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REPEATED LEAKAGE TESTS ON SMALL PANELS OF DRY-PRESS BRICKS

by

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PREFACE

The use of the small-panel test for leakage of brick masonry has been extended to study the change in leakage characteristics with time. This work is part of the program of study of masonry performance in the Atlantic Provinces which is being carried out at the Atlantic Regional Station of the Division in Halifax. The author is a research officer on the staff of the Station in charge of masonry performance studies.

Ottawa
November 1964

N. B. Hutcheon
Assistant Director

REPEATED LEAKAGE TESTS ON SMALL PANELS OF DRY-PRESS BRICKS

by

J. I. Davison

During field visits in areas where the dry-press brick previously studied (1, 2) is extensively used, there were reports of leakage in newly constructed walls containing the bricks, which ceased after a period of a year. A common explanation for the increased resistance of the walls to rain penetration was that small particles of dust and dirt, present in the air, were carried to and into the wall surface by wind and rain, thereby filling the small cracks and openings through which rain might enter.

This aroused some interest concerning the effect of repeated laboratory leakage tests on small panels containing the bricks. Accordingly, at the conclusion of the studies mentioned above, leakage tests were periodically repeated on two panels. A total of 19 tests was conducted on them over a period of two and one-half years. This report records the results of these tests.

THE PANELS

The panels were assembled following the usual procedure, and pertinent data will be found in Table I. The bricks used had IRA values ranging from 13.7 to 28.8 gm/30 sq in./min and averaged 22.7 and 22.6 gm/30 sq in./min for the two panels. These values are at the low end of the IRA range for this brick, which has values up to 100 gm/30 sq in./min, the majority of bricks being in the 40-60 gm/30 sq in./min range.

All bricks were soaked in water for 10 min prior to panel assembly. The first panel (P71) was assembled with a mortar consisting of 1 part masonry cement to 3 parts sand by volume, and in the second panel (P72) a mixture containing 1 part portland cement, 2 parts lime putty and 9 parts sand was used. Mortars were mixed to have flow values of approximately 120 per cent.

The panels were cured for two weeks under controlled conditions (70°F and 50 per cent RH). Flashing with polyethylene sheeting and Lasto-Meric was carried out during this period. The initial leakage test was conducted at the end of the curing period. This was followed by a second test one week later, and this schedule was repeated until five tests had been completed. Tests were then conducted at intervals of one month until the total reached numbered eleven, when the period between tests was increased to three months.

The final test (No. 19) was carried out about five weeks after the eighteenth test. Between tests, panels remained in the controlled atmosphere described above.

Results of leakage tests are summarized in Tables II (P71) and III (P72). During the final test on each panel, observations were timed to coincide with those recorded during the initial test, and resulting observations are combined in Tables IV (P71) and V (P72).

After the final leakage test, the panels were left to dry for two weeks and then bond-strength tests were conducted. Average bond-strength values and observations of visual examination of fractured joints are contained in Table VI.

LEAKAGE TESTS

Results reveal water penetration of both panels in measurable amounts during early tests, with reduced leakage as the tests continued. This is well illustrated in Figure 1 which depicts results graphically.

Panel P71

Leakage totals ranged from 184 to 255 ml during the five weekly tests, dropped to a 38-188 ml range during the monthly tests, and to a 10-198 ml range for the tests performed at three-month intervals. Graphical illustration of leakage totals shows a definite tendency toward lower levels as the tests continued. The lengthening of the interval between tests -- giving the panel a longer drying period -- appears to have contributed to the reduced leakage. This is illustrated in Table I which includes values for water absorbed by the panel during the individual tests. The average amount absorbed by panels during tests at weekly intervals was 423 gm. When the interval between tests was increased to one month, the average absorption rose to 548 gm and finally to 612 gm when the time interval became three months. Thus, the leakage totals decreased as the ability of the panel to hold water increased.

There are two other factors which may have contributed to increased resistance of the panel to rain penetration. The first concerns material deposited on the panel from the spray water used during leakage tests. At the end of the study period, the face of the panel subjected to the spray during leakage tests had become yellowish-brown in colour and this was particularly noticeable on the gray mortar joints. It was caused by organic impurities deposited from the water used during tests. Some of this material may have entered cracks and other openings in the surface, making it more impermeable than it originally had been.

