Leakage and bond strength tests on small panels assembled with red dry-press bricks and four mortar combinations

Davison, J. I.

Publisher's version / Version de l'éditeur:
https://doi.org/10.4224/20338307
Internal Report (National Research Council of Canada. Division of Building Research), 1960-12-01

NATIONAL RESEARCH COUNCIL

CANADA

DIVISION OF BUILDING RESEARCH

LEAKAGE AND BOND STRENGTH TESTS ON SMALL PANELS ASSEMBLED WITH RED DRY-PRESS BRICKS AND FOUR MORTAR COMBINATIONS

by

J.I. Davison

Internal Report No. 215

of the

Division of Building Research

OTTAWA

December 1960

PREFACE

The Division in the course of its studies of brick masonry at its laboratories in Halifax and in Ottawa takes advantage of opportunities to examine the properties of masonry units being manufactured and offered for sale. This is done in the first instance as an aid in understanding the various factors involved in the service performance of masonry walls which is also being studied in the field. The results of a laboratory examination of bricks produced by a small brick plant in the Atlantic area are now reported. The work was carried out at the Atlantic Regional Station of the Division by the author who is engaged in masonry studies there.

Ottawa
December 1960

N. B. Hutcheon
Assistant Director

LEAKAGE AND BOND STRENGTH TESTS ON SMALL PANELS ASSEMBLED WITH RED DRY-PRESS BRICKS AND FOUR MORTAR COMBINATIONS

by

J.I. Davison

In addition to the extruded stiff-mud bricks that are generally used in masonry construction in the Atlantic area, there is a red dry-press brick manufactured in one small plant, a family business that has been in operation since 1886. About ten years ago shale replaced clay as the basic raw material and more recently the firm installed a tunnel kiln in an effort to improve their product. There have been many problems associated with operation of the new kiln. Although these had not been completely resolved, some bricks were obtained from the plant during the summer of 1959 and leakage and bond strength tests were carried out on small panels assembled with them, using four mortar combinations. The results of these tests and pertinent data concerning the physical properties of the bricks are now reported.

PROPERTIES OF BRICKS

The shipment contained 200 bricks, and after drying (72 hr at 110°C) dimensions were checked and IRA (Initial Rate of Absorption) determined. Average dimensions were 8 1/8 in. long by 3 3/4 in. wide by 2 5/16 in. thick; IRA values ranged between 17.3 and 101.4 gm. The distribution of IRA values for the shipment is shown in Fig. 1. It will be noted that 82 per cent of the values fall in the 30- to 80-gm range while 55 per cent were within the 40- to 70-gm range.

Seventeen bricks, representative of the complete IRA range, were then selected and 24-hr submersion, 5-hr boiling tests, and underwater weighings completed. Complete records of absorption are presented in Table I where an average 24-hr submersion absorption of 7.2 per cent, an average 5-hr boiling absorption of 8.9 per cent, with an average saturation coefficient of 0.806 will be noted.

Absorption data, apparent porosity, and bulk density are compared graphically with IRA in Figs. 2 to 4, showing clearly the relationship between these properties and IRA. Results are similar to evidence reported in DBR Internal Report No. 147 (1). Absorption values and apparent porosity increase with increasing IRA while bulk density decreases.

Ten of the seventeen samples were then subjected to freeze-thaw tests and all failed at an average of sixteen cycles. There was no consistent pattern relating failures with IRA. An attempt was made to relate laboratory freeze-thaw tests with actual outdoor freezing cycles. Four bricks having IRA values 45.0, 65.0, 70.3, and 75.0 gm were set out on an exposure site in mid-January in a pan containing 1/4 in. of water. The cracks in the bricks after fifty-one freeze-thaw cycles from mid-January to the end of April (determined from records of the local Meteorological Station) can be seen in Fig. 11. Weight losses during the period ranged from 0.06 to 0.11 per cent.

PANEL ASSEMBLY

Bricks

The original schedule for panels included four mortar combinations and two variables - 115 per cent flow mortar with dry bricks (series I) and the same flow mortar with wet bricks (series II). Since all panels were assembled in duplicate, sixteen panels were to be assembled in the first two series. After a study of the IRA distribution it was decided to select bricks in 40- to 70-gm range. Later it was decided to assemble a third series of panels to investigate the effect of a higher flow mortar (130 per cent flow). It was necessary to use bricks in the 60- to 90-gm range as there were not enough remaining in the 40- to 70-gm range. Prior to panel assembly all bricks were redried (72 hr at 110°C).

Mortars

The four mortar combinations selected were:

1) 1:3 lime putty: sand
2) 1:3 masonry cement: sand
3) 1:2:9 cement: lime putty: sand
4) 1:1:6 cement: lime putty: sand

Lime putty was obtained from a local ready-mix plant where it is made from quicklime and well aged before distribution. Chezzetcook sand was used, masonry cement was "Canada Brand" and cement was "Maritime Brand". These materials are similar to those used in previous masonry projects of the DBR Atlantic Regional Station. All mortar was mixed in a Hobart mixer in accordance with procedure adopted for small panel assembly.

During panel assembly a 30-sec time interval was used between placing mortar bed and laying the next brick. Each brick received a heavy tap (4 lb dropped through 1 1/2 in.) after being placed on the mortar bed.

There were three series of panels. For the first series dry bricks were used with mortars in flow range 115 per cent, in the second series all bricks were soaked for 10 minutes in a pail of water before use with mortars in the same flow range, while in the third series dry bricks were used with higher mortar flow (130 per cent). Pertinent information concerning panel assembly will be found in Table II.

By checking the increase in weight of the completed panels against that of the dry bricks, and assuming that approximately the same amounts of mortar were required for the respective panels in both series I and series III, the water absorbed by the bricks during the soaking period (series II) was estimated to be 119.6 gm per brick. Compared with the average weight of the bricks, 2,894.8 gm, this represents an absorption of 4.1 per cent, more than 50 per cent of the average 24-hr absorption of 7.2 per cent. Absorption of this amount of water by each brick must obviously have substantially reduced the average IRA (57.5 gm).

Curing

All panels were cured for the accepted 14 days under laboratory conditions (70° temperature, 50 per cent RH). Half way through this period panels were flashed with polyethylene sheeting using Lasto-Meric as bonding agent in preparation for leakage tests.

LEAKAGE TESTS

All panels were subjected to leakage tests using the small panel leakage apparatus (DBR Internal Report No. 160 (2)). Duration of the tests was 24 hours. Results are summarized in Table III.

Series I.- There was considerable leakage for all panels. The best average result was obtained for the lime mortar panels while most excessive leakage occurred with masonry cement mortar panels. Results for the cement-lime mortar panels were inconsistent and a third panel in both cases (1:1:6 and 1:2:9 mortar) leaked excessively. It should be recorded, however, that least leakage for any panel in the group occurred for panel 5 (1:2:9 mortar; 679 ml) and the second best individual result occurred for panel 8 (1:1:6 mortar; 910 ml).

Series II.- There was a substantial improvement in leakage results for six of the panels in this series by comparison with the first series. The exception was for the lime mortar panels where total leakage was 25 per cent higher than results for the "dry brick" panels. All results were consistent. Best results were obtained with the masonry cement panels where soaking bricks before panel assembly resulted in reduction in leakage from 5,194.5 to 475.0 ml. It is also noted that leakage for 1:2:9 mortar panels at 759.5 ml was greater than the 484.0 ml total for the 1:1:6 mortar panels. In this case soaking the bricks appears to have negated the usually beneficial effect of higher water retentivity of the 1:2:9 mortar. Improved bond for panels in this series also resulted in "delaying" leakage for all but the lime mortar panels. In the first series leakage occurred in masonry cement and cement-lime mortar panels almost immediately after starting the test, while in the second series leakage started 30 to 50 minutes after the beginning of the test, despite the higher "absorption capacity" of the dry bricks in series I panels.

Series III.- Leakage results for this series were consistently better than those for series I but not as good as results for series II. Here the best results occurred with the 1:2:9 and 1:1:6 cement-lime mortar panels while greatest leakage occurred with the lime mortar panels.

General.- Results of panel leakage for each mortar are shown graphically in Figs. 5 to 8 inclusive.

It is interesting to note that best results for the dry brick/115 per cent mortar-flow combination occurred with lime mortar; masonry cement mortar panels gave best results for the wet brick/115 per cent flow panels, and the cement-lime mortar panels gave best results with the dry brick/130 per cent flow mortar.

For the twenty-four panels best leakage results were obtained with the masonry cement mortar wet brick combination while the masonry cement mortar (115 per cent flow)/dry brick combination produced the greatest leakage.

The amounts of water absorbed by panels during leakage tests are shown in Table IV where it is noted that the wet brick/115 per cent flow mortar panels absorbed the largest quantities and that the cement-lime mortar panels absorbed more water than masonry cement and lime mortar panels. In effect this means that the panels with better bond obtained by soaking bricks had greater water-retaining capacity than panels with poorer bonded mortar joints even though the dry bricks used had greater absorption capacities.

Visual observation during leakage tests indicated that leakage occurred generally at the interface between brick and mortar bed, but there also was indication of leakage through bricks in panels 7D and 22 where water appeared to be coming through the top brick of the panel.

Moisture Content Losses to Matched Pairs

In conjunction with panel assembly, moisture content losses to matched pairs of bricks were determined. The term, "matched pairs", indicates two bricks of similar IRA, the value selected being near the average value of the bricks in the panel. Choice was usually restricted by availability of bricks, and it will be noted that IRA's for series I and II were 45 and 49 gm while for series III the range was 87.0 to 91.5 gm. Results are listed in Table IV where losses are expressed as a percentage of the total moisture content of the mortar. The most significant aspect of these results is the marked reduction in moisture loss from the mortar during the 3-minute contact period with the wet bricks by comparison with losses to dry bricks.

BOND STRENGTH TESTS

After leakage tests all panels were allowed to dry in the laboratory for seven days, then bond strength tests were done using the new bond strength apparatus (DBR Internal Report No. 175 (3)). Results are shown in Table V and Fig. 10.

Series I.- Best bond strength values occurred in the cement-lime mortar panels, and results for the 1:1:6 combination were better than for the 1:2:9 panels. Extent of bond was reasonably good for lime mortar and cement-lime mortar panels. There was, however, something less than 100 per cent contact for the cement-lime panels. While extent of bond was good for lime mortar panels, carbonation of the lime was incomplete, being confined to a perimeter strip about 1/2 in. wide.

Series II.- Results for lime mortar panels were not as good as those for series I, but values for other panels were much improved. Panel 10 (lime mortar) was cured for six months after the leakage test, but there was no improvement in bonding, values in fact were somewhat less than those for panel 9 tested at the normal time (three weeks). Good extent of bond was observed for masonry cement panels. In two instances some of the mortar bed remained clinging to the upper brick after the joint fractured. Low results for the two bottom joints in panel 11 lowered the average value about five points.

