DEPARTMENT OF COMMERCE
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Letter
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THE FIRE RESISTANCE OF BRICK WALLS

BRICKS MADE OF CLAY OR SHALE

There has recently been completed at the Bureau of Standards a series of fire tests of brick walls to determine the fire protection, strength and stability under fire conditions afforded by this construction. The present letter circular, which is confined to the results obtained with bricks made of clay or shale, is intended to supply information until the report can be published.

Materials and Test Specimens. - Bricks from two surface clays and one shale were built into walls 16 feet long and 10 to 11 feet high for tests in the large furnace and 4 feet high and 4 feet wide for the tests in the small furnaee, 26 tests being made in the former and 22 in the latter. Seven fire and water tests were also made with walls of the larger size. The surface clay bricks were of medium strength, one having a medium porosity and high fusion point, and the other higher porosity and lower fusion point. The shale bricks were dense, and had high strength, with fusion point intermediate between those for the clay bricks. Most of the walls were laid up with Portland cement-lime mortar, of the proportion of 1:1¼:6, volume parts of cement, hydrated lime and sand, respectively. Two walls in common bond were laid up with 1:3 Portland cement mortar and three in 1¼:3 lime mortar. For approximately 60 per cent of the total number of walls tested the bricks were laid flat in common or American bond with one header course for every five stretcher courses. Fifteen walls were built with brick on edge according to the "rolok" designs with alternate headers and stretchers or two rows of stretchers on edge alternating with one row of headers laid flatwise. Three walls were built with the brick laid flat in the outer 4 inches and on edge in the rest of the wall, according to the "rolok-bak" designs, one header course alternating with six stretcher courses in the face and four in the backing. Gypsum, lime or Portland cement plaster was applied on one or both sides of ten of the walls. The greater number of walls tested in the large furnace were built by a masonry contractor who was awarded the work on the basis of competitive bids, and the workmanship was apparently barely up to what obtains on the average in building construction. The other walls were built by masons in the employ of the Bureau and the grade of workmanship as it concerns the degree to which the joints were filled and pointed was probably a little above the commercial average.

Method of Testing. - The walls were built into movable frames, and for the test were placed to form one wall of the furnace chamber. Some of the walls were built solidly into the frames, which were rigid enough to restrain the greater portion of the expansion of the wall during test, thus duplicating conditions where fire division walls are built between heavy floors and columns. Eleven walls were tested under working load of 160 lbs. per sq. in. of gross area for 8-inch and heavier walls and 80 lbs. per sq. in. for plain 4-inch walls, maintained constant during the fire test, to determine the adequacy in this particular. Other walls were built free from the containing frames at the sides and top, permitting free movement of the wall during test, which is representative of the unrestrained condition of walls in minor buildings or the top story of walls in higher buildings, where light, non-fire resistive interior and roof construction does not appreciably restrain the wall at the floor and roof lines.

The furnace temperatures were controlled to conform with that standard for American fire testing practice, with indicated temperatures near 927°C (1700°F) at one hour after the start of the test, 1010°C (1850°F) at 2 hours, 1093°C (2000°F) at 4 hours, 1260°C (2300°F) at 8 hours and a maximum of 1371°C (2500°F) at 10 hours and 40 minutes, this temperature being maintained constant until the end of any test extending beyond this time. Temperatures were measured at five or more points on the unexposed side as well as at points within the wall. The lateral deflections at nine or more points were also determined in the tests of large walls.

In the fire and water tests the walls were exposed to fire for one hour when they were pulled away from the furnace and a hose stream from a 1 1/8 inch nozzle under 50 lbs. per sq. in. water pressure applied over the hot side.

Stability and Load-Carrying Ability. - The deflections of restrained and loaded walls were toward the fire and attained a maximum at the center of the wall. For 8-inch walls the maximum deflections of the large walls average 2¼ inches and for the 12-inch walls, 2 inches, at from 2 to 6 hours after the start of the test. For 4-inch walls the maximum deflections averaged near 3 inches at one hour and 3½ inches at one and one-half hours. For the unrestrained walls the maximum deflections obtained at the top of the wall and were away from the fire, the average of maximums obtaining after 4 to 6 hours being about 6 inches for 8-inch and 12-inch walls. The recovery from deflections on cooling ranged from one-fourth to two-thirds of the maximums obtaining during test.

No 8-inch walls, solid or hollow, failed due to excessive deflection or under the applied working loads. Some 4-inch walls failed from both causes but not until the useful limit of the wall as determined by temperature transmission had been developed. Four-inch walls stiffened with 4 by 4 inch pilasters 20 inches apart or 4 by 8 inch pilasters 4 feet apart did

not develop excessive deflections and sustained working load of 160 lbs. per sq. in. until the end of the test which was stopped at 2½ hours. One 12-inch wall failed under the working load after 10 hours due to the fluxing away of brick that had a relatively low fusion point.

Fire Effects on Brick and Masonry. - For the restrained walls cracks on the side away from the fire of over 1/16 inch in width were rare. For the unrestrained walls cracks up to 3/8 inch were formed in 8-inch walls toward the end of the test, these being narrower or closed on the fire side. The headers were seldom found cracked in the central portion of the wall so that the integrity of the wall as a building member was maintained.

