FIRE RESISTANCE TESTS OF BRICK VENEER / WOOD FRAME WALLS

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SUMMARY

Brick veneer exposed to the fire provides in excess of a one hour fire resistance rating to wall assemblies with wood frame backing. This is true for a brick wythe that does not have a one hour rating. This fact is verified by tests of brick veneer walls with wood frame backing subjected to the standard fire test for wall construction used in the United States of America. The fire tests followed an increasing temperature at a prescribed rate. The test requires a hose stream played on the fire-exposed face. The brick veneer walls received this water stream after the full fire exposure.

INTRODUCTION

The fire resistant characteristics of brick masonry are well documented for the units themselves and for masonry walls. Research papers and model building codes contain specific information and equations to establish the fire resistant resistance ratings of masonry units and walls. These are typically based on the equivalent thickness of the wythe or wall. Equivalent thickness is the amount of solid material in the wall or wythe within a given face area.

There is little test data on the contribution of brick veneer to the fire resistance of the full wall assembly. Many code officials would assert that the brick veneer wythe must have a one hour fire rating in order to verify that the full wall assembly, containing materials other than concrete or masonry, has a one hour fire resistance rating from the brick faced-side. The International Building Code's Chapter 7, Fire-Resistance-Rated Construction, (IBC 2006) does contain fire resistance periods of clay masonry walls and required thicknesses to protect structural steel

members and steel studs. It does not do so for wood frame members. The International Residential Code (IRC 2006) refers to the International Building Code for fire resistance ratings.

Underwriter's Laboratories, a private concern that tests and rates wall assemblies, publishes a Fire Resistance Directory (UL 2006). This document does contain three brick veneer/wood frame assemblies. Each includes brick veneer made with nominal 100 mm (4 in.) thick brick as an alternative exterior material. Void area is not specified. Only one of these wall systems does not include gypsum sheathing between the brick veneer and wood framing. That assembly, U356, does provide a one hour fire resistance rating with brick on the fire-exposed side.

For more than three decades brick manufacturers in the United States have been producing brick with bed depths less than the conventional 100 mm (4 inches) nominal width. In addition, void area has increased from the 25% maximum to be qualified as a "solid" brick to values approaching 35%, which classify the brick as a hollow masonry unit. These factors result in many brick that do not have the minimum equivalent thickness to provide a one hour fire rating for the veneer itself.

The confluence of these occurrences resulted in the decision to test for the fire resistance rating of brick veneer walls faced with brick that have less than a one hour rating to see if a one hour fire rating could be achieved with these thinner hollow brick. The one hour rating is important in residential construction for separation between dwellings.

TEST PROGRAM

Test Method

ASTM E 119, *Standard Test Methods for Fire Tests of Building Constructions and Materials*, (ASTM 2005) was to evaluate the fire resistance rating of the specimens. This test method evaluates the duration for which the assembly tested will contain a fire, retain its structural integrity, or display both properties for a predetermined fire exposure time. For these tests a one hour duration was established as the maximum time. E 119 subjects the exposed face to a specified time-temperature curve, rapidly increasing in temperature initially and tapering off with time. If any component of the wall assembly begins to burn or contribute to the heat rise in the furnace the gas flow to the furnace is stopped until the temperature returns to the prescribed value.

This test method requires wall specimens of at least 9.3 m^2 (100 ft^2). The wall assembly is built in a steel frame and the frame and wall assembly are positioned as one wall of a gas-fired furnace. See Figure 1. The fire exposed face is not visible during the test. If tested wall is designated as a load-bearing assembly the prescribed load is applied with jacks to the top of the load-bearing portion of the wall.

Figure 1. Wall of Brick 2 in Frame, Being Moved to Furnace

The face of the specimen away from the fire is instrumented with nine thermocouples arranged symmetrically in three columns and three rows, uniformly spaced on the unexposed face. In the E 119 test method there are four possible failure modes:

1. Ignition of cotton waste from gases passing through the specimen,
2. A temperature rise of 139 degrees Celsius (250 degrees Fahrenheit) over ambient at any thermocouple on the unexposed side of the specimen,
3. Inability to carry the imposed load
4. Breeching of the wall assembly by the hose stream after fire exposure

At the end of the test, due to failure or the desired time is met, the fire-exposed face of the wall is removed from the oven and is subjected to a hose stream for at least 60 seconds. The water stream is played over the hot face of the specimen in a specified pattern. E 119 permits the hose stream to be applied to a second specimen that was subjected to one-half of the fire exposure time. This was not done with the specimens in this paper. The walls that were tested for the full exposure time period were subjected to the hose stream.

