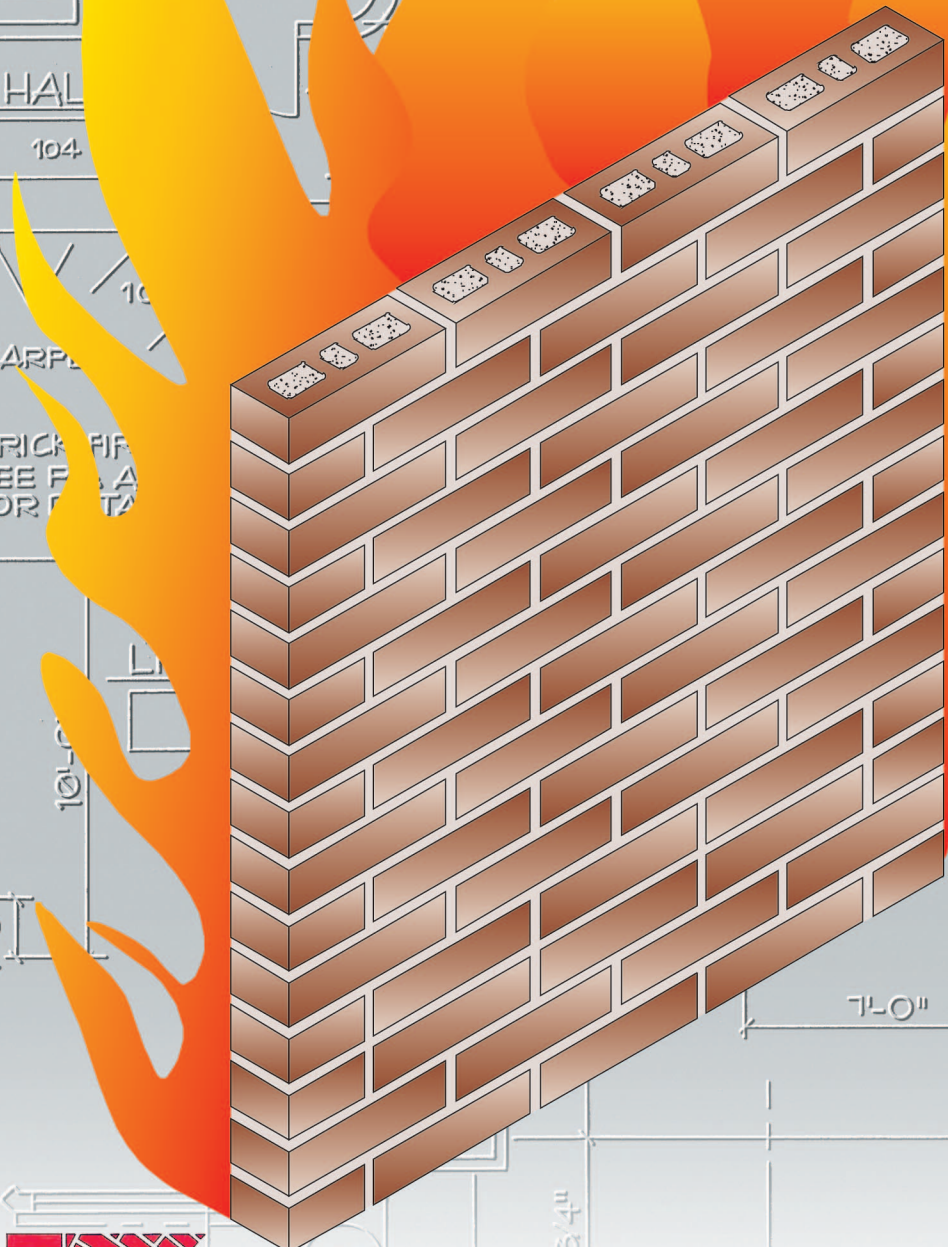


FIRE ENDURANCE RATINGS OF CLAY BRICK MASONRY



WESTERN STATES CLAY PRODUCTS ASSOCIATION

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FIRE ENDURANCE RATINGS OF CLAY BRICK MASONRY

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December 2008

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The members of Western States Clay Products Association express appreciation to Walter Dickey (1908-2002) for his tireless efforts in promoting the clay brick industry. Mr. Dickey spearheaded the initial production of this publication providing technical and editorial input that continues in this printing.

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1.0 INTRODUCTION

One of the most frequently asked questions of the designer is "How do I achieve a 1, 2, 3, or 4-hour fire rating using various clay brick masonry assemblies?"

Intuitively, we are comfortable with clay bricks as a fire resistant material because of their use as a liner in fireplaces and kilns where temperatures exceed those expected in most construction fires. In addition, we have observed the effect of fires on buildings where the only thing to remain standing is the brick. Most designers do not question that brick is non-combustible, or resistant to fire, what they question is the fire resistance of each of the brick wall configurations in hours as it relates to building code requirements.

For many wall assemblies, the information is available from BIA technical Notes 16, and the International Building Code Table 720.1. For some assemblies, the designer is allowed to use methods of calculating fire resistance. Until recently, designers had to rely on ICBO Evaluation Report #5058 to obtain 1 and 2-hour fire ratings for Adhered and Anchored Veneers. Today this information is found in Chapter 7 of the International Building Code, Table 720.1.