Extent of bond was excellent for both cement-lime mortar combinations, although average values for the 1:1:6 mortar were substantially higher than those for the 1:2:9 mortar. In the latter panels, three of the eight "breaks" occurred directly through the mortar beds; in a fourth, part of the mortar remained clinging to the upper brick leaving four "conventional" breaks with the top brick lifting from the mortar bed. Similar results were noted for the 1:1:6 mortar panels where three breaks occurred through the mortar beds, in two cases part of the mortar bed remained on both bricks while the other three resulted from a lifting of the top brick from the mortar bed.

In panel 16 a high value of 87.0 psi was obtained while a low value of 23.0 psi occurred in the bottom joint of the same panel, illustrating the great inconsistencies in bond strength results.

Series III.- Bond strength values for lime mortar panels were comparable to those for series I while those for masonry cement panels were more in line with values for series II panels. The biggest difference occurred for the cement-lime panels where series III values were substantially higher than previous results. In several cases the pressure of the clamping screws necessary to prevent slipping under heavy loading caused breaks in the relatively soft bricks (particularly panel 23) resulting in loss of values. Slipping of the clamping frame on the top brick in some cases resulted in uneven loading and premature failure. Excellent bond was observed in all cases for these panels. Highest bond strength obtained for any joint during this study was 96.7 psi for joint 4 in panel 24.

General.- Best bond strength values for cement-lime panels were obtained from the dry brick/high flow mortar combination while best values for masonry cement panels occurred with the wet brick/115 per cent flow combination. Values for lime mortar panels were all insignificant although extent of bond was excellent and bond values for the wet brick/115 per cent flow combination were inferior to the results for the other two series. Highest values were obtained with the 1:1:6 cement-lime combination in all three series.

Again there was suspicion of leakage through the bricks when excellent bond, observed after fracture of some mortar joints, was inconsistent with leakage totals for the same panels.

A visual comparison clearly indicating the effect of panel assembly conditions for the three series will be found in Figs. 12 to 15 inclusive, where fractured joints for the four mortars are shown.

INVESTIGATION OF LEAKAGE THROUGH BRICKS

In previous investigations involving leakage tests on small brick panels assembled with bricks of low IRA, it was established that leakage occurred at the interface between brick and mortar. This was observed during tests on panels that leaked and later, when leaky joints were broken, the observation was substantiated by "leakage paths" traced out on the mortar beds by dirt in the water.

As previously noted during the current study, observations both during leakage tests, and later when panels were fractured during bond strength tests, pointed to possible leakage through the bricks in addition to the usual "interface" leakage.

Therefore, a short program was set up to investigate leakage in individual bricks.

"Chimney Test"

Initial investigation of individual brick leakage involved mounting a glass cylindrical chimney (2 1/16 in. diameter by 3 1/8 in. high) on the bonding surface of the brick with some caulking compound, maintaining a head of water in the chimney and collecting that which passed through the brick in a beaker. Eight bricks ranging in IRA from 28.0 to 105 gm were tested, the length of test being 24 hours. Results are tabulated in Table VI.

There was no measurable leakage from the 28.0 gm brick although the underside was wet to touch at the end of the test.

However, there were drops of water on the bottom of the 31.5 gm brick at 7 hr and 5 ml were collected in the beaker during the test. Time for drops to appear on the bottom decreased and leakage through the bricks increased until at 75.0 gm IRA drops of water appeared on the bottom 1 1/2 hr after the start of the test and total leakage was 281 ml.

Leakage continued to increase for the two remaining high suction bricks (95.0 and 105.0 gm). However, unlike lower suction bricks where water passed through and dropped from an area directly below the chimney, leakage occurred with water oozing from various areas of the bricks making it difficult to collect. Tests on these bricks were, therefore, discontinued at 7 and 8 hr, respectively.

LEAKAGE TEST ON INDIVIDUAL BRICKS

In the light of the above evidence it was decided to try a panel-type leakage test on individual bricks. For leakage to occur in this test, water would have to pass through the brick from front to back, a greater distance than from top to bottom as in the chimney test.

Three bricks having IRA's of 25.2, 55.0 and 86.0 gm were flashed (top, bottom, and both ends) in the usual manner with polyethylene sheeting using Lasto-Meric as bonding agent. They were then individually placed in the small-panel leakage apparatus with a 4-brick dummy panel. Leakage test was then carried out for 24 hours in the usual manner. Results shown in Table VII reveal no leakage for the low-suction brick, minor leakage for the 55.0 gm brick, and substantial leakage for the high-suction brick. In comparing the above leakage totals with those obtained with the chimney test, it must be noted that the thickness (front to back) of the brick is 1 1/2 in. greater than the depth (top to bottom). This additional thickness plus the greater severity of the chimney test account for lesser totals obtained with the leakage test.

This evidence indicates that leakage totals for panels containing bricks having suction above 55 gm were made up of leakage through the bricks as well as through the interface between the brick and mortar bed.

LEAKAGE TESTS ON SMALL PANELS ASSEMBLED WITH LOW IRA BRICKS

Final phase of the study involved assembly of three small panels with bricks in IRA range 28 to 38.5 gm and masonry cement mortar, one panel corresponding to each of the three series previously studied. Leakage and bond strength results are tabulated in Table VIII. Leakage results (shown in Fig. 9) indicate a definite improvement over the previous tests but follow the same pattern in that best results occur with the wet brick/115 per cent flow combination followed by the dry brick 130 per cent flow and then the dry brick/115 per cent flow combinations. Bond strength results (shown in Fig. 10) indicate the same definite improvement as do leakage results for the dry brick/115 per cent flow combination and also improvement of the order of 10 per cent in the other two combinations. A visual comparison of fractured joints for the three series will be found in Fig. 16.

A further indication of the reduced permeability of these panels can be found by examining the water absorbed during leakage tests (Table IX). These quantities are considerably lower than those for similar panels in previous series (Table IX). It is also noted that unlike previous results water absorption totals are in line with leakage results in that they increase from a low with the wet brick/115 per cent flow combination through the dry brick/130 per cent flow panel to a high for the dry brick/115 per cent flow panel.

It must be recognized that the improved results for these panels are due to a combination of (a) better bonding between low IRA bricks and mortar, and (b) reduction or elimination of leakage through the bricks themselves.

Unfortunately, the limited supply of bricks did not permit study of these latter three panels in duplicate and also curtailed further study on leakage through bricks. This work is to be resumed when additional bricks are available, pending current renovations of the tunnel kiln at the plant.

CONCLUSIONS

This study on panels assembled with a high-suction dry-press brick manufactured in the Atlantic area has provided evidence supporting the following conclusions, some of which have already been reached by others and reported in the literature.

(1) Bricks having high suction values should be soaked before use. Soaking reduces the effective suction thus permitting better bond between mortar and bricks.

(2) Bricks bond better with mortars having flow of 130 per cent than with those having flow of 115 per cent.

(3) Soaking high-suction bricks has a more beneficial effect on extent of bond than increasing mortar flow from 115 per cent to 130 per cent, but the latter is more beneficial to strength of bond.

(4) Leakage through high-suction red dry-press bricks contributed to panel leakage totals. There is evidence in this study of leakage through bricks with IRA above 55.0 gm.

(5) Red dry-press bricks of this type are not durable as judged by freeze-thaw tests. Their absorption properties are acceptable according to CSA requirements (A82.7) for Grade MW bricks and the saturation coefficient is not far above the requirement for Grade SW bricks despite rapid failure in freeze-thaw tests.

(6) Reduction in average suction for bricks in panels of approximately 25 gm resulted in tighter panels for the three-assembly series using masonry cement mortar.

REFERENCES

(1) Relationships of properties of three types of bricks. T. Ritchie. National Research Council, Division of Building Research, DBR Internal Report No. 147, December 1958, 20p.

(2) A small-panel method for investigating moisture penetration of brick masonry. T. Ritchie. National Research Council, Division of Building Research, DBR Internal Report No. 160, September 1958, 18p.

(3) Small brick panel tests at Ottawa - apparatus and techniques for study of bond strength. P.T. Hodgins. National Research Council, Division of Building Research, DBR Internal Report No. 175, March 1959, 14p.

TABLE I

ABSORPTION DATA ON REPRESENTATIVE SAMPLES
OF RED DRY-PRESS BRICKS

IRA (gm)	Absorption 24-hr Submersion (%)	Absorption 5-hr Boiling (%)	Saturation Coefficient	Apparent Porosity (%)	Bulk Density (gm/cc)
17.3	5.1	7.0	0.728	15.3	2.22
24.6	5.7	7.6	0.750	16.4	2.17
24.8	5.4	6.6	0.818	15.7	2.20
34.6	5.7	7.0	0.814	16.5	2.20
36.4	6.6	8.8	0.750	18.6	2.12
44.3	6.6	7.8	0.846	18.5	2.18
44.3	7.4	8.4	0.881	19.8	2.16
54.1	7.6	8.7	0.873	20.7	2.13
54.1	7.6	9.5	0.800	20.3	2.14
64.0	7.7	8.9	0.865	20.8	2.12
64.0	6.8	7.9	0.861	18.7	2.17
73.8	7.5	9.5	0.789	21.8	1.60
74.1	8.3	10.5	0.790	21.9	2.09
83.8	7.6	9.8	0.776	20.7	2.11
84.6	9.4	11.8	0.800	24.0	2.04
93.5	8.9	11.3	0.788	23.3	2.05
101.4	8.0	10.3	0.777	21.6	2.09
Average	7.2	8.9	0.806	-	-

TABLE II

PANEL DATA*

Panel Number	IRA of Bricks Range (gm)	IRA of Bricks Average (gm)	Mortar Type	Mortar Flow (%)	Weight of Dry Bricks (gm)	Weight of Panels (gm)	Increase in Weight (gm)
1, 2	43.0 to 75.0	57.3	1:3 lime-sand	115.4	12,364.5	13,854.5	1,490.0
3, 4	41.0 to 72.5	57.2	1:3 masonry cement-sand	114.8	12,473.5	13,859.0	1,385.5
5, 6, 6D	39.0 to 73.8	57.4	1:2:9 cement-lime-sand	114.7	12,582.0	14,098.0	1,516.0
7, 7D, 8	38.0 to 74.0	57.1	1:1:6 cement-lime-sand	114.7	12,345.0	13,856.0	1,511.0
9, 10	40.1 to 75.0	57.3	1:3 lime-sand	113.3	12,463.5	14,502.0	2,038.5
11, 12	41.5 to 71.0	57.7	1:3 masonry cement-sand	114.2	12,492.5	14,466.0	1,973.5
13, 14	41.2 to 72.0	57.6	1:2:9 cement-lime-sand	115.4	12,301.0	14,483.0	2,182.0
15, 16	41.3 to 72.5	57.3	1:1:6 cement-lime-sand	117.1	12,324.0	14,445.0	2,121.0
17, 18	60.2 to 98.0	78.7	1:3 masonry cement-sand	129.8	11,941.5	13,266.5	1,325.0
19, 20	60.3 to 96.0	78.8	1:3 lime-sand	133.1	11,895.5	13,397.5	1,502.0
21, 22	64.0 to 93.0	78.6	1:2:9 cement-lime-sand	134.1	11,912.0	13,485.5	1,573.5
23, 24	59.3 to 94.0	77.8	1:1:6 cement-lime-sand	135.9	11,976.5	13,517.5	1,541.0

Increase in Weight - Figures represent the difference between weight of the finished panel and weight of dry bricks. For panels Nos. 1 to 8 and Nos. 17 to 24 the increase is the weight of mortar used, while for panels No. 9 to 16 the increase includes the weight of water absorbed during 10 min. soaking in addition to the weight of mortar used.

