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FIRE RESISTANCE OF PERFORATED BRICK WALLS

by

H. L. Malhotra

Summary

Fire tests have been performed on loadbearing walls made from three types of perforated bricks developed by the Building Research Station. Without any plaster walls of any type of brick had a fire resistance of the 1 hour grade and by using the appropriate plaster the fire resistance of the walls was increased to 4 hours.

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Fire Research Station,
Boreham Wood,
HERTS.

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1. Introduction

In this country there is a traditional preference for the external walls of buildings, particularly of domestic houses, to be built of brick. On the other hand, on the Continent there is a much wider application of perforated bricks and blocks both in the construction of the external walls and the internal partitions. To improve the thermal insulation of buildings in this country a cavity construction for the external walls has become standard practice, the outer leaf usually consisting of solid brick and the inner leaf of either solid bricks or lightweight concrete blocks. The normal thickness of a wall when employing a 2 in cavity is 11 inches.

Over the past few years the Building Research Station has developed a new type of perforated brick as an alternative material for the construction of external walls which, whilst presenting the appearance of a traditional solid brick, offers certain advantages over the cavity wall construction. In addition, it represents a considerable saving in weight, a significant saving in labour costs and erection time, and at the same time a saving in space resulting from the thickness of the construction being 2 in less than a normal cavity wall. The wall has a comparable performance for thermal insulation and weather protection.

2. Purpose of the investigation

The external walls of all buildings are required to possess a degree of fire resistance to comply with the requirements of Local Authority byelaws, the standard of fire resistance required depending upon the type and the size of the building and varying from $\frac{1}{2}$ to 4 hours. Perforated bricks are most likely to be used for domestic buildings where the fire resistance required is $\frac{1}{2}$, 1 or 2 hours according to size and, in some special cases, such as fire division walls, a 4 hour fire resistance grade may be called for.

This investigation was undertaken in co-operation with the Building Research Station to determine the fire resistance properties of loadbearing walls constructed of perforated bricks and any additional protection that may be required to attain the 4 hour grade of fire resistance.

3. Description of the specimens

The bricks used in this investigation consisted of extruded clay sections with through perforations or cells in the vertical direction arranged in two groups connected by four webs⁽¹⁾. Three types of brick, designated V5, V6 and V62 and shown in Plate 1, were used. The various types of brick had similar overall dimensions but varied in the size and shape of the perforations, giving voids in the range 50 to 60 per cent and weights from 6 to 8 lb. The materials used for the bricks and certain of their properties are given in Table 1.

The tests were commenced with walls made from V5 and V6 bricks with a finish of $\frac{1}{2}$ in thick cement/sand rendering on one side, the internal face of the wall. The two following tests were on unplastered walls made from V5 and V62 bricks and finally two constructions with V62 bricks (these having superseded the two previous types of brick), having a lightweight plaster finish.

The walls were constructed by the Fire Research Station staff using a cement: lime : sand mortar. The mortar was spread by hand for the first three specimens and a mortar tray specially designed for use with these bricks was employed in the remaining constructions. The details of walls and finishes are listed in Table 2 below:

TABLE 1

Properties of Perforated Bricks
(Information supplied by Building Research Station)

Test No.	Type of brick	Percentage perforations	Raw materials and manufacturer	Mean fixed size in.	Dry weight lb oz.	Compressive strength (on gross area) lb/in ²
1	V6	50	Keuper-marl and London clay (6 : 1 by vol.) Made at B.R.S. (1) and fired at R.I.B. (2)	8.78 x 8.86 x 2.70	7 3½	2950
2	V5	57	" " "	8.84 x 8.95 x 2.70	5 15	2190
3	V5	60	Weald clay made at Southwater Works of S. & D.U.B. (3)	8.78 x 8.70 x 2.73	6 2¼	2970
4, 5 & 6	V62	49	" " "	8.61 x 8.63 x 2.63	8 11	5570

(1) Building Research Station. (2) Rural Industries Bureau at Arborfield. (3) Sussex & Dorking United Brick Co. Ltd.,
Horsham.