The specimens in this paper were designated as load-bearing. A load of 11,400 N/m (780 lb/ft), representative of that on the lower floor of a typical, two-story, single family dwelling, was applied to the wood frame portion of the wall.

Specimen Construction

Typical residential wall sections were constructed for these tests. The specimens were 3.7 m (12 ft) wide x 2.7 m (9 ft) tall constructed with 50 mm x 100 mm (2 in. x 4 in.) yellow pine wood studs at 406 mm (16 in.) on center. The sheathing was 13 mm (1/2 in.) oriented strandboard (OSB) nailed to the wood studs, with a water-resistive barrier of #15 asphalt felt paper on the outside face. The interior finish was 13 mm (1/2 in.) gypsum wallboard screwed to the studs. The joints were taped and treated with joint compound and fastener heads were covered with joint compound. The gypsum wallboard was coated with white latex primer and paint. Fiberglass batt insulation with a kraft paper face was placed between the gypsum wallboard and the sheathing. The wood stud framing incorporated a double top plate, a single bottom plate and horizontal fire blocking 0.3 m (1 ft) from the bottom of the framing. This portion of the assembly conforms to prescriptive requirements of the International Residential Code (IRC 2006) for a bearing wall. The wood frame, gypsum wallboard, insulation, sheathing and water-resistive membrane were placed by research laboratory personnel.

The brick veneer was attached to the backing with 22 mm (7/8 in.) wide by 0.76 mm (22 gage) thick corrugated sheet metal anchors that were screwed to the studs. Veneer anchor spacing varied amongst the specimens to accommodate different brick heights. They were in rows at approximately 406 mm (16 in) on center vertically. Each of the brick veneers was attached with one anchor for each 0.25 m^2 (2.67 ft^2), the requirement in both the IBC and IRC. Veneer anchors were embedded in mortar for at least 38 mm (1.5 in.). For two of the veneer specimens this was in the mortar bed joints. For one brick veneer the anchors were also bent into the core of the brick below. There was a 25 mm (1 in.) air space between the inside face of the veneer and the outside face of the water-resistive barrier. ASTM International C 270 (ASTM 2006a) Type N masonry cement mortar mixed to a volumetric proportion was used.

The brick veneer was laid in half running bond by a mason contractor instructed to work to typical residential construction standards. The brick veneer was laid to the wood frame walls at least 30 days prior to testing. Curing was in ambient conditions in the laboratory. Typical temperature and humidity ranges in San Antonio, Texas for this time between construction and testing are from 14 to 35 degrees Celsius (57 to 95 degrees Fahrenheit) and 30 to 75% relative humidity.

Thermocouples were applied to the unexposed face as noted. Additional thermocouples were placed under the #15 asphalt felt paper on the fire exposed side of the OSB on walls of Brick 2 and 3. These were at the horizontal center of the specimen and at mid-height and three-fourths of the height of the specimens.

Brick Properties

Each of the three brick veneers tested was built of brick with different widths and coring percentages. See Table 1 and Figure 2. Brick 1 and 2 were from commercial construction. Brick 3 was made as a special run at a brick plant and is purposely less than the 50 mm (2 in) minimum thickness permitted by the International Residential Code. Each of the brick is classified as meeting the requirements of ASTM International C 652, *Standard Specification for Hollow Brick*, Grade SW (ASTM 2006b).

Table 1. Dimensional Properties of Brick used in Veneer

Brick Designation	Width, mm (in)	Height, mm (in)	Length, mm (in)	Void Area, %	Equivalent Thickness, mm (in)
1	90 (3.5)	57 (2.25)	190 (7.5)	34.5	58 (2.3)
2	73 (2.87)	64 (2.5)	241 (9.5)	36.5	46 (1.8)
3	44 (1.75)	57 (2.25)	197 (7.75)	26.9	32 (1.3)

Figure 2. Brick 1, 2 and 3, from left to right

TEST RESULTS

Test of Brick 1 Veneer Wall

The wall specimen with Brick 1 veneer easily passed the one hour fire resistance period and the hose stream test. Table 2 contains the observations made by laboratory personnel.