The other suggestion is that water passing through the panel may have picked up soluble lime salts from the mortar and deposited them in cracks or other voids when evaporation took place. Subsequent carbonation would then add to the resistance of the panel to water penetration. This possibility will be discussed more fully in later sections.

A study of leakage records for the first and last tests on the panel (Table IV) indicates similar patterns. The story for the last test is simply that it took longer for water to penetrate the panel, and then the rate of leakage was lower, resulting in a smaller final total. It is thought that the longer drying period before the final test was the prime contributing factor, with the other factors contributing to a smaller degree.

Visual observations during leakage tests indicated that leakage was occurring through the bricks and also probably at the brick-mortar interface. The latter was difficult to establish as apparent leakage in this area may have been water running on to the mortar joint from leaks in the brick above.

Panel P72

Leakage totals for the panel assembled with cement-lime mortar are much more dramatic. Graphical results (Figure 1) reveal "peak" totals during tests #4, #5, and #17. Visual observations during test #5, when there was excessive leakage, indicated water penetration between the polyethylene flashing and the panel. (This is a result of a breakdown in the Lasto-Meric in the presence of lime and water.) Water penetration of this nature was also observed during tests #4 and #17, and as a result the panel was reflashed after tests #5 and #17. Leakage totals for these three tests can, therefore, be discounted.

On this basis, leakage results indicate no serious penetration of the panel in measurable amounts after the seventh test.

The same factors that contributed to reduced leakage for Panel P71 were considered for Panel P72. Increased drying of the panel as the time interval between tests was lengthened is again demonstrated by larger average water absorption totals at 518, 628, and 682 gm for tests following the three drying periods.

There was staining on the face of the panel, similar to that noted on P71, with the implication of increased resistance in permeability due to a "filler" action.

The third factor, possible migration of lime salts in solution to vulnerable areas with subsequent carbonation following evaporation of the water, was considered more applicable to this panel containing a mortar with a high lime content.

There have been two mechanisms suggested for this phenomenon (1) the bond-layer theory (3), and (2) autogenous healing (3, 4).

The bond-layer theory postulates that where there is intimate bond between bricks and cement-lime mortar, there is a thin layer of material between the body of the mortar and the brick surface. The material consists essentially of carbonated lime, and is the result of the carbonation of lime deposited at the brick-mortar interface by water migrating across the interface and carrying the lime in solution.

Autogenous healing results from the ability of lime mortars to heal cracks in the mortar in a manner similar to that described above.

Both explanations were considered applicable to P72. It was thought that lime salts might be carried into the porous bricks in solution during leakage tests, and that ultimate carbonation of the lime following evaporation of the water could help reduce the permeability of the units. Evidence of this action, however, could not be obtained until the panel was broken during bond-strength tests.

Comparison of leakage records for first and last tests on P72 indicates moisture penetration to the back of the panel in fifteen min for the former and not until two hr for the latter. Measurable leakage occurred during the first hour in the first test, with only minor penetration after the second hour during the final test.

Again visual observations indicated leakage both through the individual bricks and at the brick-mortar interface, the latter being questionable due to water from the leaking bricks above, saturating the joint areas.

BOND-STRENGTH TESTS

Panel P71

Excellent bond-strength values (Table VI) were obtained for all four joints of this panel. They ranged from 44. 3 to 78. 0 psi and averaged 59. 3 psi. These are exceptionally good for masonry cement mortar and undoubtedly reflect the benefit of the long curing period under optimum conditions, created by periodically wetting the mortar during leakage tests. Visual examination of fractured joints revealed a complete extent of bond with all breaks occurring through the mortar beds instead of at the brick-mortar interface. The extent of bond and nature of the fractures are shown in Figure 2, a photograph of joints after the test.

To investigate (1) the nature of the bond between mortar and brick, and (2) the possibility of mortar penetrating the brick, some of the mortar was chipped from the units. It did not separate cleanly and invariably there was some mortar left on the brick -- a layer between the mortar bed and the unit. The brick was then broken (by chipping) to see if there was any evidence of mortar penetration. There was no visual evidence of this; a very definite boundary appeared to separate brick and mortar. This is clearly shown in the bottom photograph in Figure 2.

