NCMA TEK

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(10A)

FIRE SAFETY WITH CONCRETE MASONRY

Introduction

Fire-safety precautions and regulations are predicated to a great extent on average performance, incidence, experience, and circumstances. Fire-resistance ratings of concrete masonry walls are based on fire tests conducted by Underwriters' Laboratories, Inc., the National Bureau of Standards, National Research Council of Canada, and other recognized fire-testing laboratories. Methods of fire tests are described in ASTM E 119, "Standard Method of Fire Tests of Building Construction and Materials." The test consists of exposing one side of a wall to a fire of controlled intensity for a time equal to or greater than its rated fire-resistance time. Immediately after firing, the hot face of the wall is subjected to a fire hose stream. During the test, loadbearing walls also carry a specified compressive load; and the wall must withstand the fire and the hose stream without passage of flame or gases. Also, heat transmission through the wall must be limited to less than 250°F average gain in temperature.

Results of such tests are the most useful tools we have for estimating the performance of the types of construction materials.

Concrete Masonry in Fire Protection

The resistance of concrete masonry to fire is well established and has been found by research to be a function of the type of aggregate employed in manufacture of the units and their equivalent solid thickness. During a standard fire test, the endurance of concrete block walls (their fire resistance rating) is invariably determined by temperature rise on the unfired, cold side. Few concrete masonry walls have ever failed during the fire test due to loading or due to the sudden cooling by the fire hose stream. Fire resistance rating can be reliably estimated from a knowledge of the aggregate type used in the block and equivalent thickness. Table 1 lists the equivalent thicknesses required for the different aggregate types and fire resistance ratings found in model building codes. As may be noted, differences in the codes are minor. Similar rationale is contained in other codes such as the National Building Code of Canada.

Equivalent thickness of hollow units is calculated from actual thickness and the percentage of solid materials (see calculation of equivalent thickness). Both needed items of information are normally reported by the testing laboratory using standard ASTM procedures listed in ASTM C 140 "Methods of Sampling and Testing Concrete Masonry Units." When walls are plastered or otherwise faced with fire-resistant materials, the thickness of these materials is included in calculating the equivalent thickness effective for fire resistance.

Although numerous fire tests on concrete masonry walls have been conducted, it would be almost impossible to test all combinations of unit sizes, shapes, and aggregate types used in construction. The equivalent thickness approach enables one to reliably determine fire resistance of concrete masonry assemblages that may not have been tested. At the same time, it may sometimes be helpful or advantageous to refer to results of a particular fire test in solving a fire resistance requirement. For this purpose the information contained in Table 2 is provided. It may be noted that the tests referenced in Table 3 are for protection of steel columns with concrete masonry.

Calculating Fire Resistance

Supplementary to the equivalent thickness method and to specific fire tests, another acceptable method of determining fire resistance of masonry composite or cavity walls is by calculation. A calculation procedure is given in "Fire Resistance Classifications of Building Constuctions," Appendix B, BMS 92, National Bureau of Standards. It is used for walls composed of two or more wythes or laminae, where the fire resistance period of the wythes or laminae are known; an example of this is a cavity wall consisting of 4" solid brick, 2" air space and 4" hollow block. The fire resistance of the wall is calculated from the formula.

$$R = \left(R_1^{0.59} + R_2^{0.59} + R_3^{0.59}\right)^{1.7}$$

in this example,

- R = fire resistance period of wall
- R_1 = fire resistance period of brick wythe = 1 hr.
- R_2 = fire resistance period of air space*
- R_3 = fire resistance period of block wythe = 1 hr.

therefore

$R = (1 + 0.3 + 1)^{1.7} = (2.3)^{1.7} =$ 4.12 hrs.

*See Table 4 for $R^{.59}$ of plaster and continuous air space.

TABLE 1

Summary of Building Code Estimated Fire Resistance Ratings for Concrete Masonry Walls of Various Equivalent Thickness

Code:
UNIFORM BUILDING CODE — International Conference of Building Officials

Thicknesses shown for concrete masonry units are "equivalent thicknesses" and include plaster, lath and gypsum wallboard where mentioned and grout when cells are solidly grouted. The equivalent thickness may include the thickness of portland cement plaster or 1.5 times the thickness of gypsum plaster.

