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LOSS OF MOISTURE FROM MORTARS UPON CONTACT WITH BRICKS OF VARIOUS SUCTIONS

by

J.I. Davison

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PREFACE

Studies of brick masonry are being carried out at the Atlantic Regional Station, as well as in the Ottawa laboratories of the Division. It has already been demonstrated in both laboratories that the removal of water from a fresh mortar bed by the bricks on which it is laid has a marked influence on the bond obtained between the mortar and the bricks subsequently placed on it. Studies carried out at Halifax to provide quantitative information on the rate of moisture removal from mortar and the influence of various brick and mortar properties upon this rate are now reported. Earlier work at the Atlantic Regional Station on the leakage and bond strength characteristics of small brick masonry panels is described in DBR Internal Report No. 161.

Ottawa
April 1959

N.B. Hutcheon
Assistant Director

LOSS OF MOISTURE FROM MORTARS UPON CONTACT

WITH BRICKS OF VARIOUS SUCTIONS

by

J.I. Davison

During previous studies in the laboratory of the Atlantic Regional Station on mortar workability and later during the preliminary program of leakage tests on small panels, there was a significant decrease noted in the moisture content of mortars removed from mortar joints after a three-minute period between two bricks. Leakage tests revealed that almost all leaks occurred at the interface between the bottom of the top brick and the top of the mortar bed. Bond strength tests substantiated this by demonstrating that bond strength values were lower for the joint between the mortar bed and the top brick than for the joint between the same mortar bed and the lower brick. This point became obvious when most of the fractures that occurred when the panels were pulled apart took place between the top brick and the mortar bed.

Attention was thus drawn to the plasticity of the mortar that had been placed on a brick at the time the top brick was set in place. It was thought that in many instances the loss of moisture from the mortar bed to the lower brick might have been sufficient to prove detrimental to ultimate bonding between the mortar bed and the top brick.

This paper, therefore, records results of a study of moisture content losses from several mortars at various time intervals after contact with bricks of different suction.

General

Water is an essential ingredient in the preparation of mortar. In the case of mortars containing cement it combines chemically with the cementitious materials, and this action causes the plastic mixture to harden or "set". Prior to this chemical action, the water present in a mortar mix contributes to the plasticity or workability of the mortar. This latter property is most important in formation of good bond between brick and mortar, for if the mortar is not plastic enough to make intimate contact with all the surface area of the brick, there cannot be good extent of bond; and the resulting unbonded areas provide ready-made passages through which rainwater may pass.

Consider now what happens after a cement mortar has been mixed:

(1) Some of the water will very soon combine with aluminates and silicates in the cement to form gels.

(2) Much later some will combine chemically with constituents of the cement to form hydrates with these components.

(3) Some water will be lost from the mortar by evaporation - a process that can commence as soon as the water is added to the mixture of sand and cementitious materials.

(4) The water in the mortar mix not already accounted for by one of the above reactions exists as "free water", and its amount largely determines the plasticity or workability of the mortar at any given time after mixing.

The surface of a brick contains many small openings, pores, or capillaries. When mortar and brick make contact, the latter, therefore, absorbs water from the former through these openings and the extent to which the "free water" is extracted from the mortar in this manner is the focal point of this study.

In this investigation moisture content was determined by the oven-dry method. During the drying process the "free water" and "gel water" were accounted for by evaporation. It was assumed that there was no "water of hydration" at this early stage; thus, the only water not accounted for would be that lost by evaporation prior to oven-drying. Its significance was investigated by a series of moisture-content determinations on mortars taken from the mixing bowl immediately after mixing and at various times thereafter.

Materials

Bricks

The initial rate of absorption (I.R.A.) or suction was the determining factor in the selection of bricks for this study. Six I.R.A. or suction ranges were selected as follows:

2.0 to 3.0 gm	20.0 to 22.0 gm
6.0 to 8.0 gm	31.0 to 36.0 gm
11.0 to 13.0 gm	60.0 to 77.0 gm

There is only an 11.0-gm spread for the first three groups while there is a 57.0-gm spread for the last three groups. This is because bricks manufactured locally have suction values predominantly within the outer limits of the first three groups. A wider selection within these limits was possible, therefore, and also desirable since the over-all program of which this study is a part is primarily concerned with materials used locally. It was not possible to find one type of brick with an I.R.A. range 2.0 to 77.0 gm. The selection was, however, limited to three types:

(1) a local red brick for I.R.A. range 2.0 to 3.0 gm

(2) a local buff brick for I.R.A. range 6.0 to 36.0 gm

(3) an imported red brick for I.R.A. range 60.0 to 77.0 gm.