TABLE 2

Test No.	Type of brick	Mortar Mix cement:lime:sand	Plaster finish on exposed face ($\frac{1}{2}$ in nominal thickness)		
			Materials	Undercoat	Finish Coat
1	V6	1 : 1 : 6 (1) } 1 : 1 : 6 (1) }	cement/sand	1 : 1 : 6 (cement:lime: sand).	neat retarded hemihydrate gypsum
2	V5				
3	V5	1 : 1 : 6 (1)	none	-	-
4	V62	1 : $\frac{1}{4}$: 3 (2)	none	-	-
5	V62	1 : $\frac{1}{4}$: 3 (2)	perlite/gypsum	(3)	(4)
6	V62	1 : $\frac{1}{4}$: 3 (2)	vermiculite/ gypsum	(3)	(4)

- (1) Hand spreading.
(2) Using a mortar tray.
(3) Premixed proprietary brand of undercoat.
(4) Premixed proprietary brand of finish coat.

The fire tests were performed on 10 ft square loadbearing walls as described elsewhere⁽²⁾ in compliance with the requirements of B.S.476:1953, "Fire Tests on Building Materials and Structures", the conditions of an internal fire were simulated by exposing the appropriate face of the construction to the furnace. The age of the specimen walls at the time of the fire tests varied from 11 to 23 weeks after erection and in the case of the plastered specimens 6 to 7 $\frac{1}{2}$ weeks after plastering.

TABLE 3

SUMMARY OF FIRE TESTS ON PERFORATED BRICK WALLS

Test No.	Type of brick	Load tons	Duration of test		Mean Temp. on unexposed face °C	Fire resistance grading hr.	Remarks
			Hr.	Min.			
1	V6	60	2	14	45	2	Collapse of inner leaf.
2	V5	50	1	12	30	none	Collapse of wall at 1 hr. 12 min.
3	V5	30	1	0 $\frac{1}{2}$	27	1	Slight damage to exposed face.
4	V62	80	1	00	75	1	Collapse of inner leaf
5	V62	80	2	03	58	2	Slight damage to inner leaf
6	V62	80	4	07	76	4	Plaster coating remained intact

The load on the test walls was calculated in accordance with the recommendations of B.S. 1190 : 1957 "Hollow Clay Building Blocks" to produce the maximum design stresses, except in Test No. 3 when reduced loading was employed.

4. Results of test and discussion.

The results of the fire tests on the six specimen walls are summarised in Table 3, and the full test observations are given in the Appendix. The appearance of both the exposed and the unexposed faces of the specimens before and after the fire tests are shown in Plates 2 to 7. The temperature readings obtained on the unexposed face of the walls indicated that the insulation properties of the bricks were comparable with those obtained in fire tests on solid clay bricks of the same thickness for corresponding periods.

The first two tests on V6 and V5 brick walls with a coating of cement/sand rendering showed that the adhesion of this type of plaster to the surface provided by the bricks was poor on account of the smooth hard finish of the brick face. It also illustrated that the V6 brick with its small sized cells gave a better performance. For the next two experiments the walls were tested without any plaster finish to determine if they would achieve a fire resistance of the 1 hour grade. The V6 brick wall was successful under the design load, whereas the V5 brick wall attained this grading under a reduced load.

The low fire resistance of the perforated brick walls compared with that of walls of solid brick is probably due to their cellular structure. Exposure to high temperatures introduces thermal stresses of a high order on account of steep temperature gradients leading to the progressive fracture of the cell wall. Disintegration of the exposed face occurs and when the cracking has proceeded to the connecting webs the two "leaves" of the wall separate. Collapse of the exposed parts of the wall (Test Nos 1 and 4) or of the whole wall (Test No. 2) may then take place.

One method of increasing the fire resistance of the walls was to use special plaster. For the fifth test a coating of premixed perlite/gypsum plaster, as normally recommended by the manufacturers for use on clay bricks, was applied. The performance of this plaster did not fulfil expectations, since most of the plaster fell off the exposed face after five minutes from the start of the test. It was realised that the surface of the brickwork, with its poor adhesion properties, was such that it should be treated in a way similar to a smooth concrete finish. For the final test a premixed vermiculite/gypsum plaster was used, which from previous experience had shown remarkably good adhesion to smooth surfaces. This plaster remained in position during the 4 hour testing period and there were hardly any cracks on its surface when the test was terminated.

Although the bricks used in this investigation were manufactured from two different types of clay, no direct comparison of their properties is possible with the limited number of tests performed. The general indications are, however, that the performance of both types of clay was similar.