2.0 FIRE RESISTANCE BASICS

Fire resistance refers to the ability of a structure to act as a barrier to the spread of fire and to confine it to the area of origin. Therefore, in addition to withstanding the fire, the intent of the code is to prevent other materials adjacent to the brick from combusting after prolonged increased temperatures from fire, flame, or hot gases. Consequently, the assemblies are given a fire rating which is the time it takes for a prescribed fire on one side of an assembly to reach an average temperature on its other side that would ignite cotton waste (250°F). Refer to ASTM E119.

Fire ratings are required for load bearing and non-load bearing wall assemblies. Load bearing assemblies must be capable of withstanding the same conditions as the non-load bearing assemblies. In addition, they must be capable of supporting their prescribed design load for the duration of the fire.

Fire endurance tests alone cannot supply all of the data needed for intelligent appraisal of fire ratings

of building elements. There are simply too many different types of assemblies and combinations of materials to classify them all through actual tests. Fortunately, the theory of fire endurance ratings is sufficiently advanced to offer guidance in estimating fire endurance ratings.

The ultimate goal of this guide is to bring together in one location all of the approved fire ratings for adhered veneer, anchored veneer, structural brick veneer and load bearing brick. See Table 1.

3.0 MASONRY ASSEMBLIES

Masonry fire resistant assemblies are broken down into adhered brick veneer, anchored brick veneer, structural brick veneer, and load bearing brick.

Fire rated assemblies are often required in two directions. If the fire is on the brick side, the brick assembly must resist flames, heat, and smoke from entering to the other side of the assembly prior to the rated time. If the fire is on the other side, the fire rating may be needed to protect occupants in another room or building from the same effects. In most cases, there is a structure supporting the fire resistant materials and the fire rated assembly is required on both sides to protect the structure. If the material is the structure as is the case in load bearing and structural brick veneer, the material can adequately provide fire resistance in both directions.

In a veneer system, the stud backing is the structure and must be protected in both directions. Therefore, brick most commonly provides fire resistance on the exterior side of the stud, and gypsum or some other material provides the fire resistance on the interior face of the stud.

3.1 ADHERED BRICK VENEER

Adhered brick veneer is defined as brick veneer secured and supported through adhesion to an approved bonding material applied over an approved backing. The most common wall assembly is defined by a facing of thin brick between 1/2" to 1 1/2" in thickness applied over a plaster backing. If this combined masonry layer is 1 3/4", the masonry side of the assembly qualifies for a 1-hr fire rating. If the masonry layer is 2" or more, the masonry side of the assembly qualifies for a 2-hr fire rating. In this assembly, the plaster is applied to metal lath, which in turn is applied to wood or steel framing.

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The wood or steel framing members must be sized for all design loads. Steel studs are to be a minimum of 2 1/2". Wood framing is to be 2 x 4 minimum. Wider framing members can be used without degrading the fire resistance rating.

3.1.1 TEST PANEL CONSTRUCTION

The test panels were constructed similar to those for the earlier large program of gypsum board fire evaluation tests. Type X gypsum board was applied to one face of standard steel stud construction. Typical backing and adhered brick veneer was installed on the opposite face by masons experienced in such work.

The panel was designed for symmetrical resistance as required by the International Building Codes; however, if one designs for a situation in which fire exposure is limited to 1-face only, the resisting thickness can all be on one side.

3.1.2 FIRE TESTING

The veneered panels were exposed according to the procedures of ASTM E119 – standard furnace temperature rise; thermocouples on the unexposed face to show temperature rise; verification that there were no cracks that would allow passage of flame or hot spots; and resistance to hose stream exposure without penetration. Additional thermocouples were installed during construction to provide information on the thermal gradient through the section during the fire test. This information helped revise design alternates with greater accuracy.

3.1.3 RESULTS

All panels passed the three basic ASTM requirements with considerable margin. Although the results were somewhat conservative, indicating that thinner veneer might be used, no further refinements or reduction in design thickness was attempted. Precise refinements are not justified in variable hand placed materials, especially if no great cost benefits would result.

The maximum temperature rise on the unexposed face is permitted to be a maximum of 325°F for a single thermocouple and 250°F for the average of all thermocouples, at the specified time period. The test panels showed the following maximum and average rise of temperature. All withstood more hose stream exposure than required by code.

| | Maximum | Average |
|-----------|-----------|---------|
| Panel 1A: | 162°F pt. | 158°F |
| Panel 1B: | 145°F pt. | 135°F |
| Panel 2A: | 129°F pt. | 110°F |
| Panel 2B: | 107°F pt. | 104°F |

3.1.4 CONCLUSION

Adhered brick veneer of 1 3/4" combined masonry thickness provides 1-hour of fire resistance. Adhered brick veneer of 2" combined masonry thickness provides 2-hours of fire resistance. These fire rated assemblies are found in Table 720.1(2) Items 15-2.1, and 15-2.2.