After selection, bricks to be used were dried for 72 hours at 110°C, then cooled, wrapped in polyethylene and stored until use. Each brick was used for two tests, one flat surface being used for each test. It is recognized that different I.R.A. values are generally obtained when two surfaces of the same brick are tested; but for the purpose of this study, it was assumed that although there might be two I.R.A. values for the same brick, the suction of the brick generally fell within the limits just outlined. The use of the same brick for two tests thus provided almost similar conditions for duplicate determinations with each mortar. It was not possible to do this with bricks in the 60.0 to 77.0-gm range. Bricks available in this range had a "frog" in one face, and so it was possible to do only one test with each brick. Bricks having I.R.A. values as close as possible, however, were selected for the duplicate tests in this group.

Mortars

Three different mortars were used as follows:

(1) 1:3 - one part by volume masonry cement to three parts sand

(2) 1:1:6 - one part by volume portland cement, one part lime putty, and six parts sand

(3) 1:2:9 - one part by volume portland cement, two parts lime putty, and nine parts sand.

Chezzetcook sand was used in these mortars. It was obtained from a local supplier, air-dried, and passed through a No. 8 sieve. The portion recovered was found by analysis to fall within the limits defined by C.S.A. Specification for particle-size grading for aggregate for masonry mortar (A82.56-1950).

It is interesting to note that local tradesmen use Lawrencetown rather than Chezzetcook sand. In a laboratory analysis it was found that the former does not fall within the C.S.A. limits, having too high a percentage of fines.

Lime putty was obtained from a local supplier. Its density was found to be 79.4 lb per sq ft.

"Canada Brand" masonry cement, a product of Canada Cement Company, and "Maritime Brand" portland cement, manufactured by Maritime Cement Company, were used.

Moisture content determinations were done on samples of masonry cement, portland cement, sand, and lime putty using the oven-dry method. The first three materials were found to be moisture free, while moisture content of the lime putty was found to be 56.3 per cent.

The amounts of the respective materials used in mixing the mortars were calculated using 1/30 cu ft of compacted dry sand as a basis. This volume of sand was found to weigh 1,670.1 gm. Corresponding volumes of the respective materials were calculated and translated to weights using respective density values.

In mixing, the 1:3 mortar 240 cc of distilled water were used, and 220 cc of distilled water were used for the 1:1:6 and 1:2:9 mortars. These amounts of water produced mortars with flows in the range 112 to 118 per cent. Although flows were not an important factor in this study, an attempt was made to work with mortars in a practical flow range. Water retentivity values for the three mortars were obtained using the method outlined in A.S.T.M. Specification C91-49. Values can be seen in Table I.

Procedure

All mortars were mixed in a Hobart N50 mixer in the usual manner. The water, cement, and lime putty were put in the mixing bowl, the mixer was started and the sand was added during the first fifteen seconds of mixing at low speeds. After two minutes mixing, the speed was increased from low to medium and mixing continued for another minute. The mortar was allowed to remain in the bowl for one minute after mixing before proceeding with the experiment.

Moisture Content Determinations to Assess Loss by Evaporation

Nine glass petri plates were dried in the oven at 100°C, then cooled and weighed. A mortar sample was taken from the mixing bowl at 0 time (one minute after mixing as noted), placed in No. 1 petri plate and weighed, after which the petri plate and contents were placed in the drying oven. This procedure was repeated at 45 sec, 1 1/2 min, 2 min, 3 min, 4 min, 5 min, 10 min and 30 min. Weighing was done with a Mettler Precision Balance.

Scale divisions on the balance represent 1 gm, and accuracy is ± 0.3 gm. This balance was used because of the time element involved. The time required to weigh the samples on a double-pan torsion balance would have defeated the purpose of removing samples at such frequent intervals. Accuracy of the Mettler Balance was considered adequate enough to assess the effect of evaporation. The results for the three mortars are shown in Table II. Examination of these results indicates that moisture loss via evaporation is negligible and is, therefore, not a factor necessitating any further consideration within the scope of this study.

Moisture Content Determinations on Mortar Samples After Contact With Bricks

Mortar was taken from the mixing bowl 1 minute after mixing (0 time) and placed on the brick using the mortar frame. Excess mortar was screeded off and the mortar frame removed leaving a mortar bed 3/8-in. thick. This is the same procedure followed in preparing mortar beds during panel assembly. At 45 seconds a sample was taken from the brick and placed in one of six petri plates which had been dried previously in the oven at 100°C, cooled and weighed. Successive samples were similarly taken at 1 1/2 min, 2 min, 3 min, 4 min and 5 min. Meanwhile plates containing samples were being weighed on a double-pan torsion balance, having an accuracy of ± 0.1 gm, by a second operator.