Panel P72

Bond-strength values for the cement-lime mortar panel were not as good. Joints #1 and #2 were broken while removing the Lasto-Meric which was used as a binder for the flashing. A value of 11.7 psi was obtained for joint #3, and joint #4 also fractured while being set up for test. There evidently was not much strength in the mortar. All four breaks, however, occurred in the mortar beds -- indicating a greater strength in bond between mortar and units than in the mortar itself. There was a good extent of bond in all joints shown in the top photograph of Figure 3 where it will also be noted that there was poor perimeter bonding in several joints. These results and observations lend support to the "bond-layer" theory.

The lower photograph in Figure 3 shows the results when mortar was chipped away from the units, and when the bricks were broken to investigate possible penetration of lime. Again there was a clear demarcation between brick and mortar with no visual evidence of penetration of the brick by the mortar. There was good adhesion between brick and mortar with a thin layer of mortar remaining on the unit after the main bed had been removed.

CONCLUSIONS

(1) A reduction in leakage totals occurred as tests were repeated on small panels of dry-press bricks and (a) a 1:3 masonry cement: sand mortar, and (b) a 1:2:9 portland cement : lime putty : sand mortar. The greatest reduction occurred for the panel containing the cement-lime mortar.

(2) Three factors were noted that may have contributed to the increased resistance of the panels to moisture penetration as the tests progressed. (a) As the time interval between tests was increased from one week to one month to three months, the panels had a greater opportunity to dry out, thus increasing their capacities for absorbing water during subsequent leakage tests. This undoubtedly retarded the leakage process and resulted in lower total leakage. (b) A scum of organic impurities from the water was deposited on the face of the panels during leakage tests, filling small openings and making the surface more impermeable. (c) Carbonation of soluble lime salts carried from the mortar to the brick-mortar interface, building up the resistance to penetration in that area. There was no visual evidence to support the suggestion that some salts may have been carried in solution into the bricks and later carbonated there.

(3) Excellent bond-strength values were obtained for P71, containing masonry cement mortar. Visual observation of fractured joints indicated presence of a "bond-layer" between the brick and the mortar bed.

(4) Premature fractures through the mortar beds in three joints of P72 containing cement-lime mortar, and a low bond-strength value after a mortar-bed fracture for the fourth joint, indicated greater strength in the bond between brick and mortar than in the mortar itself. Again visual observations indicated a complete extent of bond and some evidence of a "bond-layer" between brick and mortar.

(5) Excellent extent of bond and good adherence between brick and mortar lead to the conclusion that most leakage occurred through the bricks rather than at the brick-mortar interface.

REFERENCES

(1) Davison, J. I. "Leakage and bond strength tests on small panels assembled with red dry-press bricks and four mortar combinations". DBR Internal Report No. 215, 1960.

(2) Davison, J. I. "Effect of silicone treatment on small panels assembled with high-suction dry-press bricks". DBR Internal Report No. 241, 1962.

(3) Voss, W. C. "Permeability of brick masonry walls -- an hypothesis". Proc. Amer. Soc. Testing Mats., Vol. 33, Part 2, 1933, 670-691.

(4) McBurney, J. W., M. A. Copeland, and R. C. Brink. "Permeability of brick-mortar assemblages". Proc. Amer. Soc. Testing Mats., Vol. 46, 1946, 1333-1354.

TABLE I

PANEL ASSEMBLY DATA

Date	Panel No.	IRA (gm/30 sq in./min) Bricks	Av.	Mortar Type	Flow (Per cent)	Remarks
25/4/61	P71	13.7, 17.8, 26.0 27.0, 28.8	22.7	1:3 masonry cement: sand	119.6	All bricks soaked for 10 min in water before panel assembly, with 30 sec time interval and heavy tap.
26/4/61	P72	14.0, 16.5, 27.0 26.8, 28.8	22.6	1:2:9 cement: lime: sand	122.0	

