Initial and Short Term Effects of a Clear Coating on Water Permeance of Masonry

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Abstract - The results of water permeance tests on twelve walls before and after coating with a proprietary clear water-repellent are reported. The walls were then retested after six months outside exposure. Half of the single-wythe walls were brick, the other half, normal weight concrete masonry units. Half of the walls used masonry cement mortar, the other half, portland cement-lime mortar. Comparison of results revealed a significant reduction in the amount of leakage, an increase in the amount of time required to achieve maximum rate of leakage, and a decrease in the percentage of damp area as a result of the application of the coating. After six months outdoor exposure, retests of the walls showed little effect from exposure.

KEY WORDS: Water permeance, coatings, brick, concrete masonry, masonry, concrete block.

1. INTRODUCTION

One of the primary functions of a building enclosure is to prevent permeance or infiltration of wind-driven rain to the interior. In masonry construction, proper selection of a wall system, good workmanship, proper detailing, and material compatibility are important in minimizing, if not eliminating, the water permeance problem. In some buildings, when one or more of these details is improper, water permeance may result. In such cases, one solution may be the application of a clear, water-repellent coating.

The paper presents an evaluation of the resistance to water penetration of masonry walls before and after being treated with an oil and sterate modified mineral gum. The paper also considers the effect of 6 months outdoor exposure on the performance of the water repellent. The paper does not consider the effect of the coating on vapor transmission, if any.

2. RESEARCH OBJECTIVES AND SCOPE

The purpose of the research was to evaluate the effectiveness of a particular water repellent when applied to masonry walls constructed of either brick or normal weight concrete masonry units using either masonry cement mortar or portland cement-lime mortar. A total of twelve single-wythe walls were tested-six of brick, and six of concrete block. Within each group of six walls, three were constructed of masonry cement mortar, and three of portland cement-lime mortar.

In order to determine the effectiveness of the water repellent, each wall was first tested uncoated, using ASTM E514-79, "Standard Method of Test for Water Permeance of Masonry." The walls were then coated and the water permeance tests repeated. The third phase of this research included retesting the walls for water permeance after storage in an outdoor exposure for a period of approximately six months.

3. MATERIALS

3.1 Brick

The brick used in the construction of the brick masonry walls were of approximately 5.7 x 8.9 x 20.3 cm dimension with three cores. The brick was found to be in compliance with ASTM C216, "Facing Brick" Specifications. Material properties were tested in accordance with ASTM C67, "Sampling and Testing Brick and Structural Clay Tile," the results of which are reported in Table 1.

3.2 Concrete Block

The concrete block used were of nominal 15.2 x 20.3 x 40.6 cm dimension, normal weight aggregate units with two cores. They were tested in accordance with ASTM C140, "Sampling and Testing Concrete Masonry Units." Properties of the units are presented in Table 2.

3.3 Mortar

3.3.1 Portland Cement-Lime Mortar - Type N Portland cement-lime mortar was used in accordance with the requirements of ASTM C270, "Mortar for Unit Masonry." Water was added as required by the mason, and the flow averaged 109%.

3.3.2 Masonry Cement Mortar - The masonry cement mortar used was Type N, certified to be in compliance with ASTM C91, "Masonry Cement." Mortar was mixed according to manufacturers instructions.

3.4 Other Materials

Portland cement was certified to be in compliance with ASTM C150, "Portland Cement." Lime was certified to be in compliance with ASTM C207. Masonry sand was a natural sand available locally with a sieve analysis in conformance with ASTM C144, "Aggregate for Masonry Mortar."

3.5 Mixing

All ingredients were proportioned by weight on the basis of unit weights determined in the laboratory. Mixing was done in a 0.07 m^3 paddle-type mixer using sufficient water to produce a workability satisfactory to the mason. The size of each batch was such that a single mason could use it in not more than two hours. He was permitted to re-temper the mortar as required during that time.

4. FABRICATION OF TEST SPECIMENS

4.1 Construction

Walls were constructed in the testing laboratory in Lowry Hall, Clemson University, by an experienced journeyman mason using construction methods which may be considered excellent.

The brick walls were single wythe, approximately 117 cm wide and 130 cm high (Fig. 1). They were constructed on a 15.2 cm inverted steel channel where they remained throughout the test program period. Bedjoints were moderately furrowed and headjoints were completely filled with mortar. The top and edges of brick walls were parged with approximately 1 cm of mortar.