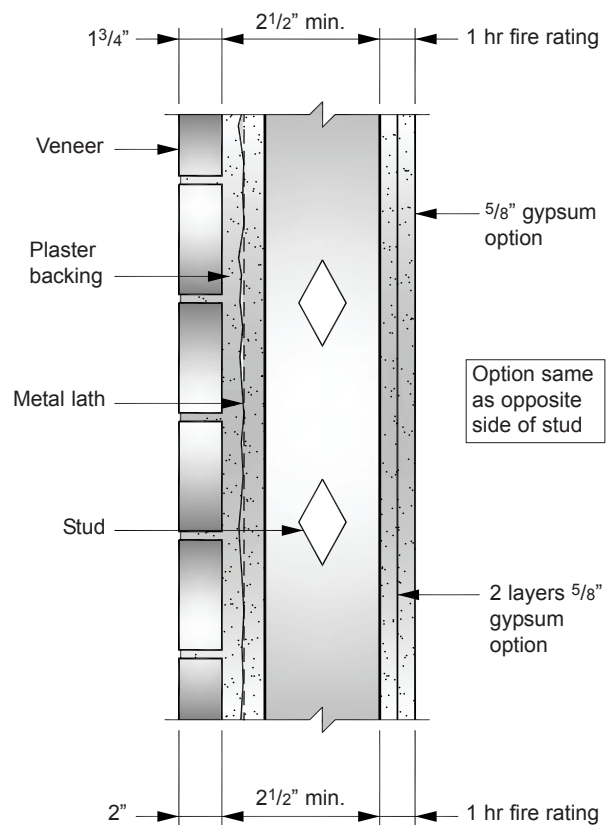


Figure 1 Adhered brick veneer.

3.2 ANCHORED BRICK VENEER

Anchored brick veneer is defined as brick veneer secured to an approved backing by mechanical fasteners. The most common wall assembly is defined by a facing of brick between 2" and 5" in width anchored through mechanical connectors to wood or steel framing.

Excerpts from Table 720.1(2)

| TABLE 720.1(2) [Excerpt] RATED FIRE-RESISTANCE PERIODS FOR VARIOUS WALLS AND PARTITIONS | | | | | | |
|---|----------|---|--------|--------|--------|--------|
| MATERIAL | ITEM NO. | CONSTRUCTION | 4 hour | 3 hour | 2 hour | 1 hour |
| 1. Brick of clay or shale | 1-1.1 | Solid brick of clay or shale. | 6 | 4.9 | 3.8 | 2.7 |
| | 1-1.2 | Hollow brick, not filled. | 5.0 | 4.3 | 3.4 | 2.3 |
| | 1-1.3 | Hollow brick unit wall, grout or filled with perlite vermiculite or expanded shale aggregate. | 6.6 | 5.5 | 4.4 | 3.0 |
| | 1-2.1 | 4" nominal thick units at least 75 percent solid backed with hat-shaped metal furring channel 3/4" thick formed from 0.021" sheet metal attached to the brick wall on 24" centers with approved fasteners, and 1/2" Type X gypsum wall board attached to the metal furring strips with 1" long Type S screws spaced 8" on center. | - | - | 5 | - |

3.2.1 FIRE RESISTANCE

From the fire endurance test, additional information was provided which reduced the thickness of the veneer to 2" with a 1/2" air space for a 1-hour fire rating and a 2" veneer with a 1" air space for a 2-hour fire rating.

Table 720.1(2) of the International Building Code item numbers 1-1.1 through 1-2.1 can also be used to determine the minimum equivalent thickness for brick to achieve a fire rating from 1 to 4 hours. This section of the table is used for veneer brick and structural brick in load bearing and non-load bearing construction.

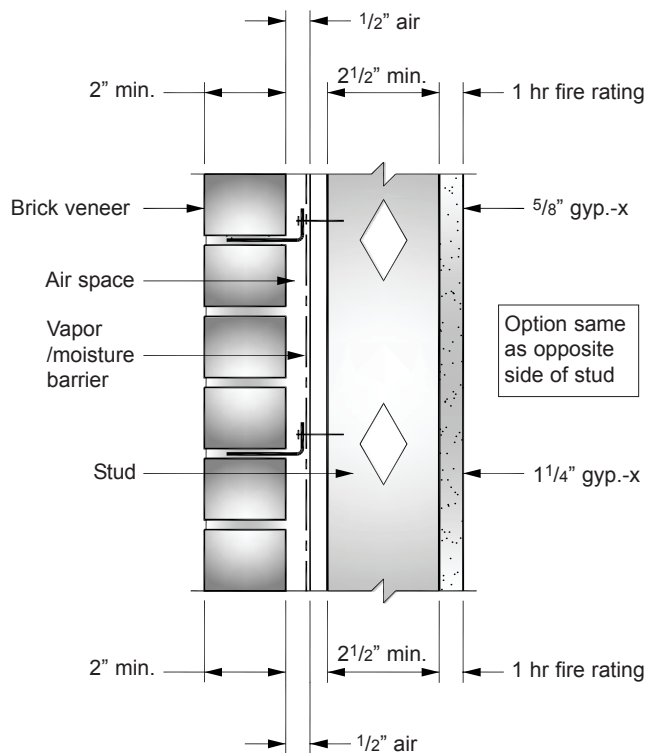


Figure 2 Anchored brick veneer.

3.3 STRUCTURAL BRICK VENEER

Structural Brick Veneer is defined as a masonry assembly of brick, mortar, grout, and reinforcing that is designed similar to anchored brick veneer. It carries no gravity loads other than its own weight, the weight of windows, and possibly other miscellaneous loads. In addition, it is not part of the lateral load resisting system. The difference is that the structural brick veneer is reinforced and grouted to allow the brick to span much further between wall ties. Structural brick veneer does not generally require a backup system to carry lateral loads within the panel. In the Structural brick veneer, the lateral loads are transferred through tension and compression stresses in the masonry.