TABLE II

SUMMARY OF RESULTS OF LEAKAGE TESTS FOR PANEL P71

Test No.	Date	Total Leakage, ml	Wt. of Panel at Start of Test, gm	Wt. of Panel at End of Test, gm	Water Absorbed During Test, gm	Remarks
1	9/5/61	184	14, 220	14, 725	505	Dampness noted on back of panel in 13 min. First leakage at 26 min.
2	16/5/61	255	14, 339	14, 740	401	Dampness noted in 15 min. First leakage at 20 min.
3	23/5/61	228	14, 308	14, 740	432	Dampness noted in 15 min. First leakage at 20 min.
4	29/5/61	200	14, 337	14, 738	401	21 ml leakage in first 2 hr.
5	6/6/61	234	14, 375	14, 750	375	First leakage at 25 min.
6	11/7/61	38	14, 340	14, 858	518	First leakage at 20 min.
7	2/8/61	89	14, 330	14, 850	520	First leakage at 30 min.
8	29/8/61	188	14, 323	14, 870	547	First leakage at 30 min.
9	17/10/61	164	14, 262	14, 852	590	First leakage at 16 min. Leakage always occurs through bricks.
10	4/12/61	78	14, 270	14, 845	575	First leakage at 45 min.
11	15/1/61	153	14, 320	14, 855	535	Dampness noted at 16 min. Leakage at 30 min.
12	16/4/61	54	14, 240	14, 845	605	Dampness noted at 30 min. Leakage at 45 min.
13	10/7/62	198	14, 243	14, 857	614	Dampness noted at 40 min. Leakage at 60 min.
14	17/10/62	122	14, 270	14, 885	615	First leakage between 1st and 2nd hr.
15	7/1/63	10	14, 275	14, 877	602	Dampness noted at 2 hr.
16	8/4/63	27	14, 265	14, 888	623	Leakage noted at 1 hr.
17	9/7/63	50	14, 265	14, 880	615	Leakage noted at 1 hr.
18	8/10/63	73	14, 355	14, 955	600	Leakage noted at 30 min.
19	13/11/63	103	14, 400	14, 980	580	Leakage noted at 22 min.

TABLE III

SUMMARY OF RESULTS OF LEAKAGE TESTS FOR PANEL P72

Test No.	Date	Total Leakage, ml	Wt. of Panel at Start of Test, gm	Wt. of Panel at End of Test, gm	Water Absorbed During Test, gm	Remarks
1	10/5/61	112	14,065	14,670	605	Dampness noted on back of panel in 15 min. Leakage at 45 min.
2	16/5/61	162	14,182	14,675	493	Dampness noted in 15 min. Leakage at 30 min from bricks and brick-mortar interface.
3	24/5/61	19	14,150	14,665	515	Dampness noted at 26 min. Leakage at 45 min. Brick No. 3 leaking.
4	1/6/61	275	14,135	14,673	538	Dampness at 12 min. Leakage at 30 min, between panel and flashing.
5	7/6/61	2,653	14,235	14,676	441	No measurable leakage during first hr. Leakage between panel and flashing.
6	11/7/61	8	14,198	14,805	607	Dampness in 45 min. Leakage in 60 min.
7	2/8/61	78	14,194	14,795	601	No indication of moisture penetration at 30 min.
8	29/8/61	Nil	14,175	14,795	620	Dampness in 45 min. Leakage at 60 min.
9	17/10/61	12	14,115	14,798	683	Leakage at 1 hr.
10	4/11/61	Nil	14,127	14,783	656	Dampness and slight leakage at 3 hr.
11	15/1/61	8	14,200	14,800	600	Dampness at 2nd hr. Slight leakage at 4 hr.
12	16/4/62	Nil	14,103	14,795	692	Dampness at 2 hr. Slight leakage at 3 hr.
13	11/7/62	Nil	14,105	14,795	690	Dampness and slight leakage at $1\frac{1}{2}$ hr.
14	18/10/62	Nil	14,135	14,775	640	Dampness and slight leakage at 2 hr.
15	8/1/63	8	14,150	14,825	675	Dampness at 2 hr. Slight leakage at 3 hr.
16	9/4/63	5	14,138	14,825	687	Dampness at 1 hr. Slight leakage at 2 hr.
17	11/7/63	57	14,136	14,840	704	Dampness and some leakage at $1\frac{1}{4}$ hr. Some leakage around flashing.
18	9/10/63	28	14,213	14,897	684	Dampness at 1 hr. Slight leakage at 3 hr.
19	14/11/63	17	14,246	14,900	654	Dampness and slight leakage at $1\frac{1}{2}$ hr.