The damage to the bricks was confined to those next to the fire except for tests lasting over 8 hours. Cracks parallel with the face of the wall were formed in some of the bricks from ½ to 1 inch from the fire side. Shale bricks were more susceptible to cracking than clay bricks. Walls laid up with lime mortar had lower deflections and fewer and smaller cracks than those laid up in cement or in cement-lime mortar, but the mortar was weaker after the fire test. The full discussion of fire effects and possibility of reuse involves a greater amount of detail than can be given in the present letter circular.

Fire Resistance Classification. - According to present specifications for fire tests, the classification for load-bearing walls is based on ability to sustain working load and to prevent temperature transmission through the wall to such extent as to endanger combustible materials in contact with the unexposed side. The average temperature rise permitted is 139°C (250°F) or a maximum rise of 181°C (325°F) for any single point. The temperatures are measured under asbestos felt pads, 4/10 inch thick, placed against the unexposed side of the wall. The periods given in the following table are determined mainly by temperature transmission although the limit for the 12-inch walls is determined by load carrying ability of walls made from some of the bricks. The periods given are within the lower range of values obtaining in the tests. The factor of safety that should be applied to them would depend on the variation in material and workmanship to be expected in building construction beyond that present in the tests, the drier condition of party and fire walls after years of service in the interior of heated buildings as compared with that of the walls tested, and the increase in temperature on the unexposed side after the prescribed temperature limit was reached and the fire shut off. Information on the extent of these effects was developed in the tests but a discussion of them, as of factors of safety generally, is considered beyond the scope of the present letter circular. Considering the efforts made to obtain representative material and workmanship

and proper seasoning of the walls, it is believed that the test conditions were representative of what can generally be obtained in fire tests and that the results are correspondingly comparable.

The fire and water tests developed nothing that would change the conclusions based on the fire endurance tests.

The above periods apply for both bearing and non-bearing walls unless otherwise indicated (**) when for periods approaching that given, the non-load-bearing classification applies, although such walls are safe for bearing purposes at lower periods. For bricks laid flatwise and for periods not exceeding 6 hours, either Portland cement, cement-lime, or lime mortar of volume proportions not leaner than 1:3, cement or lime, and sand, respectively, can be used. For walls with bricks on edge and for all walls having periods of over 6 hours, Portland cement or cement-lime mortar should be used.

When combustible or non-fire resistive floor members enter into solid walls, or hollow walls filled at the floor lines, they must project not more than 4 inches into the wall, and must be so placed and protected as to have not less than 4 inches of solid material above, below and between them, if the given resistance periods are to be developed. Such hollow walls should have 4 inches of solid brickwork beneath the joists and have the hollow space filled with brick and mortar up to 4 inches above the top of the joists for the full thickness of the wall. For hollow walls without filling at the floor lines combustible or non-fire resistive members can project into them from only one side since otherwise openings might be formed through the wall.

In order that credit be allowed for plaster it must be applied to an average thickness of not less than one-half inch, and be of an acceptable grade of neat gypsum plaster or portland cement, mixed with not more than three volume parts of sand.

This letter circular is submitted for your information and is not released for publication.

ULTIMATE FIRE RESISTANCE PERIODS OF BRICK WALLS

BRICKS MADE OF CLAY OR SHALE

Nominal thickness	Type	Building members projecting into wall	Fire resistance period
4-inch unplastered	solid	none or incombustible	1 hour
4-inch plastered both sides	ditto	ditto	2½ hours
8-inch unplastered	ditto	ditto	5 hours
ditto	ditto	combustible	2 hours
8-inch plastered both sides	ditto	none or incombustible	9 hours
ditto	ditto	combustible	4 hours
12-inch unplastered	ditto	none or incombustible	(10 hours* (13 hours**
ditto	ditto	combustible	9 hours
8-inch unplastered	Hollow "Rolok"	None or incombustible	2½ hours
ditto	ditto	Combustible. Hollow spaces at floor line filled	2 hours
8-inch plastered both sides	ditto	None or incombustible	5 hours
ditto	ditto	Combustible. Hollow spaces at floor line filled	4 hours
ditto	ditto	Combustible, (from one side only) Hollow spaces at floor line not filled	2½ hours
12-inch unplastered	ditto	None or incombustible	5 hours
ditto	ditto	Combustible. Hollow spaces at floor lines filled	5 hours
ditto	ditto	Combustible (from one side only) Hollow spaces at floor line not filled	3½ hours
12-inch plastered both sides	ditto	None or incombustible	9 hours
ditto	ditto	Combustible. Hollow spaces at floor line filled	9 hours
ditto	ditto	Combustible (from one side only) Hollow spaces at floor line not filled	6 hours
8-inch brick-faced, plastered back side	Hollow "Rolok-bak"	None or incombustible	5 hours
ditto	ditto	Combustible. Hollow spaces at floor line filled	4 hours
ditto	ditto	Combustible. Hollow spaces at floor lines not filled	2½ hours
12-inch brick-faced, unplastered	ditto	None or incombustible	10 hours**
ditto	ditto	Combustible. Hollow spaces at floor lines filled	9 hours**
ditto	ditto	Combustible. Hollow spaces at floor lines not filled	6 hours

* Determined by load-carrying ability
**Determined by temperature transmission only