall be not less than 1,500 pounds per square inch of gross cross-sectional area tested in the position as laid in the wall, and the compressive strength of any individual brick thus tested shall be not less than 1,000 pounds per square inch. (See Appendix, par. 9-4.)

Concrete brick subjected to a 24-hour immersion test shall absorb not more than 12 per cent of their dry weight, except that for such brick weighing less than 125 pounds per cubic foot the average absorption in per cent by weight shall be not more than 12 multiplied by 125 and divided by the unit weight in pounds per cubic foot of the concrete under consideration. (See Appendix, par. 9-5.)

All cements and limes used in mortar shall conform to the requirements of the standard specifications for these materials issued by the American Society for Testing Materials. (See Appendix, par. 10-2.)

Sand used in mortar shall be clean and free from animal or vegetable matter. (See Appendix, par. 10-1.) (For precautions necessary in laying brickwork in freezing weather or in warm dry weather see Appendix, par. 13-5.)

Sec. 3. Lateral Support.—Solid brick walls shall be supported at right angles to the wall face at intervals not exceeding eighteen times the wall thickness in the top story or twenty times the wall thickness elsewhere. Such lateral support may be obtained by cross walls, piers, or buttresses, when the limiting distance is measured horizontally, or by floors when the limiting distance is measured vertically. Sufficient bonding or anchorage shall be provided between the wall and the supports to resist the assumed wind force, acting in an outward direction. Piers or buttresses relied upon for lateral support shall have sufficient strength and stability to transfer the wind force, acting in either direction to the ground. When walls are dependent upon floors for their lateral support, provision shall be made in the building to transfer the lateral forces resisted by all floors to the ground. (See Appendix, par. 12.)

Sec. 4. Working Stresses.—The maximum allowable compressive stresses in brick masonry due to combined live and dead loads shall not exceed the following limits. (See Appendix, par. 9-2.)

Brick masonry stresses

Unit	Maximum unit working stresses (pounds per square inch)		
	Portland cement mortar	Natural cement or cement-lime mortar	Lime mortar
Brick (clay), medium grade	170	130	90
Sand-lime brick	170	130	90
Concrete brick	170	130	70

Where the effects of eccentric loading and lateral forces are fully analyzed and allowance made for them in the design, or under local concentrated loads applied to a limited proportion of the total area of the wall, the working stresses in this table may be increased by 50 per cent. (See Appendix, par. 15.)

NOTE.—See Appendix, paragraphs 13 and 14, respectively, for effect of different factors on strength and stability of masonry.

SEC. 5.—THICKNESS OF EXTERIOR WALLS OTHER THAN IN SKELETON CONSTRUCTION.[2]—The thickness of solid brick bearing walls shall be sufficient at all points to keep the combined stresses due to live and dead loads for which the building is designed within the limits prescribed by section 4. (See Appendix, par. 15.)

The minimum thickness for solid brick exterior bearing or party walls shall be 12 inches for the uppermost 35 feet of their height, and shall be increased 4 inches for each successive 35 feet or fraction thereof measured downward from the top of the wall; except that the top story exterior bearing wall of a building not exceeding three stories or 40 feet in height, or the wall of a one-story commercial or industrial building may be 8 inches thick, provided that such 8-inch wall does not exceed 12 feet unsupported height and that the roof beams are horizontal; and except that exterior solid brick bearing walls of one and two family dwellings may be 8 inches thick when not more than 30 feet in height. When gable construction is used for such dwellings, an additional 5 feet is permitted to the peak of the gable. (See Appendix, par. 16.)

Where solid brick exterior bearing or party walls are stiffened at distances not greater than 12 feet apart by cross walls, or by internal or external offsets or returns, at least 2 feet deep, they may be 12 inches thick for the uppermost 70 feet, measured downward from the top of the wall, and shall be increased 4 inches in thickness for each successive 70 feet or fraction thereof.

NOTE.—See Appendix, paragraphs 2-2 and 13-5 for influence of workmanship; paragraph 21, for discussion of wall heights. See Part II, section 3, and Appendix, paragraph 12, for lateral support of walls.

The minimum thickness of solid brick exterior nonbearing walls shall be 12 inches for the uppermost 70 feet of their height, and shall be increased 4 inches for each successive 35 feet or fraction thereof, measured downward from the top of the wall, except that the top story wall of a building not exceeding three stories or 40 feet in height, or the wall of a one-story commercial or industrial building may be 8 inches thick, provided that such 8-inch wall does not exceed 12 feet unsupported height, and that the roof beams are

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[2] For thickness requirements for walls in skeleton constructed buildings, see Part II, sec. 44. For discussion on allowable percentage of openings, see Appendix, par. 18-9.

horizontal; and except that solid brick nonbearing walls of one and two family dwellings may be 8 inches thick when not more than 30 feet in height. When gable construction is used for such dwellings an additional 5 feet is permitted to the peak of the gable. (See Appendix, pars. 16 and 18. For interior wall requirements, see Part II, secs. 36 to 39, also 41 and 42.)

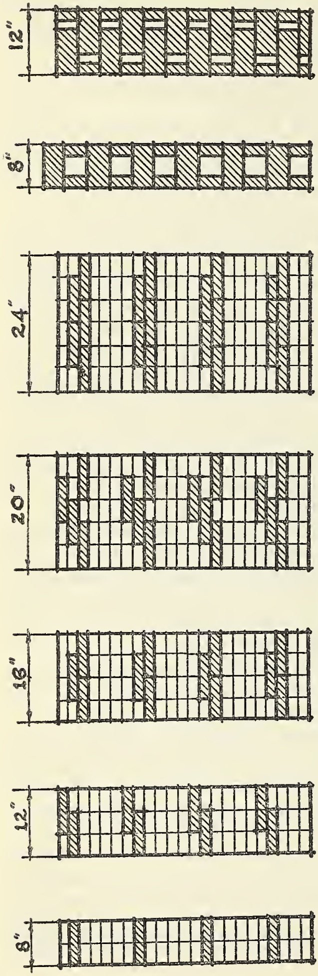

Fig. 1.—*Desirable methods of bonding brick walls of various thicknesses and types*

Sec. 6. Bond.—In all brick walls at least every sixth course on both sides of the wall shall be a header course or there shall be at least one full length header in every 72 square inches of each wall surface. In walls more than 12 inches thick the inner joints of header courses shall be covered with another header course which shall break joints with the course below. (See fig. 1 and Appendix, par. 19.)

Where running bond is used, every sixth course on each face shall be bonded into the backing by cutting the face brick course and using diagonal headers behind it or by using a split brick.

Note.—For requirements applying to veneered walls, see Part II, Article VI.

Sec. 7. Piers.—The unsupported height of piers shall not exceed ten times their least dimension. (See Appendix, par. 20.)

SEC. 8. CHASES AND RECESSES.—There shall be no chases in 8-inch walls or within the required area of any pier, and no chase in any wall or pier shall be deeper than one-third the wall thickness. No horizontal chase shall exceed 4 feet in length, nor shall the horizontal projection of any diagonal chase exceed 4 feet.

Recesses for stairways or elevators may be left in walls, but in no case shall the walls at such points be less than the required thickness of walls of the fourth story above the ground floor unless reinforced by additional piers, by steel or reinforced concrete girders, or steel or reinforced concrete columns and girders, securely anchored to the walls on each side of such recesses. Recesses for alcoves and similar purposes shall have not less than 8 inches of material at the back. Such recesses shall be not more than 8 feet in width and shall be arched over or spanned with lintels.

The aggregate area of recesses and chases in any wall shall not exceed one-fourth the whole area of the face of the wall in any story.

No chases or recesses shall be permitted in fire or fire division walls that will reduce the thickness below the minimum specified in this code. (See Part II, secs. 36 to 39.)

Openings for doors and windows shall have well-buttressed arches or lintels of masonry, or of metal with bearing at each end of not less than 4 inches on the wall. On the inside of openings less than 4 feet wide, in which the thickness of arches and lintels is less than that of the wall supported, timber may be used, which will rest at each end not more than 2 inches on the wall and be chamfered or cut to serve as arch centers. (See Appendix, par. 18-4, and par. 32 for discussion of anchorage.)

ARTICLE III.—WALLS OF HOLLOW TILE, CONCRETE BLOCK OR TILE, AND HOLLOW WALLS OF BRICK

SEC. 9. QUALITY OF MATERIALS.—*Hollow tile.*—Hollow tile used for exterior bearing walls or piers or for party walls shall be of quality at least equal to the "medium class" as prescribed by the Tentative Specifications for Hollow Burned-Clay Load-Bearing Wall Tile of the American Society for Testing Materials. (See Appendix, par. 24-1 and -2.)

When used for nonbearing purposes and not exposed to the weather, hollow tile may be of quality not inferior in any respect to the "soft class" described in the above specifications.

NOTE.—For quality of tile used in partitions, see Part II, sections 41 and 42.

Concrete block or concrete tile.—The average compressive strength of concrete block or tile used for exterior or party walls or piers shall be not less than 700 pounds per square inch of gross sectional area tested in position as used in the wall. The absorption of concrete block or tile shall not exceed 10 per cent under a 24-hour immersion test, except that where concrete block or tile have an average compressive strength of over 1,200 pounds per square inch gross area, or where they are not exposed to dampness, or where they are coated with stucco, the requirement as to absorption may be waived. For block or tile made of concrete weighing less than 140 pounds per cubic foot, the average absorption in per cent by weight shall be not more than 10 multiplied by 140 and divided by the unit weight in pounds per cubic foot of the concrete under consideration. (See Appendix, par. 9-5.)

Tests on concrete block shall be conducted in accordance with the Standard Specifications of the American Concrete Institute. (See Appendix, par. 24-3.)

Brick.—Brick for hollow walls shall conform to requirements of Part II, section 2.

Mortar.—Either Portland cement mortar as defined in section 1, or a special cement-lime mortar mixed in proportions of 1 part Portland cement, 1 part slaked lime (lime putty) or dry hydrated lime, and not more than 4 parts sand, shall be used for walls of hollow unit construction or hollow walls of brick.

SEC. 10. LATERAL SUPPORT.—Walls of hollow tile or of concrete block or tile, and all hollow walls of brick shall be supported at right angles to the wall face at intervals not exceeding sixteen times the wall thickness in top stories, or eighteen times the wall thickness elsewhere. Such lateral support may be in the form of cross walls, piers, or buttresses when the limiting distance is horizontal, or by floors when the limiting distance is vertical. Sufficient bonding or anchorage shall be provided between the wall and the supports to resist the assumed wind force acting in an outward direction. Piers or buttresses relied upon for lateral support shall have sufficient strength and stability to transmit the wind force, acting in either direction, to the ground. When walls are dependent on floors for their lateral support provision shall be made in the building to transfer the lateral force resisted by all floors to the ground. (See Appendix, par. 12.)

SEC. 11. WORKING STRESSES.—The maximum allowable compressive stresses in masonry of hollow tile, concrete block or concrete tile, or hollow walls of brick, due to combined live and dead loads, shall not exceed 80 pounds per square inch of gross sectional area, when laid with Portland cement mortar, and 70 pounds per square inch of gross sectional area when laid with special cement-lime mortar. (See section 9, Mortar. See also Appendix, par. 25-1.)

SEC. 12. THICKNESS AND HEIGHT OF EXTERIOR WALLS OTHER THAN IN SKELETON CONSTRUCTION.[3]—Walls of hollow tile, concrete block or

[3] For thickness requirements for walls in skeleton constructed buildings, see Part II, sec. 44. For discussion on allowable percentage of openings, see Appendix, par. 18-9.

tile, or hollow walls of brick shall not exceed 50 feet in height above the top of foundation walls.

The thickness of walls of the above materials and types shall be sufficient at all points to keep the stresses due to combined live and dead loads for which the building is designed within the limits prescribed by section 11.

The minimum thickness of exterior walls of hollow tile, or concrete block or tile, or of hollow-wall construction shall be 12 inches for the uppermost 35 feet of their height, and at least 16 inches for the remaining lower portion; except that the top story wall of a building not exceeding three stories or 40 feet in height, or the wall of a one-story commercial or industrial building may be 8 inches thick, provided that the roof beams are horizontal; and except that exterior walls of one and two family dwellings may be 8 inches thick for the uppermost 20 feet. When gable construction is used for such dwellings an additional 5 feet is permitted to the peak of the gable. (See Appendix, par. 16-6.)

Where walls are stiffened at distances not greater than 12 feet by cross walls or by internal or external returns at least 2 feet deep, the thickness may be 12 inches throughout, except that the top story, or for one and two family dwellings the uppermost 20 feet, may be 8 inches as previously provided. (See Appendix, par. 16-1 and -4. For interior wall requirements see Part II, secs. 36 to 39, also 41 and 42.)

Sec. 13. Bond.—Where two or more hollow units are used to make up the thickness of a wall, the inner and outer courses shall be bonded at vertical intervals not exceeding three courses by lapping at least one cell completely over a cell of the unit below.

Sec. 14. Beam Supports.—Suitable provision shall be made at each line of floor beams in hollow walls or walls of hollow units, to shut off the spaces above from those below, and to ensure good bearing for beams and uniform distribution of loads. (See Appendix, par. 26.)

Sec. 15. Piers.—Hollow tile or hollow concrete block or tile shall not be used for isolated piers unless solidly filled with concrete. The unsupported height of such piers shall not exceed 10 times their least horizontal dimension. (See sec. 1, definition 12, and Appendix, par. 26.)

Sec. 16. Chases and Recesses.—Chases and recesses in walls of hollow tile, hollow concrete block or tile, or in hollow walls of brick shall not exceed in extent those permitted for solid brick walls under the same conditions. Chases and recesses shall not be cut in walls of the above types, but may be built in. No chases or recesses shall be permitted in fire walls that will reduce the thickness below the minimum specified in this code.

Openings for doors and windows shall have well-buttressed arches or lintels of masonry or metal with bearing at each end of not less than 4 inches on the wall. On the inside of openings less than 4 feet wide, in which the thickness of arches and lintels is less than that of the wall supported, timber may be used, which will rest at each end not more than 2 inches on the wall and be chamfered or cut to serve as arch centers.

ARTICLE IV.—WALLS OF PLAIN CONCRETE

SEC. 17. CONCRETE MATERIALS.—Monolithic concrete construction containing not more than two-tenths of 1 per cent of reinforcement shall be classed as plain concrete.