TABLE IV

COMPARISON OF LEAKAGE RESULTS DURING

FIRST AND LAST TESTS ON PANEL P71

Time	Test #1	Test #19
0	No immediate leakage.	No immediate leakage.
13 min	Joint #1 darkening right side.	No change.
22 min	Joint #1 100 per cent dark but not wet. Joint #2 darkening at right side.	Slight leakage through brick #1.
26 min	Joint #1 and brick #1 leaking on to joint #2 and brick #2.	Joint #1 wet. Water droplets on face of brick #2.
30 min	Joint #2 wet and leaking. Water droplets on brick #2.	Joint #1 100 per cent wet and leaking on to joint #2. Bricks #1 and #2 wet and leaking slightly. Joints #3 and #4 and bricks #3, #4, and #5 unchanged.
45 min	Joint #3 100 per cent dark, joint #4 dark at centre.	No further change.
60 min	All 4 joints 100 per cent dark and leaking slightly - not enough to measure.	Joint #2 100 per cent dark and wet.
1 hr + 25 min		Wet spot - left side joint #4.
2 hr	Leakage 10 ml 12 "rivelets" noted from cracks and pores in brick #1.	All four joints 100 per cent wet. No measurable leakage.
3 hr	Leakage 30 ml)	Entire face of panel wet and leaking - total 4 ml.
4 hr	)	Leakage 8 ml.
5 hr	Leakage 9 ml.	Leakage 8 ml.
6 and 7 hr	Leakage 15 ml.	Leakage 12 ml.
7 - 24 hr	Leakage 120 ml.	Leakage 71 ml.
	Total leakage - 184 ml.	Total leakage - 103 ml.
	Water absorbed - 505 ml.	Water absorbed - 580 ml.

TABLE V

COMPARISON OF LEAKAGE RESULTS DURING

FIRST AND LAST TESTS ON PANEL P72

Time	Test #1	Test #19
0	No immediate leakage.	No immediate leakage.
15 min	Dark spot centre of joint #3 and brick #3.	No change.
30 min	Joint #3 100 per cent dark but not wet and brick #3 90 per cent dark.	No change.
45 min	Joints #2, #3, and #4 and bricks #1, #3, #4 100 per cent dark and damp. Joint #1 darkening at centre and brick #2 80 per cent dark. Water droplets on face of brick #5. Leakage = 3 ml.	No change.
60 min	All joints wet and leaking slightly. All bricks dark. Nos. 3, 4, and 5 leaking. Leakage = 3 ml.	No change.
2 hr	Leakage = 8 ml.	Water droplets on face of all 5 bricks at $1\frac{1}{2}$ hr.
3 hr	Leakage = 14 ml)	Leakage = 3 ml.
	)	
4 hr	)	Leakage = 5 ml)
		)
5 hr	Leakage = 5 ml.	)
6 hr	Leakage = 5 ml.	Leakage = 4 ml)
		)
7 hr	Leakage = 5 ml.	)
	12 leakage points noticed in brick #1.	
7 - 24 hr	Leakage = 69 ml.	Leakage = 5 ml.
	Total leakage = 112 ml.	Total leakage = 17 ml.
	Water absorbed = 538 ml.	Water absorbed = 654 ml.

TABLE VI

BOND-STRENGTH VALUES

	Panel P71		Panel P72	
	Value (psi)	Remarks	Value (psi)	Remarks
Joint 1	50.0	Excellent bond. 60 per cent of fracture through mortar bed. No indication of moisture penetration.	-	Broken removing Lasto-Meric coating. Break occurred through mortar bed.
Joint 2	64.7	Same as (1). 70 per cent of fracture through mortar bed.	-	Same as (1).
Joint 3	78.0	Same as (1). 80 per cent of fracture through mortar bed.	11.7	100 per cent extent of bond. Break through mortar bed. No evidence of moisture penetration.
Joint 4	44.3	Same as (1).	-	Broken setting up. Break through mortar bed.
Average	59.3	Excellent values for masonry cement mortar.	11.7	Good extent of bond. All breaks through mortar bed. No evidence of any moisture penetration.