Table 2. Observations for Brick 1 Fire Test

Time	Observation
0:00	Start of test.
17:30	Smoke exiting top right corner.
29:00	Smoke continues.
40:00	Steaming from top corners.
43:00	Steaming continues.
52:00	No flames or bowing.
60:00	End of test. No flames, maintained load
Post Test	Brick veneer remained intact. Minimal damage to OSB.

The fire exposed face of Brick 1 veneer, after both the fire test and the hose stream, is shown in Figure 3. The maximum temperature rise on any of the thermocouples was 10.6 degrees C (19 degrees F) and the average of all thermocouples was 9.4 degrees C (17 degrees F). The hose

stream was conducted for 65 seconds. The wall assembly did not allow passage of water. There was no visible cracking in the veneer prior to or following the hose stream. After the wall cooled slight mortar loss in a few head and bed joints was noticed.

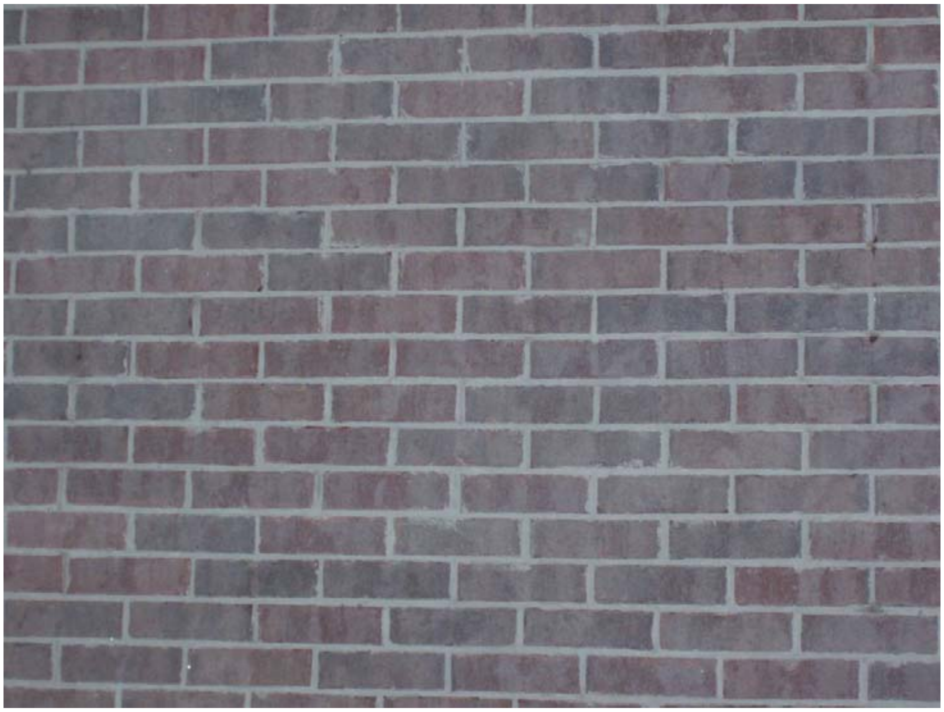

Figure 3. Veneer of Brick 1 after Fire Exposure for 1 Hour and Hose Stream

Test of Brick 2 Veneer Wall

The wall specimen with Brick 2 veneer also easily passed the one hour fire resistance period and the hose stream test. Table 3 contains the observations made by laboratory personnel.

Table 3. Observations for Brick 2 Fire Test

Time	**Observation**
0:00	Start of test.
16:20	Steam exiting from top.
25:00	No smoke or flaming on unexposed face.
35:00	Minimal steam exiting from center-top.
46:45	Minimal smoke from top edge.
50:00	Light smoke from top.
60:00	End of test. No flames, maintained load
Post Test	Brick veneer remained intact. Minimal damage to OSB.

The fire exposed face of Brick 2 veneer, after the hose stream application, is shown in Figure 4. There was visible bowing of the plane of the veneer and a vertical crack about 380 mm (15 in.)

long, extending down from the top center of the veneer prior to the hose stream. The maximum temperature rise on any of the thermocouples was 11.7 degrees C (21 degrees F) and the average of all thermocouples was again 9.4 degrees C (17 degrees F). The hose stream was conducted for 65 seconds. The wall assembly did not allow passage of water. The building paper had a slight embrittlement and the OSB was slightly charred near the crack. There was minor loss of mortar from one bed joint, approximately 50 mm (2 in.) long. The maximum temperature rise registered by the thermocouples on the OSB was 128 degrees C (231 degrees F).