Materials for bearing walls and piers of plain concrete shall be mixed in proportions of 1 part of Portland cement to not more than 3 parts of sand and 5 parts of coarse aggregate, by volume, or a mixture of fine and coarse aggregates giving an equivalent strength and density.

Coarse aggregate shall consist of crushed stone, gravel, or crushed slag, 85 per cent of which is retained on a No. 4 screen, and shall be graded in size from small to large particles. The particles shall be clean, hard, durable, and free from deleterious material. (See Appendix, par. 27.)

Cement for plain concrete shall conform to the requirements of the Standard Specifications and Tests for Portland Cement of the American Society for Testing Materials.

Fine aggregate shall consist of sand, washed stone screenings or other similar inert materials, or a combination thereof, having clean, hard, strong, durable uncoated grains and free from injurious amounts of dust, lumps, soft or flaky particles, shale, alkali, organic matter, loam or other deleterious substances; and shall range from fine to coarse. Not less than 95 per cent shall pass a No. 4 sieve, and not more than 30 per cent shall pass a No. 50 sieve, when tested according to standard practice prescribed by the American Society for Testing Materials.

SEC. 18. LATERAL SUPPORT.—Plain concrete walls shall be supported at right angles to the wall face at intervals of not exceeding twenty times the wall thickness. Such lateral support may be in the form of cross walls, piers, or buttresses when the limiting spacing is horizontal, or by floors when the limiting distance is vertical. Sufficient bonding or anchorage shall be provided between the wall and the supports to resist the assumed wind force acting in an outward direction. Piers or buttresses relied upon for lateral support shall have sufficient strength and stability to transfer the wind force, acting in either direction, to the ground. When walls are dependent upon floors for their lateral support provision shall be made in the building to transfer the lateral force resisted by all floors to the ground. (See Appendix, par. 12.)

Sec. 19. Working Stresses.—The maximum allowable stresses in masonry of plain concrete of the proportions specified in section 17 as a minimum due to combined dead and live loads shall not exceed 400 pounds per square inch in compression, 35 pounds per square inch in tension or diagonal tension; or 90 pounds per square inch in punching shear. When plain concrete of greater strength is used the foregoing stresses may be increased to 20 per cent of the ultimate compressive strength for concrete in compression, 2 per cent in tension or diagonal tension, and 4½ per cent in punching shear.

Sec. 20. Thickness of Walls.—The minimum thickness of plain concrete bearing walls shall be 10 inches for the uppermost 35 feet of their height and shall be increased 4 inches for each successive 35 feet or fraction thereof, measured downward from the top of the wall, except that the top-story wall of a building not exceeding three stories or 40 feet in height, or the wall of a one-story commercial or industrial building may be 8 inches thick, provided that such 8-inch wall does not exceed 12 feet unsupported height and that the roof beams are horizontal, and except that exterior bearing walls of one and two family dwellings may be 6 inches thick when not more than 30 feet in height. When gable construction is used for such dwellings an additional 5 feet is permitted to the peak of the gable. (See Appendix, par. 16.)

When plain concrete bearing walls of buildings more than three stories high are stiffened at points not more than 12 feet apart by cross walls, or by internal or external offsets or returns at least 2 feet deep, they may be 10 inches thick for the uppermost 70 feet of their height and shall be increased 4 inches in thickness for each successive 70 feet or fraction thereof.

The minimum thickness of plain concrete exterior nonbearing walls shall be 10 inches for the uppermost 70 feet of their height, and shall be increased 4 inches for each successive 35 feet or fraction thereof, measured downward from the top of the wall; except that the top story wall of a building not exceeding three stories or 40 feet in height, or the wall of a one-story commercial or industrial building may be 8 inches thick, provided that such 8-inch wall does not exceed 12 feet unsupported height, and that the roof beams are horizontal; and except that exterior nonbearing walls of one and two family dwellings may be 6 inches thick when not more than 30 feet in height. When gable construction is used for such dwellings an additional 5 feet is permitted to the peak of the gable. (For discussion of heights, see Appendix, par. 21.)

Hollow monolithic walls of plain concrete shall have the same net cross sectional area of material, irrespective of the space within the wall, as required for solid walls. The inner and outer parts of such walls shall be securely braced and tied together with noncorrodible ties or other means to bring them into common action. Where floor and roof systems are carried by such walls, provision shall be made for the distribution of these loads to the full cross section of the wall. (See Appendix, par. 27.) For interior wall requirements, see sections 36 to 39, also 41 and 42.

Sec. 21. Reinforcement.—Reinforcement, not less than two-tenths of 1 per cent computed on a vertical height of 12 inches, shall be placed over all wall openings and at corners of the structure to prevent cracks. Floor and roof connection details shall be designed to transmit safely the vertical and horizontal loads imposed.

Sec. 22. Piers.—The unsupported height of isolated piers of plain concrete shall not exceed ten times their least dimension. (See sec. 1, definition 12.)

Sec. 23. Chases and Recesses.—Chases and recesses in plain concrete walls shall not exceed in extent those permitted for solid brick walls under the same conditions. (See Part II, sec. 8.)

ARTICLE V.—STONE WALLS

Sec. 24. Working Stresses.—The maximum allowable compressive stresses in rubble stonework due to combined live and dead loads shall not exceed 140 pounds per square inch when laid in Portland cement mortar, 100 pounds per square inch in natural cement or cement-lime mortar, and 70 pounds per square inch in lime mortar.

The maximum allowable compressive stress in ashlar masonry due to combined live and dead loads shall not exceed the following limits:

Unit	Maximum unit working stresses (pounds per square inch) laid in—		
	Portland cement mortar	Cement-lime or natural cement mortar	Lime mortar
Granite	800	640	400
Limestone	500	400	250
Marble	500	400	250
Sandstone	400	320	160

Sec. 25. Lateral Support and Thickness.—Rubble stone walls shall be 4 inches thicker than is required for solid brick walls of the same respective heights, but in no part less than 16 inches.

The minimum thickness for walls or piers of ashlar masonry properly bonded shall be the same as required for solid brick walls and piers under similar conditions.

The lateral support for stone walls shall conform to the same requirements specified for solid brick walls, Part II, section 3. (For discussion of heights, see Appendix, par. 21.)

Sec. 26. Bond.—Bond stones extending through the wall and uniformly distributed shall be provided to the extent of not less than 10 per cent of the area, and there shall be at least one bond stone for every eight stretchers.

Sec. 27. Chases and Recesses.—Chases and recesses in stone walls shall not exceed in extent those permitted for solid brick walls under the same conditions. (See Part II, sec. 8.)

ARTICLE VI.—VENEERED WALLS

Sec. 28. Quality of Materials.—Materials used in the backing and veneering of veneered walls shall conform in all respects to the requirements prescribed for such materials in Part II, sections 2, 9, and 17. Stone or architectural terra-cotta ashlar, or other approved masonry material used for veneering, shall be not less than 3 inches thick. In stone ashlar each stone shall have a reasonably uniform thickness, but all stones need not necessarily be the same thickness.

Sec. 29. Working Stresses.—The maximum allowable compressive stresses on the backing of veneered walls, due to combined live and dead loads, shall not exceed those elsewhere prescribed for masonry of the type which forms such backing. In no case shall the veneering be considered a part of the wall in computing the strength of bearing walls, nor shall it be considered a part of the required thickness of the wall.

Sec. 30. Attachment of Veneering.—When walls are veneered with brick, terra cotta, stone or concrete trim stone the veneering shall be tied into the backing either by a header for every 300 square inches of wall surface, or by substantial noncorrodible metal wall ties spaced not farther apart than 1 foot vertically and 2 feet horizontally. Headers shall project at least 3¾ inches into the backing, and anchors shall be of substantial pattern. When veneering is used special care shall be taken to fill all joints flush with mortar around wall openings. (See Appendix, par. 32-8.)

Sec. 31. Height of Veneered Walls.—Veneered walls shall not exceed 40 feet in height above foundations.

ARTICLE VII.—FACED WALLS

Sec. 32. Quality of Materials.—Materials used in the backing and facing of faced walls shall conform in all respects to the requirements prescribed for such materials in Part II, sections 2, 9, and 17.

Materials used for facing shall be not less than 3¾ inches thick, and in no case less in thickness than one-eighth the height of the unit, excepting that spandrel and other recessed panels, when approved, may be higher than eight times their thickness, provided they are of the minimum thickness required.

Sec. 33. Working Stresses.—The maximum allowable compressive stresses on faced walls due to combined live and dead loads shall not exceed those elsewhere prescribed for masonry of the type which forms the backing. Where bonded to the backing as provided in section 35 the full cross section of the facing may be considered in computing bearing strength.

Sec. 34. Thickness.—Faced walls shall be not less in thickness than is required for masonry walls of the type which forms the backing. Where bonded to the backing as provided in section 35 the facing may be considered a part of the wall thickness.

Sec. 35. Bond.—Brick facing shall be bonded to walls of brick or of hollow tile, or of concrete block or tile with at least one header course in every six courses, or there shall be at least one full length header in every 72 square inches of wall surface.

Stone ashlar facing shall have at least 20 per cent of the superficial area not less than 3¾ inches thicker than the remainder of the facing to form bond stones, which shall be uniformly distributed throughout the wall.

When some stone in every alternate course are at least 7½ inches thick, bonded into the backing at least 3¾ inches, and at least 20 per cent of the superficial area of the wall is constituted of such bond stone uniformly distributed, the ashlar facing may be counted as part of the wall thickness. Every stone not a bond stone and every projecting stone shall be securely anchored to the backing with substantial noncorrodible metal anchors. (See Appendix, par. 32-8.)

ARTICLE VIII.—FIRE WALLS, FIRE DIVISION WALLS, AND PARTITIONS

Sec. 36. Brick and Plain Concrete Fire Walls.—Solid brick or plain concrete fire walls shall be not less in thickness than required for exterior bearing walls of corresponding height, but not less than 12 inches, except that solid brick fire walls for buildings of residential occupancy shall be not less than 8 inches thick for the uppermost 20 feet of height and shall be at least 12 inches thick for the remaining lower portion; and except that plain concrete fire walls for such structures may be 8 inches throughout. No 8-inch fire wall shall be broken into, subsequent to building, for the insertion of structural members. (See Appendix, par. 7-6, -8, and -9, and par. 17. For definitions of fire and fire division walls, see Part II, sec. 1.)

Party walls which function also as fire walls shall conform to requirements for fire walls.

A separation of at least 4 inches of solid masonry shall be provided in all fire and party walls between combustible members which may enter such walls from opposite sides.

Sec. 37. Fire Walls of Hollow Tile, Concrete Block or Concrete Tile, or of Hollow Wall Construction.—Fire walls of hollow tile or concrete block or concrete tile shall be not less than 16 inches thick in any part, except that for residental buildings they may be not less than 12 inches thick throughout. Hollow walls of brick used as fire walls shall be not less than 12 inches thick throughout. No fire walls of the above types shall be broken into, subsequent to erection, for the insertion of structural members. (See Appendix, par. 7-5 and -6, and par. 17.)

Where combustible or unprotected steel building members frame into hollow party or fire walls of thickness not greater than 12 inches, they shall not project more than 4 inches into the wall and shall be so spaced that the distance between embedded ends is not less than 4 inches. The space above, below, and between them shall be filled solidly with burnt-clay materials, mortar, concrete, or equivalent fire-resistive material, to a depth of not less than 4 inches on all sides of the members.

All open cells in tile or blocks occurring at wall ends shall be filled solid with concrete for at least a depth of 6 inches, or closure tile set in the opposite direction shall be used.

Party walls which function also as fire walls shall conform to requirements for fire walls.

Sec. 38. Fire Division Walls.—Fire division walls of solid brick or plain concrete shall be not less than 8 inches thick.

Fire division walls of hollow tile, or of concrete block or tile, shall be not less than 12 inches thick in any part, and for buildings of storage and heavy manufacturing occupancy they shall be not less than 16 inches thick throughout. Hollow walls of brick used as fire division walls shall be not less than 12 inches thick throughout. (See Appendix, pars. 7 and 17.)

Sec. 39. Alternate Requirements for Fire and Fire Division Walls.—Wall constructions that in fire tests conducted according to accepted standards develop safe fire-resistance periods of one and one-half hours may be permitted for fire walls and fire division walls between residence occupancies, if otherwise adequate in point of strength and stability. For general mercantile and manufacturing occupancies, excluding buildings or portions of buildings used for storage, wall constructions developing, on the same basis, a safe fire-resistance period of three hours shall be similarly permitted.

Note.—For requirements for lateral support of walls, see Part II, sections 3, 10, and 18.

Sec. 40. Parapet Walls.—In commercial or industrial buildings and in residential buildings over three stories high, all fire or party walls shall project above the roof as parapets.

Where not otherwise specified parapet walls shall be at least 32 inches high, but not higher than four times their thickness unless laterally supported. They shall be at least as thick as the top story wall, except that they need not in any case be more than 12 inches thick.

In residential buildings not more than three stories high parapet walls shall extend through combustible roofs to a height of at least 12 inches above the roof. All parapet walls shall be coped. (See Appendix, par. 29.)

Sec. 41. Bearing Partitions.—All interior bearing walls, except fire walls, fire division walls, and party walls, are considered as bearing partitions.

For bearing partitions, materials meeting the ordinary accepted local standards for the purpose may be used.

Where not utilized as party, fire, or fire division walls solid brick bearing partitions shall be not less than 8 inches thick, and those of hollow tile, concrete block or concrete tile, or hollow walls of brick shall be not less in thickness than one-eighteenth of the height between floors or floor beams. (For conditions governing concentrations see sec. 4.)

Sec. 42. Nonbearing Partitions.—For nonbearing partitions, materials meeting the ordinary accepted local standards for the purpose may be used.

Brick nonbearing partitions shall be not less than 3¾ inches thick for a height not exceeding 12 feet between floors or floor beams and for a length not exceeding 20 feet between vertical supports. Nonbearing partitions of hollow tile, concrete block or concrete tile, hollow walls of brick or of gypsum block or other similar materials shall be built solidly against floor and ceiling construction below and above, and shall not exceed the following unsupported heights:

Thickness exclusive of plaster	Maximum unsupported height	Thickness exclusive of plaster	Maximum unsupported height
Inches	*Feet*	*Inches*	*Feet*
2	8	6	20
3	12	8	25
4	15		

ARTICLE IX.—FOUNDATION WALLS

Sec. 43. Foundation Walls.—Foundation walls for solid-wall construction shall be of stone, solid brick, concrete (plain, rubble, or reinforced), or concrete block. Solid brick foundation walls and those of concrete block or coursed stone shall be not less in thickness than the walls immediately above them and in no case less than 12 inches thick, except that when the inclosure is not excavated, they may be 8 inches thick if included within the allowable height of 8-inch walls. When built of concrete cast in place, foundation walls shall be at least as thick as the walls supported, but in no case less than 8 inches. When built of rubble stone, they shall be at least 16 inches thick. Rough or random rubble without bonding or level beds shall not be used as foundations for walls exceeding 35 feet in height nor shall coursed bonded rubble walls be used as foundations for walls exceeding 75 feet in height. (See Appendix, par. 18-1.)