5. Conclusions

Fire resistance tests have been performed on loadbearing walls of three types of perforated brick developed by the Building Research Station, as described in this report. Without any plaster finish the walls qualified for a fire resistance of the 1 hour grade. To obtain higher resistance to fire special type of plaster is necessary for the exposed face and with $\frac{1}{2}$ in nominal coating of vermiculite/gypsum plaster the wall could attain a fire resistance of the 4 hour grade under the design load.

6. Acknowledgments

The author wishes to thank the Building Research Station for providing the information on the bricks and the specification for their use, and his colleagues at the Fire Research Station for assistance with the tests.

7. References

- (1) BUTTERWORTH, B. and FOSTER, D. Development of the fired-earth brick V Proposal for development in Britain. Transactions of the British Ceramic Society. Vol. 58, No. 2, February 1959.
- (2) DAVEY, N. and ASHTON, L. A. Investigations on Building Fires Part V. Fire Tests on Structural Elements, National Building Studies Research Paper No. 12, London 1953. H.M.S.O.

APPENDIX

LOG OF TESTS

Test No. 1. V6 brick wall; cement/sand rendering on unexposed face

Time hr. min.	Observation
0 00	Test commenced.
0 02	Appearance of a vertical crack on the unexposed face.
0 20	Skim coat separating from rendering on exposed face.
0 30	More cracks appear on unexposed face; main crack $\frac{1}{8}$ in wide.
0 40	Peeling of plaster coating on exposed face.
1 00	A piece of plaster, 2 ft x 3 ft, has fallen down exposing brickwork; remaining plaster moving away from the wall. Some disintegration of brick facing.
1 42	Approximately 25 per cent of plaster has come off by now and disintegration of exposed facing continues.
2 06	Nearly $\frac{2}{3}$ of plaster has fallen by now.
2 14	Collapse of inner leaf; test terminated.

Test No. 2. V5 brick wall; cement/sand rendering on unexposed face

Time hr. min.	Observation
0 00	Test commenced.
0 02	Plaster skim coat commences to peel off.
0 12	Nearly 50 per cent of plaster has fallen down; remaining plaster moving away from the brickwork.
0 14	Most of the plaster has come off by now; appearance of a vertical crack on the unexposed face.
0 18	Explosive disintegration of facing in the furnace.
0 30	More cracks appear on unexposed face.
0 40	Nearly $\frac{3}{4}$ of the bricks on exposed face have suffered damage.
1 12	Sudden collapse of the wall; test terminated.

Test No. 3. V6 brick wall; no plaster finish

Time hr. min.	Observation
0 00	Test commenced.
0 08	A vertical crack appears on the unexposed face.
0 14	Exposed brick facing commences to peel.
0 30	Disintegration of the bricks on the exposed face continues.
0 45	Appearance of diagonal cracks on unexposed face.
1 00	Vertical crack now $\frac{1}{8}$ in wide; test terminated at 61 minutes.

Test No. 4. V62 brick wall; no plaster finish

Time hr. min.	Observation
0 00	Test commenced.
0 08	Appearance of a vertical crack on unexposed face.
0 18	Another crack observed on unexposed face; the brick face on exposed side commences to disintegrate.
0 25	Sudden buckling of wall towards furnace and noises indicating the fracture of the webs.
0 30	Exposed part of the wall buckling considerably towards the furnace.
0 42	Collapse of inner leaf in the furnace; outer leaf still intact and supporting the allied load.
1 00	Vertical crack on unexposed face now $\frac{1}{8}$ in wide; test stopped.

Test No. 5. V62 Brick wall; Perlite/gypsum plaster on exposed face

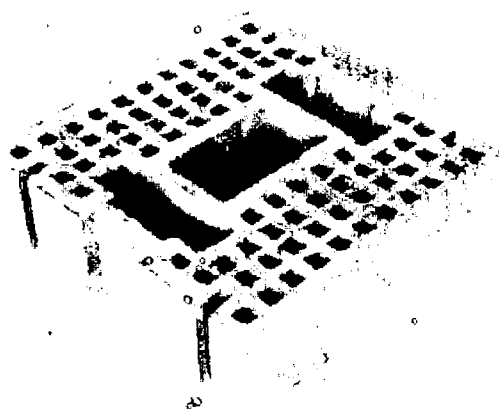
Time hr. min.	Observation
0 00	Test commenced.
0 03	Large pieces of plaster falling off the exposed face.
0 05	Nearly 75 per cent of plaster off by now.
0 07	Appearance of a vertical crack on unexposed face.
0 28	Some disintegration of exposed brick facing.
0 38	More vertical cracks appear on unexposed face.
1 00	Disintegration of inner facing confined to the bottom of the wall.
1 30	Inner leaf bulging towards the furnace.
2 03	No further change; test terminated.