Method of Sampling

Prior to removing samples from the brick, the mortar bed was divided roughly into 18 sections, 6 samples being taken as shown in Fig. 4. Samples were removed from the brick with a steel spatula. Each sample weighed approximately 20 gm.

All samples remained in the drying oven at 100°C overnight, minimum oven-time being sixteen hours. After removal from the oven samples were allowed to cool to room temperature and were then re-weighed.

Calculations

Moisture content was obtained from the formula:

$$M.C.\ (\%) = \frac{W_1 - W_2}{W_2 - W} \times 100$$

Where W = weight of empty petri plate
W_1 = weight of petri plate and sample from brick
W_2 = weight of petri plate and sample after drying.

Results are shown in Tables III, IV, and V, and graphically in Figs. 1, 2, and 3.

Effect of Reduced Moisture Content on Plasticity of a Mortar

Some mortars having lower moisture-content values similar to those found in the above study were prepared, and flow values obtained in order to determine the effect of this moisture loss on the plasticity of the mortar.

The three mortars were used and mixed, using lesser amounts of water to reproduce moisture contents found for these mortars after contact with bricks in I.R.A. range 11.0 to 13.0 gm. Results are shown in Table VI.

Results

1:3 Mortar

Loss of total moisture from this mortar to the various bricks ranged from a low of 17.6 per cent after a 45-sec contact with a low I.R.A. brick to 63.9 per cent after a 5-min contact with a brick of high suction. During the first 45 sec of contact 17.6 to 28.5 per cent of the total moisture in the mortar was absorbed by the various bricks. Results are erratic for bricks having low suction, but a more uniform pattern of moisture loss develops as I.R.A. of the bricks increases.

1:1:6 Mortar

Loss of total moisture from this mortar ranged from 5 per cent after 45-sec contact with a low suction brick to 42.8 per cent at 5-min contact with a high I.R.A. brick. Total moisture loss after 45-sec contact with the six bricks ranged from 5 to 17.6 per cent. Moisture-loss pattern was again erratic for bricks with low suction but became quite regular as brick suction increased.

1:2:9 Mortar

Loss of total moisture from this mortar ranged from 0.6 per cent after 45-sec contact with a low I.R.A. brick to 39.5 per cent after 5-min contact with a high suction brick. Total moisture loss after a 45-sec contact with the six bricks ranged from 0.6 to 13.4 per cent. As in the case of the other two mortars, greater uniformity developed in results with increasing brick suction.

General Observations

(1) Examination of the graphs indicates:

(a) Moisture loss from all mortars is greatest during the initial stages of contact with a brick

(b) Increasing water retentivity of 1:1:6 and 1:2:9 mortars is reflected by a "levelling off" of curves for these mortars by comparison with 1:3 mortar curve.

(2) Table VI shows that early loss of moisture from mortars upon contact with bricks reduces their flow values to levels at which plasticity of the mortar is not sufficient to ensure good bond with another brick.

(3) It is also interesting to note the increasing discrepancy, as lime content in the mortars is increased, between calculated moisture contents and values obtained at 0 time using the oven-dry method.

Mortar	Calculated Value	Oven-Dry Value
1:3	11.9%	11.9%
1:1:6	16.8%	15.9%
1:2:9	19.1%	17.2%

Calculated and "obtained" values for the 1:3 mortar made with masonry cement were identical but the oven-dry value for the 1:1:6 mortar was less than the calculated value, and there was an even bigger difference for the 1:2:9 mortar. Lime putty with a moisture content of 56.2 per cent was used in preparing the latter two mortars, and this figure was used in obtaining their calculated moisture-content values.

(4) Visual observations of the cross-section of mortar samples as they were removed from bricks in the higher suction ranges revealed a definite moisture gradient. The layer nearest the brick appeared coarse and dry while succeeding layers had a much more plastic appearance.

Conclusions

A substantial reduction in the moisture content of a mortar takes place upon contact with bricks, and this reduction increases as the suction of the brick increases. Greatest moisture loss takes place during the initial stages of contact; and during this time, with bricks of high suction, moisture losses are sufficient to lower plasticity of the mortar to a point where it is not capable of good bonding with another brick.

Moisture losses become smaller as the lime content of the mortar increases, the greatest losses occurring with a 1:3 masonry cement mortar and high suction brick, the smallest losses with a 1:2:9 mortar and low suction brick.

It would seem, therefore, that the time lapse between laying a mortar bed and placing the bricks upon it is critical with respect to ultimate bonding between the two. This aspect will be investigated in a later study.