3.3.1 FIRE RESISTANCE

Table 720.1(2) of the International Building Code item numbers 1-1.1 and 1-1.3 can also be used to determine the minimum brick thickness to achieve a fire rating from 1 to 4 hours. This section of the table is used for structural brick veneer. Since the structural brick veneer assembly was tested with vertical loads, the brick is capable of giving the same fire rating in both directions. No additional framing or fire resistant material is required.

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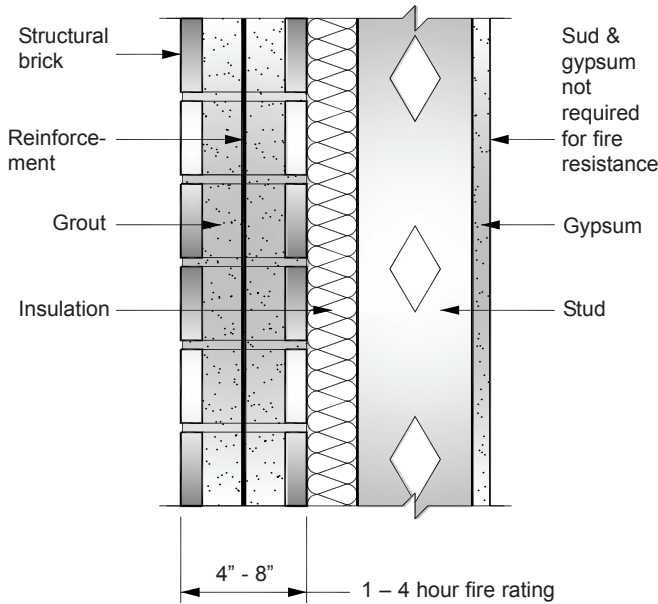


Figure 3 Structural brick veneer.

3.4 STRUCTURAL LOAD BEARING BRICK

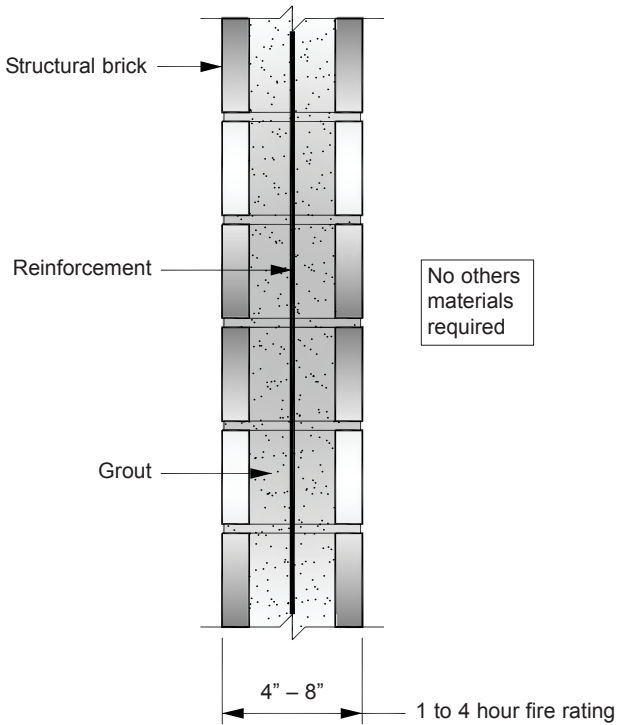


Figure 4 Structural load bearing brick.

Structural load bearing brick is defined as a masonry assembly of brick, mortar, grout and reinforcing that is designed to support all gravity and lateral loads. These masonry elements are generally part of the lateral load resisting system. Greater fire endurance performance and economics can be achieved through the use of reinforced masonry. Fire ratings of 3 and 4 hours can be achieved through the use of up to 8" of hollow clay brick as shown on Figure 4.

3.4.1 FIRE RESISTANCE

Table 720.1(2) of the International Building Code item numbers 1-1.1 through 1-2.1 can also be used to determine the minimum brick thickness to achieve a fire rating from 1 to 4 hours. This section of the table is used for structural brick in load bearing and non-load bearing construction.

4.0 CALCULATED FIRE ENDURANCE RATINGS

As it is impossible to define all of the possible configurations that might be conceived in a wall design, Section 721.4 of the IBC along with IBC Standard 7-7 provides greater assistance in designing with Clay Brick. This section and the standard list more precise rating values for thicknesses of brick, mortar, air space, cement, gypsum plaster, wall board, insulation, studs, siding, etc. They also include more precise calculations for calculating Equivalent Thickness = $T_e = V_r/LH$; R-ratings when adding plaster is defined as $R = (R_n^{0.59} + pl)1.7$ and combinations of clay brick, insulation, air and plaster can be defined using the exponential equation $R = (R_1^{0.59} + R_2^{0.59} + R_n^{0.59} + A_1 + A_2 + \dots PI)^{1.7}$ where R is the fire resistance of each material layer, A is the resistance of each air layer and PI is the resistance of gypsum plaster.

Table 1 identifies a list of R , A , and PI values for use in determining the Fire endurance of miscellaneous clay masonry assemblies.

IBC Standard 7-7 lists 8 rules that are helpful in making a quick assessment of the fire endurance of building elements when fire test data on the elements are not available.