*Figures are average for duplicate panels.

TABLE III

LEAKAGE RESULTS

Panel Number	Total Leakage (ml)	Remarks
1, 2	1,862.0	Leakage at 20 min - maximum rate 2 ml/min during 2nd hr
3, 4	5,194.5	Leakage at 2 min - maximum rate 19 ml/min at 20 to 30 min
5, 6D*	2,463.0	Leakage 1.5 to 4 min - results inconsistent
7, 7D, 8	3,430.7	Leakage immediate to 10 min - results inconsistent
9, 10	2,319.8	Leakage at 22 min - maximum rate 23 to 40 ml/min between 30 to 60 min mark
11, 12	475.0	Leakage at 45 min - maximum rate 20 to 35 ml/hr
13, 14	759.5	Leakage at 30 to 50 min - maximum rate 36 to 42 ml/hr
15, 16	484.0	Leakage at 40 to 42 min - maximum rate 26 ml/hr
17, 18	2,116.0	Leakage at 18 min - maximum rate 3.4 ml/min at 60 min mark
19, 20	3,115.0	Leakage at 14 to 20 min - maximum rate 4 ml/min between 25 min and 2 hr mark
21, 22	1,405.0	Leakage at 24 to 38 min - maximum rate 3.5 ml/min at 25 to 30 min mark
23, 24	1,542.5	Leakage at 4.5 to 8.0 min - maximum rate 2 to 8 ml/min between 20 and 45 min mark

*Results for panel No. 6 were discarded because overnight leakage was incomplete.

TABLE IV

WATER ABSORBED (ml) BY PANELS DURING LEAKAGE TEST

Mortar Type	Series I	Series II	Series III
1:3 lime	1,490	2,036	1,502
1:3 masonry cement	1,386	1,973	1,325
1:2:9 cement-lime	1,512	2,177	1,574
1:1:6 cement-lime	1,511	2,121	1,541

M/C LOSSES TO MATCHED PAIRS OF BRICKS DURING PANEL ASSEMBLY

Mortar Type	Series I		Series II		Series III	
	IRA of Pair (gm)	M/C Loss (% Total)	IRA of Pair (gm)	M/C Loss (% Total)	IRA of Pair (gm)	M/C Loss (% Total)
1:3 lime	48.0	27.8	45.5	15.2	91.5	34.1
1:3 masonry cement	48.8	40.7	46.1	13.4	91.5	44.0
1:2:9 cement-lime	47.2	33.6	46.1	9.4	87.0	36.5
1:1:6 cement-lime	48.3	42.6	45.9	11.3	87.0	42.8

TABLE V

BOND STRENGTH VALUES

Panel Number	Average Bond Strength (psi)	Remarks
1, 2	2.3	Good extent of bond - no strength - perhaps 1/2 in. of carbonation
3, 4	13.0	Poor extent of bond - maximum 40 per cent extent
5, 6, 6D	29.5	Good bond for Nos. 5 and 6 - inferior for 6D
7, 7D, 8	30.6	Some examples of good bond - very poor extent of bond in others
9, 10	(0.85) (0.33)	Bottom value obtained after 6 months curing period
11, 12	28.6	Good extent of bond - average lowered by two values in panel No. 11
13, 14	32.2	100 per cent extent of bond - many breaks through mortar bed, hard to explain leakage
15, 16	55.3	Again 100 per cent extent of bond - with many breaks in mortar bed, no visual evidence of leakage
17, 18	25.6	Some unbonded areas noted - otherwise good bond
19, 20	2.0	Good extent of bond - no strength
21, 22	63.2	Some unbonded areas - high strength, hard to hold bricks
23, 24	77.4	Good strength - some unbonded areas, high value 96.7 psi, hard to hold bricks

TABLE VI

LEAKAGE THROUGH BRICKS
(Chimney Test)

IRA of Bricks (gm)	Total Leakage (ml)	Remarks	Water Absorbed by Bricks (ml)
28.0	Nil	Bottom of brick wet to touch, no drops of water on bottom, 32 ml water in chimney at end (total added 325 ml)	148.8
31.5	5	Drops of water on bottom of brick at 7 hr, 42 ml of water in chimney at end (total added 325 ml)	146.1
38.2	52	Drops of water on bottom of brick at 4½ hr, chimney empty at end of test (320 ml water added)	153.1
45.0	92	Drops of water on bottom of brick at 2 3/4 hr, chimney empty at end of test (450 ml water added)	186.8
65.0	161	Drops of water on bottom of brick at 2 hr, chimney empty at end of test (445 ml water added)	-
75.0	281	Drops of water on bottom of brick at 1½ hr, chimney empty at end of test (500 ml water added)	99.5
95.0	152 (7 hr)	Drops of water on bottom of brick at 1 3/4 hr, test discontinued because water was oozing from various sections of brick, not all dropping in containers	-
105.0	189 (8 hr)	Drops of water on bottom of brick in 1 hr, test was discontinued because water was "flooding" from all sections of brick	-

TABLE VII

LEAKAGE THROUGH BRICKS

IRA of Bricks (gm)	Total Leakage (ml)	Remarks
25.2	Nil	Back of brick wet to touch at end of test
55.0	3	Back of brick wet at 48 min, leakage occurred between 1 and 6 hr
86.0	403	Back of brick wet at 25 min, leakage steady throughout test, maximum during second hour
Bricks were tested by the usual small panel leakage test, being assembled in the apparatus with a "dummy" panel of four bricks.		

TABLE VIII

DATA FOR PANELS OF LOW SUCTION (28.0 to 38.5 gm) BRICKS

Series No.	IRA of Bricks Range (gm)	IRA of Bricks Average (gm)	Mortar Type	Mortar Flow (%)	Weight of Dry Bricks (gm)	Weight of Panels (gm)	Increase in Weight (gm)
I	28.2 to 37.0	33.3	1:3 masonry cement	117.0	12,521	13,837	1,316
II	28.0 to 38.5	33.7	1:3 masonry cement	115.5	12,815	14,518	1,703
III	28.0 to 37.0	33.3	1:3 masonry cement	129.6	12,712	14,015	1,303

LEAKAGE RESULTS FOR LOW SUCTION BRICK PANELS

Series No.	Total Leakage (ml)	Remarks
I	1,623	Leakage at 6 min, maximum rate 2 to 3 ml/min at 40 to 60 min
II	267	Leakage at 2 min, maximum rate 1.3 ml/min at 20 to 25 min
III	1,051	Leakage at 1 3/4 hr maximum rate 12 ml/hr

BOND STRENGTH RESULTS FOR LOW SUCTION BRICK PANELS

Series No.	Bond Strength Value (psi)	Remarks
I	21.8	80 to 90 per cent extent of bond
II	31.5	Excellent bond in top joint, no strength in second joint
III	26.6	Excellent bond in top two joints, poor extent of bond in lower joints

TABLE IX

WATER ABSORBED BY LOW-SUCTION BRICK PANELS DURING LEAKAGE TEST

Series No.	Water Absorbed (ml)
I	813
II	658
III	797

M/C LOSSES TO MATCHED PAIRS DURING ASSEMBLY OF MASONRY CEMENT MORTAR-LOW SUCTION BRICK PANELS

Series No.	IRA of Pairs (gm)	M/C Loss (Per cent Total M/C)
I	38.2	36.9
II	26.1	42.1
III	38.2	40.4