When assessing the results recorded in this study, and in particular in noting the inconsistencies especially with low I.R.A. bricks, the following considerations should be noted:

(1) The purpose of this study was to learn something of the aspect of moisture loss from mortar during early stages of contact with bricks; it is, therefore, not an exhaustive study on moisture content losses. Figures for moisture content are usually an average of two tests. A greater number of tests undoubtedly would have been desirable.

(2) It is suspected that different areas of a brick surface have suction values differing from the I.R.A. of the brick. This would tend to produce inconsistent results for mortar samples taken from different parts of the same brick. These inconsistencies could be eliminated by using six bricks having the same I.R.A. for the six samples of each mortar. Such a program would require a large number of bricks, and the study would require much more time.

(3) Larger samples might also help to eliminate inconsistencies. However, the samples used were convenient to work with and adequate for the purpose of this study.

TABLE I

WATER RETENTIVITY OF MORTARS

MORTAR	INITIAL FLOW	WATER RETENTIVITY VALUE
1:3	118.5	73.4
1:1:6	116.0	79.0
1:2:9	116.0	91.4

1:3 Mortar - 1 part by vol. Masonry Cement: 3 parts Sand

1:1:6 Mortar - 1 part by vol. Portland Cement: 1 part Lime Putty: 6 parts Sand.

1:2:9 Mortar - 1 part by vol. Portland Cement: 2 parts Lime Putty: 9 parts Sand.

TABLE II

MOISTURE CONTENT (%) OF MORTARS
AT DIFFERENT TIMES AFTER MIXING

TIME	MORTAR 1:3	1:1:6	1:2:9
0	11.9	15.9	17.2
45 sec.	11.6	16.0	17.6
$1\frac{1}{2}$ min.	11.6	16.0	17.9
2 min.	11.8	16.2	17.7
3 min.	12.0	16.1	17.7
4 min.	11.8	15.9	17.5
5 min.	11.5	15.8	17.6
10 min.	11.8	15.8	17.6
30 min.	11.8	16.1	17.2

Time "0" was 1 minute after completion of mixing.

All results are average of 2 tests--except 1:2:9 mortar which is average of 4 tests.

TABLE III

M.C. VALUES AND % OF TOTAL MOISTURE LOSS FROM 1:3 MASONRY CEMENT MORTAR AT DIFFERENT TIMES AFTER CONTACT WITH BRICKS OF DIFFERENT I.R.A.

	I.R.A. OF BRICKS - GM.											
	2.5		7.0		12.6		20.2		35.0		60.3 & 60.4	
TIME	M.C. %	% LOSS	M.C. %	% LOSS	M.C. %	% LOSS	M.C. %	% LOSS	M.C. %	% LOSS	M.C. %	% LOSS
45 sec.	9.8	17.6	9.4	21.0	9.8	17.6	9.2	22.7	8.5	28.5	9.1	23.5
1½ min.	10.5	11.8	9.5	20.1	8.9	25.2	8.7	26.9	8.1	31.9	8.1	31.9
2 min.	10.1	15.1	9.0	24.3	8.9	25.2	7.8	34.3	7.0	41.2	7.7	35.2
3 min.	9.2	22.7	8.0	32.8	8.0	32.8	6.8	42.8	6.8	42.8	6.9	42.0
4 min.	8.9	25.2	7.7	35.2	6.9	42.0	6.4	46.2	5.5	53.8	6.5	45.4
5 min.	8.1	31.9	7.0	41.2	5.9	50.4	5.8	51.3	4.3	63.9	5.1	57.1

% loss is the loss at each time interval compared with moisture content at "0" time. For the latter value see Table II.

All results are average of 2 tests.

I.R.A., initial rate of absorption, is the amount of water (gm.) absorbed per 30 sq. in. of flat surface when a brick is immersed in 1/8 in. water for 1 minute.

TABLE IV

M.C. VALUES AND % OF TOTAL MOISTURE LOSS FROM 1:1:6 MORTAR AT DIFFERENT TIMES AFTER CONTACT WITH BRICKS OF DIFFERENT I.R.A.