Test No. 6. V62 Brick wall; Vermiculite/gypsum plaster on exposed face

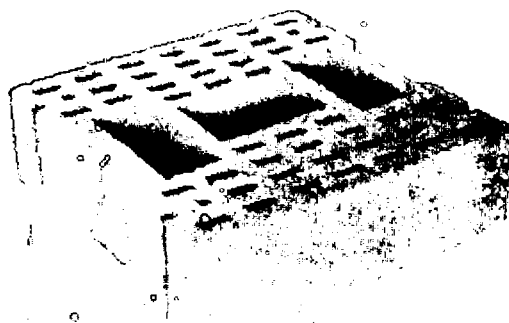
Time hr. min.	Observation
0 00	Test commenced.
0 24	Appearance of a vertical crack on unexposed face.
0 30	No cracks on the plaster finish visible on exposed face.
1 10	The vertical crack $\frac{1}{16}$ in wide.
2 00	The vertical crack now $\frac{1}{8}$ in wide; no other change.
2 20	Appearance of two diagonal cracks.
4 07	Plaster coating on exposed face intact; no other change. Test terminated.



V5

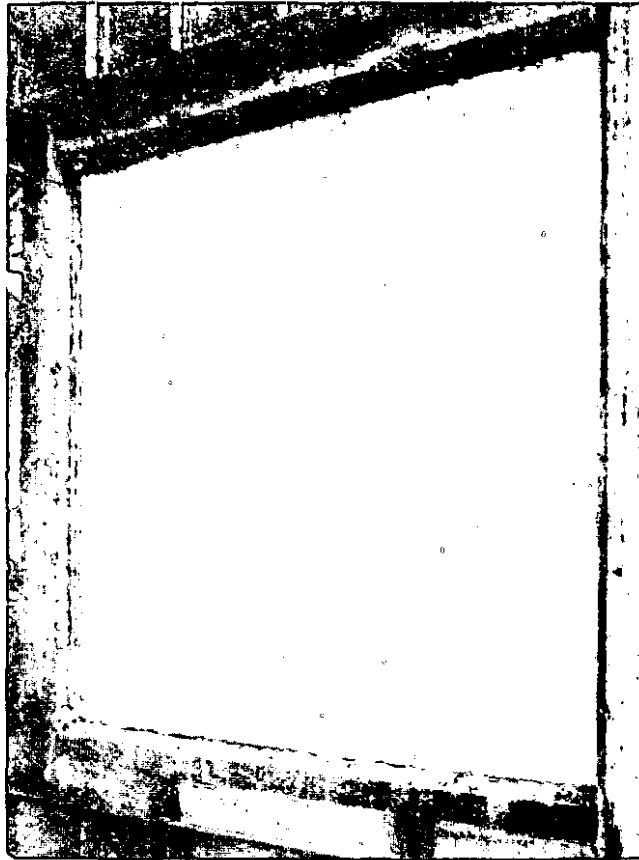


V6

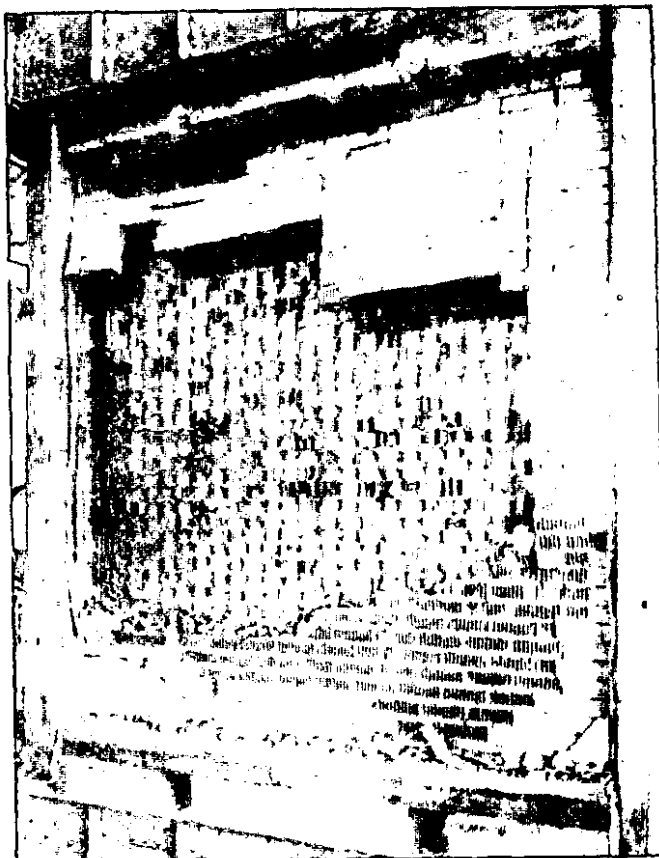


V62

TYPES OF PERFORATED BRICKS TESTED

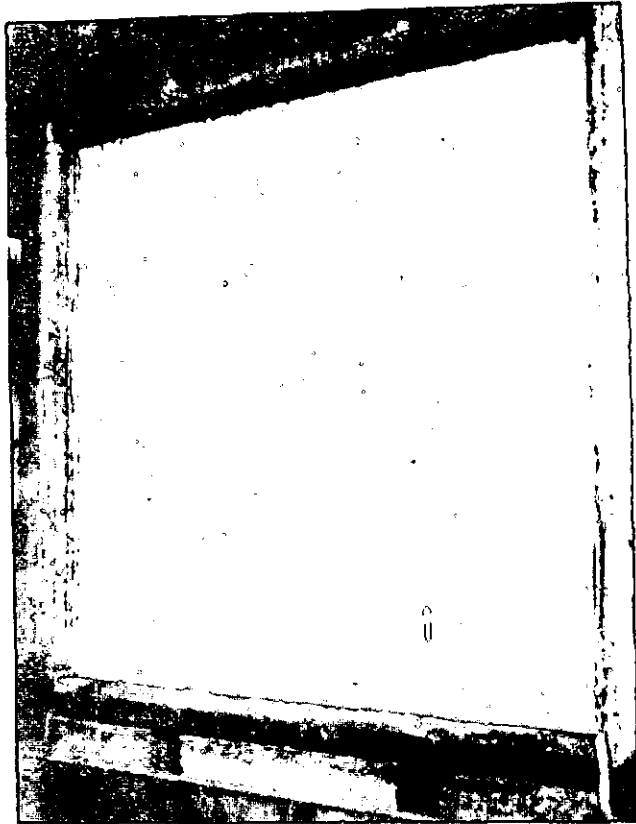


EXPOSED FACE BEFORE TEST

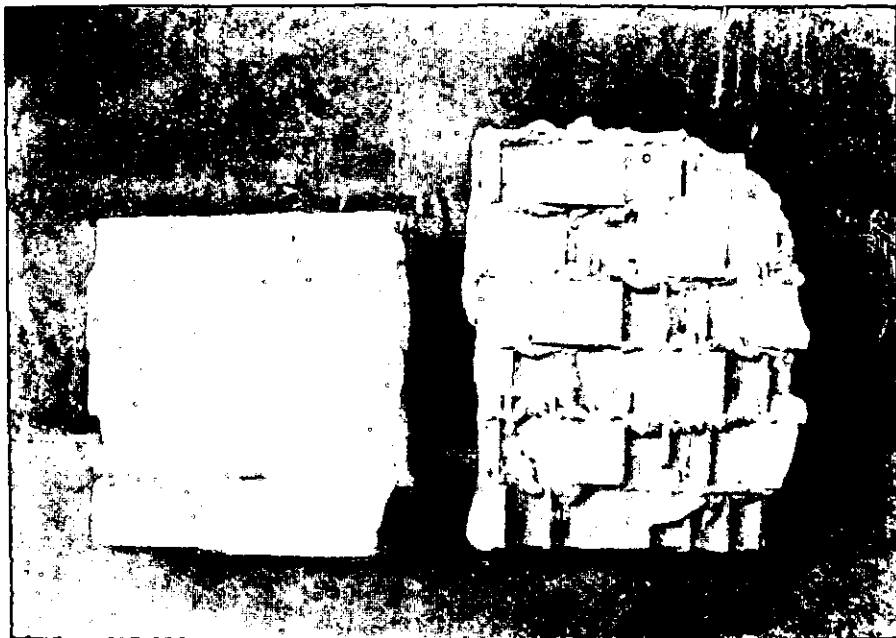


EXPOSED FACE AFTER FIRE TEST
(2 HR 14 MIN)