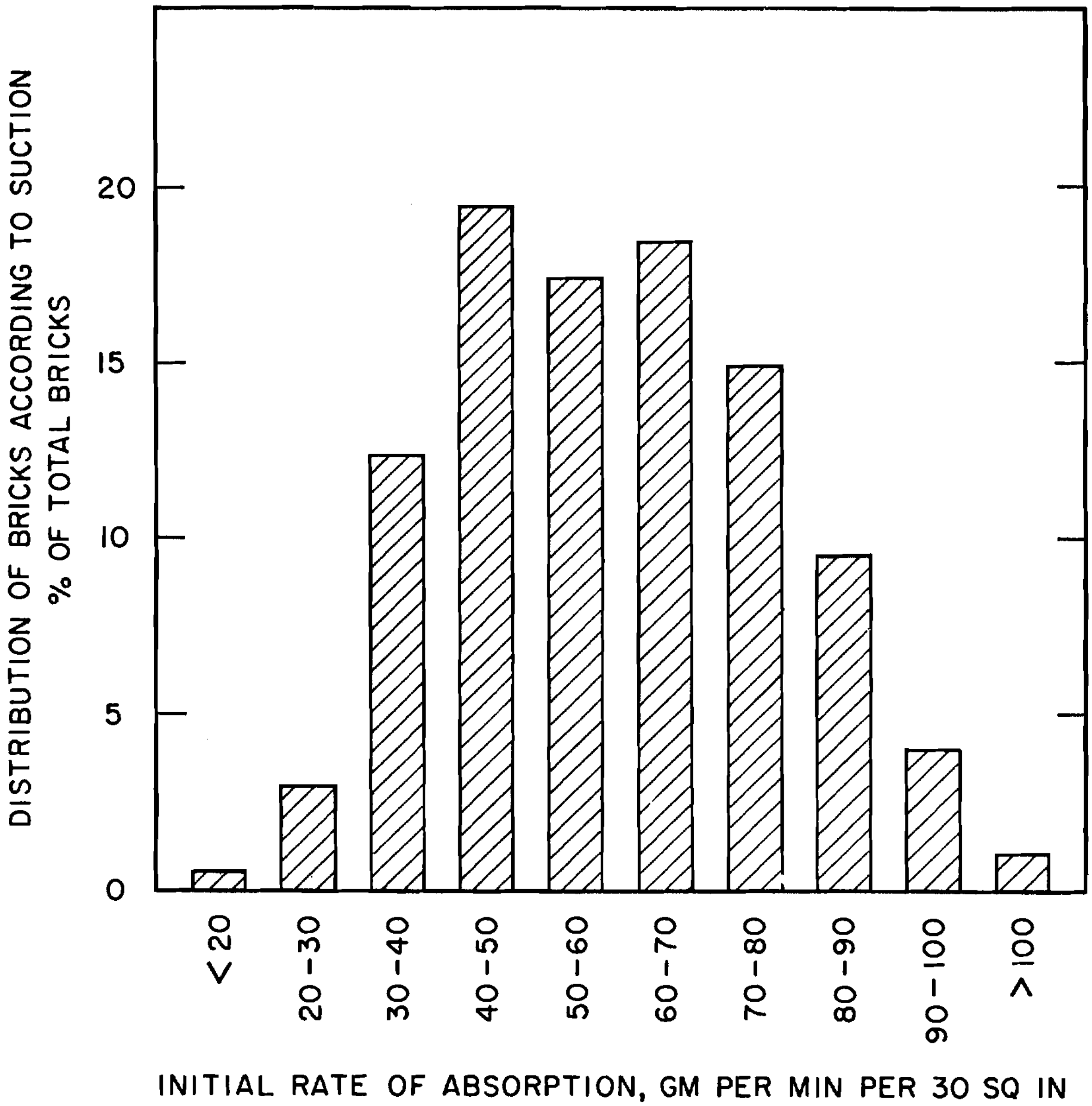

FIGURE I

NUMBER OF BRICKS IN SELECTED RANGES OF SUCTION, AS A PERCENTAGE OF THE TOTAL NUMBER OF BRICKS IN THE LOT

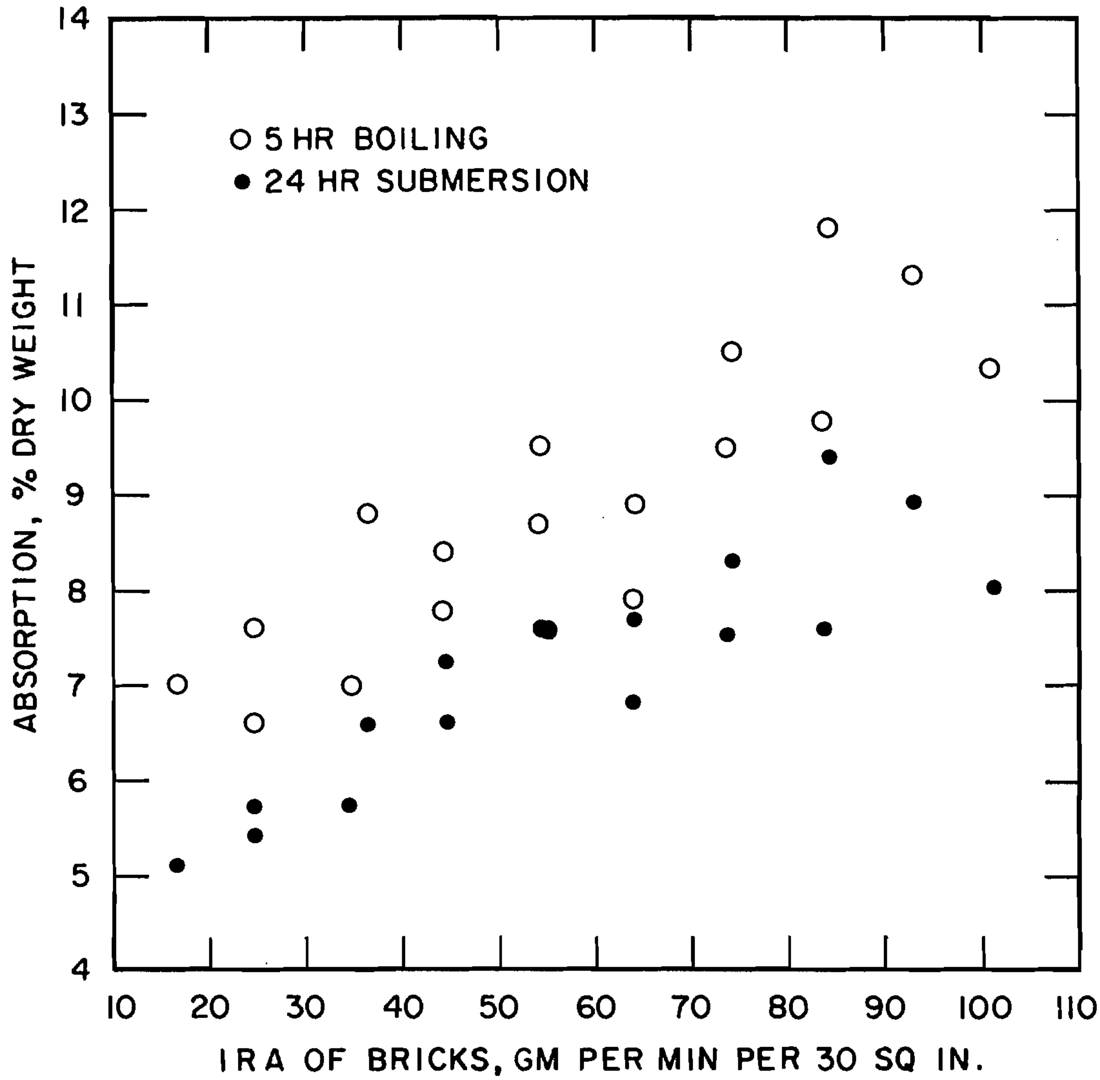

FIGURE 2

COMPARISON OF 24 HR SUBMERSION AND 5 HOUR BOILING ABSORPTIONS WITH INITIAL RATE OF ABSORPTION

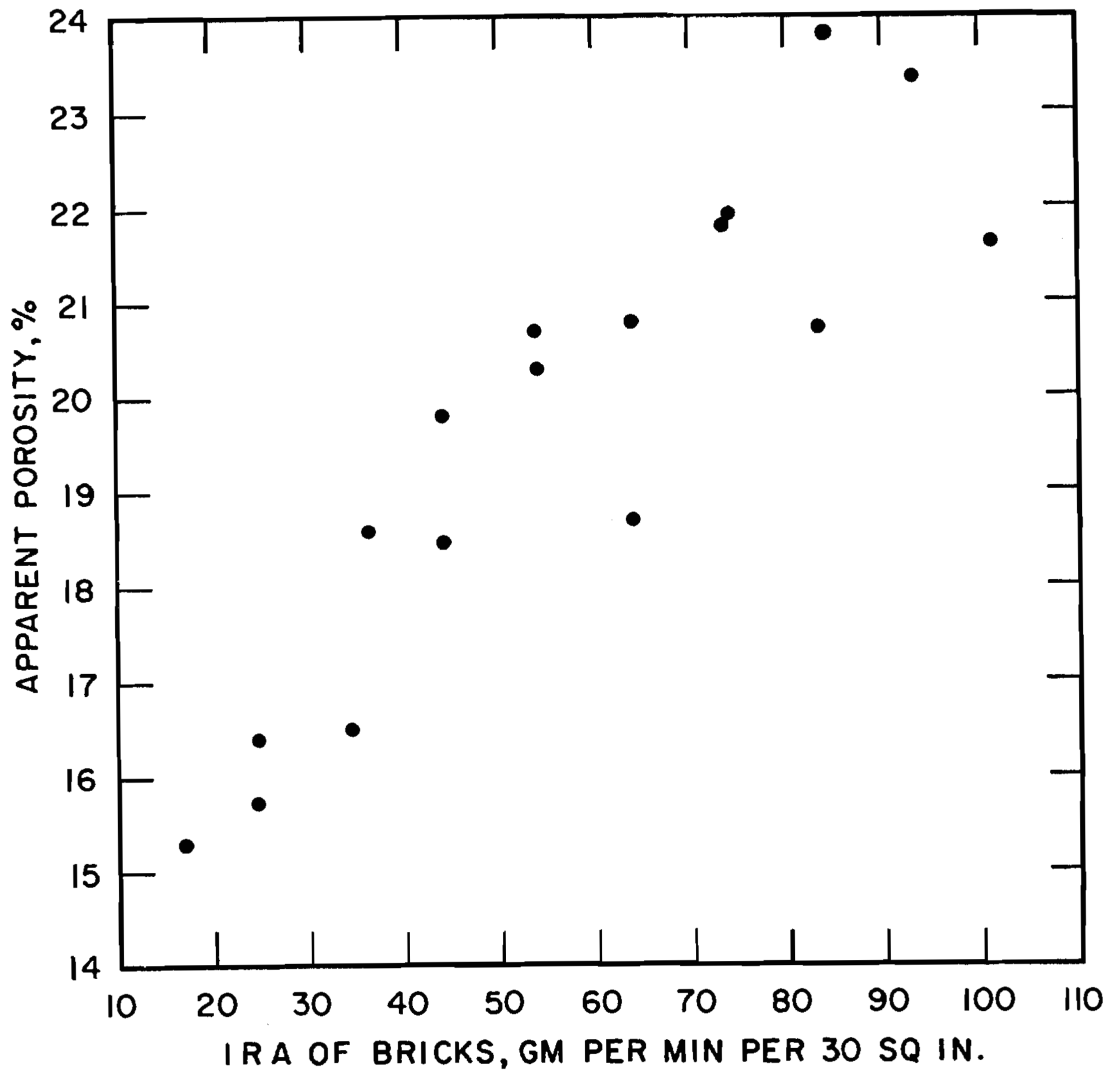

FIGURE 3

COMPARISON OF APPARENT POROSITY WITH INITIAL RATE OF ABSORPTION