Figure 4. Veneer of Brick 2 after Fire Exposure for 1 Hour and Hose Stream

Test of Brick 3 Veneer Wall

The wall specimen with Brick 3 veneer also passed the one hour period and the hose stream test. Table 4 contains the observations made by laboratory personnel.

Table 4. Observations for Brick 3 Fire Test

Time	Observation
0:00	Start of test.
22:15	Light steam exiting from left-top corner.
26:30	Light steam continues.
45:00	No smoke or flames on unexposed side.
56:30	No smoke; no flames.
59:45	No smoke; no flames.
60:00	End of test. No flames, maintained load.
Post Test	Brick veneer mortar joints separated in several locations, allowing substantial damage to occur to OSB.

The fire exposed face of Brick 3 veneer, prior to the hose stream, is shown in Figure 5. The veneer experienced several horizontal, one vertical and one diagonal cracks near the top of the veneer wythe after the fire test. The maximum temperature rise on any of the thermocouples was 32 degrees C (57 degrees F) and the average of all thermocouples was 26 degrees C (47 degrees F). The hose stream was conducted for 65 seconds. The wall assembly did not allow passage of water. The veneer remained intact through the hose stream application. Portions of the building paper had burned; the OSB was burning and charred in many locations. The maximum temperature rise registered by the thermocouples on the OSB was 390 degrees C (702 degrees F).

Figure 5. Veneer of Brick 3 after Fire Exposure for 1 Hour

DISCUSSION

Building Code Requirements

The International Building Code assigns fire resistance ratings of masonry based on the equivalent thickness of the wall. The equivalent thickness, T_E, is calculated by Equation (1).

$$T_E = V_n/LH \quad (1)$$

Where V_n is the net volume of the unit; L is its length; and H is its height.

For hollow brick, those with greater than 25% void area, an equivalent thickness of 58 mm (2.3 in.) is required to obtain a 1 hour fire resistance rating. The only brick in this test series that achieved the one hour rating by equivalent thickness is Brick 1. Cracking in the brick wythe increased as the equivalent thickness of the brick decreased.

The International Building Code also includes a provision for protection of foam plastic insulation in Section 2603.5. A thermal barrier which will provide resistance to an E 119 fire test for 15 minutes is required. The thermal barrier is not required if the foam plastic is in a concrete or masonry wall and is covered by a 25 mm (1 in.) thickness of masonry. Thus, the fire resistance of thinner masonry sections has been recognized to some extent. The same provision is found in the International Residential Code, Section R314.5.

The thermocouples on the OSB in Specimens 2 and 3 held near ambient temperatures for approximately 12 and 8 minutes, respectively and approximately 100 degrees C (212 degrees F) for about 45 and 25 minutes, respectively. The first of these likely relates to heat conduction through the brick and air space; the second to cracking in the veneer.

In order for the combustible components of the wall to ignite, the temperature at the surface of the moisture-resistive barrier would have to reach its ignition temperature, approximately 265 degrees C (509 degrees F). That can happen by conduction through the brick, or by breeching of the brick veneer through cracking and warping. Specimen 3 was the only one where ignition of combustible components occurred. The first of the OSB mounted thermocouple reached that ignition temperature after 43 minutes. That apparently happened after the veneer cracked. It is significant that the brick veneer protected the combustible materials from ignition well beyond the time of cracking.

All of the wall specimens clad with brick veneer achieved a one hour fire resistance rating. This is in spite of the fact that the brick wythes tested do not, in and of themselves, have a one hour fire resistance rating. Brick 3 has a thickness less than the 50 mm (2 in.) required for anchored masonry veneer by the International Residential Code and the 67 mm (2 5/8 in.) required by the International Building Code. This research proves that a brick veneer wythe with an equivalent thickness of at least 32 mm (1.3 in.) will provide a wood frame structural wall with a one hour fire resistance rating with the fire exposure on the veneer face.

CONCLUSIONS

The wall specimens in these tests, with construction typical of brick veneer in residential construction today, achieved a one hour fire resistance rating.

Brick veneer wythes with less than a one hour fire resistance rating provide at least a one hour fire rating resistance for wood frame walls.

Brick veneer can contribute substantially more fire resistance as a part of a wall system than the same equivalent thickness of brick would provide as a stand-alone wall.

Cracking in the veneer wythe increased as the equivalent thickness of the brick decreased.

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