The joints were tooled to a concave configuration on only the side of the wall exposed to the test conditions.

The single-wythe concrete block walls were approximately 104 cm wide and 142 cm high, constructed on an inverted 20.3 cm steel channel (Fig. 2). The mason used face-shell bedding, and headjoints were constructed the full width of the face shells. A single course of brick was first laid on which the flashing was placed. The flashing width was sufficient to completely obstruct the concrete block cores. The ends of the block walls were parged, but the top was not because of the large core openings. However, parging was later added to the top of the concrete block walls to reduce air infiltration of the coated walls.

4.2 Curing

The walls were stored in the laboratory for 28 days after construction. The walls constructed of masonry cement mortar were covered with polyethylene sheets in order to maintain high relative humidity. Portland cement lime mortar walls were not covered.

The laboratory did not have temperature or humidity control. However, temperature and humidity were continuously monitored with a hygrothermograph. The laboratory was in conformance to the requirements of temperature range in ASTM E514. However, the relative humidity occasionally was monitored at 75%, an amount in excess of the 70% upper limit permitted in ASTM E514.

4.3 Outdoor Storage

After the walls were tested without coating, then retested with coating, they were moved to a location just outside the laboratory. They were securely braced with the coated face oriented to the south. The walls were exposed from August 20, 1980 to February 20, 1981.

In moving the walls, special precautions were taken to minimize accidental cracking. Each wall was vertically post-tensioned using 4 threaded rods each with a diameter of 1.27 cm. They were moved with a fork lift and kept in a vertical position at all times.

Weather data for Greer Airport located 72 km northeast of Clemson is summarized in Fig. 3. The weathering index (ASTM C216) for the period was 860.

5. TESTING EQUIPMENT AND PROCEDURE

The walls were tested in groups of three prior to application of the coating. Water flows were monitored using calibrated rotameters, with one rotameter dedicated to each wall chamber. Air pressure was monitored with a manometer attached to each wall chamber. The water was supplied to the chambers using a recirculating pump which recycled the overflow water. Test conditions were equivalent to 14 cm of rain per hour and a wind of 99 km/h, both applied continuously to each wall for a period of 72 hours.

There were two unexpected events which occurred during the test program. Wall No. 1 experienced a flexural tensile failure as the air pressure was gradually increased to 0.479 kN/m^2. A third clamp added to each side of the walls prevented the recurrence of this phenomenon. The affected wall was post-tensioned externally with four 1.27 cm diameter threaded rods and the tests continued. Before the wall was post-tensioned, water passed through the flexural tension crack profusely. However, after post-tensioning, no

visible water appeared to come through the crack. In fact, the wall which underwent flexural tension failure and subsequent post-tensioning had the best resistance to water permeance of its group.

A second anomaly was observed to occur in all of the concrete block walls. Before the application of the coating, the walls were tested simultaneously in groups of three. However, after application of the coating, the air supply system in the laboratory was not sufficient to maintain the required air pressure. Air was passing through the walls at a substantially greater rate apparently because of the absence of absorbed water. It was therefore necessary to test each of the coated concrete block walls separately. It should be noted that the test conditions for the coated concrete block walls were very severe in terms of the volume of air pumped into the chamber in order to maintain the required pressure of 0.48 kN/m^2.

6. APPLICATION TECHNIQUE FOR COATING

After each set of walls was initially tested, they were allowed to dry in laboratory air until there was no visible water on the surface. An additional 24 hours then elapsed before application of the clear coating. A garden type pressurized sprayer with the nozzle adjusted to discharge a low-pressure stream rather than a spray was used. Application began at the top of the wall moving the wand slowly in a horizontal direction, repeatedly until the liquid coating had run down the face of the wall at least 30 cm below the point of application. A minimum of 30 cm "run-down" was maintained throughout the treatment of the wall. After coating was applied with the sprayer, the wall was brushed with a soft bristle brush to help work the material into the surface.

An attempt was made during application of the coating to collect the run-off at the bottom of the wall. It was estimated that only about half of the run-off was reclaimed using the collection system devised. Nevertheless, the run-off data is presented in Table 3 in addition to the application rates. The application rates given in Table 3 have not been corrected for run-off.