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| Table 1 Fire Resistance (R) in Hours | | | |
|--|-------------------|--------------------------------|-------------------------|
| Masonry Assembly | | Actual Wall Thickness (inches) | Fire Resistance (hours) |
| Adhered Veneer | ASTM C1088 | 1.75" * | 1 |
| | | 2" * | 2 |
| Anchored Veneer | ASTM C216 | 2" to 5" | 3 |
| Structural Veneer and Load Bearing Brick Solid 75% | ASTM C216 | 3.5" | 1 |
| | | 5.5" | 2 |
| | | 7.5" | 3 |
| | | 8" | 3 |
| | | 10" | 4 |
| 8" Cavity wall with 2" air space | | 10" | 4 |
| 10" Cavity wall with 2" air space Hollow – cells not filled | ASTM C652 | 3.5" | 1 |
| | | 5.5" | 1 |
| | | 7.5" | 2 |
| Hollow – all cells filled¹ | ASTM C652 | 3.5" | 1 |
| | | 5.5" | 3 |
| | | 7.5" | 4 |
| Air (A) | | 1/2" to 3 1/2" | 0.30 |
| Plaster (PI) | | 1/2" | 0.30 |
| | | 5/8" | 0.37 |
| | | 3/4" | 0.45 |

Notes:

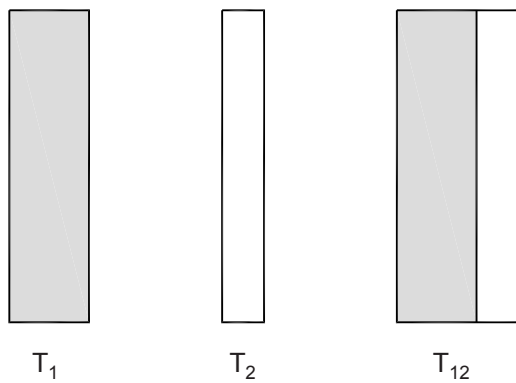
* Thickness includes plaster bedding.

¹ Cells may be filled with perlite, vermiculite, expanded shale aggregate or grout.

4.1 RULE 1

The "thermal" fire endurance of a construction assembly consisting of a number of parallel layers is greater than the sum of the "thermal" fire endurance characteristic of the individual layers when exposed separately to fire.

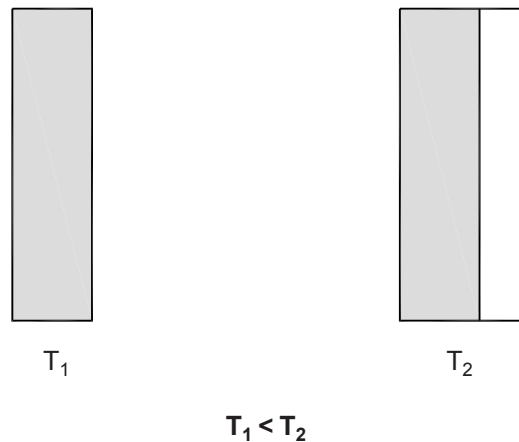
Rule 1



4.2 RULE 2

The fire endurance of a construction assembly does not decrease with the addition of further layers.

Rule 2

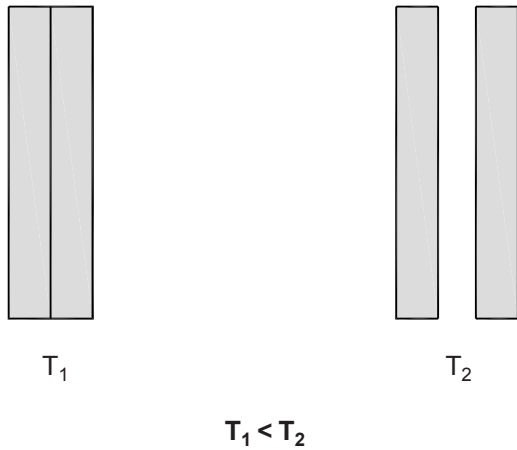


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4.3 RULE 3

The fire endurance of a construction assembly containing continuous air gaps or cavities is greater than the fire endurance of similar constructions of the same weight, but containing no air gaps or cavities.

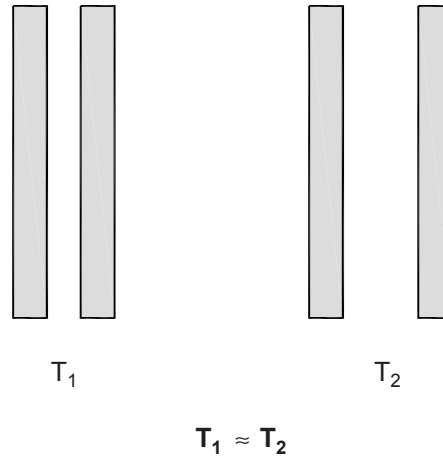
Rule 3



4.5 RULE 5

The fire endurance of a construction assembly can not be increased by increasing the thickness of a completely enclosed air layer.

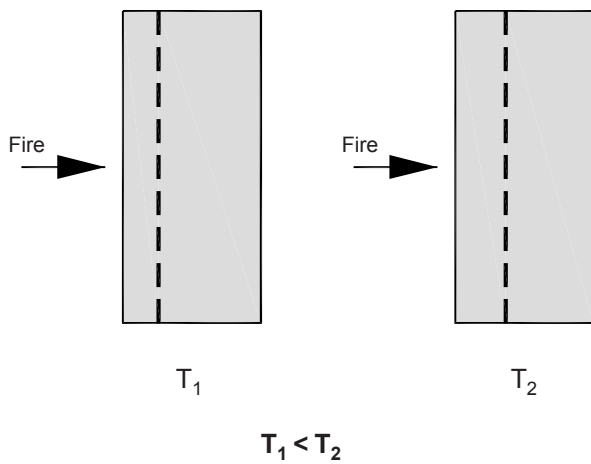
Rule 5



4.4 RULE 4

The farther and air gap or cavity is located from the exposed surface, the more beneficial is its effect on the fire endurance.