Foundation walls for hollow tile, concrete block or tile, hollow walls of brick, or frame construction, shall be of the same thicknesses, respectively, as required in the paragraph above, and shall be built of brick, stone, concrete (plain, rubble, or reinforced), hollow tile, concrete block or tile, or hollow walls of brick. Tile foundation walls shall be not less than 12 inches thick.

When the stresses due to earth pressure and superposed building load exceed the maximum working stress elsewhere specified for brick masonry, and the additional stresses are not otherwise provided for, the wall thickness shall be increased to bring them within these limits. (See Appendix, par. 30.)

Foundation walls for frame construction shall extend at least 8 inches above the adjoining ground surface.

All foundation walls shall extend below the level of frost action.

Materials for foundation walls shall be equal in quality in all respects to those required for exterior bearing walls, except that mortar containing lime in greater proportions by volume than 1 part to 1 part of cement and 6 parts of sand shall not be used for exterior foundation walls below grade. (See Appendix, par. 30-2.)

ARTICLE X.—SKELETON CONSTRUCTION

Sec. 44. Panel and Inclosure Walls.—Panel walls in buildings of skeleton construction shall be not less than 8 inches thick if of solid brick, hollow tile, concrete block or tile, plain concrete, or hollow walls of brick. Inclosure walls shall be not less than 8 inches thick nor less in thickness than one-twentieth the horizontal distance between anchors. (See Appendix, par. 6-2.)

ARTICLE XI.—NEW TYPES OF MASONRY CONSTRUCTION

Sec. 45. New Masonry Construction.—The use of new or improved masonry materials or methods not covered by this code may be permitted, providing that they conform to specifications insuring reasonable uniformity of the product; and that the stability and durability of such construction, and its resistance under fire exposure shall have been satisfactorily demonstrated. Working stresses shall be fixed at not more than 20 per cent of the average ultimate strength of masonry walls constructed of such materials, as determined by responsible authorities. (See Appendix, par. 31.)

ARTICLE XII.—MISCELLANEOUS REQUIREMENTS

Sec. 46. Anchoring Walls.—All walls shall be securely anchored and bonded at points where they intersect. (See Appendix, par. 32.)

Sec. 47. Use of Existing Walls.—An existing brick wall may be used in the renewal or extension of a building; or may be increased in height beyond that allowed by this code for walls of its existing thickness and materials of construction, provided that such wall is structurally sound or can be made so by reasonable repairs. Walls increased in height shall be at least 4 inches thicker than is required by this code for newly constructed walls of such increased height, and in no case shall linings be less than 8 inches thick and laid in Portland cement mortar. The foundations and lateral support shall be equivalent to those elsewhere required for newly constructed walls under similar conditions. All linings shall be thoroughly bonded into existing masonry by toothings of brick or stone to assure combined action of wall and lining. Such toothings shall be distributed fairly uniformly throughout the wall and shall aggregate in vertical cross-sectional area not less than 15 per cent of the total vertical area of the lining. (See Appendix, pars. 22 and 32-1.)

No existing wall shall be used for renewal or extension of a building, or increased in height without special written permission from the building official.

Sec. 48. Corbeling of Chimneys.—No brick wall less than 12 inches thick shall be used to support a corbeled chimney. Such corbeling shall not project more than 6 inches from the face of the wall, and in all such cases the corbeling shall consist of at least five courses of brick. No chimney shall be corbeled from a wall built of hollow tile, hollow concrete block, concrete tile, or hollow walls of brick.

Sec. 49. Cornices.—The centers of gravity of stone cornices shall be inside of the outer wall face. Terra cotta or metal cornices shall be structurally supported from the roof of the building.

PART III.—APPENDIX

PARAGRAPH 1. PURPOSE

The Appendix consists of explanatory matter referring to Part II and is a vital part of this report. The committee believes that every building code should be accompanied by an appendix which should contain sufficient explanation of the code requirements to make them easily understandable and such other information on good practice as is not easily obtainable elsewhere in concise form.

PARAGRAPH 2. JUSTIFICATION FOR REQUIREMENTS, AND INFLUENCE OF BUILDING INSPECTION

1. It is recognized that the requirements recommended in Part II constitute in some particulars relaxations from those in force in certain cities and parts of the country. These modifications of existing practice are justified by the facts developed through the committee's investigations. In addition to the test data discussed in the following pages the experience has been noted of several large cities which for many years have utilized wall heights, thicknesses, and stress limits fully as liberal as those recommended in Part II. The success resulting with these moderate requirements in many places and under varied circumstances is the most satisfactory answer to the objections to their adoption in localities where present requirements are more conservative.

The recommendations are predicated on the assumption that good materials and workmanship will be used and all necessary care taken in assembling the various parts of the structure. Certain existing code provisions applying to walls and other structural details, which might be classified as extreme, reflect in part the purpose of their writers to offset poor design or workmanship by a greater factor of safety. In effect such codes penalize the builder, by requiring additional material and labor because of a city's failure to provide, or compel the provision of adequate and competent supervision of building operations. It is felt that the extra expense thus caused more than warrants energetic measures to insure such supervision, and that it is the duty of all concerned with planning and supervising building construction, both to the public and to their clients, to use every influence toward securing it.

2. Where responsible supervision can be assured the code requirements recommended in this report are believed safe. Where inspection is of uncertain character relaxation of more restrictive or expensive existing requirements is not advocated. In modifying their code provisions to reduce cost, local authorities should insist upon supervision of construction by an adequate experienced personnel.

At the same time, city building inspectors should avoid the other extreme. There is a tendency for the building inspection departments of municipalities to forget that theirs is primarily a police function, concerned only with public safety, and to lay too much stress on matters which are good building practice, but have nothing to do with the police power. This is reflected to a considerable extent in some recent building codes, and in preparing these recommendations the effort has been made to keep them within the bounds of simplicity necessitated by safety considerations alone.

3. The committee for the most part has confined itself to structural requirements and has avoided matters of administration. The public discussion of the tentative report, however, discloses a strong sentiment for placing greater responsibility on those charged with building construction, and a few remarks on this subject seem desirable.

The municipal building inspector is not and should not be held wholly responsible for safety of buildings. His duty, like that of the policeman, is to prevent dangerous conditions, so far as his facilities will permit, but reasonable precautions having been taken, he is no more responsible for failures than the policeman for crimes. The builder or his accredited representative, having undertaken erection of the structure, is responsible for safe prosecution of the work. Building erection, especially of the large structures now prevalent, is an operation of great complexity involving numerous possibilities of mishap, both to those engaged in the work and to future occupants. The risks involved and the knowledge demanded of those in charge are far greater than in the case of many trades or occupations now rigidly controlled. Nevertheless, such work is frequently undertaken by those having practically no experience and often assuming an antagonistic attitude toward the building inspector's efforts to insure safety.

In view of these facts some discretion should be accorded building officials as to who may be granted permits. The committee does not necessarily advocate licensing of builders, but does hold that local practice should strongly favor the issuance of permits only to responsible individuals experienced in building work and competent to assume responsibility for their employees and subcontractors; and that building officials should be empowered to refuse permits to those known to be unfit for the work proposed or who have failed formerly to cooperate sufficiently with municipal inspection to insure reasonable safety. This means that permits would be issued only to the builder, architect, or person who is responsible for erection of the building, and not necessarily to the owner.

PARAGRAPH 3. STATUS OF THE COMMITTEE'S RECOMMENDATIONS

1. It has been called to the committee's attention that some misunderstanding exists regarding the legal status of its recommendations. It should be recognized that the committee's functions are purely advisory. Its recommendations can not be considered in any sense as obligatory, but are issued to make available to those locally responsible for exercise of the police power the latest and most reliable information obtainable on building regulations.

2. The recommended code requirements are in all cases the minimum consistent with safety predicated upon proper design and good workmanship. The scope of the police power, upon which all such ordinances depend for authority, does not justify requirements which are merely good building practice, and where such requirements are included in codes they are apt to be found unenforceable.

When two or more materials or methods of construction are mentioned in this report as satisfying a certain requirement, it does not follow that they are considered on a par in all desirable respects, but merely that they meet the standards of performance regarded as essential.

3. It is not intended that these recommendations shall be regarded as fixed. Building laws can continue to be of the highest usefulness only when they reflect progress in the art of building construction. Many of the injustices and discrepancies of existing building codes result from delay in their revision to meet changing conditions. It is planned that these recommendations shall be amended at intervals, keeping pace with changes in building art. In this way it is hoped that best assistance may be rendered those responsible for revision and enforcement of building ordinances.

PARAGRAPH 4. FUNCTION OF WALLS

Under prevailing interpretations of the police power there are certain definite requirements which masonry walls in buildings must meet.

1. They must not fail structurally under loads or conditions incidental to the building's occupancy.

2. They must resist moisture penetration to an extent which will insure sanitary living or working conditions, and the permanency of the wall itself or of members framing into it.

3. Under fire exposure their stability must be such as to avoid premature collapse endangering firemen, and they must discharge the functions of support and heat insulation, necessary to prevent undue fire loss.[4]

PARAGRAPH 5. VARIATION IN CODE REQUIREMENTS

So far as can be determined from an examination of present municipal regulations, experience in satisfying these requirements has not resulted in uniform practice. The committee had reference to four independent investigations on this subject.

1. An analysis by the Bureau of Standards of the requirements of 134 building codes, representing all parts of the country, disclosed the following facts.

Average requirements and limitations of 134 codes for brick foundations and solid exterior walls for dwellings

THICKNESS WITHIN FIRE LIMITS ONLY

Foundation, in inches	Stories				Limits of			
	First	Second	Third	Fourth	Height	Length	Width	Area
	Inches	*Inches*	*Inches*	*Inches*	*Feet*	*Feet*	*Feet*	*Sq. ft.*
12.5	9.7				15.5	65.9	23.7	1,311
13.7	11.0	9.7			28.7	69.8	24.3	1,311
16.2	13.1	11.8	10.5		41.5	80.2	24.4	
18.5	16.0	13.5	12.3	11.2	53.7	80.6	24.9	

THICKNESS WITHIN OR OUTSIDE OF FIRE LIMITS

Foundation, in inches	First	Second	Third	Fourth	Height	Length	Width	Area
12.5	9.2				15.3	65.7	23.5	1,244
13.6	10.4	9.2			28.5	69.7	23.9	1,404
16.2	12.8	11.5	10.2		41.5	81.8	22.9	
18.5	14.4	13.2	12.0	11.0	54.0	83.6	25.0	

[4] The protection of stored commodities or prevention of interior deterioration is also an important function of walls and should be considered. It does not come within the police power.

Among the 134 codes there were 3 different minimum thicknesses prescribed for one-story residential buildings, 4 for two-story dwellings, 8 for three-story dwellings, and no less than 12 different minimum thickness arrangements allowable for the different stories of four-story buildings. Other conditions being equal the thickest four-story wall contained 125 per cent more brick than the thinnest. A similar situation was found to exit in regard to walls of hollow tile and hollow concrete block.

2. A compilation by the Common Brick Manufacturers' Association of America of the allowable thicknesses of solid brick exterior walls of dwellings as given in 113 building codes and summarized as follows:

Minimum allowable thickness of solid brick exterior walls for dwellings according to building codes of 113 cities

Dwellings	Walls	Cities
One-story	8-inch	88
Do	Over 8-inch	25
Two-story	8-inch, both stories	44
Do	Over 8-inch, first story	38
Do	Over 8-inch, both stories	31
Three-story	8-inch, all stories	8
Do	Over 8-inch, first story	17
Do	Over 8-inch, first and second stories	30
Do	Over 8-inch, all stories	53

3. An investigation was made by the committee of code requirements for panel walls supported at each story, with the following results:

Of 84 municipal building codes examined, 30 do not distinguish between panel walls supported at every story and bearing walls or nonbearing walls not thus supported.

Six codes recognize panel walls as a separate class, but require that their thickness for the lower stories be increased with the height of the building in the same manner as for walls not thus supported.

Forty-eight ordinances specify minimum allowable thicknesses for brick panel walls: Of these, 18 call for 8-inch thickness, and 30 call for 12 or 13 inch thickness in such walls.

Thirty-three codes specify thicknesses for tile panel walls as follows: 14 require 8-inch thickness, and 19 call for 12 or 13 inch thickness.

In 39 cases specific requirements for thickness of reinforced concrete panel walls are given, namely: 2 require 4-inch thickness, 4 require 6-inch thickness, 16 require 8-inch thickness, 12 require 12-inch or 13-inch thicknesses.

Only one code specifically mentions the use of concrete units for panel walls, the thickness required being 12 inches.

Fourteen codes make no difference between the various masonry materials, merely stating the thickness. Of these, six call for an 8-inch wall and eight call for a 12-inch wall.

Two codes forbid such walls to be thinner than one-sixteenth or one-twentieth of their height between horizontal supports.

One code specifies that panel walls shall not be longer than 20 feet between vertical supports, but does not limit their height.

Nine codes limit the height between horizontal supports, requiring that the thickness be increased if the limits are exceeded. These limits vary between 10 and 20 feet. In some cases they apply to specific materials only and in other cases their application apparently is general.

Ten codes limit both height and length of panel walls supported at each story, the limits varying from 12 by 12 feet to 14 by 30 feet. In most cases the larger limits are for the thinnest walls.

Two codes regulate thickness on basis of square feet of wall surface.

Three codes require party wall panels to be 4 inches thicker than exterior walls.

Omitting from consideration the codes which require increased thickness with increasing height of building, the average of the panel wall thicknesses specified in the 84 codes was 10.86 inches for brick, 10 inches for hollow tile, and 8.57 inches for reinforced concrete.

4. An analysis of requirements regarding necessary thickness of brick bearing walls for eight-story structures in 20 codes chosen at random disclosed 18 different sets of requirements, and doubtless further investigation would have discovered others. These variations, furthermore, bore no particular relation to requirements governing other factors which should affect the wall thickness.