It should be noted that the application rate used for the brick walls was within the recommended application rates of the manufacturer (2.45 - 3.68 m^2/ℓ). However, the application rate for concrete masonry was considerably higher than that recommended. The manufacturer's recommended application rate did not produce a 30cm "run-down". The average coverage for concrete masonry walls in this project was 0.59 m^2/ℓ. This is considerably less than the recommended coverage rate for concrete masonry of 1.47 - 2.45 m^2/ℓ. The reader is cautioned against the use of the data developed in this research project for coverage rates which differ from those used herein.

7. TEST RESULTS AND ANALYSIS

During the 72-hr. testing period, observations required in ASTM E514 were recorded. These observations are presented in Tables 4, 5 and 6. In addition to the tables, graphs of flow rate vs. time (Figs. 4,5) and percentage damp area vs. time (Figs 6,7) are presented as visual indications of typical performance of the walls before and after coating and after exposure.

There are several ways to evaluate the effectiveness of the coating. Of particular significance is the effect of the coating on maximum rate of flow, the amount of time required to achieve maximum rate of flow, and extent of damp area. The maximum rate of leakage for uncoated brick walls averaged 0.3 liters per hour (ℓ/hr). Only one of those walls leaked after coating, and at a maximum rate of 0.16 ℓ/hr compared to its maximum uncoated rate of 0.75 ℓ/hr. Outdoor exposure for 6 months resulted in a further reduction in flow.

The average maximum rate of leakage for uncoated concrete block walls was 90 ℓ/hr. After coating, only two of six walls continued to leak, Wall No. 4 at a 99% reduced rate, and Wall No. 6 at an 81% reduction. Exposure to outdoors for 6 months resulted in further decreases in leakage.

The amount of time required for maximum rate of leakage to occur for uncoated walls ranged from 1/2 hr to 7 hrs, averaging 2.2 hrs. After coating, the three of twelve walls that leaked experienced a maximum flow on the average of 22 hours after the test began. After 6 months exposure, the same three walls experienced maximum flow, an average of 50 hrs after beginning the test.

The maximum percentage of damp area was reduced from an average of 93% to an average of 20% by the application of the coating. This value increased slightly after 6 months exposure. In fact, exposure appeared to increase maximum percentage of damp area of concrete masonry walls from 15% (coated, unexposed) to 33% (coated, exposed).

The time to visible moisture, and time to visible water were not as greatly affected by the coating as were other observations. Notable improvement was, however, observed in Walls 4, 8, 9, 10 and 12. Outdoor exposure further increased the times, on the whole.

Water permeance ratings are also included in Table 4. Six of the twelve walls improved in rating classification by at least one category due to application of the coating. Five of the six walls were concrete masonry. After 6 months exposure, five walls improved in rating, four were unchanged, and three diminished in rating.

8. SUMMARY AND CONCLUSIONS

Twelve masonry walls were constructed and tested for water permeance according to ASTM E514. The walls were then coated with a single application of proprietary clear coating and retested. They were then retested after outdoor exposure for six months. Comparison of test results of the uncoated and initial test results on coated walls (i.e. without exposure) revealed the following:

1) The maximum rate of leakage was significantly decreased, if not completely eliminated, in all walls.

2) The amount of time required to achieve maximum rate of leakage was increased from an average of 2.2 hrs to an average of 22 hrs in those walls in which leakage was not completely eliminated.

3) The maximum percentage of damp area was reduced from an average of 93% to an average of 20%.

4) The amount of time required for observing visible moisture and visible water was significantly increased in five of twelve walls.

5) Half of the walls improved in rating classification by at least one category.

Comparison of coated wall tests before and after outdoor exposure revealed the following:

6) Extent of damp area of concrete masonry walls increased after outdoor exposure, but rate of leakage decreased.

7) Outdoor exposure for six months generally did not result in diminished performance of the coating (exception is in previous conclusion).

These conclusions are based on the coverage rates (Table 3) used on the concrete masonry walls which are lower than recommended by the manufacturer. Future testing will determine the effectiveness of the coating after an additional twelve months outdoor exposure.

9. PROPOSED FUTURE TESTING

In order to determine the continued effect of outside exposure on the effectiveness of the coating, the walls will be stored outdoors with the treated surfaces facing a southern exposure for an additional period of twelve months. The walls will then be returned to the laboratory and retested for water permeance.