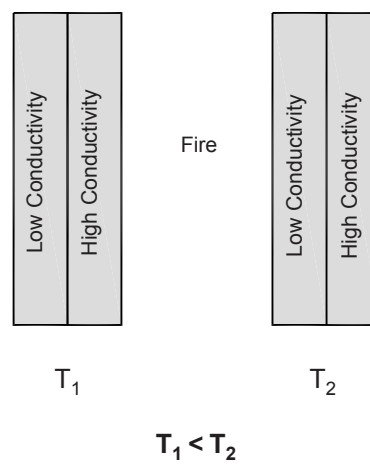
Rule 4



4.6 RULE 6

Layers of materials of low thermal conductivity are better utilized on that side of the construction on which fire is more likely to happen.

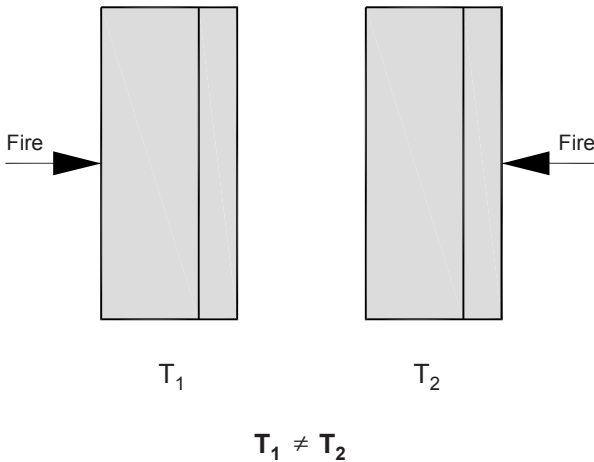
Rule 6



4.7 RULE 7

The fire endurance of asymmetrical construction assemblies depends on the direction of heat flow.

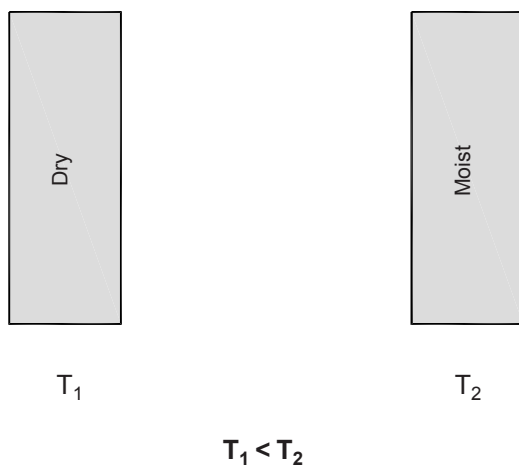
Rule 7



4.8 RULE 8

The presence of moisture, if it does not result in explosive spalling, increases the fire endurance.

Rule 8



5.0 CONSIDERATIONS

When backing materials are used to provide support for the fire resistive materials, the backing material shall be protected with the same fire resistance rating on both sides.

Although life safety is the primary reason for incorporating fire resistance in construction, when considering tradeoffs such as gypsum, or sprinklers, other issues should also be considered such as, fire separation, property protection, water damage, replacement costs and reuse of structure.

APPENDIX – WALL DETAILS

A.1 MATERIALS:

A.1.1 Thin Veneer Brick Units: Units are produced from clay or shale in thicknesses from 1/2 to 1 1/2 inches (12.7 to 38 mm) and comply with ASTM C1088, Grade TBS or better.

A.1.2 Face Brick Units: Units are made from clay or shale in thicknesses exceeding 1 1/2 inches (38 mm) and comply with ASTM C216 for veneer facing units; Type FBS or better and Grade SW in Severe Weather regions.

A.1.3 Hollow Brick Units: Units are made from clay or shale in thicknesses exceeding 4 inches (38 mm) and comply with ASTM C652 for hollow clay brick; Grade HBS or better and Grade SW in Severe Weather regions; Unit strength as specified for the job.

A.1.4 Mortar: Type S as set forth in Table 2103.8(1) or Table 2103.8(2) of the IBC.

A.1.5 Plaster Backing: Portland cement plaster complying with Section 718 and Section 2507 of the IBC.

A.1.6 Lath: Minimum 3.4 pounds per square yard (1.8 kg/m³) metal lath complying with Section 2507 of the IBC.

A.1.7 Steel Framing: Framing with either gypsum plaster or gypsum wallboard must comply with Table 720.1(2) of the IBC.

A.1.8 Wood Framing: Framing with either gypsum wallboard or gypsum plaster must comply with Table 720.1(2) of the IBC.