Construction	Minimum Finished Thickness Face-to-Face (2) (In Inches)			
	4 Hr.	3 Hr.	2 Hr.	1 Hr.
Expanded Slag or Pumice	4.7	4.0	3.2	2.1
Expanded Clay or Shale	5.7	4.8	3.8	2.6
Limestone, Cinders or Air Cooled Slag	5.9	5.0	4.0	2.7
Calcareous or Siliceous Gravel	6.2	5.3	4.2	2.8

Code: BOCA BASIC/NATIONAL BUILDING CODE — Building Officials Conference of America, Inc.

Thicknesses shown for concrete masonry units are "equivalent thicknesses" and include plaster, lath and gypsum wallboard where mentioned and grout when cells are solidly grouted. The equivalent thickness may include the thickness of portland cement plaster or 1.5 times the thickness of gypsum plaster. Where combustible members are framed into wall, the wall must be of such thickness or be so constructed that the thickness of material between the end of each member and the opposite face of the wall, or between members set in from opposite sides, will be not less than 93% of the thickness shown in the table. 1109.6.2 Increasing ratings: Walls composed of hollow concrete masonry units having a nominal thickness 8 inches or greater and having a fire rating of at least two hours shall be classified as four hours when the hollow spaces are completely filled with insulation, grout or a dry granular material, such as expanded slag, clay, shale or sand.

	Minimum Equivalent Thickness, Inches, for Ratings of*						
	4 hrs	3 hrs	2 hrs	1½ hrs	1 hr	¾ hr	½ hr
Expanded Slag or Pumice	4.7	4.0	3.2	2.7	2.1	1.9	1.5
Expanded Clay, Shale or Slate	5.1	4.4	3.6	3.3	2.6	2.2	1.8
Limestone Cinders or Slag	5.9	5.0	4.0	3.4	2.7	2.3	1.9
Calcareous and Siliceous Gravel	6.2	5.3	4.2	3.6	2.8	2.4	2.0

Wall or Partition Assembly	Members Framed Into Wall or Partition			
	None or Noncombustible			
	4-Hr.	3-Hr.	2-Hr.	1-Hr.
Concrete Masonry Units				
Expanded Slag or Pumice Aggregates	4.7	4.0	3.2	2.1
Expanded Shale, Clay or Slate Aggregates	5.1	4.4	3.6	2.6
Limestone, Cinders, or Unexpanded Slag Aggregates	5.9	5.0	4.0	2.7
Calcareous Gravel Aggregates	6.2	5.3	4.2	2.8
Siliceous Gravel Aggregates	6.7	5.7	4.5	3.0

Code: SOUTHERN STANDARD BUILDING CODE — Southern Building Code Congress

Note (a) Where combustible members are framed into the wall, the wall must be of such thickness or be so constructed that the thickness of solid material between the end of each member and the opposite face of the wall, or between members set in from opposite sides, will not be less than 93% of the thickness shown in table.

Note (b) Equivalent thickness is the average thickness of the solid material in the wall. It may be found by taking the total volume of a wall unit, subtracting the volume of core spaces, dividing this by the area of the face of the unit. Where walls are plastered or faced with brick the thickness of plaster or brick may be included in determining the equivalent thickness. The minimum nominal thickness of non-load bearing concrete masonry walls (not including thickness of plaster) shall be not less than 3" for single wythe walls and not less than 10" (two 4" wythes plus 2" air space) for cavity walls.

CALCULATING EQUIVALENT THICKNESS

Equivalent thickness is the solid thickness that would be obtained if the same amount of concrete contained in a hollow unit were re-cast without core holes.

CALCULATING ESTIMATED FIRE RESISTANCE EXAMPLE

An 8" hollow masonry wall is constructed of expanded slag units reported to be 55%* solid. What is the estimated fire resistance of the wall?

(modular units)

Eq Th = 0.55 x 7.625 in. = 4.19 inches

From Table: 3 hr. Fire Resistance requires 4.00 inches

** Percentage solid can be calculated from net area or net volume values as determined by ASTM C 140 "Methods of Testing Concrete Masonry Units."*