Variation, such as demonstrated above, arises in part from the fact that standards of performance are unequal; that exposures and allowable working stresses vary; and that materials and workmanship differ widely in different localities. It also is due in very large measure to local custom, unchecked by adequate knowledge of construction practice elsewhere, and to slavish copying of other ordinances without due regard for the circumstances attending their adoption. In theory, at least, minimum standards of performance should be uniform, irrespective of location and other conditions, except, perhaps, those due to climate, and when departure is made from minimum standards scientifically determined the reasons for such departure should be carefully considered.

Part II of this report presents all the requirements which the Building Code Committee considers essential to meet such uniform standards of performance, and states these recommended requirements in the minimum terms considered necessary for protection of the public health and safety.

PARAGRAPH 6. WALLS IN SKELETON CONSTRUCTION

1. In skeleton construction that portion of a panel wall between window sill and floor is sometimes called an apron wall. The portion between the window top and the floor construction above is occasionally designated as a spandrel wall.

2. In view of some confusion which exists in use of the terms "panel wall" and "curtain wall," their definition in a code is con-

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sidered necessary. Inclosure walls, as defined in Part II, section 1, refer only to nonbearing walls inclosing a structure, but not necessarily built between columns or piers and only sufficiently anchored to them or to floors to insure stability against lateral forces. They may be supported at each story or at intervals of two or more stories, as best suits the design.

3. Several critics of the tentative draft of this report suggested that the definition of " panel wall " be expanded to include those supported at every second or third floor line, or at intervals of 20 or 30 feet. It was evident, however, that several of these criticisms referred to a somewhat different method of construction. The committee has included these other types of walls under the term " inclosure walls."

4. The tentative draft of this report permitted the use of metal fabric and cement plaster, or " gunite " walls. The consensus of opinion obtained indicated that such walls do not properly belong under the heading of masonry. The committee, therefore, has omitted them.

5. Some existing codes regulate the thickness of walls in skeleton construction according to the length, height, or area in square feet between columns and floors. If the limitations on spacing of lateral supports recommended in Part II are observed, this will be unnecessary. It is established, in fact, that the expansion of such walls under intense heat is less destructive, and the deformations are less, if the panels are long, than if they approach a square in shape.

PARAGRAPH 7. FIRE AND FIRE DIVISION WALLS

1. In order adequately to discharge its functions, a fire wall must be thick enough to prevent communication of fire by heat conduction. It must have such stability as to remain intact after complete combustion of the contents of the building on one side of the wall; and its structural integrity must be such as to be not seriously affected by any wreckage resulting from the fire or its extinguishment.

2. It is no longer customary in steel and reinforced concrete construction to build self-supporting fire walls up through a structure independently of the floors, even though such walls are sometimes specified in codes. The walls are supported by the structural frame or floor system in each story, and usually divided into moderately small panels built between piers or columns. In case of fire, this method of restrained construction serves to limit the heat deformation in a single unit to an amount which does not endanger the integrity of the wall. Such walls are termed " fire division walls " in this report to distinguish them from the walls commonly known as "fire walls."

3. Exhaustive tests under severe conditions at the Bureau of Standards indicate that well-built 8-inch solid brick walls supported at each story with no combustible members framing into them are reliable as fire stops, and that so long as the floor and roof construction maintain their integrity, a safe fire barrier exists between buildings or parts of buildings separated by such walls. (See also Appendix, par. 17.)

4. The type of wall defined in Part II, section 1, as a "fire wall" is the result of experience antedating successful fire resistive skeleton construction. Walls of considerable mass and stability, extending unbroken from foundations to parapet, were and are necessary in "ordinary" and "mill construction," where floors can not be depended upon to resist the full duration of a fire and are liable to collapse, or where beams and girders depend on such walls for support. The modern method of skeleton construction provides floors, girders, and columns which support the walls and partitions instead of being supported by them.

Experienced observers hold that high independent fire walls between buildings or parts of a building of ordinary construction are as apt to fail in event of a severe fire as the floors or roofs of well-built fire-resistive skeleton structures, even though the fire walls conform to the usual rigid requirements. Consequently the panel wall between floors in buildings of fire-resistive skeleton construction is an adequate alternative for the old type of fire wall.

With these considerations in mind the committee has provided for two types of fire-resistive walls, the first corresponding to existing standards, to be required for "mill construction" buildings and those of "ordinary" or wood joist construction; the second to be permitted wherever fire barriers are necessary within or between buildings of skeleton construction. (See also Appendix, par. 17.)

To prevent a fire lapping around the ends of a fire wall or fire division wall the committee recommends that no openings be permitted in the exterior walls of a building within five feet of their intersection with fire walls. For the same reason, fire walls in frame construction should be built with wings at each end where they intersect the exterior walls. Such wings should be the full height of the fire wall and extend at least five feet on each side of the fire wall in the plane of the exterior wall.

5. The requirements of Part II for hollow fire and fire division walls, or those of hollow units, recognize the possibility of their remaining unplastered. Such walls usually are plastered and an extra element of safety is thus introduced, as observation of such walls under fire exposure discloses that plaster applied to both surfaces is of considerable value in delaying transmission of dangerous temperatures and in preventing damage to the units. Plaster also adds to the stability of thin tile walls, though not in proportion to the additional thickness. Its use on tile and concrete-block walls is strongly advocated, especially in the case of party and fire walls.

6. The intent of Part II, section 36, is that no attempt shall be made to break into an 8-inch party wall for insertion of building members, subsequent to its erection. It was felt that if joists or other timbers were installed at the time of erection with ends staggered and the masonry joints between them carefully filled with mortar, such minimum thickness might be safely employed. Where members are inserted subsequently, it is very difficult to be sure that joist ends are properly staggered and that no dangerous crevices are left in the wall at the floor line. A similar but more drastic requirement was made for walls of hollow units because of the greater danger that breakage of such units will open communication between opposite sides of the wall.

7. The requirements of Part II, section 36, permit the uppermost 20 feet of a fire wall in a building for residential purposes to be 8 inches thick with joists inserted. This, of course, does not mean that such walls will occur in the upper stories of high buildings, for codes do not, in general, permit the use of joisted or mill construction in buildings over five stories in height. Exterior walls receive support from but one direction and the use of 8-inch thickness, therefore, was limited to the top stories of buildings not over three stories high, with further restrictions as to support and roof framing. (See Part II, sec. 5.)

8. Requirements for control of fire-wall openings are not considered within the scope of this report.

9. The suitability of lime mortar for fire and fire division walls has been questioned, but there appear to be no positive data indicating that it is unsafe for solid brick walls. Hollow walls or those of hollow units are required to be laid with cement or cement-lime mortar, whether or not functioning as fire walls. (See Part II, sec. 9.) (See also Appendix, par. 17-2, for discussion of mortars in fire walls.)

PARAGRAPH 8. CONCRETE CONSIDERED AS MASONRY

1. Strictly speaking the term "masonry" is limited to the use of stone units. In the early history of building trades, a mason was a workman who dealt with stone work only. A mason, which also implied stonecutter, was a somewhat different type of mechanic than he who now builds with brick and tile. These terms, together with that of plasterer, have come down to us from the ancient guilds, but have gained recently a more general application.

2. Modern practice has developed the wall of mass concrete, and that of rough stone grouted with mortar, having the same functions and general requirements as masonry of the older types. It was decided that these should be termed masonry and treated in the same report with walls laid up with masonry units.

3. Walls of reinforced concrete owe their strength and stability largely to factors other than those governing masonry walls and therefore have been omitted from the scope of this report.

PARAGRAPH 9. QUALITY OF BRICK

1. The requirements of many building codes date from a time when burned clay units were practically the only materials classed as brick. In order to prevent any misunderstanding of its recommendations, therefore, the committee believes it best to point out specifically as in Part II, section 1, note 2, that for the purposes of this report, unless otherwise stated, units of other materials having the same general shape and size as brick are included with those of clay, it being understood that all units shall meet the test specifications provided herein.

2. The Building Code Committee has adopted the standard specification of the American Society for Testing Materials for medium brick as the basis of a minimum requirement for clay and sand-lime

building brick used in load-bearing masonry. On account of practical code enforcement difficulties, no provision has been made for recognition of several grades of building brick as described in the society's standard specification. It is reported, however, that several localities are using successfully a thoroughly burned brick with high compressive strength and absorption considerably exceeding the American Society for Testing Materials limits for "medium" brick. No undesirable weathering of such brick is reported, though used in some cases under extremely adverse conditions, and the 2,500 pound alternative requirement, therefore, has been inserted to permit their use.

Where a particular make of brick has been in general local use for a period of years and has shown satisfactory service and weather resistance; or where such brick have demonstrated satisfactory durability when tested by not less than 100 alternate freezings and thawings, or where climatic conditions make absorption limits unimportant, the absorption requirements may be waived for all ordinary purposes, subject to supervision by the building officials having jurisdiction.

Where it is established to the satisfaction of those in authority that the quality of brick available for load-bearing masonry is uniformly higher in compressive and transverse strength than the medium grade described by the American Society for Testing Materials standard, it is recommended that reasonable increases based on compressive strength of the units, be allowed in the unit working stresses recommended in Part II, section 4.

The use of so-called "hollow brick" also should be permitted if they meet the requirements of Part II, section 2.

The following classification of brick is taken from the Standard Specifications for Building Brick of the American Society for Testing Materials:

Name of grade	Absorption limits		Compressive strength on edge		Modulus of rupture	
	Mean of 5 tests	Individual maximum	Mean of 5 tests	Individual minimum	Mean of 5 tests	Individual minimum
	Per cent	*Per cent*	*Pounds per square inch*	*Pounds per square inch*	*Pounds per square inch*	*Pounds per square inch*
Vitrified brick	5 or less	6	5,000 or over	4,000	1,200 or over	800
Hard brick	5–12	15	3,500 or over	2,500	600 or over	400
Medium brick	12–20	24	2,000 or over	1,500	450 or over	300
Soft brick	20 or over	No limit.	1,000 or over	800	300 or over	200

The standard specifications of the American Society for Testing Materials represent an agreement of manufacturers and producers as to standards of quality. They are the best available at the present time and the standards for structural materials are recommended for the general purposes of those drafting or revising building codes.

3. Careful provision should be made for utilization of masonry building materials or methods not included in this code, or which may hereafter be developed, by regulating their use on a performance basis similar to that which underlies the requirements of Part II for those already well known. (See also Appendix, par. 31.)

4. Much consideration was given to the requirements for concrete brick. It was at first decided that all brick should be tested on edge in accordance with the specification of the American Society for Testing Materials for building brick. However, in view of the fact that both that society and the American Concrete Institute have issued tentative specifications permitting concrete brick to be tested flatwise, these recommendations were finally changed accordingly. Specifications for concrete brick should be set high enough so that they will not be unduly friable in handling. (See also Appendix, par. 13-1.)

5. The modification for light concrete is made necessary by the increasing manufacture of units made from light aggregates.

PARAGRAPH 10. MORTAR MATERIALS

1. Sand varies widely in its characteristics and may seriously affect the strength of mortar. Where masonry is stressed to the utmost, or where materials are of doubtful character the mortar should be tested, and should develop a compressive strength not less than the following:

Strengths of mortars under typical field conditions

Aggregates, by volume	Water	Compressive strength at 28 days. Average of five 2-inch cubes or cylinders stored in air
	Per cent [1]	*Pounds per square inch*
1 : 3 Portland cement and sand	22	500
1 : 1 : 6 Portland cement, hydrated lime and sand	25	200
1 : 1 : 4 Portland cement, hydrated lime and sand	25	300
1 : 3 Hydrated lime and sand	30	30

[1] Percentages in terms of total weight of dry materials. The water proportions given are those ordinarily used for mortar for laying brick; not those necessarily resulting in the greatest mortar strength.

2. There are not, at present writing, sufficient data on the performance of proprietary mortar cements by which to judge their suitability for load-bearing masonry. Where such cements have been used for some time successfully there is no reason why their use should be prohibited.

The influence of small proportions of clay and loam on strength of mortar is so irregular it was felt unwise to set a permissible limit on their presence. The requirement that sand be clean permits exaction of a high standard where considered necessary by the authorities and makes for ease of enforcement under practical working conditions.

3. No quality requirement for mixing water was given in Part II, as recent extensive investigations apparently show that the kinds and amounts of impurities carried in solution or suspension in water from even the most doubtful sources have no particular effect on the strength of concrete. The same is assumed to be true of mortar. (See par. 13–5, Workmanship, for discussion of retempered mortar.)

4. In proportioning cement and lime for mortar it is convenient to remember that a bag of Portland cement equals about 1 cubic foot, and a bag of hydrated lime equals about 1¼ cubic feet; also that 1 cubic foot of stiff lime putty is approximately equal to a bag of dry hydrated lime. The limiting proportions of sand and cement specified in Part II, section 1, are based on the assumption that damp sand will ordinarily be used. If sand is thoroughly dry, a slightly smaller relative volume is advisable.

PARAGRAPH 11. TESTS OF COMPRESSIVE STRENGTH OF BRICK MASONRY

In recommending maximum working stresses for brick masonry the commmittee had reference to a number of test series, which are here listed. These tests included in all 637 piers and 81 short walls, and constitute the greater part of data on this subject, published in English.

1. Tests of 33 brick piers at Watertown Arsenal in 1884, under supervision of J. E. Howard.
2. Tests of 53 brick piers at Watertown Arsenal in 1886 and 1891, under supervision of J. E. Howard.
3. Tests of 14 brick piers at University of Toronto in 1918, under supervision of P. Gillespie in interest of Toronto Building Department.
4. Tests of 50 brick piers at Bureau of Standards laboratory, Pittsburgh, Pa., in 1915, under supervision of J. G. Bragg.
5. Tests of 14 brick piers with special reinforced joints at Cornell University, in 1898 and 1899, under supervision of E. J. McCaustland.
6. Tests of 70 brick piers at Columbia University under supervision of James S. MacGregor, in 1914 and 1915.
7. Tests of 54 brick piers made at Technical High School in Stockholm sometime previous to September, 1916, under direction of H. Kreuger.
8. Tests of 26 brick piers at Watertown Arsenal in 1904, under supervision of J. E. Howard.
9. Tests of 13 brick piers at Watertown Arsenal in 1905, under supervision of J. E. Howard.
10. Tests of 15 brick piers at Watertown Arsenal in 1906, under supervision of J. E. Howard.
11. Tests of 32 brick piers at Watertown Arsenal in 1907, under supervision of J. E. Howard.
12. Tests of 17 brick piers at laboratory of School of Practical Science, 1895 and 1896, under supervision of J. Keele.
13. Tests of 59 brick piers conducted under supervision of Committee of Royal Institute of British Architects, 1895 to 1897.
14. Tests of 16 brick piers at University of Illinois Engineering Experiment Station in 1907, by Arthur N. Talbot and Duff A. Abrams.
15. Tests of 4 brick piers cut from masonry of wrecked building 16 years old in New York City, made at Columbia University in 1922 under supervision of R. P. Miller.