A.2 WALL CONFIGURATION:

A.2.1 Adhered Veneer: Metal lath is installed in compliance with Section 2506.1 of the UBC. Where lath is attached to steel framing, minimum 1-inch-long (25.4 mm), No. 6 drywall screws are used. For exterior walls, a weather-resistive barrier described in Section 2510.6 of the IBC is required. The Portland cement plaster is applied in compliance with Sections 2510, 2511, and 2512 of the IBC to a minimum 3/4-inch (19.1 mm) thickness. The thin veneer units are applied in compliance with Section 1405.9 of the IBC in running bond. For one-hour fire resistance, the total thickness of plaster, mortar and brick veneer shall be at least 1 3/4 inches (45 mm). For two-hour fire resistance, the total thickness of plaster, mortar and thin brick shall be at least 2 inches (51 mm).

A.2.2 Anchored Veneer: Anchored veneer is installed in compliance with Section 1405.5 of the IBC for 2-to-5-inch-thick (51 to 127 mm) units and Section 1405.6 of the IBC for units up to 10 inches (254 mm) thick. Stud spacing is limited to 16 inches (406 mm) on center, and a weather-resistive barrier complying with Section 1403.2 of the IBC is required on the exterior side of exterior walls. Anchored units may be used for one-hour or two-hour fire-resistive assemblies.

A.3 INSTALLATION:

Details of one-hour and two-hour nonbearing walls are noted in Figures 5 and 6. For symmetrical one-hour fire resistance, each face shall have not less than one layer of 5/8-inch-thick (15.9 mm) Type X gypsum wallboard, or equivalent gypsum plaster, or 1 3/4 inch (45 mm) thickness of masonry veneer. For two-hour fire resistance, each face shall have not less than two layers of 5/8 inch-thick (15.9 mm) Type X gypsum wallboard, or equivalent gypsum plaster, or 2 inch (51 mm) thickness of masonry veneer.

A.3.1 Structural Brick Veneer and Structural Load Bearing Brick: Both structural brick systems are installed by combining brick, mortar, reinforcing and grout to provide a structure that combines load resistance to fire resistance. Structural brick fire ratings are generally defined by their equivalent thickness - the more solid the wall, the higher the fire rating. The International Building Code defines the minimum equivalent thickness required to achieve various fire ratings from 1 to 4 hours. Structural brick are defined as hollow without insulation and hollow

with insulation. Hollow units with insulation are to be filled solid with insulation materials and the equivalent thickness is the actual thickness of the wall.

A.4 FIRE RATED WALL SECTIONS

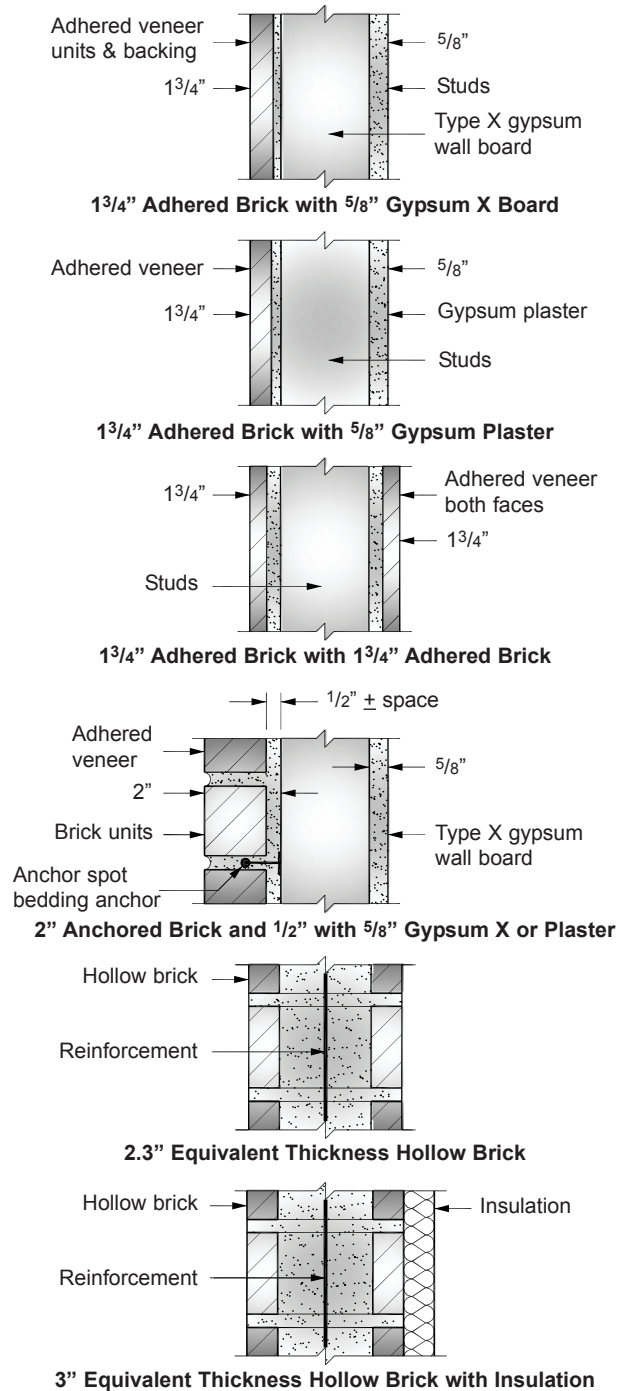


Figure 5 1-hour wall sections.