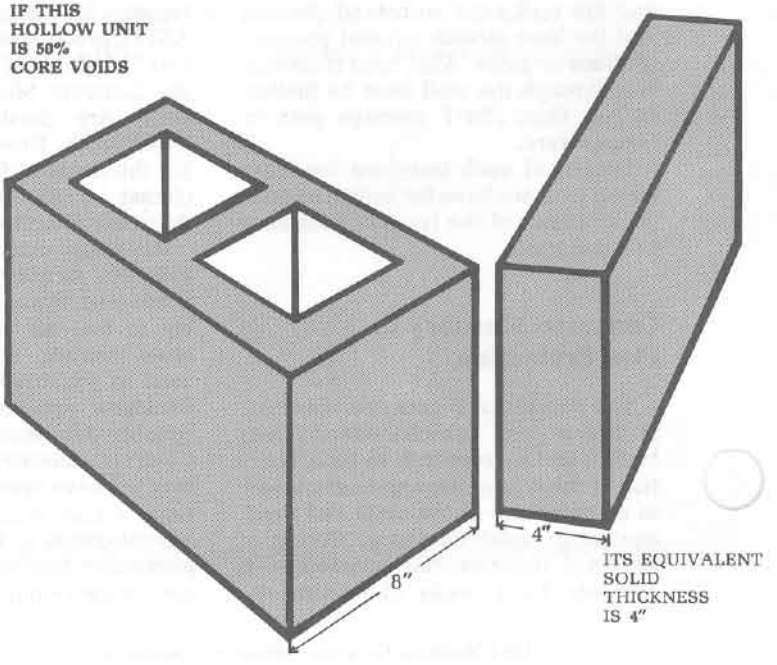


TABLE 2

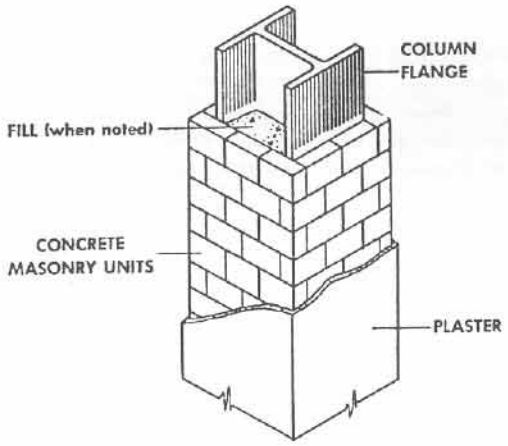
Fire Tests—Masonry Walls

Aggregate Type	Details of Construction	Rating
Pumice	10 in. units 60% solid; unplastered (2)	4 hrs.
	4 in. units 100% solid; unplastered (8)	3 hrs.*
	4 in. units 75% solid; plastered on one side with 5/8 in. gypsum and sand plaster (8)	2 hrs.*
	4 in. units 63% solid; unplastered (1,2)	1 hr.*
Expanded Slag	10 in. unplastered cavity wall of two 4 in. wythes 2 in. apart; units 63% solid (1,2)	4 hrs.
	4 in. units 63% solid; plastered on one side with 1/2 in. 1:3 gypsum and sand plaster; other side faced with 3-3/4 in. brick (1,2)	4 hrs.
	6 in. units 76% solid; unplastered (1,2)	3 hrs.
	6 in. units 61% solid; unplastered (1,2)	2 hrs.*
	6 in. units 50% solid; plastered on one side with 1/2 in. 1:3 gypsum and sand plaster (1,2)	2 hrs.*
	4 in. units 76% solid; plastered on one side with 1/2 in. 1:3 gypsum and sand plaster (1,2)	2 hrs.*
	3 in. units 76% solid; plastered on both sides with 1/2 in. 1:3 gypsum and sand plaster (1,2)	2 hrs.*
	4 in. units 63% solid; plastered on one side with 1/2 in. 1:3 gypsum and sand plaster (1,2)	1½ hrs.*
	4 in. units 63% solid; unplastered (1,2)	1 hr.*
Expanded Shale, Clay and Slate	10 in. units 60% solid; unplastered (1,2)	4 hrs.
	6 in. units 89.1% solid; unplastered (7)	4 hrs.*
	6 in. units 61% solid; unplastered; faced with 2-1/4 in. brick (1,2)	4 hrs.
	6 in. units 89.4%; unplastered (8)	4 hrs.*
	8 in. units, minimum face shell thickness 1-1/2 in., minimum end shell thickness 1-5/16 in. and minimum web thickness 3-1/16 in. unplastered. Concrete studs built into wall on 2 ft. centers by filling every third cell along the length of the wall. Each stud reinforced with 1/2 in. round bar. (3)	2 hrs.*
	4 in. units 76% solid; unplastered on one side with 1/2 in. 1:3 gypsum and sand plaster (2)	2 hrs.*
	6 in. units 68.8% solid; unplastered (5)	2 hrs.*
	4 in. units 100% solid; unplastered (6)	2 hrs.*
	6 in. units 61% solid; unplastered (1,2)	1½ hrs.*
	3 in. units 76% solid; plastered on both sides with 1/2 in. 1:3 gypsum and sand plaster (1,2)	1½ hrs.*
	4 in. units 67.7% solid; unplastered (8)	1 hr.*
Cinder	4 in. units 63% solid; plastered on one side with 1/2 in. 1:3 gypsum and sand plaster; other side faced with 3-3/4 in. brick (1,2)	4 hrs.
	6 in. units 61% solid; unplastered faced with 2-1/4 in. brick (2)	4 hrs.
	10 in. unplastered cavity wall of two 4 in. wythes 2 in. apart; units 63% solid (1,2)	3 hrs.
	6 in. units 61% solid; plastered on one side with 1/2 in. 1:3 gypsum and sand plaster (1,2)	2 hrs.*
	6 in. units 50% solid; plastered on both sides with 1/2 in. 1:3 gypsum and sand plaster (1,2)	2 hrs.*
	6 in. units 61% solid; unplastered (1,2)	1½ hrs.*
Calcareous Gravel	8 in. units 78% solid; unplastered (10)	3 hrs.
	8 in. units 57% solid; unplastered (10)	2 hrs.
	4 in. units 63% solid; plastered on both sides with 1/2 in. 1:3 gypsum and sand plaster (1,10)	1½ hrs.*
	6 in. units 66.3% solid; unplastered (8)	1½ hrs.*
	10 in. unplastered cavity wall of two 4 in. wythes 2 in. apart; units 63% solid (1,10)	1 hr.
	4 in. units 73.5% solid; unplastered (8)	1 hr.*
Siliceous Gravel	12 in. unplastered wall consisting of 8 in. units 57% solid and 4 in. units 67% solid (1,10)	4 hrs.
	12 in. units 58% solid; plastered both sides with 1/2 in. 1:3 gypsum and sand plaster (10)	4 hrs.
	6 in. units 64.5% solid; unplastered (8)	1½ hrs.*
	4 in. units 74% solid; plastered on both sides with 1/2 in. 1:3 gypsum and sand plaster (1,10)	1 hr.*
	4 in. units 71.6% solid; unplastered (8)	1 hr.*