16. Tests of 135 clay, sand-lime and concrete brick piers at Columbia University in 1921 and 1922, under supervision of A. H. Beyer and W. J. Krefeld.

17. Tests of 12 thin brick walls in 1920 by Dr. Oscar Faber in interests of British Government.

18. Tests of 33 brick walls at Bureau of Standards laboratory in Pittsburgh in 1920 and 1921, under supervision of A. H. Stang.

19. Tests of 32 piers and short columns of clay and sand-lime brick, made by senior classes at Purdue University in 1906 and 1907.

20. Tests of 32 brick piers at Bureau of Standards laboratory in Washington in 1922 and 1923, under supervision of S. H. Ingberg.

21. Tests of 18 large and 18 small walls of sand-lime brick at Bureau of Standards laboratory in Washington in 1924, under supervision of A. H. Stang.

The widely different circumstances under which these walls and piers were built and tested preclude a general summary or average of results in arriving at unit working stresses for masonry. It was possible, nevertheless, by segregating groups of experiments, alike except in one particular, to trace with some certainty the effects of various conditions on compressive strength, and to obtain light on desirable factors of safety and working stresses. (See Appendix, pars. 13 and 14.)

PARAGRAPH 12. LATERAL SUPPORT OF WALLS

1. Part II, section 3, means in brief that if vertical supports, such as columns, piers, or cross walls, are provided not more than twenty times the wall thickness apart, there need be no limits to the distance between floors; or that when floors are spaced not over twenty wall thicknesses apart the support of piers or other vertical members is not required.

2. Spacing of Pilasters, Cross Walls, and Other Vertical Supports.—The nature and necessary frequency of vertical supports, matters commonly specified in building codes, depend on a number of factors. In small residential buildings the walls are short, and the support afforded by closely spaced partitions and floors is sufficient to make buttresses or pilasters unnecessary. In commercial or industrial buildings the heavier floor construction and loading assist in giving the necessary stability. When floors are relied upon to support walls against lateral forces the accumulated wind force will generally be transferred to the end or cross walls by means of the floors, acting as horizontal beams; though partial assistance is sometimes effected by stairway or elevator inclosures, chimneys, etc. The distance which floors can safely be depended upon to transfer the lateral forces is influenced by the width of the floor and also by the material of which it is composed. A slab of concrete is much more rigid than a floor of frame construction, and properly can be counted upon for a greater length than the latter. The committee suggests as suitable limits of distance of transfer for buildings of ordinary width the following allowable lengths, with the understanding that in exceptionally narrow buildings these lengths should be reduced, while in very wide buildings they may be increased. For wood joist construction, sixty times the minimum wall thickness; for steel frame, fire resistive construction, or mill or slow burning construction, ninety times the

minimum wall thickness; for reinforced concrete construction one hundred and twenty times the minimum wall thickness.

3. Story Heights.—The story height or the unstayed height is recognized as having an important influence on the stability of walls. Experimental data on safe limits are insufficient for conclusions, but a wide survey of results in practice indicates that for solid brick and plain concrete walls the slenderness ratio of 20 adopted in Part II, section 3, is the maximum reasonably consistent with the thickness requirements adopted. A slightly lower limit was placed on hollow walls or those of hollow units because such walls are of lighter weight, mortar beds are narrower, and resistance to heat effects less certain. Consideration was given to the use of stories as units of wall height, but in view of the variation in story heights employed in different parts of the country the committee decided this method of stating minimum requirements is not sufficiently definite. The permissible spacing of supports, however, is thought to be such as will allow economical utilization of wall height in any region.

4. The critical tension in walls generally occurs in the top story of nonbearing walls, since the direct load is here the least and the wind force the greatest. The following stresses were computed for the midstory section of such walls assumed of full section without openings and with full support, but no continuity at the floor and roof lines. The assumed wind pressure was 30 pounds per square foot.

Computed tension in top-story nonbearing walls of full section

Ratio of height to thickness (t)	Tension			
	8-inch walls		12-inch walls	
	Solid brick	Hollow tile	Solid brick	Hollow tile
	Pounds per square inch	*Pounds per square inch*	*Pounds per square inch*	*Pounds per square inch*
20t	57	60	54	58
18t	45	48	43	47
16t	36	39	33	37

The stresses are in all cases computed on the full gross section of the wall. This assumption approximates the actual condition at all mortar joints of well-laid solid brick walls and hollow tile walls with tile laid on side or edge. For hollow tile walls laid with cells vertical and cross webs not in alignment the actual stresses at the mortar joints will be about 125 per cent higher than given in the table, although the adhesion of extruded mortar to the vertical surfaces and the upsetting of wire-cut tile may increase the tensional resistance above that computed on the net bearing area. Where cross webs are in perfect alignment the stresses will be about 75 per cent higher. Openings in the wall will increase the stresses about in ratio of total horizontal cross section to the remaining net wall section. Where walls are attached or built into rigid floor or roof construction above and below there is an additional element of strength since before the wall can fail by overturning it must in tipping lift the construction above, thereby increasing the direct load assumed by the wall from the floor construction, thus increasing the stability of the wall.

There is little experimental data available on the transverse strength of brick and tile masonry as limited by the tension in horizontal joints. Tests made at various times at the Bureau of Standards on nine walls of side construction tile tested under center or 2-point lateral load and a small direct load (5 to 20 pounds per square inch) gave an average value of 92 pounds per square inch outer fiber stress in tension, with a range from 40 to 252 pounds per square inch. The mortar proportions varied from 1:3 Portland cement and sand, to 1:½:3½ Portland cement, hydrated lime, and sand, all measurements by volume. Similar tests of two solid brick walls gave tension values of 173 and 124 pounds per square inch and for a hollow brick wall (Ideal all-rowlock) 136 pounds per square inch as computed for the gross wall section, and 151 pounds per square inch as computed for the net bearing section, the mortar being 1:3 Portland cement and sand. It is apparent that the tensional stress can not exceed the tensional strength of the mortar and may be less due to lack of perfect adhesion between the mortar and masonry units.

5. In general, a 4-inch increase in wall thickness is not considered adequate as a substitute for the independent support prescribed in Part II. It is strongly recommended where exposures are extreme or high winds prevail that long bearing walls be broken as often as possible by angles or cross walls, and that chimneys, elevators, and stair shafts be so placed as to reinforce such long walls whenever possible.

PARAGRAPH 13. ELEMENTS AFFECTING STRENGTH OF BRICKWORK

Following is a list of the factors affecting brick masonry strength which through study of the experiments mentioned in paragraph 11, it is possible to evaluate.

1. Masonry strength as related to strength of individual brick.
2. Mortar, materials and proportions.
3. Ratio of height of wall or pier to its thickness.
4. Bond and jointing.
5. Workmanship.
6. Age of masonry.
7. Manner of loading.

1. Masonry Strength as Related to Strength of Individual Brick.—Practically all the test series studied indicate that, other conditions being equal, the compressive strength of brick masonry is roughly proportional to that of single brick. Recent experiments seem to indicate that the ratio of wall strength to brick strength is considerably greater for clay brick of low compressive strength than for those of medium grade or better. Apparently the ratio between strength of masonry and that of individual brick increases as the brick strength decreases, at least down to a strength approximately equivalent to the " medium grade " of the A. S. T. M. specifications.

Experiments at Columbia University (see item 16, par. 11) indicate that when laid in Portland cement mortar, concrete brick averaging from 1,500 to 2,500 pounds per square inch compressive strength tested flatwise, will make a wall about as strong as one built of clay brick averaging 3,000 to 5,000 pounds per square inch tested edgewise.

Tests recently made at the Bureau of Standards on piers and walls laid in cement-lime mortar also indicate that masonry of concrete brick has greater strength than that of clay brick having equal unit strength tested individually.

Test data furnished by the Bureau of Standards indicate that, in general, the compressive strength of brick walls built of several varieties of brick, all laid in cement-lime mortar, varies from 15 to 40 per cent of the strength of the individual brick when the latter are tested flatwise, with the range running considerably higher when compared with the compressive strength edgewise.

Tests on concrete brick piers in the investigation at Columbia University mentioned above showed ratios of pier strength to brick strength tested flatwise ranging from 43 to 95 per cent when 1 to 3 Portland cement mortar was used. These results were exceptionally high and have been the subject of much discussion.

The various investigations to which the committee had access indicate that for any particular variety of brick the actual strength of masonry is dependent upon other properties than strength of the units alone. Undoubtedly quality of the mortar and the effectiveness of the bond between brick and mortar are important factors in the problem. The latter, in turn, is influenced by the percentage and rate of absorption of the brick and particularly by the degree of roughness of the brick surface. The tests give evidence that masonry built of rough-surfaced brick has higher relative strength to the individual units than develops with smooth-surfaced brick. This may be responsible to some extent for the good showing made in tests of concrete and sand-lime brick of low compressive strength and rough surface texture. For further information on compressive strength ratios of brick masonry to individual units and their relation to the factor of safety, see paragraph 14, experimental data.

Sufficient data are not available on the ratio between modulus of rupture of single brick and the compressive strength of piers to afford a good basis for code requirements, and the variations thus far disclosed are so wide, for clay brick at least, that no useful ratio can be said to exist. Concrete brick, on the other hand, showed a fairly definite ratio in the tests at Columbia University (see item 16, par. 11). Indications are that the different processes used in making clay brick influence its modulus of rupture more strongly than its crushing strength. In the course of recent compressive tests on brick walls the headers broke first in almost every case, indicating that the modulus of rupture is an important element in determining the strength of brick masonry. For ease of code enforcement, however, it seems that the crushing strength is a better criterion and more easily interpreted than the modulus of rupture. No attempt, therefore, has been made to base working stresses on the modulus of rupture of brick, although it is admitted that the transverse test is a better indication of quality than has generally been held.

2. Mortar, Materials, and Proportions.—Customs regarding the composition and proportions of mortar vary in different localities, but it was considered by the committee that sufficient guidance to those drafting building codes would be afforded if recommendations were made for five types of mortar, proportioned by volume, as follows:

1 part Portland cement to not more than 3 parts sand, with permissible addition of lime not to exceed 15 per cent of the cement.

1 part natural cement to not more than 3 parts sand.

1 part Portland cement, 1 part lime, and not more than 6 parts sand.

1 part Portland cement, 1 part lime, and not more than 4 parts sand.

1 part lime to not more than 4 parts sand.

Some question was raised by critics of the tentative report as to the desirable richness of lime mortar. Limes vary in their sand-carrying capacity, but general experience is that proportions of 1 to 4 are adequate for all demands likely to be made on lime mortar masonry.

The addition of a certain percentage of lime to Portland cement mortar is much preferred to its substitution for part of the cement, as being easier to control and resulting in better mortar. Addition rather than substitution is recommended by the manufacturers of both cement and lime.

Investigation of numerous test series showed that with conditions otherwise equal the strength of masonry laid with 1 to 3 or 1 to 4 lime mortar did not in any case average more than 70 per cent of that laid with Portland cement mortar, and in certain cases fell as low as 30 per cent. In assigning lime mortar masonry a working stress slightly more than one-half that for cement mortar masonry, the committee is influenced rather by long experience with its successful use under moderate loading than by its performance in comparative tests. Lime mortar is known to increase in strength more slowly than cement mortar, and tests soon after laying probably are not a fair indication of bearing strength. Masonry in a building, on the other hand, is likely to be subjected to full load within two or three months and dependence on possible future strength is unjustifiable.

The data available indicate that masonry built with cement-lime mortar, as defined in Part II, varies in strength from 70 to 85 per cent of that laid with cement mortar to which a small percentage of lime has been added. The limits on working stresses, therefore, have been placed approximately at 80 per cent of those for cement mortar masonry.

There are no data available on the strength of masonry laid with natural cement mortar in which the cement is known to have complied with American Society for Testing Materials specifications. Many early tests, however, were made with natural cement mortar, and the results indicate that so far as strength is concerned the material is adequate for all ordinary purposes.

3. Ratio of Height to Thickness.—Neither observation of the behavior of masonry under practical conditions nor study of comparative test records indicates that the strength of brick masonry

is affected to any extent by increases of the slenderness ratio between 4 and 20. The headers of walls recently tested in compression gave way first, the circumstances indicating failure in tension or transverse bending, and the ultimate compressive strength of the specimen is about coincident with this point of failure. The ratio of height to thickness of the wall is less important apparently than the spacing of headers. (See Appendix, par. 19.)

4. Bond and Jointing.—In spite of the foregoing, proof is not conclusive that, within the limits set in Part II, the frequency of headers determines the strength of masonry. The limit set in section 6 is based on standards of general practice rather than on experimental investigations. The tests on brick walls mentioned above indicate the advisability of closer header spacing in thin sections where compressive strength is important. Special bonding stones or metal mesh between courses have proved ineffective unless placed in every course, when they improve the strength considerably. The disadvantages of bond stones spalling under heat exposure more than offset the additional strength supplied, and the practical difficulties of placing metal mesh in masonry joints greatly limit its usefulness. For load-bearing masonry, joints should preferably be as thin as is consistent with full bedding of the brick, but they apparently may be as much as three-eighths inch without affecting compressive strength.

5. Workmanship.—The recommendations of Part II are based on the understanding that supervision or inspection will be such as to insure good workmanship and utilization of materials. (See also Appendix, par. 2.)

The following suggestions as to what should be considered good practice in brickwork have been received from various authorities on the subject:

Care should be taken to insure even and complete bedding of the masonry units, and joints should be of sufficient thickness to permit this. Vertical joints of exterior face courses should be buttered and bricks carefully shoved to place. Mortar should not be placed on the beds with a shovel or from the hod, but may, if desired, be placed with special spreading devices. End joints of interior face courses should also be carefully filled if the wall is to be furred.

Where dryness is more important in brickwork than compressive strength no particular attempt to fill interior vertical joints by shoving or slushing in mortar is necessary.