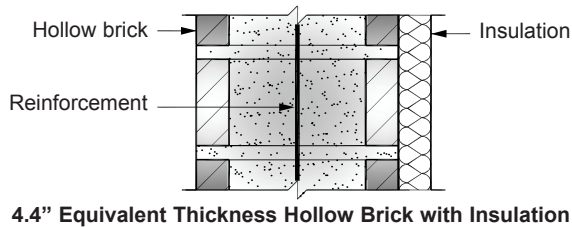
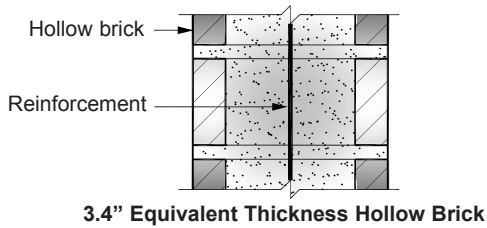
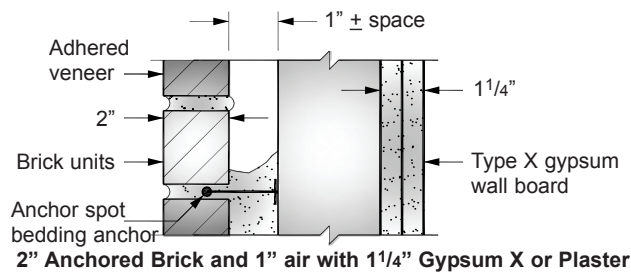
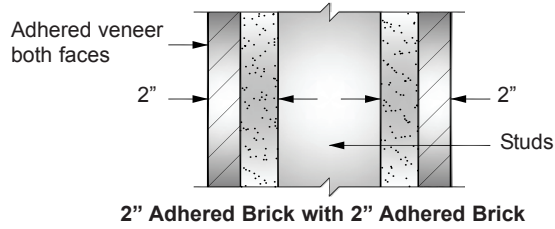
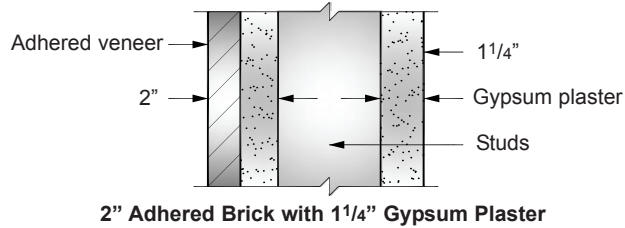
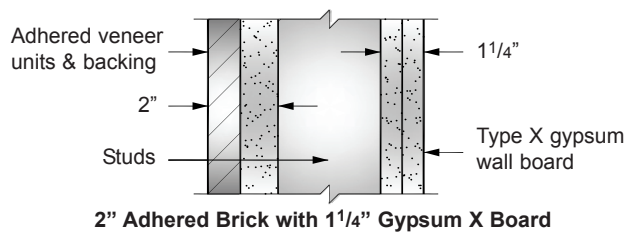


Figure 6 2-hour wall sections.

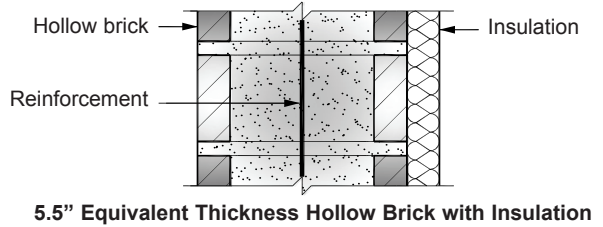
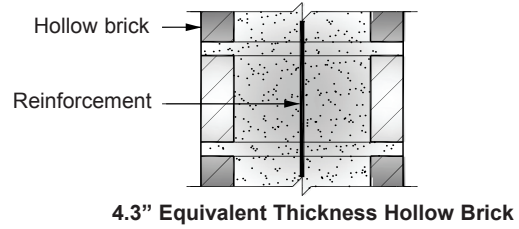


Figure 7 3-hour wall sections.

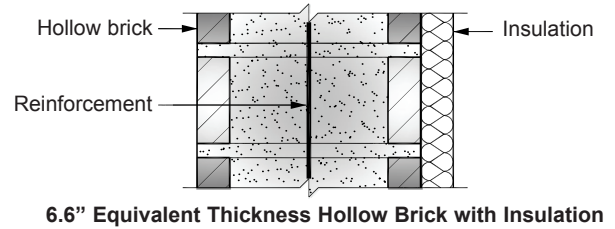
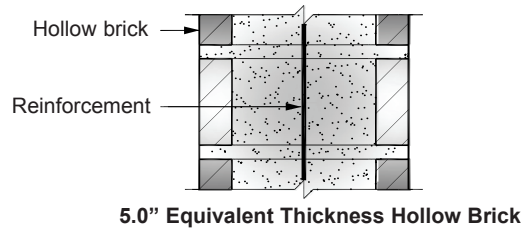


Figure 8 4-hour wall sections.

ALLIED ASSOCIATES AND WEB ADDRESSES

- | | | |
|----------|---|--|
| 1 | Arizona Masonry Guild | www.masonryforlife.com |
| 2 | Masonry Advisory Council | www.maconline.org |
| 3 | Masonry Industry Promotion Group | www.masonrypromotion.com |
| 4 | Masonry Institute of America | www.masonryinstitute.org |
| 5 | Masonry Institute of Oregon | www.mioctio.org |
| 6 | Masonry Institute of Washington | www.masonryinstitute.com |
| 7 | Rocky Mountain Masonry Institute | www.rmmi.org |
| 8 | Utah Masonry Council | www.utahmasonrycouncil.org |