TEST No. 1. V6 BRICK WALL WITH CEMENT/SAN
RENDERING



EXPOSED FACE BEFORE FIRE TEST

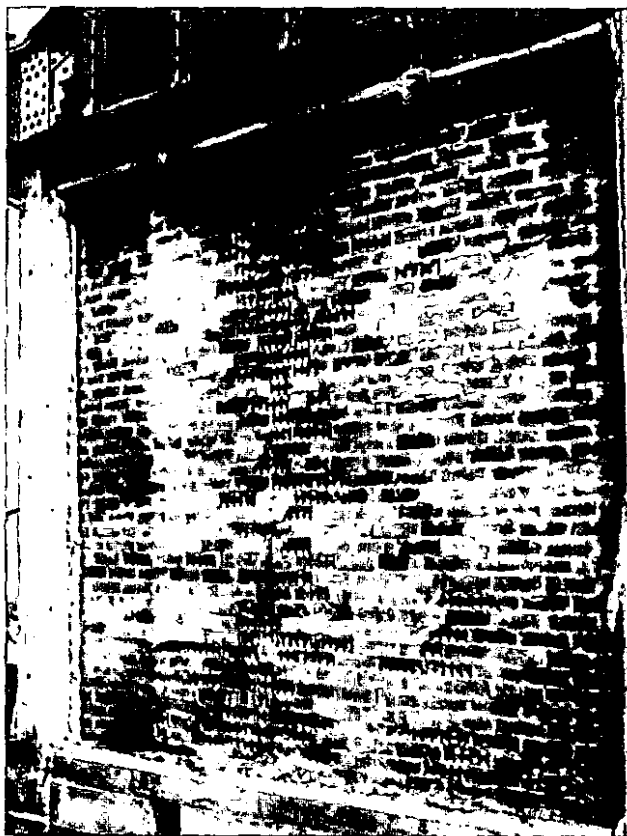


A PIECE OF THE COLLAPSED WALL

TEST No. 2. V5 BRICK WALL WITH CEMENT/SAND
RENDERING



EXPOSED FACE BEFORE TEST



EXPOSED FACE AFTER FIRE TEST (1 HOUR
TEST No. 3. V5 BRICK WALL WITHOUT
PLASTER FINISH

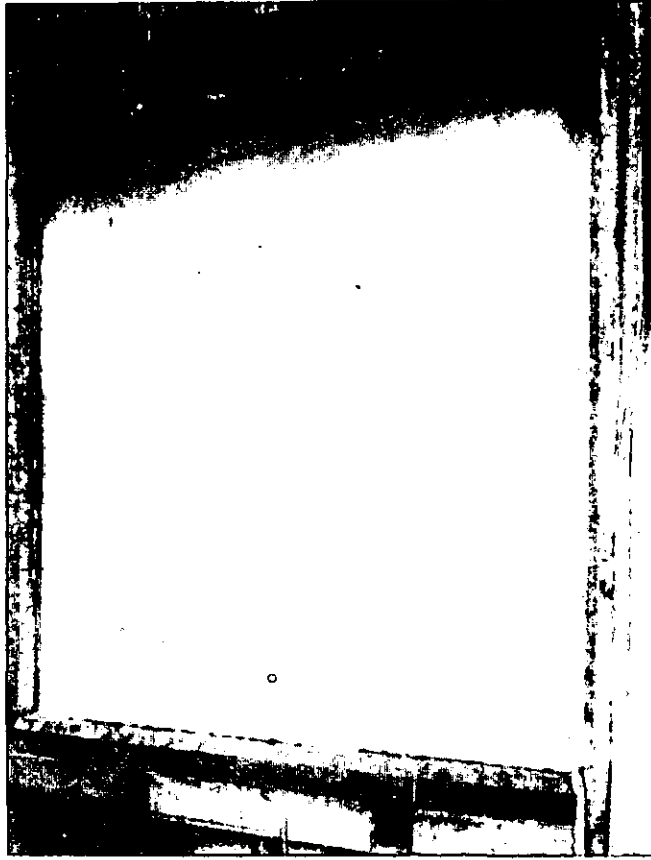


EXPOSED FACE BEFORE TEST



EXPOSED FACE AFTER TEST (1 HOUR)