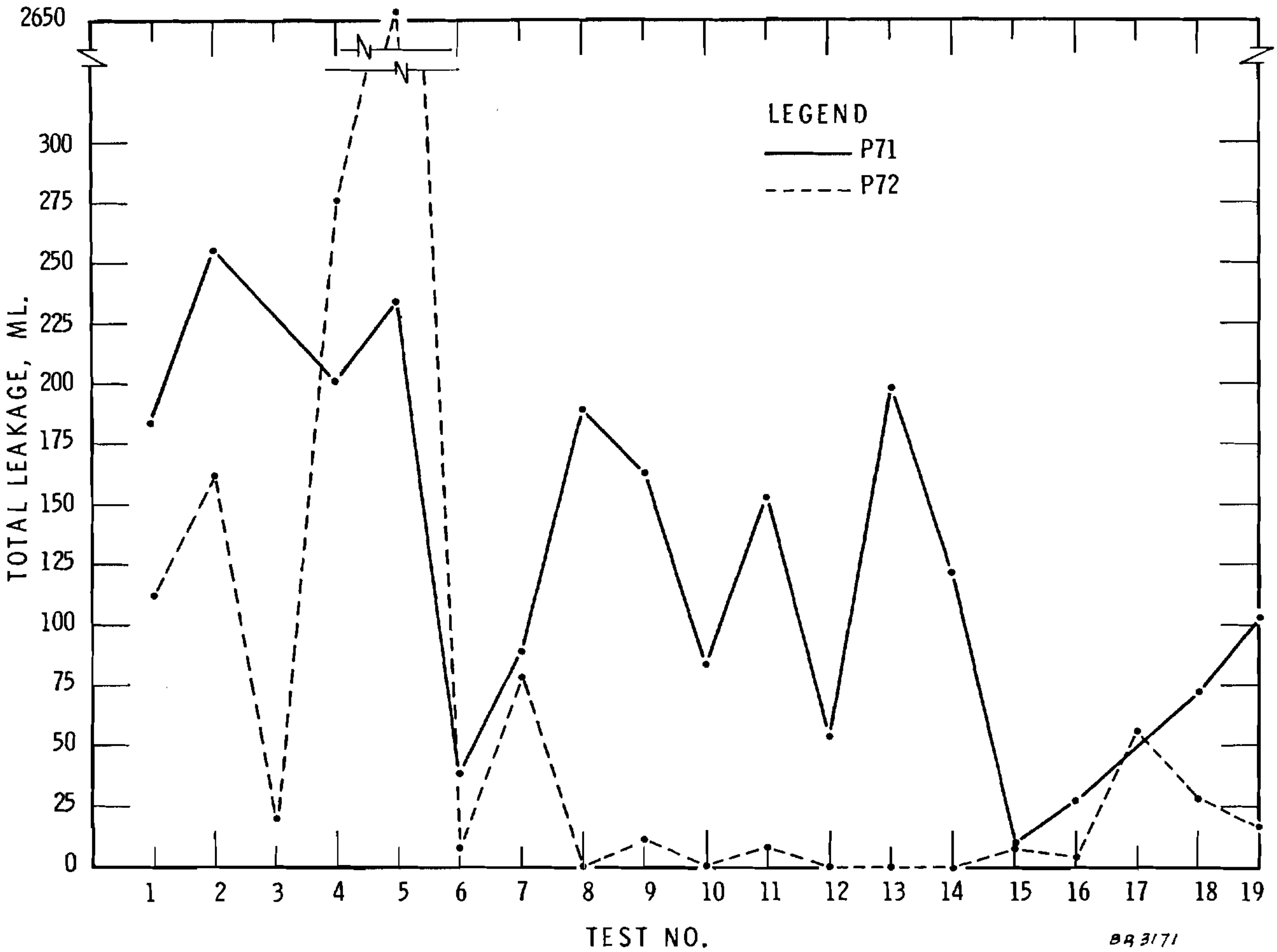

FIGURE 1
LEAKAGE RESULTS FOR PANELS P71 AND P72

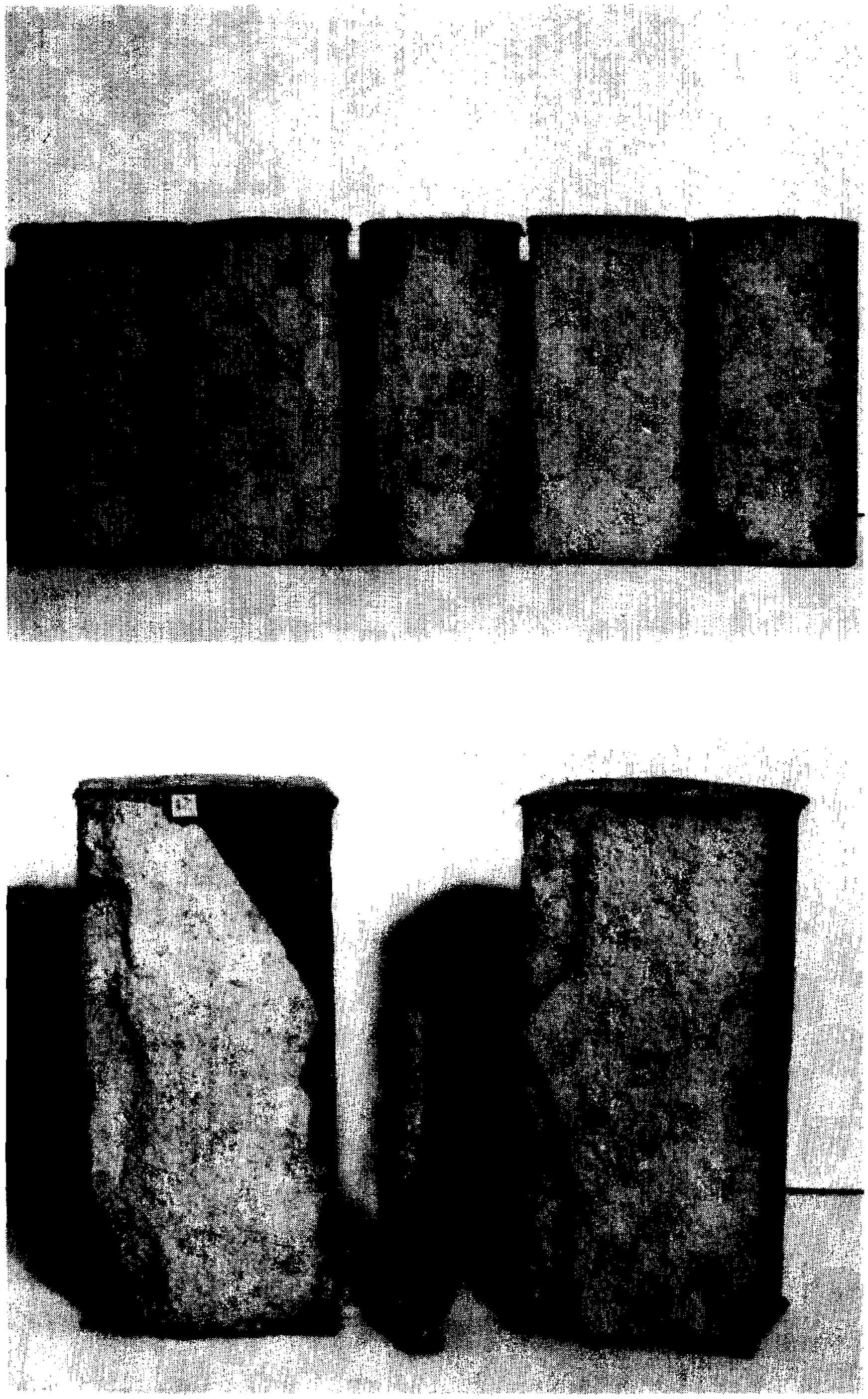

FIGURE 2

Panel P71

Top - Fractured joints. Note complete extent of bond and breaks through mortar beds.

Bottom - Mortar has been chipped away and bricks broken. No evidence of mortar penetrating brick. Note clean separation of brick and mortar on sample in middle.