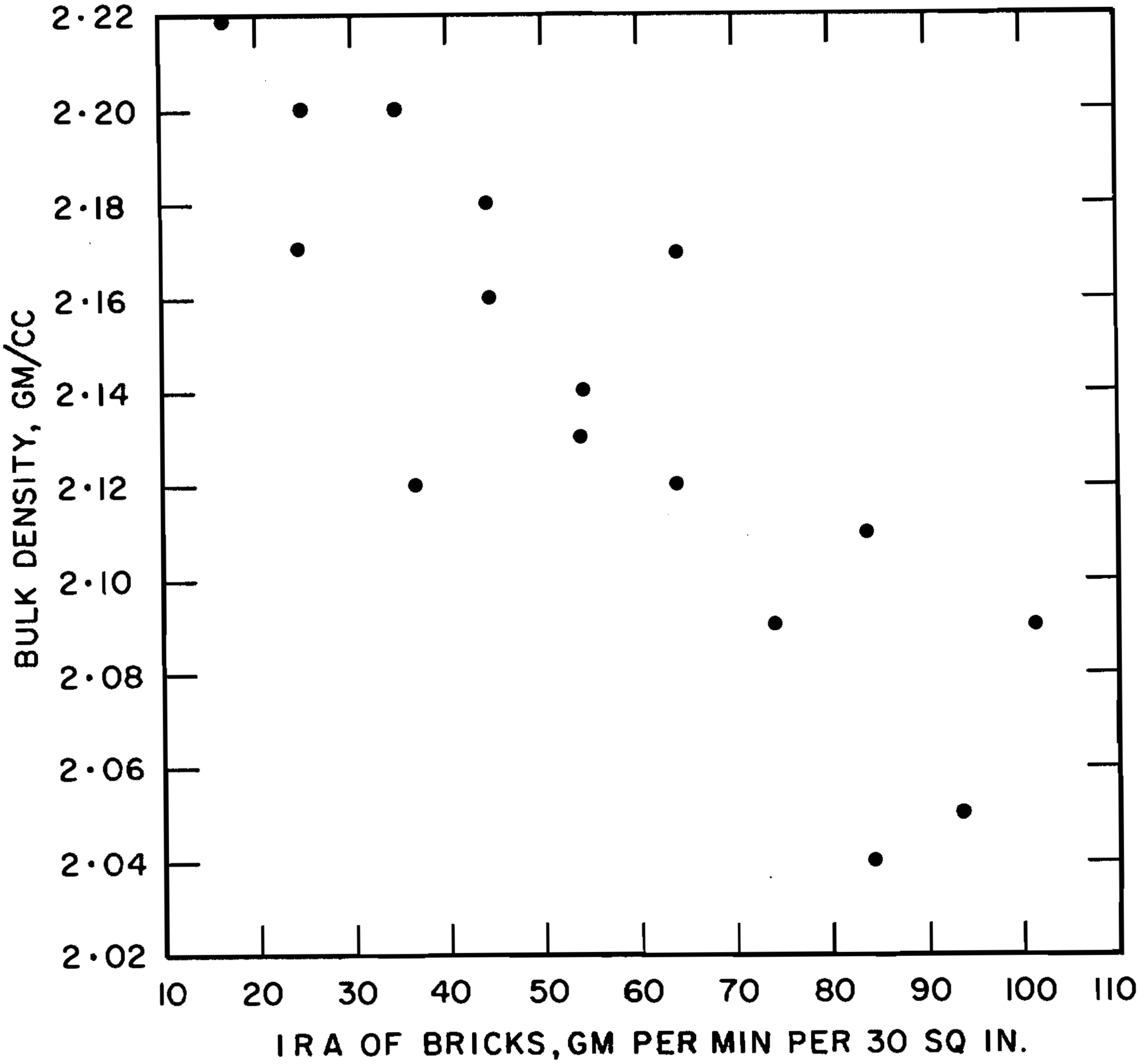

FIGURE 4

COMPARISON OF BULK DENSITY WITH INITIAL RATE OF ABSORPTION

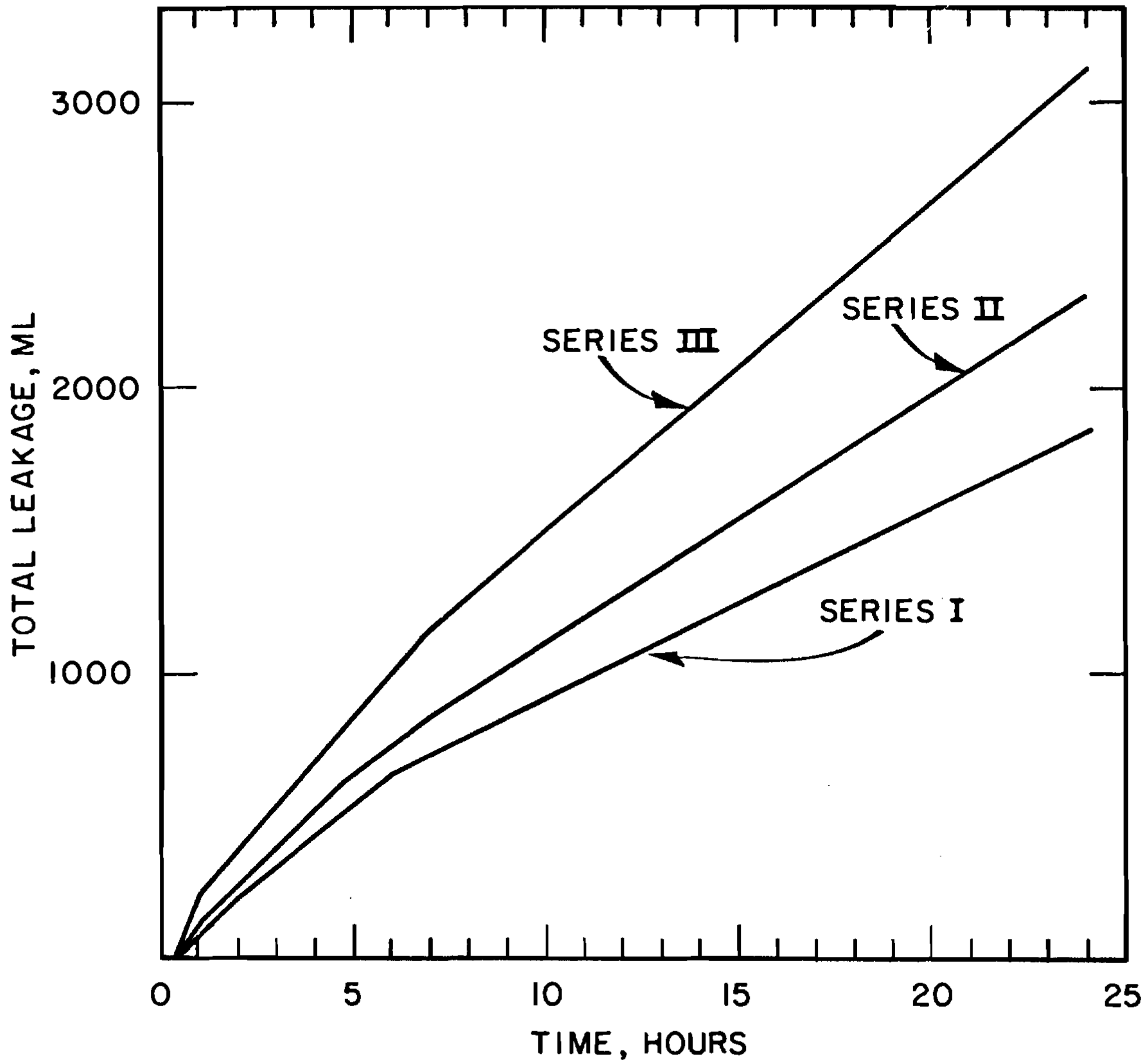

FIGURE 5

COMPARISON OF LEAKAGE PATTERNS FOR THE THREE SERIES OF LIME MORTAR PANELS

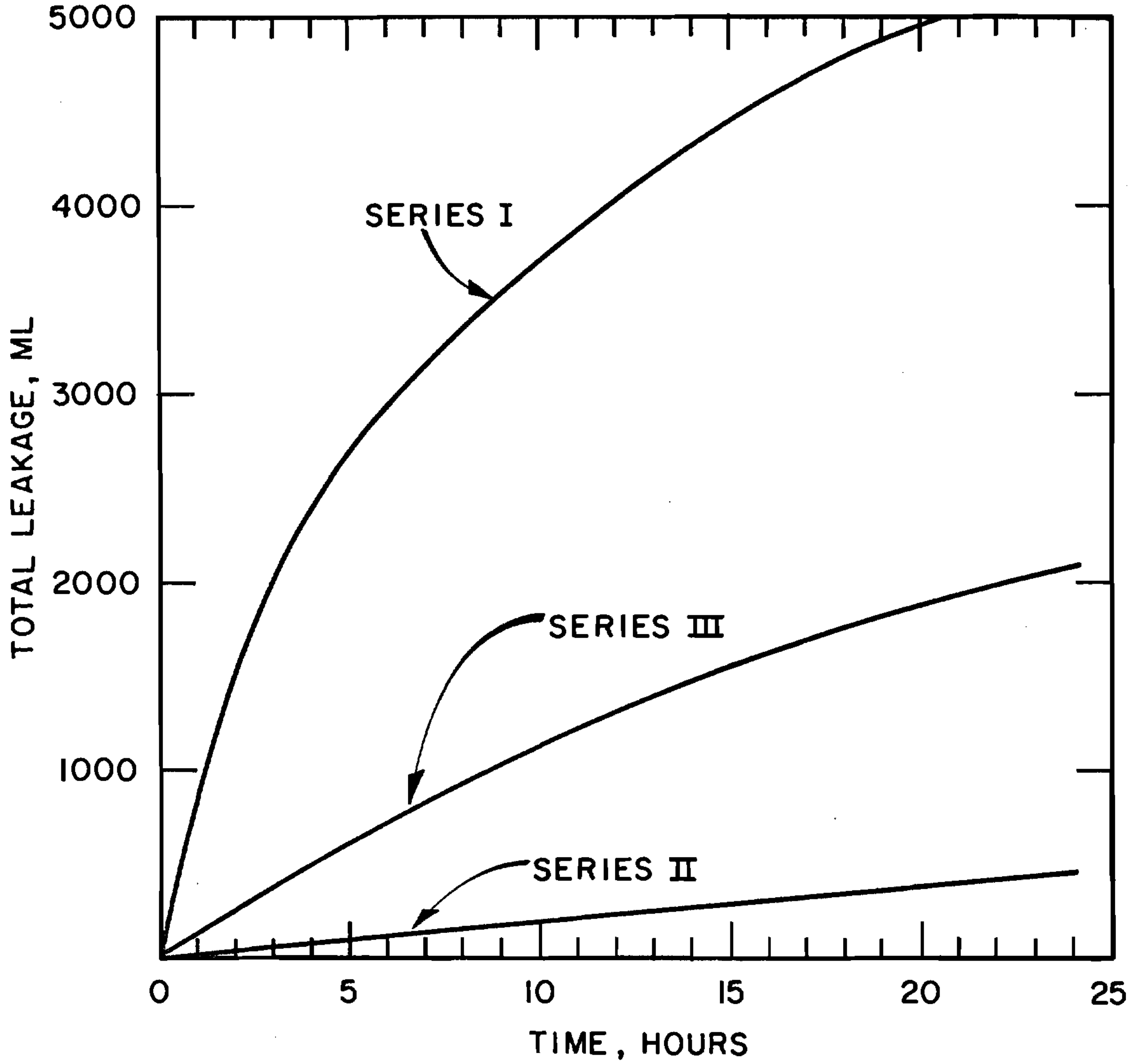

FIGURE 6

COMPARISON OF LEAKAGE PATTERNS FOR THE THREE SERIES OF MASONRY CEMENT MORTAR PANELS

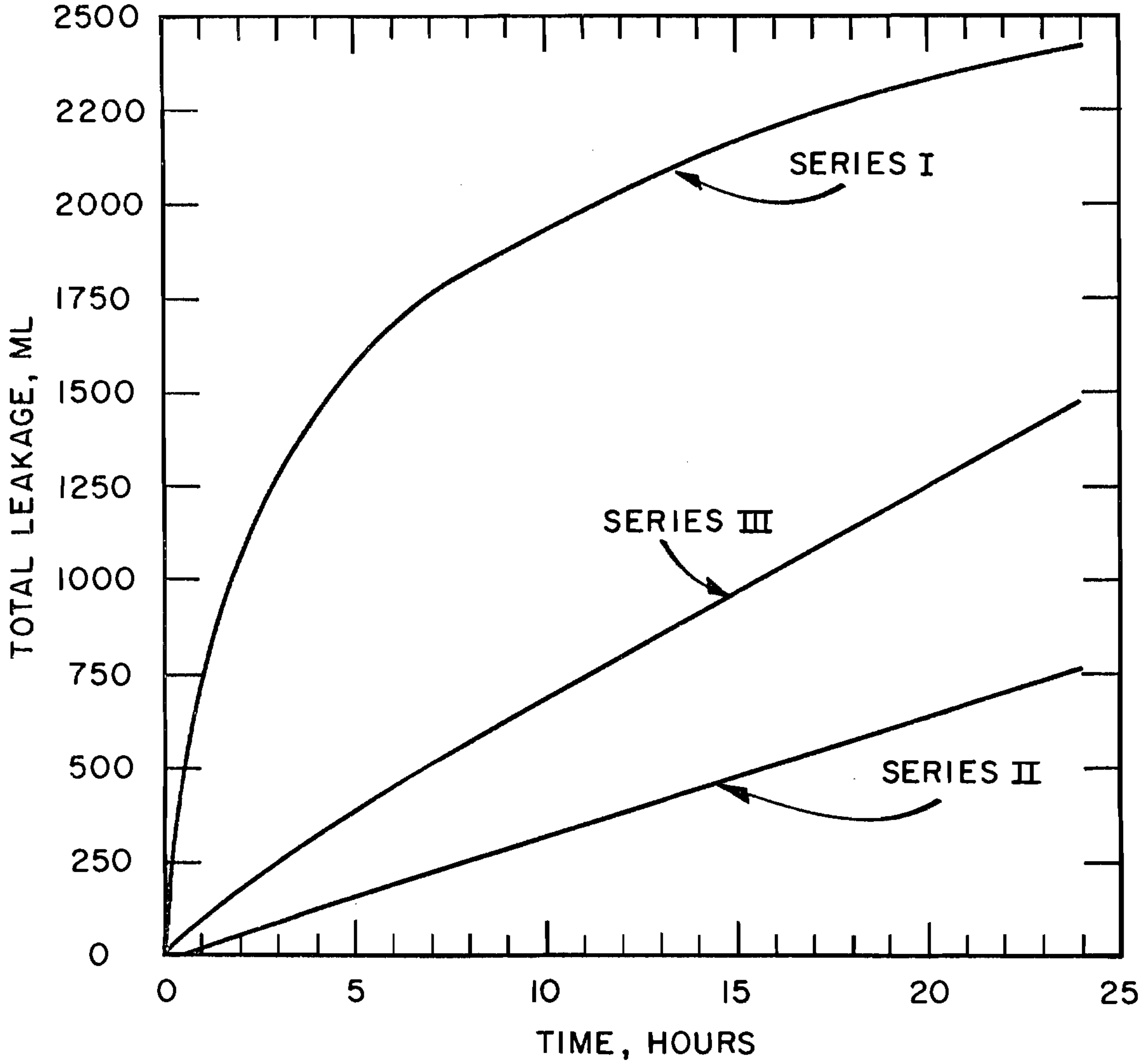

FIGURE 7