TIME	I.R.A. OF BRICKS - GM. 2.3		7.2		12.6		21.2		35.6		66.5 & 67.5	
	M.C. %	% LOSS	M.C. %	% LOSS	M.C. %	% LOSS	M.C. %	% LOSS	M.C. %	% LOSS	M.C. %	% LOSS
45 sec.	15.1	5.0	14.0	11.9	14.9	6.3	13.6	14.5	13.1	17.6	13.1	17.6
1½ min.	13.8	13.2	13.3	16.3	13.2	17.0	13.3	16.3	11.8	25.8	11.9	25.1
2 min.	14.4	9.4	12.7	20.1	12.9	18.9	13.1	17.6	11.8	25.8	11.2	29.5
3 min.	14.4	9.4	12.2	23.3	12.7	20.1	11.9	25.1	10.8	32.1	11.0	30.8
4 min.	13.7	13.8	13.0	18.2	12.2	23.3	11.6	27.0	10.0	37.1	10.7	32.7
5 min.	13.8	13.2	12.6	20.8	11.9	25.1	11.1	30.2	9.2	42.0	9.1	42.8

% loss is the loss at each time interval compared with moisture content at "0" time. For the latter value see Table II.

All results are average of 2 tests.

I.R.A., initial rate of absorption, is the amount of water (gm.) absorbed per 30 sq. in. of flat surface when a brick is immersed in 1/8 in. of water for 1 minute.

TABLE V

M.C. VALUES AND % OF TOTAL MOISTURE LOSS FROM 1:2:9 MORTAR
AT DIFFERENT TIMES AFTER CONTACT WITH BRICKS OF DIFFERENT I.R.A.

	I.R.A. OF BRICKS - GM.											
	2.6		7.0		11.8		21.7		34.0		76.4 & 77.0	
TIME	M.C. %	% LOSS	M.C. %	% LOSS	M.C. %	% LOSS	M.C. %	% LOSS	M.C. %	% LOSS	M.C. %	% LOSS
45 sec.	17.1	0.6	15.6	9.3	15.6	9.3	16.2	5.8	15.3	11.0	14.9	13.4
1½ min.	16.3	5.2	14.6	15.1	14.7	14.5	14.8	14.0	13.3	22.7	14.3	16.9
2 min.	16.3	5.2	15.5	9.9	14.3	16.9	13.7	20.3	13.7	20.3	13.4	22.1
3 min.	16.0	6.9	14.7	14.5	13.3	22.7	12.8	25.6	12.6	26.7	13.3	22.7
4 min.	15.8	8.1	14.3	16.9	13.0	24.4	12.2	29.1	11.3	34.3	12.3	28.5
5 min.	16.6	3.5	14.6	15.1	11.6	32.6	10.4	39.5	11.4	33.7	12.3	28.5

% loss is the loss at each time interval compared with moisture content at "0" time. For the latter value see Table II.

All results are average of 2 tests.

I.R.A., initial rate of absorption, is the amount of water (gm.) absorbed per 30 sq. in. of flat surface when a brick is immersed in 1/8 in. water for 1 minute.

TABLE VI

FLOW VALUES FOR MORTARS
WITH REDUCED MOISTURE CONTENTS

MORTAR					
1:3		1:1:6		1:2:9	
M.C. %	FLOW %	M.C. %	FLOW %	M.C. %	FLOW %
11.1	119.0	15.4	112.5	17.5	109.5
9.9	86.5	14.9	82.5	15.6	69.5
9.0	61.0	13.2	60.0	14.7	63.0
8.3	32.0	12.9	56.0	14.3	62.5

M.C. values for 1:3 and 1:1:6 mortars obtained from tests with brick having I.R.A. 12.6 gm.--values for 1:2:9 mortar with brick having I.R.A. 11.8 gm.