10. ACKNOWLEDGEMENTS

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TABLE 1 - BRICK PROPERTIES

SAMPLE	COMPRESSIVE STRENGTH (MN/m^2)	ABSORPTION (%) 5 Hr. COLD	24 Hr. COLD	5 Hr. BOIL	SATURATION COEFFICIENT	INITIAL RATE OF ABSORPTION ($g/194\ cm^2$)
1	117	5.28	5.33	7.35	.73	7.8
2	119	5.53	5.81	7.99	.73	13.5
3	129	5.57	5.80	7.95	.73	12.0
4	141	5.10	5.47	7.36	.74	9.5
5	139	5.02	5.28	7.27	.73	9.0
Average	129	5.30	5.54	7.58	.73	10.4

TABLE 2 - CONCRETE MASONRY UNIT PROPERTIES

SAMPLE	UNIT WT (kN/m^3)	COMPRESSIVE STRENGTH (MN/m^2) GROSS AREA	NET AREA	ABSORPTION %	MOISTURE CONTENT %
1	20.7	12.2	21.5	7.41	11.43
2	20.9	12.6	21.7	6.36	10.81
3	20.9	11.8	20.3	6.74	10.00
4	20.9	12.6	19.8	6.32	12.00
5	21.0	12.7	20.0	6.16	10.26
6	20.7	12.7	19.8	6.18	8.21
Average 1-3[a]	20.8	12.2	21.2	6.84	10.75
Average 4-6[a]	20.9	12.6	19.9	6.22	10.15

[a]Units 1-3 were stretcher units, 4-6 single corner units

TABLE 3 - COATING APPLICATION DATA

WALL #	APPLICATION RATE (m^2/l)	RUNOFF COLLECTED %	MASONRY UNIT	MORTAR
1	2.95	29	BR[a]	MC[b]
2	3.11	36	BR	MC
3	3.06	33	BR	MC
4	0.71	6	CM[c]	MC
5	0.54	5	CM	MC
6	0.74	6	CM	MC
7	0.47	4	CM	PC[d]
8	0.51	4	CM	PC
9	0.61	6	CM	PC
10	3.38	28	BR	PC
11	3.21	29	BR	PC
12	3.80	33	BR	PC
Average Brick Wall	3.26	31		
Average Block Wall	0.59	5		

[a]Brick

[b]Masonry Cement Mortar

[c]Concrete Masonry

[d]Portland Cement-Lime Mortar

TABLE 4 - DAMP AREA AND RATINGS BEFORE AND AFTER COATINGS

Wall No.	Masonry Unit	Mortar	EXTENT OF DAMP AREA (%) 24 Hrs. Uncoated	24 Hrs. Coated	24 Hrs. Exposed[b]	48 Hrs. Uncoated	48 Hrs. Coated	48 Hrs. Exposed[b]	72 Hrs. Uncoated	72 Hrs. Coated	72 Hrs. Exposed[b]	Rating[a] Uncoated	Rating[a] Coated	Rating[a] Exposed[b]
1	BR	MC	98	5	0	100	10	2	100	10	3	P	P	E
2	BR	MC	95	32	<0.5	99	56	3	99	56	4	P	P	E
3	BR	MC	91	33	16	96	38	19	98	42	23	P	P	P
4	CM	MC	83	18	20	83	20	20	87	20	22	L	F	P
5	CM	MC	93	10	20	93	10	30	93	8	33	L	P	F
6	CM	MC	83	37	33	83	37	37	83	37	38	L	L	L
7	CM	PC	85	12	13	85	12	25	85	12	33	L	P	F
8	CM	PC	93	2	7	93	10	22	93	13	32	L	F	F
9	CM	PC	83	7	18	83	8	28	80	2	38	L	F	P
10	BR	PC	96	27	7	98	32	8	100	24	9	P	P	P
11	BR	PC	96	19	8	99	21	13	99	12	15	P	P	F
12	BR	PC	95	2	4	97	2	5	99	2	6	P	E	F

[a] Ratings are defined in ASTM E514-79

[b] Exposed to outdoor climate for 6 mos.