TEST No. 4. V62 BRICK WALL WITHOUT
PLASTER FINISH

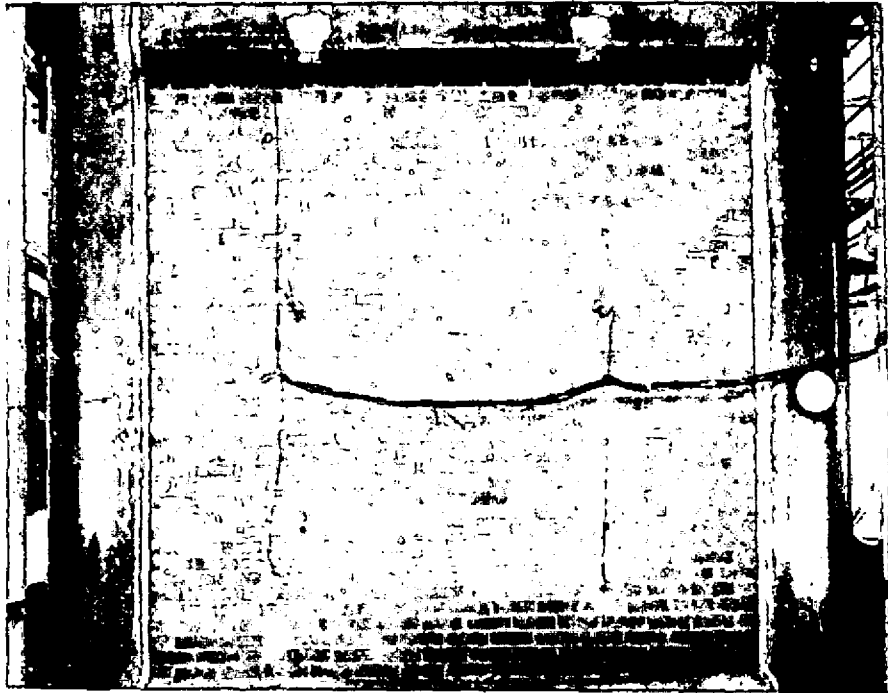


EXPOSED FACE BEFORE TEST

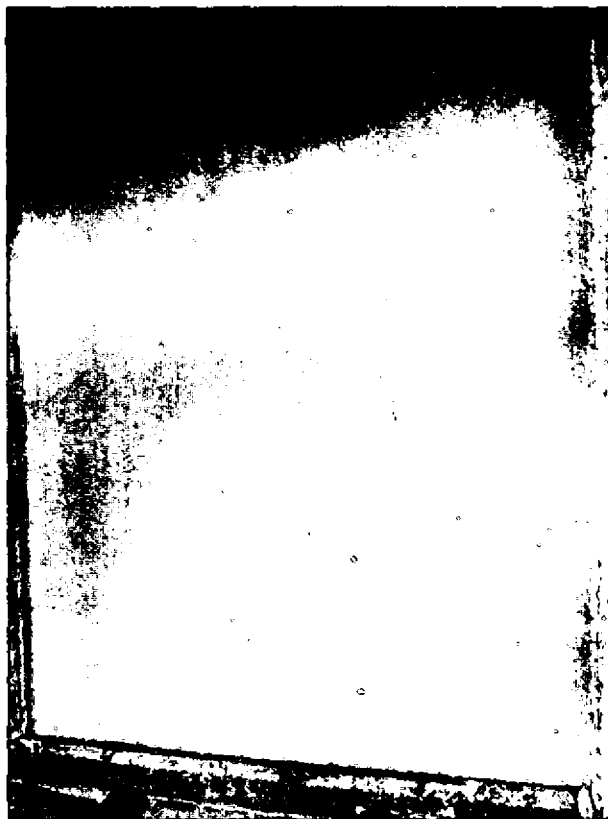


EXPOSED FACE AFTER TEST
(2 HR 3 MIN.)