COMPARISON OF LEAKAGE PATTERNS FOR THREE SERIES OF 1:2:9 CEMENT-LIME MORTAR PANELS

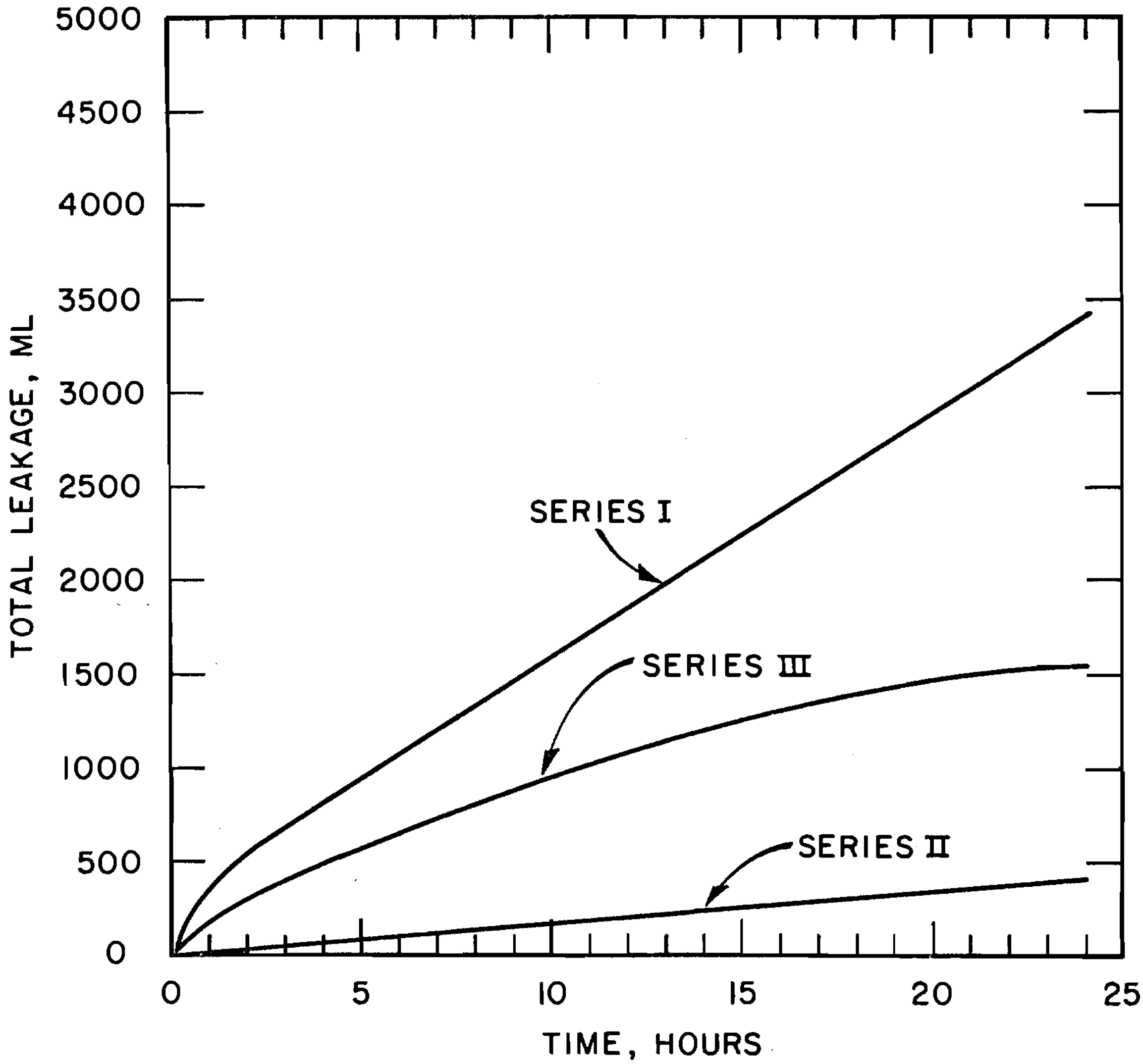

FIGURE 8

COMPARISON OF LEAKAGE PATTERNS FOR THE THREE SERIES OF 1:1:6 CEMENT-LIME MORTAR PANELS

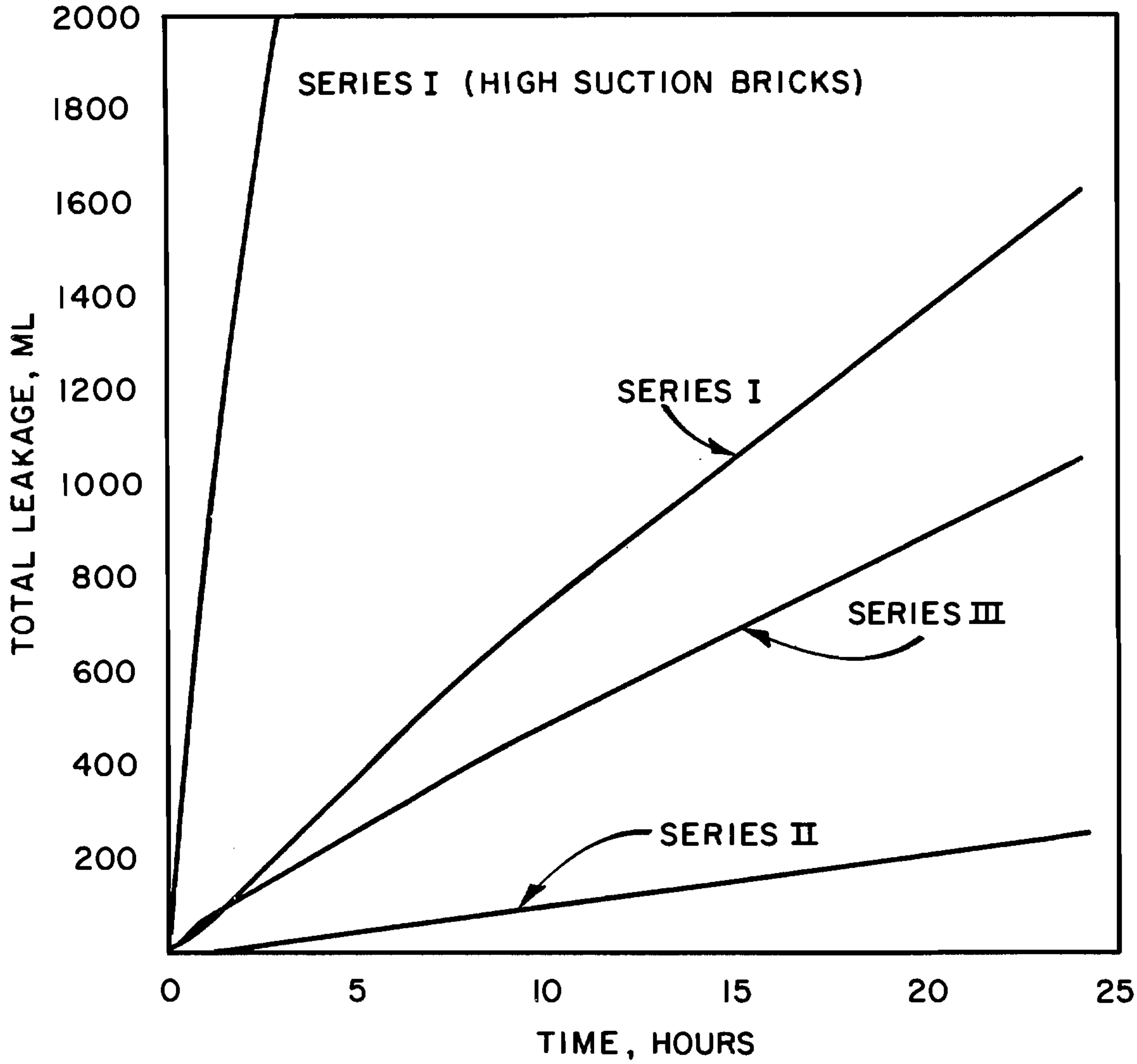

FIGURE 9

LEAKAGE PATTERNS FOR LOW SUCTION (28·0 – 38·5 GM) BRICK-MASONRY CEMENT PANELS. NOTE COMPARISON WITH PATTERN FOR HIGH SUCTION (41·0 – 72·5 GM) BRICK-MASONRY CEMENT PANELS