TABLE 5 - RATES OF LEAKAGE

Wall No.	RATE OF LEAKAGE (1/hr)									MAXIMUM RATE OF LEAKAGE (1/hr)		
	24 Hrs.			48 Hrs.			72 Hrs.					
	Uncoated	Coated	Exposed	Uncoated	Coated	Exposed	Uncoated	Coated	Exposed	Uncoated	Coated	Exposed
1	.0542	-[a]	-	-	-	-	.0780	-	-	.2101	-	-
2	.3001	< .0500[b]	-	.1200	<.0500	-	.0961	-	-	.5099	-	-
3	.5708	.1531	<.0500	.2820	.0810	.0662	.2461	.0901	.0666	.7499	.1560	.0666
4	34.22	.5947	.4754	32.71	.5160	.4876	28.50	.4198	.4815	57.95	.7196	.6378
5	36.65	-	-	30.32	-	-	30.59	-	-	62.27	-	-
6	36.65	5.73	5.18	32.40	2.80	5.23	30.59	7.49	6.62	58.14	11.09	6.62
7	61.28	-	-	49.82	-	-	48.60	-	-	101.40	-	-
8	110.55	-	-	90.02	-	-	73.21	-	-	136.20	-	-
9	75.69	-	-	55.19	-	-	44.40	-	-	123.02	-	-
10	.0963	-	< .0500	.0840	-	<.0500	<.0500	-	<.0500	.1650	-	-
11	.0542	-	-	<.0500	-	-	<.0500	-	-	.0840	-	-
12	.0542	-	-	<.0500	-	-	<.0500	-	-	.0840	-	-

[a] The symbol - indicates no leakage

[b] ASTM E514 defines a leak as a rate of leakage $\geq$ 0.05 l/hr

TABLE 6 - TIME REQUIRED FOR VARIOUS LEAKAGES

Wall No.	TIME TO[a] VISIBLE MOISTURE			TIME TO[a] VISIBLE WATER			TIME FOR[a] LEAKAGE TO BEGIN			TIME FOR MAX.[a] RATE OF LEAKAGE		
	Uncoated	Coated	Exposed[c]	Uncoated	Coated	Exposed[c]	Uncoated	Coated	Exposed[c]	Uncoated	Coated	Exposed[c]
1	5	6	60 hrs	5	6	60 hrs	60	-[b]	-	150	-	-
2	5	10	21 hrs	7	12	26.5 hrs	20	-	-	150	-	-
3	5	6	3	7	10	5	20	165	24 hrs	300	21 hrs	72 hrs
4	<5	15 hrs	75	10	18 hrs	80	14	20 hrs	105	30	32 hrs	8 hrs
5	<5	6	2.5 hrs	10	12	24 hrs	12	-	-	60	-	-
6	<5	<5	< 5	10	5	<5	12	10	< 5	30	13 hrs	72 hrs
7	<5	5	110	< 5	75	8 hrs	< 5	-	-	60	-	-
8	<5	20 hrs	110	< 5	21 hrs	18 hrs	< 5	-	-	30	-	-
9	<5	45	100	< 5	13 hrs	2.7 hrs	< 5	-	-	30	-	-
10	<5	20	5	15	3 hrs	10	90	-	-	120	-	-
11	<5	10	12 hrs	15	16	12 hrs	225	-	-	420	-	-
12	<5	90	105	5	-	9 hrs	150	-	-	300	-	-

[a] Minutes unless otherwise stated

[b] The symbol - indicates no leakage

[c] Exposed to outdoor climate for 6 mos.