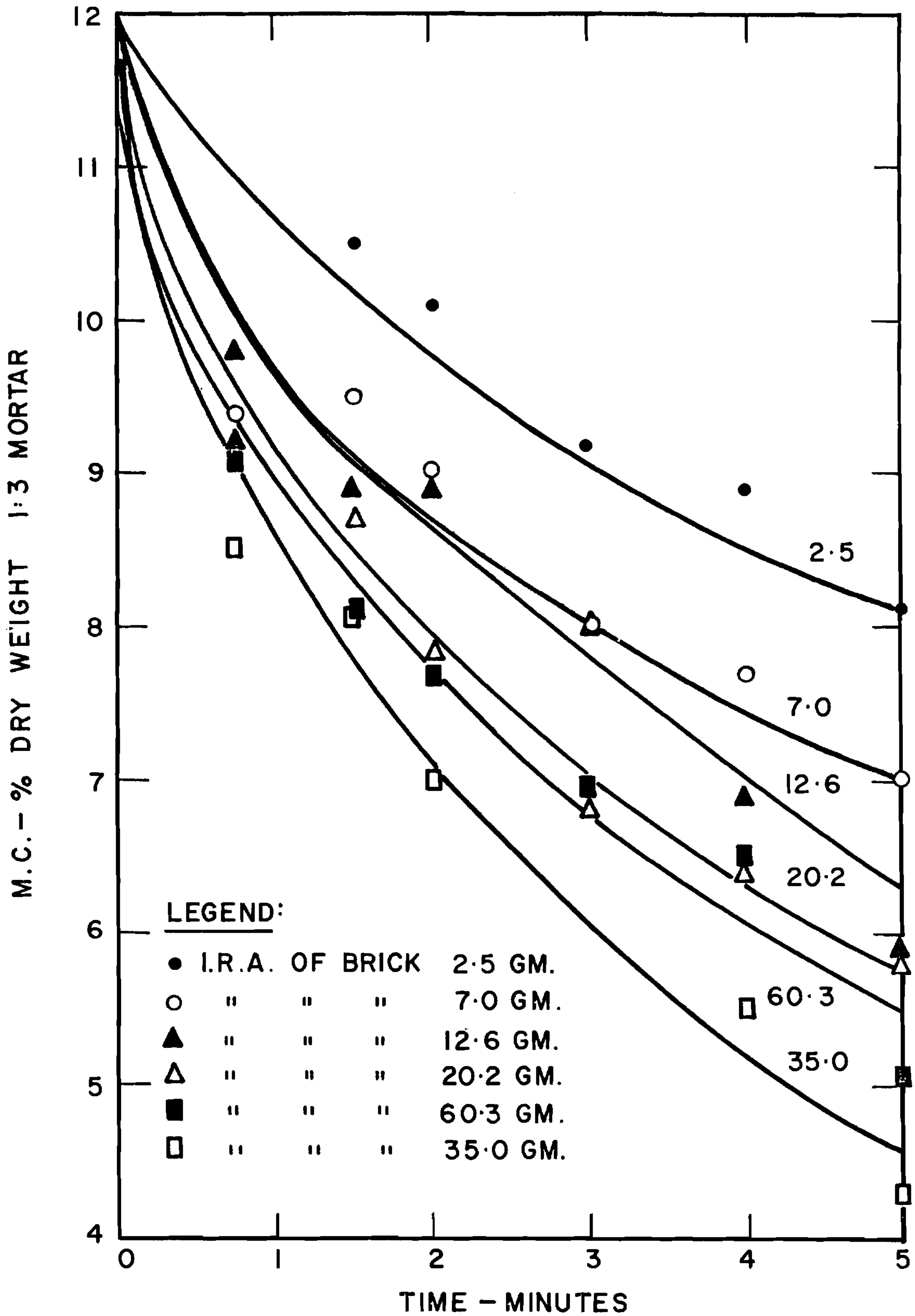
M.C. – % DRY WEIGHT 1:3 MORTAR
TIME – MINUTES
2·5
7·0
12·6
20·2
60·3
35·0
LEGEND:
I.R.A. OF BRICK 2·5 GM.
" " " 7·0 GM.
" " " 12·6 GM.
" " " 20·2 GM.
" " " 60·3 GM.
" " " 35·0 GM.