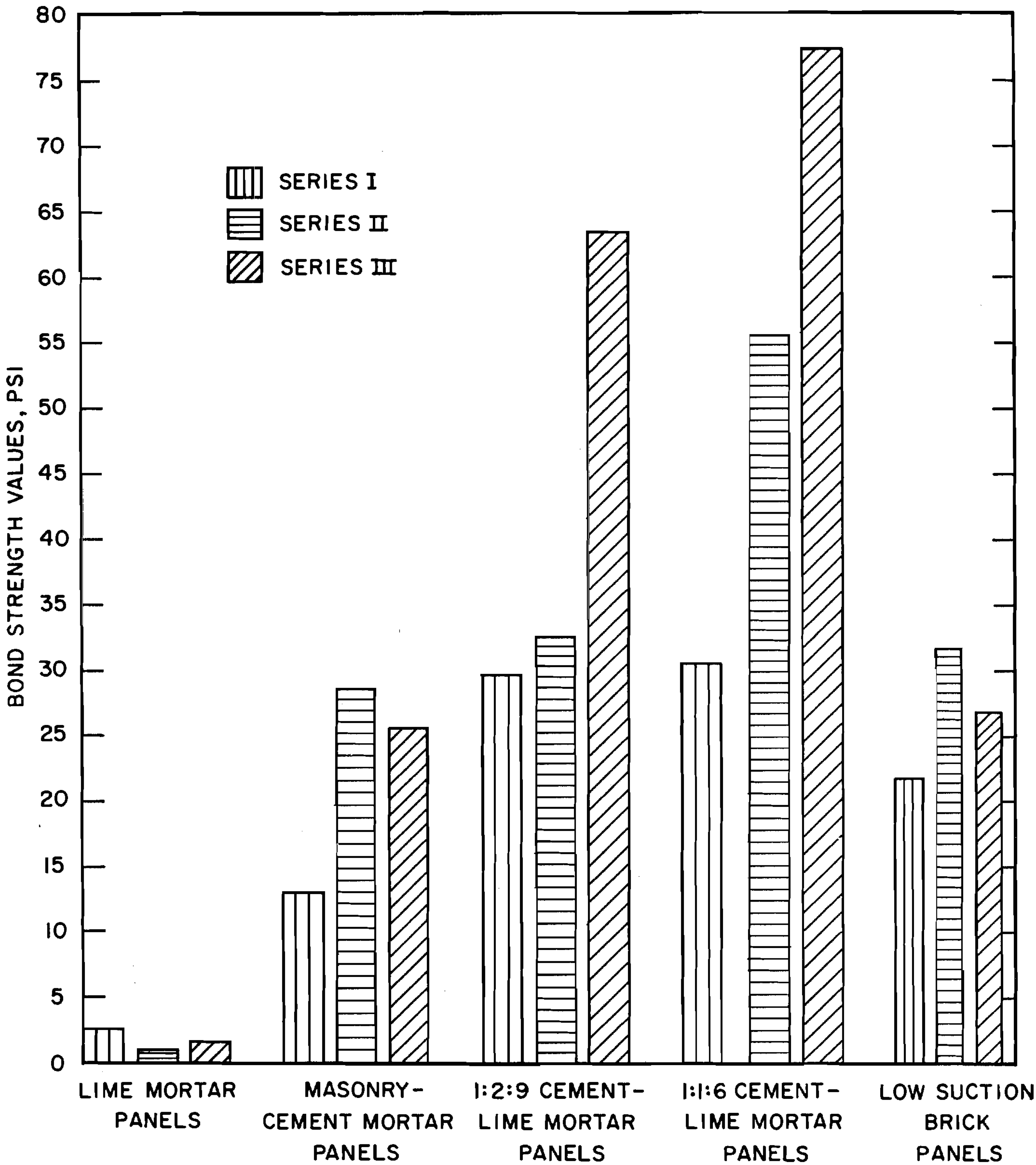

FIGURE 10

COMPARISON OF BOND STRENGTH VALUES FOR VARIOUS PANELS

BR 2350-10

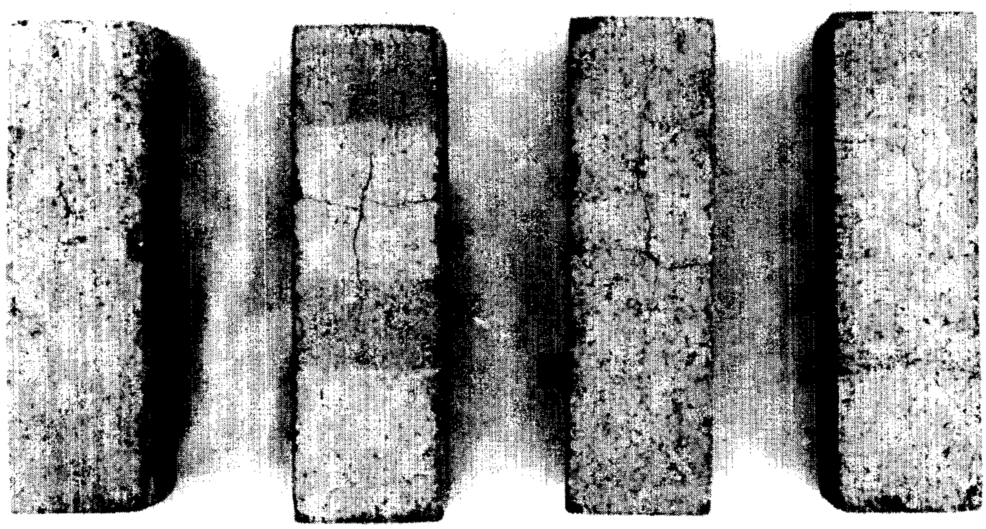

Figure 11

Cracks in bricks after 51 freeze-thaw
cycles on exposure site
(January to April 1960).

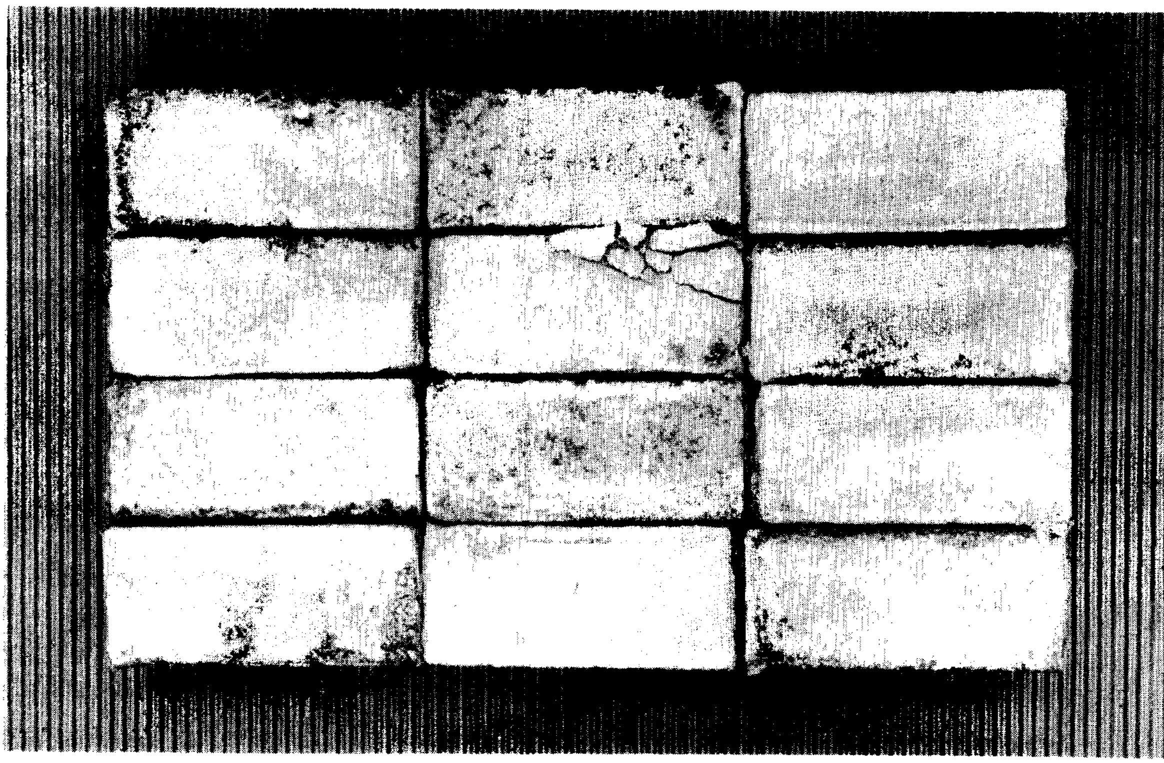

Figure 12

Comparison of panels assembled with lime mortar:
left - dry bricks, 115 per cent flow mortar;
centre - wet bricks, 115 per cent flow mortar;
right - dry bricks, 130 per cent flow mortar.

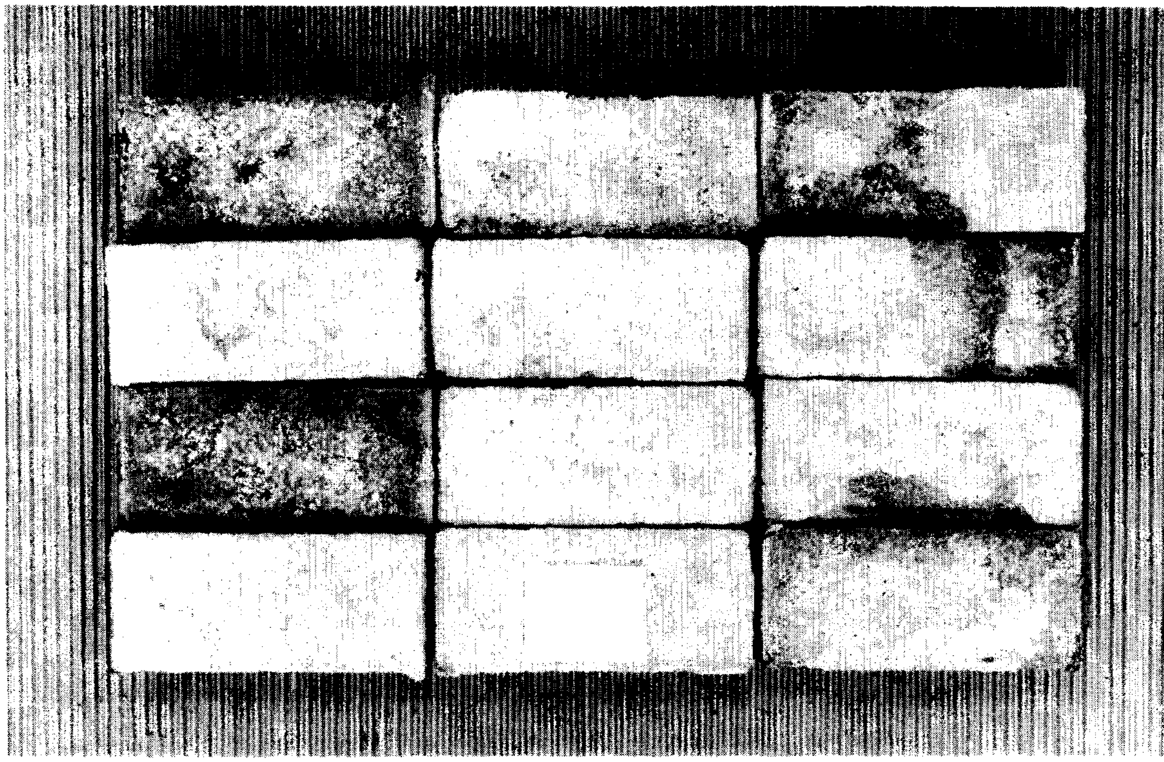

Figure 13

Comparison of panels assembled with masonry cement mortar:
left - dry bricks, 115 per cent flow mortar;
centre - wet bricks, 115 per cent flow mortar;
right - dry bricks, 130 per cent flow mortar.