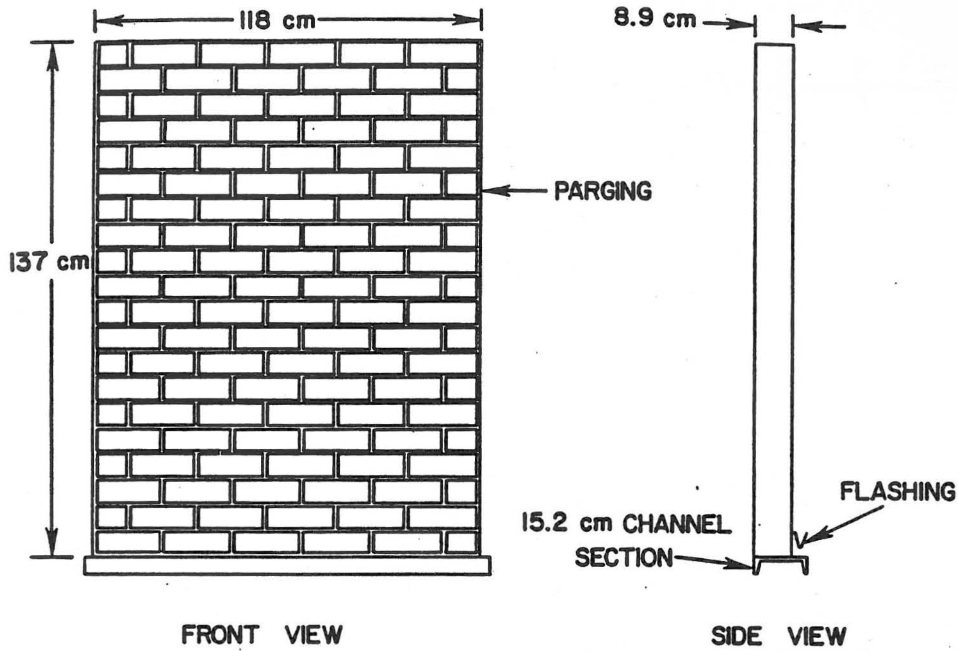

Fig. 1. Typical Brick Wall Specimen

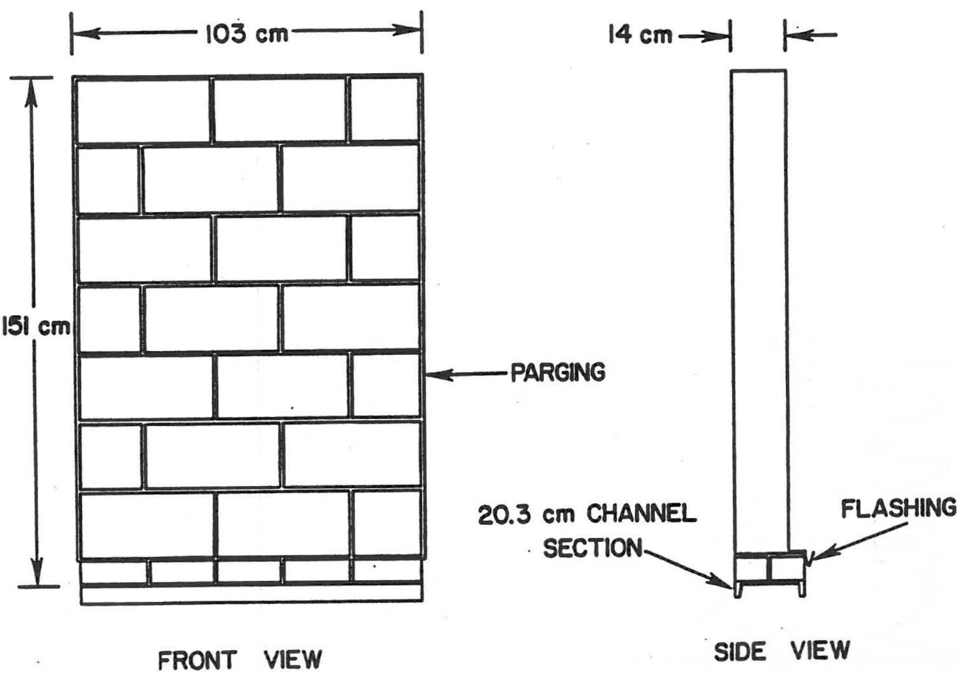

Fig. 2. Typical Concrete Masonry Wall Specimen

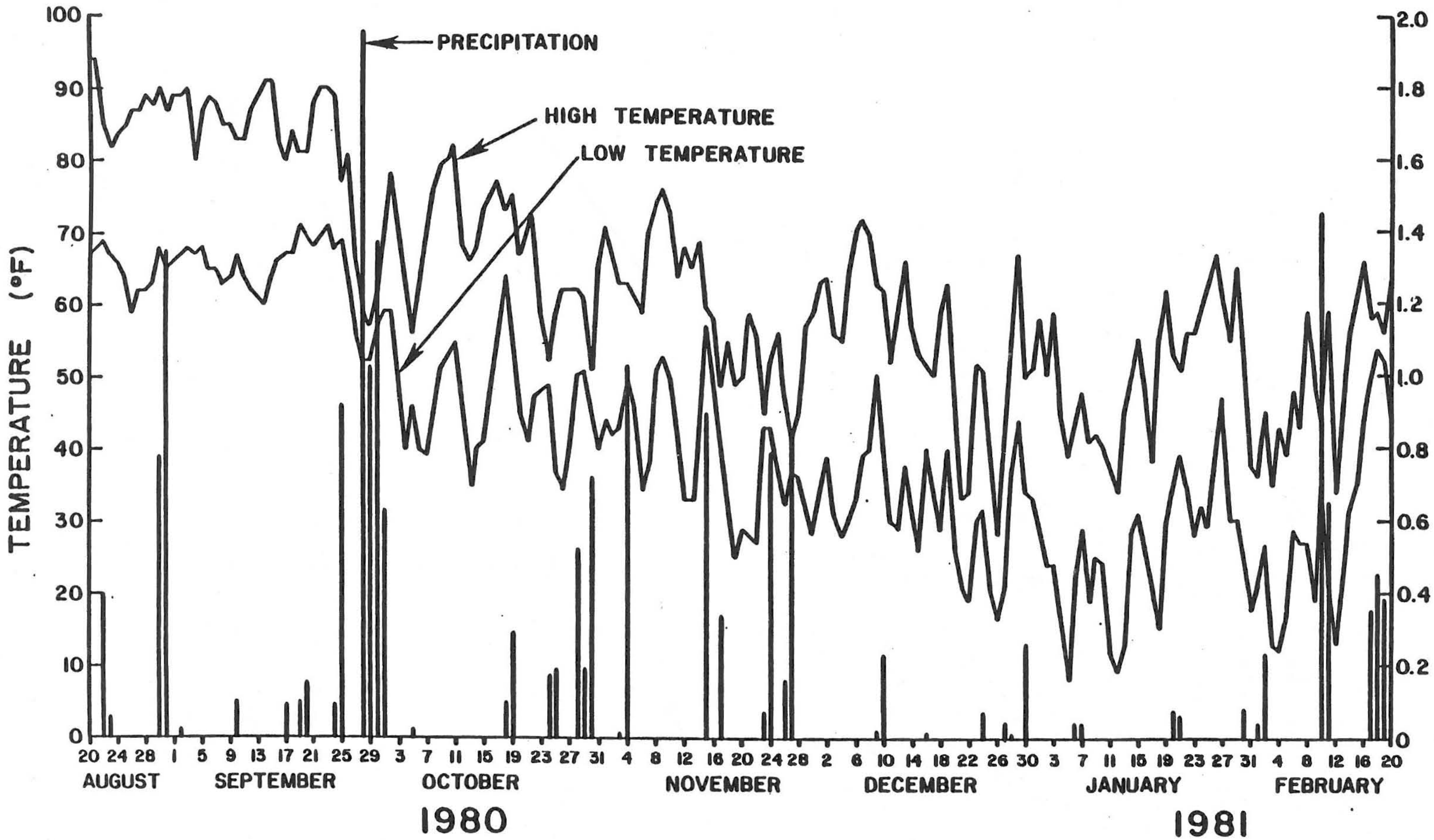