FIGURE 1

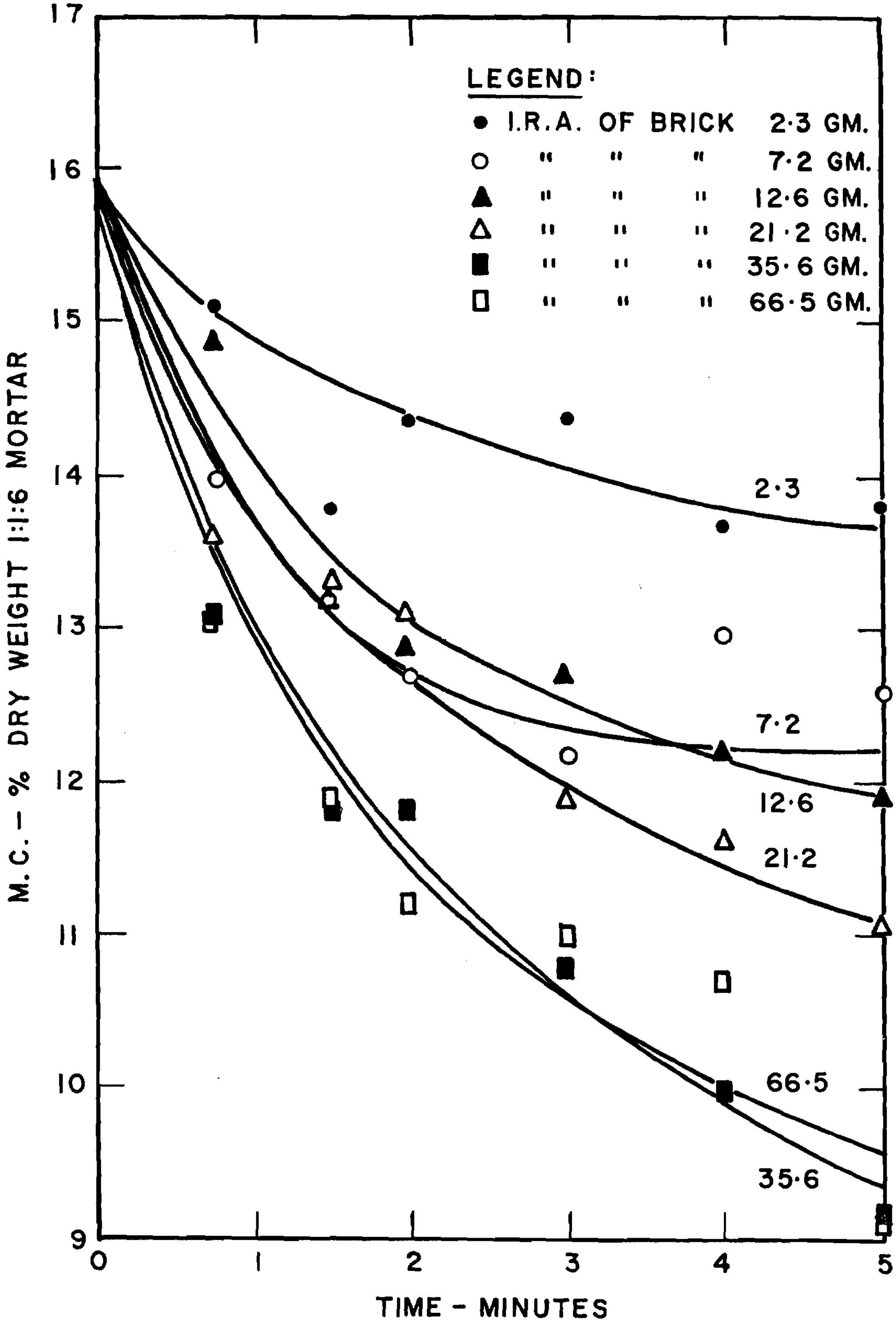
LEGEND:
● I.R.A. OF BRICK 2·3 GM.
○ " " " 7·2 GM.
▲ " " " 12·6 GM.
△ " " " 21·2 GM.
■ " " " 35·6 GM.
□ " " " 66·5 GM.
2·3
7·2
12·6
21·2
66·5
35·6
M.C. – % DRY WEIGHT 1:1:6 MORTAR
TIME – MINUTES
17
16
15
14
13
12
11
10
9
0
1
2
3
4
5