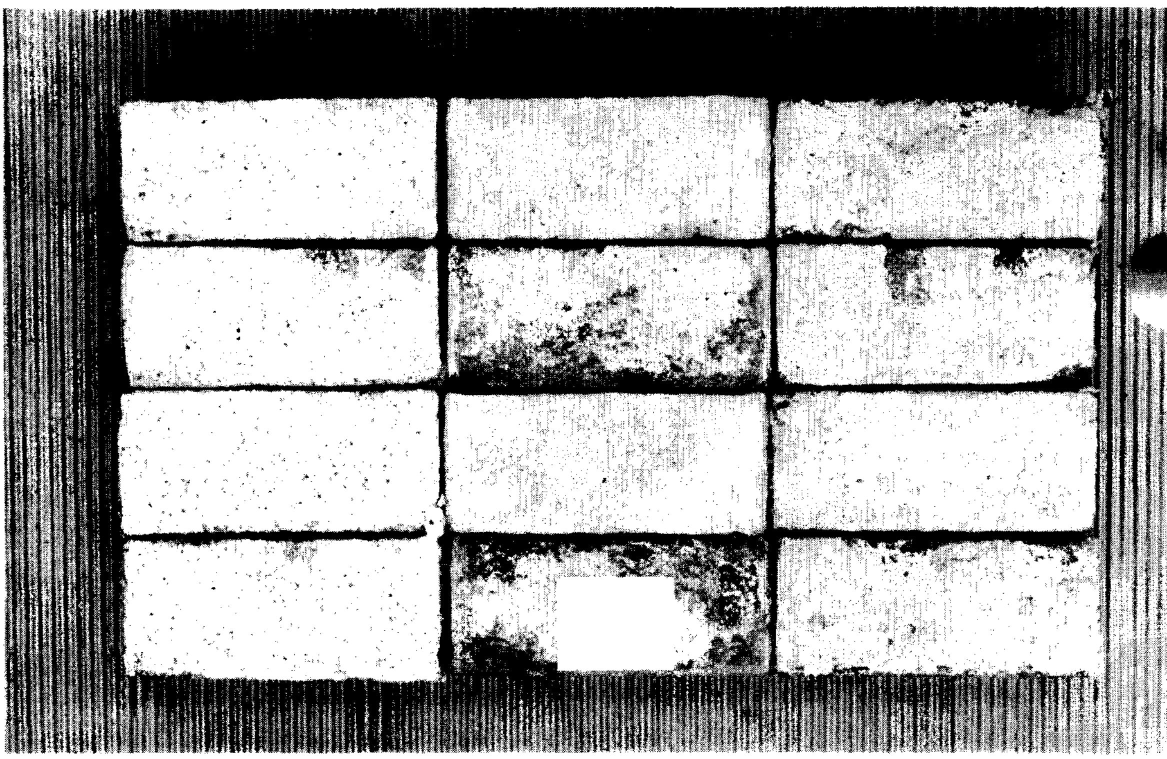

Figure 14

Comparison of panels assembled with
1:2:9 cement-lime mortar:
left - dry bricks, 115 per cent flow mortar;
centre - wet bricks, 115 per cent flow mortar;
right - dry bricks, 130 per cent flow mortar.

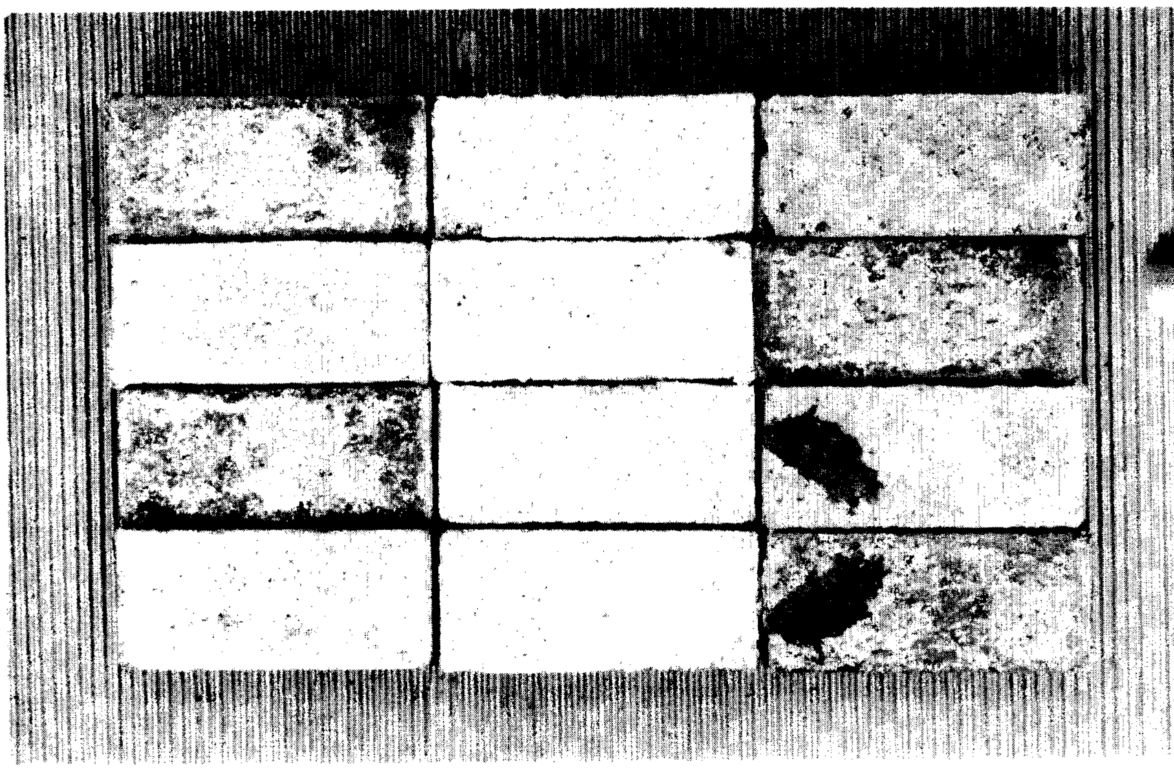

Figure 15

Comparison of panels assembled with
1:1:6 cement-lime mortar:
left - dry bricks, 115 per cent flow mortar;
centre - wet bricks, 115 per cent flow mortar;
right - dry bricks, 130 per cent flow mortar.

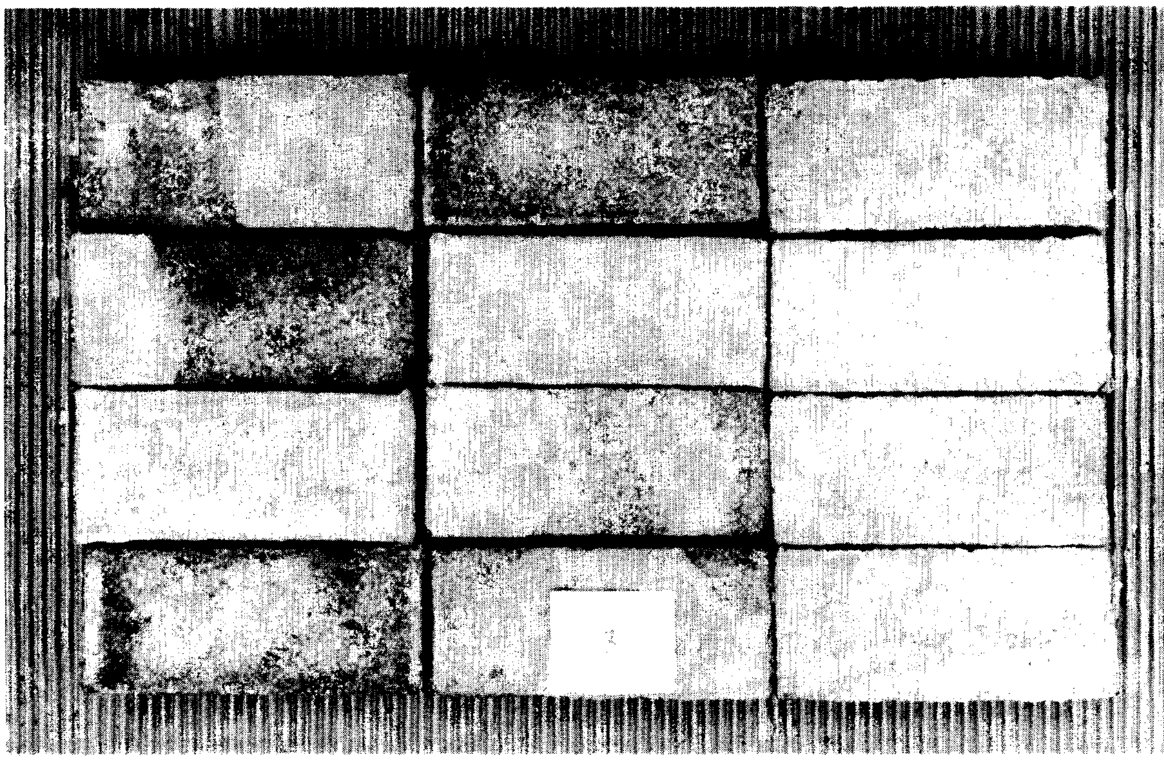

Figure 16

Comparison of panels assembled with
bricks having suction 28.0 to 38.5 gm
and 1:3 masonry cement mortar:
  left - dry bricks, 115 per cent flow mortar;
  centre - dry bricks, 130 per cent flow mortar;
  right - wet bricks, 115 per cent flow mortar.