Fig. 3. Weather Data for Period of Outdoor Exposure

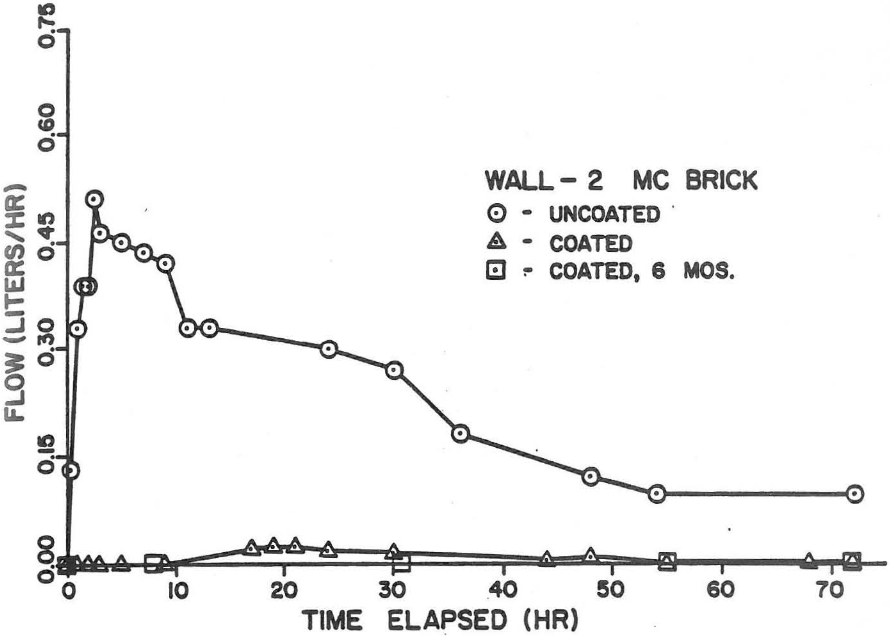

Fig. 4. Volume of Water Collected on Flashing vs. Time for Wall No. 2