During warm and dry weather all brick should be thoroughly wet just previous to being laid in order that good adhesion may be obtained between brick and mortar and so that sufficient water will be left in the mortar to permit its acquiring full set.

Brick should be thoroughly dry when laid in cold weather, and for best results both bricks and mortar should be warm, so that the latter may obtain at least a partial set before it is frozen.

The tentative draft offered opportunity for report of experience with retempered mortar. Such data as were obtained indicate that mortars of hydraulic cement lose considerably in strength if retempered after initial set, but that these losses are not sufficient seriously to affect the strength of masonry not stressed near the working limits. Except under experienced supervision and for nonbearing masonry it is recommended that use of retempered mortar be forbidden.

6. Age of masonry.—Working stress requirements, and, in fact, all recommendations of Part II, are based on the assumption that brick masonry is not unlikely to be loaded within a period of two months to the full extent contemplated in the design. No provision is made in the recommended working stresses for construction loads, as it is considered that builders should not be penalized to provide insurance against careless construction practice. It is doubtful if reduction in working stresses for this reason would be effective if made.

7. Manner of loading.—Experimental data indicate a sharp decrease in bearing capacity when loading is eccentric. This decrease ranges from 25 to 50 per cent in different series of experiments with solid walls loaded one-fourth their width off center, but was only 7.3 per cent for hollow walls of brick, due probably to the large number of headers and the greater proportion of solid material near the wall surfaces. Available data are not complete enough to justify detailed conclusions, but indicate strongly that eccentricity must be considered and that its influence may be computed quite closely by accepted rules of mechanics.

PARAGRAPH 14. FACTORS OF SAFETY FOR BRICKWORK

Working stress requirements for brickwork determined by interpretation of test data on compressive strength of walls and piers depends on whether the ultimate compressive strength, or the load at which cracks, snapping sounds, or other test phenomena occur, is chosen as the point of failure.

It is established, however, that in individual cases the relation between the stress causing initial signs of failure and the maximum stress is less certain and the human element more influential on observation than in the case of recorded maximum stresses. For this and other reasons the committee has based its requirements on a study of ultimate compressive stresses.

It has been customary in building code practice to consider that established stress limits represented a "factor of safety" of 10 based on crushing strength of the units used in the wall or pier. This, to a certain extent, is unlike practice with other materials, such as steel, concrete, and lumber, where the unit strength of the whole structural member is practically the same as that of small specimens. If, in masonry, the factor of safety were applied to the wall or pier as a whole, it would be comparable to the factor used with other materials and would be much less than 10. The committee has followed this policy and has chosen its factor of safety with relation to the ascertained stresses at failure of brick masonry rather than the crushing strength of individual units.

A factor of safety should be increased with the number or importance of unregulated or uncontrollable elements affecting the strength of a material. Conversely, as conditions of use and standards of quality are better defined and controlled the factor of safety may be reduced. There has been some attempt in the past to regulate quality of brick, but for the most part it appears that safety of brick masonry has resulted rather from design for fictitious floor loads and from empirical thickness requirements than from any considerable margin of compressive strength over permissible working stresses. Certain occupancies, especially warehouses, support their full assumed live loads, but in most cases brick walls are never actually subjected to the live loads they are assumed to carry.

In arriving at its recommendations for maximum working stresses the committee has had reference both to careful investigation of test data bearing on the subject and to successful practice in cities, such as New York and Boston, where the quality of materials and the conditions of use are known to have been fairly well controlled.

Experimental data.—Examination of a large group of test data, including practically all series of importance which have been made in this country in recent years, shows an average ratio of 25 per cent between the strength of masonry and that of brick from which it is built, when tested on edge. This ratio applies only for brick within the lower ranges of strength ordinarily used for building purposes. It increases for brick testing below 2,000 pounds per square inch and decreases for brick averaging above 3,500 pounds per square inch. If brick averaging 2,400 pounds per square inch tested on edge are accepted as representative of the more unfavorable conditions, the average ultimate compressive strength of bearing masonry as regulated by Part II would be about 600 pounds per square inch. This affords a factor of safety of about 3.5 over the maximum unit working stress provided by Part II, section 4, for piers of medium brick loaded concentrically and 2.4 for piers on which the stress due to all factors approaches the maximum allowed in Part II.

To show the possibility of strength variation of piers built of the same grade of materials under similar conditions, 85 small groups were selected, alike in all particulars so far as could be discovered from the reports. The maximum individual variation from the average strength of each group was computed and was found to be less than 25 per cent in all except four cases, which ranged from 27 to 35 per cent. In 42 groups the variation was less than 10 per cent. Variations above and below the average were about equally balanced.

These experiments as noted were all upon masonry piers. Comparison of results from the tests of masonry walls (see par. 11, item 18) shows that variations in strength between similar specimens and variations in the ratio of masonry strength to strength of individual brick are as great for walls as for piers, thus indicating that the influence of workmanship and of variation in strength of materials is not necessarily better compensated throughout the length of a wall than in piers.

PARAGRAPH 15. STRESSES IN BRICKWORK

1. Though brick work is very old, its design to any appreciable extent on a working stress basis is comparatively recent. Walls and piers for many years were proportioned on an empirical basis entirely, and inspection of old structures indicates that most errors were well on the side of safety. Working stresses as first established reflected this prevailing spirit of caution, and have since increased considerably. The figure of 250 pounds per square inch for good brick in Portland cement mortar was first written into the code of New York City in 1898 and has been widely copied.

Coincidently with increase of working stresses the number and extent of windows in certain types of buildings increased also. Steel and reinforced concrete construction permitted this without risk and there was a strong tendency for brick bearing wall structures to compete. It results that much modern brickwork approaches the maximum allowable working stresses prescribed in codes, and that careful analysis of the factors involved is necessary to make sure these stresses are not exceeded. The requirements advocated in Part II are predicated on the assumption that stress computations will take into account the effects of eccentric loading, the local reactions of lintels or spandrel arches, the possibility of lateral forces due to merchandise within or wind pressure without, and of any other unusual conditions affecting stress distribution.

2. In computing stresses in bearing walls it is usual to include those due to the total amount of dead loads above the level in question plus the full live loads for the roof and uppermost floor, and certain arbitrary percentages of the live loads on floors below the upper, except in buildings used for storage or warehouse purposes where no reduction in the floor live loads should be made. Wind forces should be considered as producing bending from floor to floor, and also for high narrow buildings, as producing overturning moments on the building as a whole.

Further bending stresses are produced by eccentric bearing of the floor system on the wall. A safe assumption for the latter condition is to assume an effective moment at the floor line equal to the floor reaction on the wall of the given story times the distance of the center of application of this reaction from the center of the wall, neglecting all bending effects from the floors above and below; and at the center of the story height, a moment one-half of that at the floor lines. This assumes the wall supported against lateral movement at the floor lines, but otherwise not continuous. Investigations postulated on continuity of the wall throughout its height indicate somewhat lower moments than those resulting with the assumption made.

Stresses in walls are further increased above those computed for the full wall area, by openings and chases in the walls, and by concentrated loads, such as floor beam and lintel reactions. The loads on an arch or lintel are generally considered as those of the wall and wall bearings coming within an equilateral triangle having the width of the opening as base. The stress produced by heavy beam reactions, particularly where the end of the beam is built solidly into the masonry should be taken into account in computing maximum wall stresses. The reactions immediately under light closely spaced joists need be added only to the general wall load for the purpose of determining direct stresses, since they are distributed into the masonry within a comparatively short distance below the bearings, adding in all cases bending stresses produced by eccentric bearings. The eccentricity of the loads is usually increased by the deflection of the floors, producing maximum pressures at the inner face of the wall.

Computation of stresses for typical buildings indicates that with the given limitations on story heights, the thinnest wall thicknesses permitted by the recommendations of Part II, section 4, are adequate for the relatively light loads involved in residence occupancy, but that for heavier floor loads and floor constructions it will frequently be necessary to increase thicknesses beyond these minima.

PARAGRAPH 16. THICKNESS OF BRICK WALLS

1. Wall thicknesses specified in Part II are nominal, referring to the minimum thickness obtainable with building units of standard size. It is common in some parts of the country to designate brick walls as 9, 13, and 17 inches in thickness, but with the standardization of brick and tile sizes now becoming general, it is more correct to express the dimensions as 8, 12, and 16 inches.

2. The difference in treatment of residential and commercial buildings less than 30 feet in height is based in part on the results of a series of questionnaires, submitted to building inspectors, insurance rating organizations, and fire chiefs. These returns may be summarized as follows:

Building inspectors.—Of about 80 building inspectors who expressed their opinions on this subject, 75 per cent approved the use of 8-inch walls for two-story residences and 15 per cent considered them adequate for three-story buildings. These replies were concerned only with one and two family dwellings. For light commercial occupancies 7 respondents only would allow 8-inch walls up to three stories, 30 would permit them two stories in height, and 14 would confine them to one story. Thirteen inspectors consider that commercial occupancies demand a 12-inch wall under all circumstances, 5 would make the first story of a three-story commercial structure 12 inches; and 2 would require the lower two stories to be 12 inches or thicker.

Insurance organizations.—Through their work in adjusting claims these have much experience with the relative stability of 8 and 12 inch walls, as affected by fires. The consensus of opinion among the 37 reports received strongly supported the 12-inch wall as having greater resistance to bulging and collapsing under heat effects; against damage from falling timbers; and as providing a superior fire stop between small buildings. Its salvage value also is greater, though this, of course, is an item with which a building code is not concerned.

Fire chiefs and fire marshals.—Practically all of the 55 respondents who had fought fires in buildings with 8 and 12 inch walls favor the latter as less likely to collapse under a hot fire or the action of floor beams, with resultant danger to firemen.

In view of the above consensus of opinion and of considerations elsewhere mentioned, and of the heavier floor loads and hotter fires to be expected in commercial buildings, the committee decided to limit 8-inch walls for these occupancies to one story.

3. In permitting the same minimum wall thickness for commercial or industrial buildings as for the larger residential buildings, the committee had reference to the following considerations.

Commercial occupancies which involve vibration likely to affect wall stability will, in practically all cases, involve live loads which necessitate a wall thicker than the minimum.

The effects of even the hottest fires on 12 and 16 inch solid brick walls were shown by the Bureau of Standards' tests to be unimportant as regards transfer of heat through the walls or their deformation within the period of exposure to be expected with residential occupancy.

Heavier floor loads, where not exceeding the allowable unit stresses, increase the vertical components of the applied pressure and add to the stability of walls against lateral forces, thereby giving the industrial building an advantage as compared to the residential building.

Within the economic height limits of buildings with brick bearing walls the industrial or commercial building is more apt to have a rigid interior framework than the residential building.

4. In arriving at the minimum wall thicknesses prescribed in Part II the committee had in mind the usual heights to which bearing walls are erected under present economic conditions. When such walls are used for buildings over seven stories in height, special conditions may affect considerably the desirable thickness, and competent professional authority should be consulted.

5. Critics of the tentative draft of this report have suggested that the 12-inch thickness provided in Part II, section 5, might extend down to the nearest line of floor beams in case the 35-foot limit fell between floors. The 35-foot height, however, allows space for three fair height stories. A 12-inch wall four stories in height is believed undesirable under the circumstances, and three very high stories at the top of a building are likewise considered inadvisable. With these restrictions in mind the 35-foot limit without modification is seen to involve no particular hardship.

6. In stating that roof beams must be horizontal where 8-inch walls are used for top stories, it was the intention merely to distinguish between so-called flat roofs and those where lateral thrust may be developed by the roof beams.

PARAGRAPH 17. HEAT TRANSMISSION OF MASONRY WALLS

1. Experiments at the Bureau of Standards with brick masonry walls of various thicknesses and types of construction have shown that an 8-inch solid wall properly restrained, will prevent heat transmission to an extent threatening combustion of inflammable materials in contact with the wall for a period considerably greater than the duration of the average fire. The walls were tested according to the fire test specifications tentatively approved by the American Engineering Standards Committee and adopted by other organizations; the test conditions being probably equivalent in intensity and duration to the general maximum fire conditions obtaining in buildings. Temperatures on the outside of the 8-inch solid clay brick walls did not rise to a point threatening combustion of inflammable material resting against them on the opposite side until from five to six hours after the tests were started, and heat transmission through a 12-inch wall was even slower. Walls of sand-lime or concrete brick transmitted heat less readily than walls of clay brick. Dangerous temperatures[5] on the outside of 4-inch brick

[5] Combustible material is liable to begin to char at a temperature of 375 to 425° F. depending upon conditions. In fire tests 300° is assumed as the permissible temperature on the side of a wall opposite to that exposed to the fire, before the wall is considered to have reached the danger point as a reliable fire barrier.

walls were reached in from one and one-half to two hours, but distortion due to unequal expansion was such as to indicate the probability of undesirable cracks in less time. Eight-inch hollow walls of brick afforded less insulation than solid walls; temperatures of 300° F., on the outer surfaces being reached in from two and one-half to three hours. Temperatures on the outside of 12 and 13 inch hollow walls of brick were only 200° F. after six hours' test, indicating their reliability as fire walls where 8-inch hollow walls are inadequate.

Temperatures in the interiors of walls increase more rapidly than on the outside surfaces and the results indicate that 8-inch party walls having wood or unprotected metal joists inserted are unwise where fires of long duration are probable.

2. Deflections of 1 to 5 inches occurred in the walls exposed to the fire test at the centers of the panels. Unrestrained walls deflected at the top more than restrained walls at the center and were found less likely to come back to the original position after cooling. Twelve-inch restrained walls recovered practically all deformation on cooling and 8-inch walls from one-half to two-thirds. More cracking occurred in brickwork with cement and cement-lime mortar than with lime mortar, but the greater strength and resistance to lateral forces and erosion obtained with the cement mortars indicate these advantages outweigh the consideration of cracks. Furthermore, the lime mortar disintegrated badly under heat action causing considerable loss in masonry strength. The results indicate that so far as distortion is concerned, 12-inch restrained walls would be usable after a fire of average severity, and 12-inch unrestrained walls in some cases; while 8-inch walls, either solid or hollow, are apt to show permanent distortion unfitting them for further use after severe fires.

3. The point has been raised that if a satisfactory contact is not secured at the top of division walls built between fire-resistive floors or beams they will be unstable under fire conditions. Experience with such walls under test shows that the heat expansion forces them tightly against the floors or girders at the top long before much deflection can take place. Due to deflection which always occurs toward the fire, the upper edge of the unexposed side of an 8-inch wall will be parted from the under surface of the floor above, after two or three hours' exposure, but observation of several cases has disclosed no heat transmission at this location greater than may occur at any crack in the wall surface. There is small chance, furthermore, that combustible material will be stored close to the openings thus caused.