TEST No. 5. V62 BRICK WALL WITH PERLITE
GYPSUM PLASTER

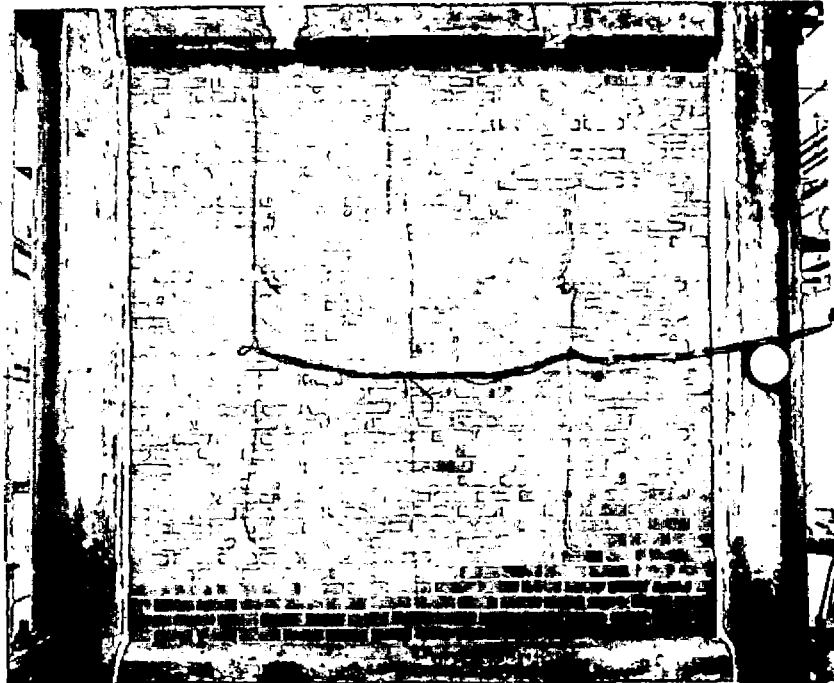


UNEXPOSED FACE BEFORE TEST

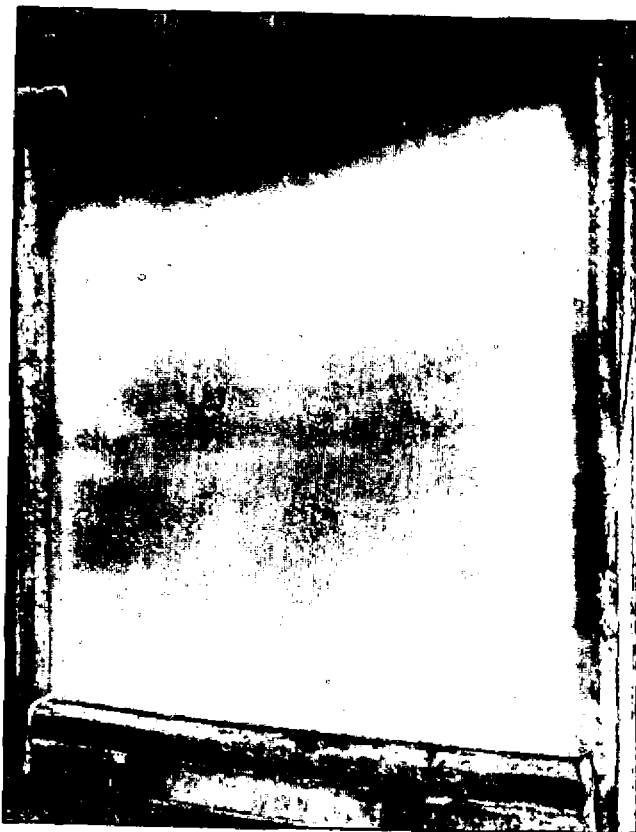


EXPOSED FACE BEFORE TEST

TEST No. 6. V62 BRICK WALL WITH VERMICULITE/
GYPSUM PLASTER FINISH



UNEXPOSED FACE AT 4 HOURS



EXPOSED FACE AFTER FIRE TEST
(4 HR 7 MIN)

TEST No. 6. V62 BRICK WALL WITH VERMICULITE/
GYPSUM PLASTER FINISH