*Nonbearing

TABLE 3
Column Protections

Steel Columns



Concrete Masonry Units	3 in. concrete block, hollow, cinder; fill of cinder concrete slabs and mortar with 1¼ in. mortar between column and blocks . (9)	4 hrs.
	4 in. concrete masonry units, solid, expanded clay or shale (rotary kiln); 1½ in. space between column and masonry units. No. fill.(4)	4 hrs.

TABLE 4
Fire Resistance Properties for Miscellaneous Components

Component		R*
1/2 in. 1:3 sanded gypsum plaster	one side	.30
	both sides	.60
5/8 in. 1:3 sanded gypsum plaster	one side	.37
	both sides	.75
3/4 in. 1:3 sanded gypsum plaster	one side	.45
	both sides	.90
Continuous air space 1/2 in. to 3-1/2 in.	one space	.30
	two spaces	.60

Reference: "Fire Resistance Classifications of Building Construction," BMS 92, National Bureau of Standards.

References

(1) "Fire Resistance Classifications of Building Construction," National Bureau of Standards Report BMS 92, 1942.

(2) "Fire Resistance of Walls of Lightweight Aggregate Concrete Masonry Units," National Bureau of Standards Report BMS 117, 1950.

(3) Report of Raymond E. Davis, Consulting Engineer, University of California, April 14, 1948 (unpublished).

(4) National Research Council of Canada, Fire Study No. 6, February, 1962.

(5) Fire Test of Nonbearing Wall, Fire Study No. 10, December, 1963, National Research Council of Canada.

(6) Fire Test of Nonbearing Wall, Fire Study No. 11, January, 1964, National Research Council of Canada.

(7) National Research Council of Canada, Fire Study No. 12, January, 1964.

(8) Fire Endurance of Selected Non-Loadbearing Concrete Masonry Walls, National Research Council of Canada, Fire Study No. 25, March, 1970.

(9) "Fire Test of a Building Column," National Bureau of Standards Technical News Bulletin No. 246, October, 1937.

(10) "Fire Resistance of Walls of Gravel-Aggregate Concrete Masonry Units," National Bureau of Standards Report BMS 120, 1951.

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