Care should be taken to ensure that spaces at the tops of all such walls are completely filled with mortar, and the walls tightly wedged.

Twelve-inch walls under similar circumstances do not part from the floor surface above to an appreciable extent.

In view of the foregoing, the committee has decided that walls thick enough to meet the general requirements for stability and compressive strength will be of sufficient thickness to withstand ordinary fire exposures and that except in the case of fire walls between buildings or parts of buildings where very hot or long continued fires may be expected, no account need be taken of resistance to heat transmission in deciding upon the necessary thickness of walls. (See also Appendix, par. 18-7.)

The proper protection of openings of every character in such walls is much more vital than the consideration of wall thickness.

PARAGRAPH 18. FACTORS AFFECTING STABILITY OF WALLS

Consideration was given to a number of factors, which by affecting the stability of walls, exert an influence on thickness requirements additional to that of unit working stresses. Building codes frequently recognize the importance of these factors by calling for greater wall thickness or other precautions where their influence is thought to be dangerous, and it is believed that a statement as to their relative effects on stability will be useful.

1. Foundation Conditions.—The stresses and wall thicknesses recommended in Part II are based on the assumption that foundations will be sufficient to prevent settlement threatening the integrity of the wall. For the purposes of wall design it should be assumed that foundations are adequate and the wall is a unit.

2. Vibration.—Ordinarily vibration due to street or railway traffic or to machinery within a building does not seriously affect good brickwork. Where such vibration is excessive, additional wall thickness is of doubtful value. Where there is possibility of earthquake shocks extra care should be taken to anchor intersecting walls together, and to tie the structural frame of the building to the walls. Observations made after the recent earthquake in Japan are to the effect that high masonry walls should not be built in localities subject to earth shocks.

3. Height and Width of Buildings.—From a structural viewpoint no limits are recommended affecting the relation of height to width of buildings built with brick or plain concrete bearing walls. Under present conditions such buildings are scarcely ever built over six stories and for walls of this height the effects of greater or less width on stability is usually unimportant. For extremely high and narrow buildings increased wall thickness will not generally confer the additional stability required.

4. Methods of Anchorage.—Regulations affecting the methods of supporting or anchoring floor timbers, or of attaching walls to intersecting walls or partitions, are considered outside the scope of Part II of this report. In general, such connections should be rigid in nature; adequate to transmit such lateral forces as may occur and to develop the full supporting effect between structure and wall; and of a design which admits release of the floor beam or slab in case of fire without serious resulting damage to the wall. If these conditions are met the wall thicknesses permitted in Part II will be found sufficient so far as this factor is concerned. Nonbearing as well as bearing walls should be anchored into the floor construction since they are in themselves less stable. (See Appendix, par. 32.)

5. Rigidity of Floors.—The question has been raised as to whether, other conditions being equal, the rigidity of fireproof or monolithic or mill constructed floors does not differ sufficiently from that of joisted floors to justify different wall thicknesses for build-

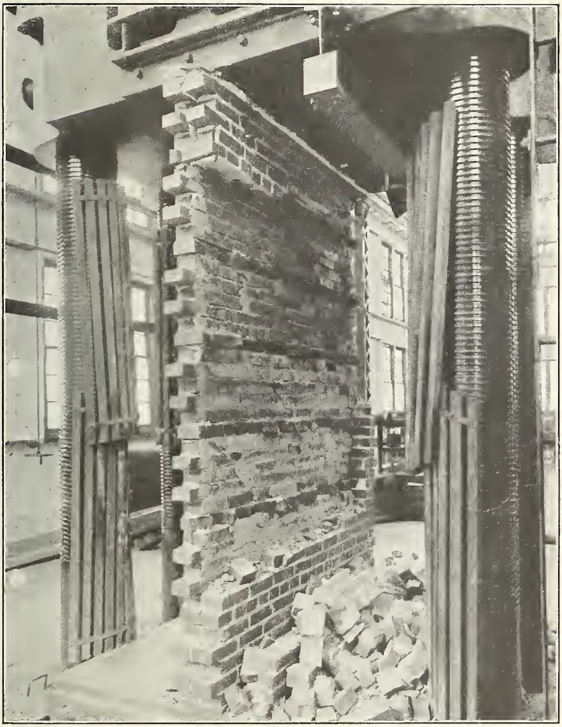

Fig. 2.—*Compression test of 8-inch solid wall of brick. Note failure due to breakage of headers. Bureau of Standards, Washington, D. C.*

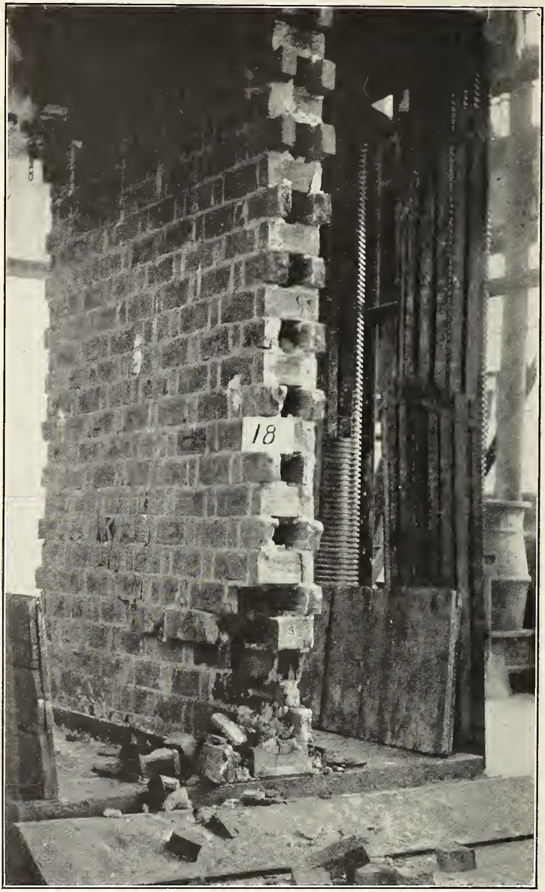

Fig. 3.—*Compression test of 8-inch hollow wall of brick. Bureau of Standards, Washington, D. C.*

ings of these types. The committee has received no evidence tending to establish the importance of this difference.

6. Influence of Span.—Many building codes establish limits of span for floors supported by bearing walls, requiring a greater wall thickness where such limits are exceeded. This practice is believed to date back to the era when working stresses for masonry were not limited directly, but by controlling the live loads likely to come upon the walls. Where masonry stresses are kept within the limits prescribed in Part II, the span of floor beams should not affect the required thickness of masonry walls.

7. Fire Exposure.—Results of a fire-test series at the Bureau of Standards, made with 11 by 16 foot wall panels of various thickness, indicate clearly that if sufficient provision is made, as in Part II, for bearing strength and structural stability and for joist release, fires of the usual duration and intensity will not seriously displace 12-inch brick walls. In the case of the 8-inch exterior walls permitted for one and two family dwellings three stories high and top stories of other low buildings, the consequences are considered to be relatively unimportant, even if failure should occur.

8. Wind Pressure.—In some places which are subject to high winds, trouble is experienced with thin masonry walls, but no evidence has been received indicating that where the structural framework of a building affords reasonably rigid support to the inclosing walls, the pressure resulting from maximum wind velocities in most parts of this country is an important factor in wall design. Neither an 8-inch nor a 12-inch wall of any considerable height has the inherent stability to resist high wind pressures, but if the building inclosed possesses sufficient mass and stiffness to resist collapse as a whole, it appears that, so far as wind pressure is concerned, even the lesser wall thicknesses may be employed freely within the limits prescribed in Part II.

9. Percentage and Arrangement of Openings in Walls.—It is customary in about one-third of existing codes to require that bearing walls be increased 4 inches in thickness when a certain percentage of the wall section (varying in different codes from 25 to 55 per cent) in any horizontal plane is removed for openings. This practice is a survival from the period when maximum masonry stresses were not prescribed and the increase of thickness was required to take care of possible excessive stresses in walls thus reduced in section. If the compressive stresses in masonry walls and piers are kept within the limits prescribed in Part II, and if serious eccentricity in loading of piers and short wall sections is avoided, it is believed unnecessary to require increases in wall thickness on account of openings.

PARAGRAPH 19. BOND FOR BRICK WALLS

Recent tests on brick walls and piers show that failure usually occurs through breaking of the headers and indicates the need of a greater proportion of these than is generally customary in load-bearing masonry. (See figs. 2, 3, and 4.) A lesser ratio of headers to stretchers is permissible for nonbearing brick walls or for the attachment of brick veneer.

PARAGRAPH 20. HEIGHT OF BRICK PIERS

1. The tests of brick masonry piers (see Appendix, par. 11) disclosed very little difference between the strength of piers five and ten times their least dimension in height, other conditions being equal. Not enough data are available by which to establish the relative strength and stability for piers of greater slenderness ratio. In the tentative draft of this report recommendations allowing wall sections an unsupported height of twenty times their thickness and piers only ten times their least dimension were strongly criticized, and it was apparent that the line between piers and walls must be drawn more definitely than is now customary code practice. The limit established in Part II, section 7, will not cause hardship with ordinary window and story heights, but will avoid very thin wall sections where stories are high and openings closely spaced.

2. Bond stones at intervals in the pier section are not advocated. They provide opportunity for concealing poor workmanship; they do not add materially to the bearing capacity of brickwork; and they are apt to split under fire exposure, causing failure of the pier.

PARAGRAPH 21. HEIGHT OF MASONRY WALLS

In view of the liberal requirements recommended for solid brick, stone, and plain concrete walls, consideration was given to the question whether they should be limited in total height. There are certain types of structures, however, for which such limitations are unnecessary and in fact undesirable. In general, economic factors will influence choice of steel or reinforced concrete for buildings over 75 feet high. Where brick or plain concrete bearing or nonbearing walls are used for greater heights they should receive very careful inspection, both as to design and workmanship. Foundation and footing design should also be carefully investigated.

PARAGRAPH 22. LINING EXISTING WALLS

Old walls should be cleaned of all plaster or other coating before the lining is built in order to afford good bond for the mortar. In addition to toothing, it is well to provide anchorage by suitable wrought iron or steel anchors placed in staggered rows not more than 2 feet apart vertically and horizontally. Such anchors may be attached to the old wall by through or expansion bolts, or by other approved methods.

PARAGRAPH 23. LINTELS

Arch lintels may be constructed successfully of hollow tile, but the most practical form of tile lintel is made by butting a sufficient number of tile end to end, filling the cells completely with concrete, and inserting reinforcement rods in the lower tier of cells, thereby obtaining the effect of a reinforced concrete beam. The coarse aggregate for such filling should not exceed one-half inch diameter.

PARAGRAPH 24. QUALITY OF HOLLOW TILE AND CONCRETE BLOCK OR CONCRETE TILE

1. During the last two years compression and absorption tests of hollow tile from 28 representative sources have been made by the Bureau of Standards. Freezing tests are also being made on tile

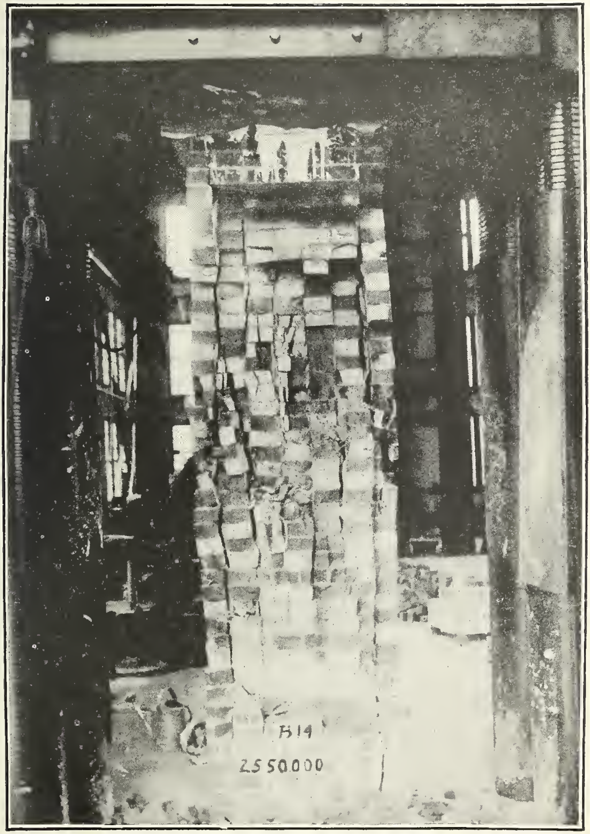

FIG. 4.—*Compression test of large brick pier in 10,000,000-pound machine. Bureau of Standards laboratory at Pittsburgh*

from 18 sources. Basing judgment on structure, strength, and freezing effects tile from all but four sources could be used in a wall exposed to the weather. The absorption of each of these four lots of tile was above 16 per cent.

All of these absorption figures were based on determinations with specimens which had been saturated by boiling 5 hours, but comparative tests at the bureau have shown that the differences in absorption indicated by 1 and 5 hour boiling tests are not significant. Due to the thinness of material tile differ in this respect from clay brick, for which a 5-hour test is advisable.

The bureau's experience is that the determination of absorption by boiling is preferable, as it requires less time and gives more definite and conclusive results. For sampling, the method given in the tentative specifications for Hollow Burned-Clay Load-Bearing Building Tile of the American Society for Testing Materials is recommended. Tile having an average absorption greater than 16 per cent should not be used in a wall exposed to the weather, or in foundation walls unless it shows adequate resistance in freezing tests.[6] As different types of clays are used in the manufacture of hollow building tile, color should not be taken as indicative of percentage absorption or quality.

2. Tentative specifications for quality and testing of clay hollow load-bearing wall tile have been adopted by the American Society for Testing Materials.

The following are excerpts from these tentative standards:

According to the results of physical tests, tile shall be classified as hard, medium, soft, on the basis of the following requirements:

Class	Percentage absorption		Compressive strength based on gross area			
			End construction		Side construction	
	Mean of 5 tests	Individual maximum	Mean of 5 tests	Individual minimum	Mean of 5 tests	Individual minimum
Hard	12 or less	15	1,800 or more	1,400	1,000 or more	700
Medium	12 to 16	19	1,800 to 1,400	1,000	1,000 to 700	500
Soft	16 to 25	28	1,400 to 1,200	700	700 to 500	350

Where end construction tile are used on side, they must meet the requirements of that construction, and vice versa.