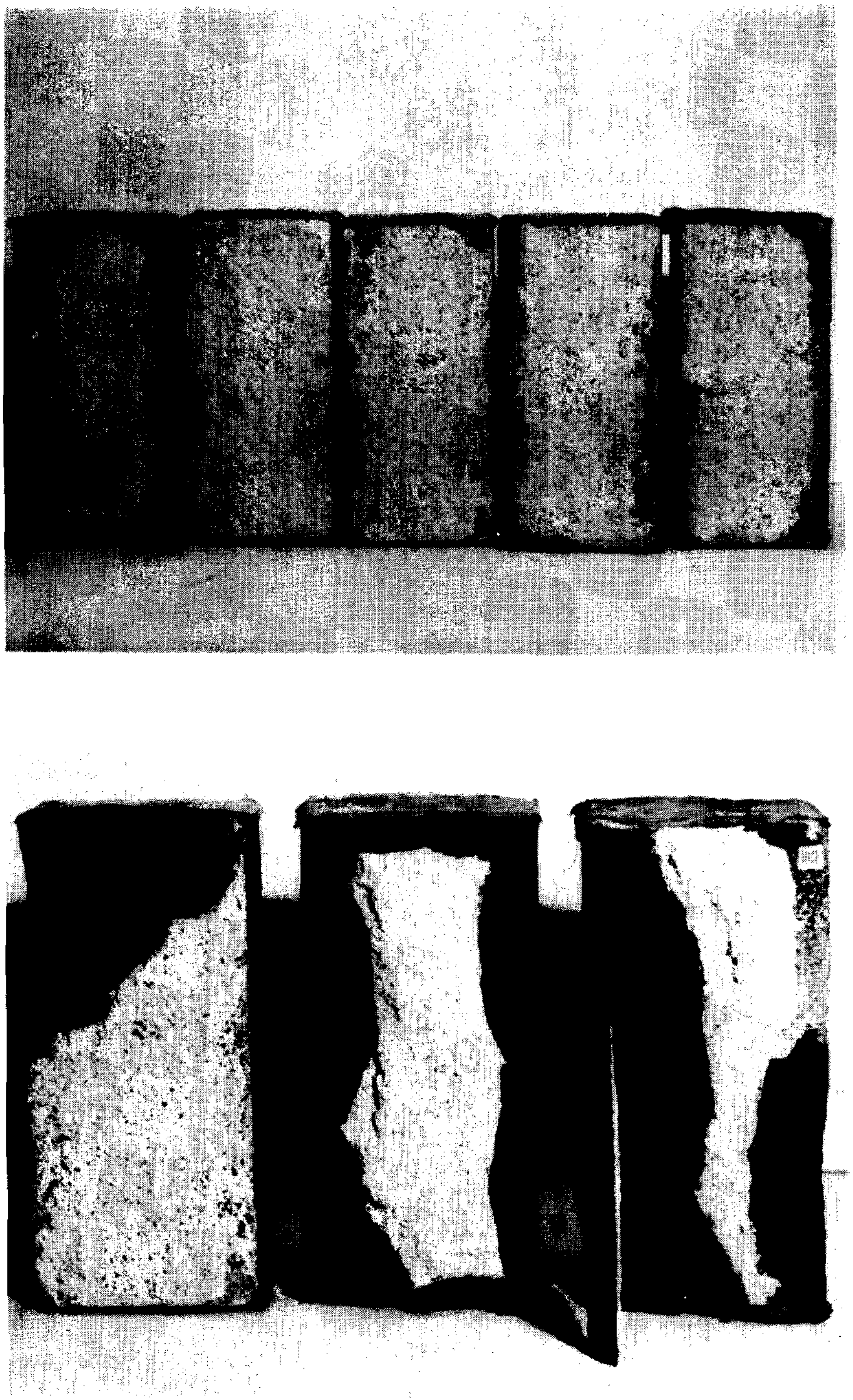

FIGURE 3

Panel P72

Top - Fractured joints. Note complete extent of bond and breaks through mortar beds.

Bottom - Mortar has been chipped away and bricks broken. No evidence of mortar penetrating bricks. Note clean separation between brick and mortar on sample in front of brick on the right.