FIGURE 2

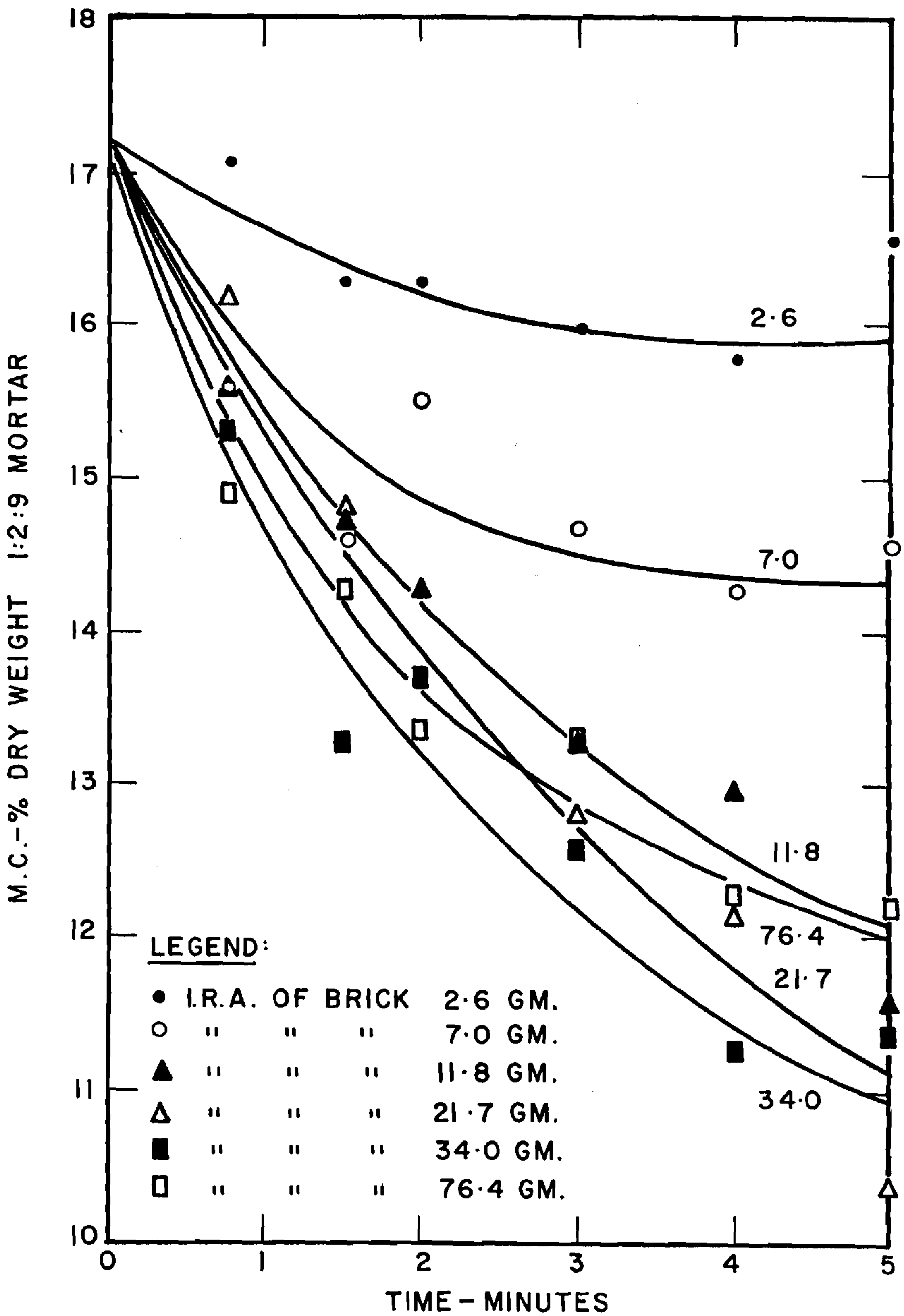
M.C.-% DRY WEIGHT 1:2:9 MORTAR
TIME - MINUTES
18
17
16
15
14
13
12
11
10
0
1
2
3
4
5
2·6
7·0
11·8
76·4
21·7
34·0
LEGEND:
I.R.A. OF BRICK 2·6 GM.
" " " 7·0 GM.
" " " 11·8 GM.
" " " 21·7 GM.
" " " 34·0 GM.
" " " 76·4 GM.

FIGURE 3

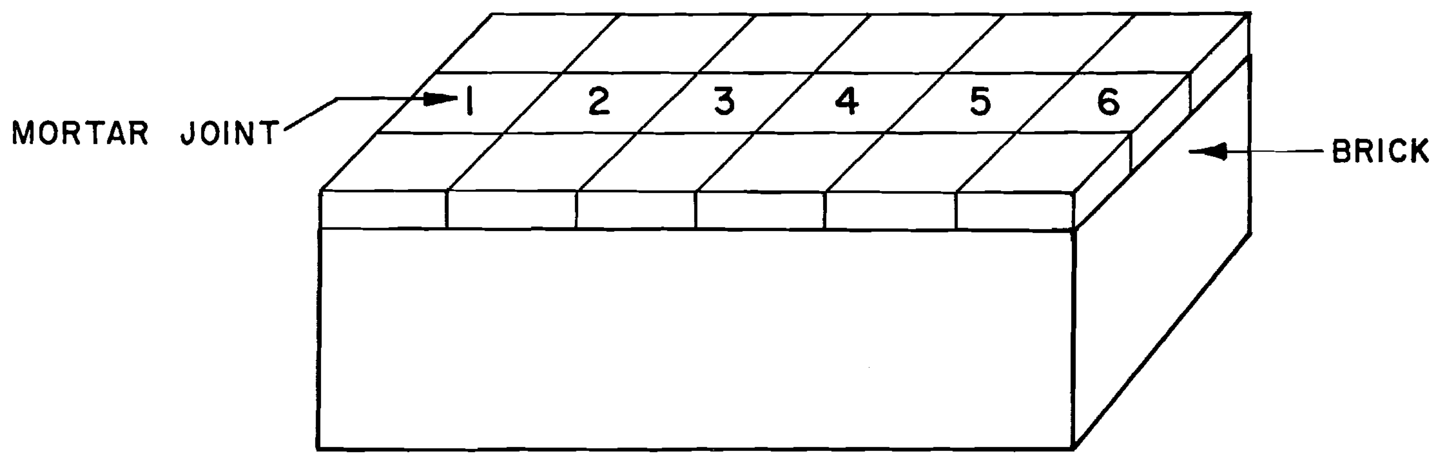

FIGURE 4 MORTAR SAMPLES FROM BRICK