Tile under these specifications shall have the following dry weights determined as hereinafter specified:

Size of unit (in inches)	Number of cells	Standard weight
		Pounds
3¾ by 12 by 12, end construction	3	20
6 by 12 by 12, end construction	6	30
8 by 12 by 12, end construction	6	36
10 by 12 by 12, end construction	6	42
12 by 12 by 12, end construction	6	48
3¾ by 5 by 12, side construction	1	9
8 by 5 by 12, side construction	2	16
8 by 5 by 12 (L shaped), side construction	4	16
8 by 6¼ by 12 (T shaped), side construction	4	16
8 by 7¾ by 12 (square), side construction	6	24
8 by 10¼ by 12 (H shaped), side construction	7	32

A tolerance of 5 per cent from the standard weights and a variation of not to exceed 3 per cent in the standard sizes is permitted.

[6] See Appendix, par. 9-2, for freezing test requirements for building brick.

3. For purposes of code enforcement it has been found desirable that concrete units be marked with the manufacturer's distinctive brand, and that the product be tested from time to time by a reliable laboratory. Specifications for testing concrete blocks can be obtained from the secretary of the American Concrete Institute.

4. The crushing strength required for acceptable concrete block and tile is justified as being within the average demonstrated strength of the material, also by the fact that the comparatively thick shells and webs of the former afford a better distribution of stress in the mortar joints.

PARAGRAPH 25. WORKING STRESSES FOR HOLLOW WALLS

1. After thorough consideration, the working stresses for tile laid with cells vertical and those with cells horizontal have been made the same. Tile laid with cells horizontal has the same net bearing area in the wall as it has when tested individually in that position. With end construction tile, some or all of the vertical cross webs may not be vertically aligned as set in the wall, thereby reducing the effective bearing area below that in tests of individual units. It is believed that this condition, together with the somewhat more uniform bedding of tile laid horizontally offsets the difference in strength between individual units tested with cells vertical and horizontal. The stresses given in Part II, section 11, will in almost all cases permit utilization of tile to the full limits of height and thickness permitted, and the factor of safety involved is considered adequate. When walls of hollow tile are built entirely with cells vertical and with webs carefully superposed their strength is materially increased, and may in some cases be 50 per cent greater than when tile are laid horizontally.

2. The committee's investigations have shown the desirability of thorough tests by responsible authorities to determine the relative strength of tile walls laid both with cells horizontal and vertical. An extensive series of tests is now in progress at the Bureau of Standards, but will not be completed in time to utilize results in this report.

3. It is the committee's belief that tile units should not be used having a thickness greater than 8¼ inches, measured at right angles to the wall face. For walls over 8 inches thick, more than one unit should be used to make up the thickness, and bond should be provided.

4. Recent tests by the Bureau of Standards indicate that hollow walls of brick laid in all-rowlock bond (see fig. 3) have practically the same compressive strength as solid walls of the same thickness when loads are applied concentrically, and somewhat greater strength if loaded eccentrically. In the absence of fuller experience with its possibilities of adaption to various building details, and for large buildings, the committee hesitates to approve its use for heights or stresses exceeding those prescribed in Part II.

The committee limits its recommendations for use of hollow walls of brick to the type built with alternate headers and stretchers in each course and known as "all-rowlock bond," until it obtains sufficient information on the merits of other types to justify their recognition. (For discussion of hollow concrete walls, see Appendix, par. 27-2 and -3.)

PARAGRAPH 26. SUPPORT FOR SLABS, BEAMS, AND GIRDERS

The requirements of Part II assume that adequate measures will be taken to distribute local reactions of beams and heavy girders throughout the wall. Hollow walls or those of hollow units should have two or three solid courses of brick beneath the joists, or the course of hollow units on which the joists rest should be filled solid with concrete. The filling of isolated piers of hollow units with concrete is believed to add to their stability and to increase their serviceability under fire exposure. No increase in loading is warranted because of the filling.

PARAGRAPH 27. CONCRETE WALLS—SOLID AND HOLLOW

1. Materials.—The maximum permissible size of large aggregate for thin walls should be governed by the thickness of the smallest construction member in which the concrete is placed, in general not more than one-third of such least dimension.

In the process of manufacturing aggregate there often are small amounts of grits or coarse sand that come over the screens with the coarse aggregate. A tolerance of 15 per cent of such material speeds up production, lowers prices, and does not appreciably affect results with plain concrete. For the purposes in mind it is of little importance whether the screen prescribed for separating coarse aggregates has round or square holes.

Where crushed slag is used as an aggregate for building construction it should meet the requirements of the tentative specifications for concrete aggregates of the American Society for Testing Materials.

The admixture of lime in volume not to exceed 10 per cent of the volume of cement may safely be permitted for plain concrete walls. (See Appendix, par. 10-4.) Where walls of plain concrete exceed 35 feet in length, expansion joints should be provided to prevent unsightly cracks in the structure.

2. Several systems of construction are used which produce hollow or double walls of plain concrete. Usually there are two shells, each 3 or 4 inches thick, with an air space between. The inner and outer parts of such walls generally are tied together with wires or metal strips sufficient for stability in small dwellings, but if the area of both walls is needed for compressive strength and stability, positive means is required to bring them into common action. Unless some device or method adequate to do this is provided, the use of such walls for commercial structures over two stories in height or residences more than three stories is not advocated.

3. It is recognized that a hollow wall of plain concrete having the same net cross sectional area as one of concrete block would be somewhat thicker. It may be said, however, that concrete block are better controlled as to quality, and their action under load is better known at this time than that of hollow concrete walls.

4. Attention is especially directed to the fact that quartz gravel or other gravel having high siliceous content is a poor fire resistive aggregate, and should not be used in concrete liable to be subjected to fire, unless adequately protected.

PARAGRAPH 28. WALLS AND PIERS OF STONE MASONRY

1. Where cut or squared stone of small size, such as quarry wastes, are used to lay up solid walls of moderate height the thickness need not be greater than that required for solid brick walls.

2. The tentative draft of this report restricted stone piers to open or unexcavated places on account of their tendency to spall under heat exposure. This requirement has been omitted as too stringent. Piers in unexcavated spaces are apt to be poorly constructed. Those in monumental buildings and other similar locations are seldom exposed to intense heat until the building has reached a state of destruction which renders their failure unimportant.

PARAGRAPH 29. PARAPET WALLS

1. To satisfy architectural considerations and eliminate expense the requirements for parapet walls have been omitted wherever possible. When not provided along the edges of flat roofs on high building, iron railings or other suitable barriers should be furnished for protection of firemen and safety of occupants.

2. Unless carefully moisture-proofed with stucco or other protective material, clay hollow building tile are undesirable for parapet walls in parts of the country where freezing conditions occur. When not thus protected they are apt to become filled with water, which may freeze and break the tile.

PARAGRAPH 30. FOUNDATION WALLS

1. It has been customary to require that foundation walls be made thicker than those immediately above them. The committee does not believe this necessary in all cases. A foundation wall acts both as a bearing wall and a retaining wall. As a bearing wall it has few or no openings compared to the walls above it, and its unit compressive stresses are usually lower. As a retaining wall it owes practically all its stability to the weight resting upon it, and except in very thin walls the addition of 4 inches of thickness increases its resistance to side thrust very little. Where analysis of the forces acting upon it discloses combined stresses greater than those provided in Part II, sections 4, 11, and 19, or where such forces may cause tension in the masonry, the thickness should be increased.

2. Foundation walls should be waterproofed with cement plaster, or other effective means, and unless surrounded by sand or gravel, or otherwise naturally drained, should have open tile drains around the footings on the outside discharging into an outfall at a lower level.

PARAGRAPH 31. NEW MASONRY CONSTRUCTION

1. A building code should encourage progress in the art of construction, and to this end should provide for approval and utilization of new materials or methods immediately on demonstration that they meet the requirements of the situation under which it is proposed that they be used. Two sections therefore have been included in Part II (No. 39 on alternate requirements for fire and division walls, and No. 45 on new masonry construction) and several minor references made which provide for such action.

2. The adequacy for fire and fire division walls of a special grade of cinder concrete blocks of less thickness than prescribed in sections 37 and 38 for such walls of hollow units has already been demonstrated, and other similar possibilities are now under investigation. The successful use of gypsum masonry units, properly protected against moisture, for exterior walls is reported in several localities, and specifications for quality of structural gypsum products are under consideration by a subcommittee of the American Society for Testing Materials. Commercial production of hollow units of lime is also understood to be contemplated.

A somewhat greater factor of safety is recommended for masonry of such new materials, or constructed by novel methods until such time as it has demonstrated continuing strength and integrity under service conditions.

PARAGRAPH 32. ANCHORAGE OF WALLS

1. The following is a description of what is considered good practice in satisfying the requirements of Part II, section 47. Where walls are not built at the same time, the perpendicular joint should be regularly toothed with 4-inch offsets, and the joint should be provided with anchors not less than 2 by ⅜ inch metal, with bent up ends or cross pins to form anchorage; such anchors should be not less than 3 feet long, extending 18 inches on each side of the joint and spaced not more than 3 feet apart in height.

2. Each tier of floor joists should be securely anchored to masonry walls with T-shaped steel anchors at intervals of not more than 6 feet. Anchors should be attached in a way to afford easy release in case of fire burning through the joists.

3. The ends of lapped joists resting upon girders or bearing partitions should be securely spiked. When abutted they should be connected with steel straps or dogs.

4. Joists running parallel to masonry inclosing walls should be anchored to the walls at least once between bearings with steel anchors. Such anchors should extend back and engage at least three joists.

5. Girders should be anchored to the walls and fastened to each other in suitable manner with steel straps.

6. When inclosing walls are of wood, each joist, beam, and girder entering same should be securely spiked or anchored to the wall construction. Where joists rest upon ledger or ribbon boards they should be securely spiked to the studs.

7. The roof structure where resting on masonry walls should have steel anchors not less than four-tenths square inch in cross section, extending down into the wall not less than 2 feet, and spaced not over 6 feet apart.

8. Anchors for attachment of facing or veneering to the backing, as required in Part II, sections 30 and 35, should be not less than three-sixteenths by 1 inch in cross section, and should either be bent or of sufficient length to develop their full strength in bond. Such anchors should be thoroughly protected from moisture, or should be of noncorrodible metal.

PARAGRAPH 33. PROFESSIONAL ASSISTANCE RENDERED

Representatives of the following organizations cooperated in preparation of this report. Their suggestions were not in all cases adopted, and their complete indorsement of the report is not implied, but the committee wishes to acknowledge their helpful interest and assistance:

American Concrete Institute.
American Face Brick Association.
American Institute of Architects.
American Institute of Consulting Engineers.
American Institute of Steel Construction.
American Society of Civil Engineers.
American Society of Safety Engineers.
American Society for Testing Materials.
Associated Engineers of Spokane.
Associated Metal Lath Manufacturers.
Builders Exchange of Norfolk.
Building Officials Conference.
Building Trades Employers' Association of the city of New York.
Detroit Engineering Society.
Engineering Association of Nashville.
Engineering Society of Western Massachusetts.
Engineers' Club of Minneapolis.
Florida Engineering Society.
General Contractors of San Francisco.
Indiana Engineering Society.
Indiana Limestone Quarrymen's Association.
National Board of Fire Underwriters.
National Brick Manufacturers' Association.
National Fire Protection Association.
National Lime Association.
National Sand and Gravel Association.
New York Board of Fire Underwriters.
Office of Supervising Architect, United States Treasury Department.
Oregon Chapter, American Association of Engineers.
Portland Cement Association.
Rochester Engineering Society
Safety Institute of America.
The American Society of Mechanical Engineers.
The Cleveland Engineering Society.
The Common Brick Manufacturers' Association of America.
The Connecticut Society of Civil Engineers.
The Gypsum Industries.
The Hollow Building Tile Association.

PARAGRAPH 34. SELECTED BIBLIOGRAPHY OF INFORMATION ON MASONRY CONSTRUCTION

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Proceedings of the American Society for Testing Materials. (Published annually by the society, 1315 Spruce Street, Philadelphia, Pa.)

Proceedings of the American Concrete Institute. (Published annually by the institute, 1807 East Grand Boulevard, Detroit, Mich.)

Proceedings of the Building Officials' Conference. (Published annually by the conference.)

1a. Brick: Quality of Materials.—*Brick, cement, lime, etc.*—Standards of the American Society for Testing Materials. Issued triennially by the society. Present issue 1924, pages 578–583. Also Tentative Standards, issued annually.

1b. Brick Masonry.—*Working stresses.*—1. Tests of eight brick piers at Watertown Arsenal in April, 1882, under supervision of F. E. Kidder, in the interests of the Massachusetts Charitable Mechanic Association. *Variables.*—Mortars. *Tests.*—Compressive strength of bricks and piers. Kidder, F. E., crushing strength of bricks and of brick piers, (1) American Architect and Building News, vol. 11, pp. 256–258; June 3, 1882. (2) The Architect's and Builder's Pocket-Book, by F. E. Kidder, 1st ed., pp. 169–173; 1885. (3) Abridged in Kidder's The Architects' and Builders' Handbook, 17th ed., pp. 271–272; 1921.

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3. Tests of 33 brick piers at Watertown Arsenal, etc. *Variables.*—Bricks, mortars, breaking of joints, bricks flat and on edge, height and cross section of piers solid and hollow, and age. *Tests.*—Compressive strength of bricks, mortars, and piers; compression of mortars and of piers. Tests of Metals, etc., pp. 69–124; 1884. Trans. Am. Soc. of Civil Engineers, vol. 18, p. 274; June, 1888. Royal Institute British Architects, Report on Brickwork Tests, pp. 138–139; 1905 (abridged).

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10. Tests of 26 brick piers at Watertown Arsenal, in 1904, etc. *Variables.*—Bricks, mortars, and age. *Tests.*—Strength and elasticity, Tests of Metals, etc., pp. 421–449; 1904. (Tests on Bricks, pp. 453–455.)

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2. Fire tests on 19 concrete block panels. See item 2a, 4.

3. Fire tests on 3 concrete brick walls. See item 1c, 3.

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PUBLICATIONS IN RELATION TO HOUSING AND MUNICIPAL REGULATION

[These publications may be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C., payments to be made by money order or New York draft; currency at sender's risk. Postage or foreign money not accepted.]

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