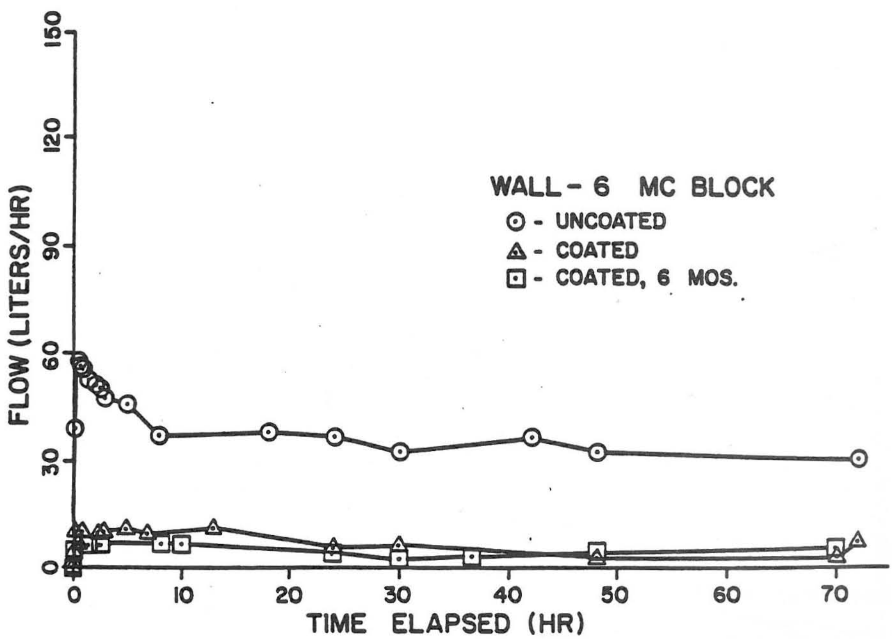

Fig. 5. Volume of Water Collected on Flashing vs. Time for Wall No. 6

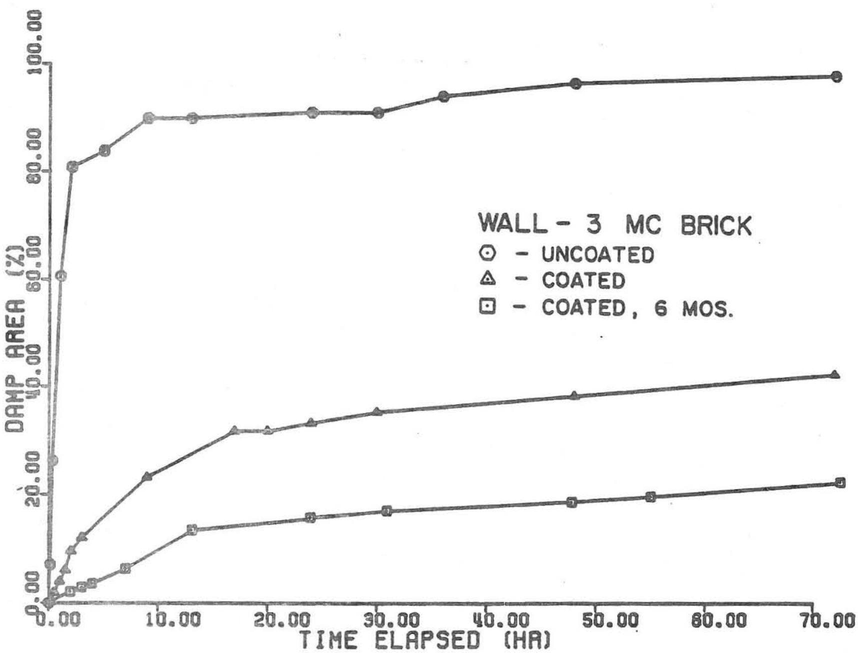

Fig. 6. Damp Area vs. Time - Wall No. 3

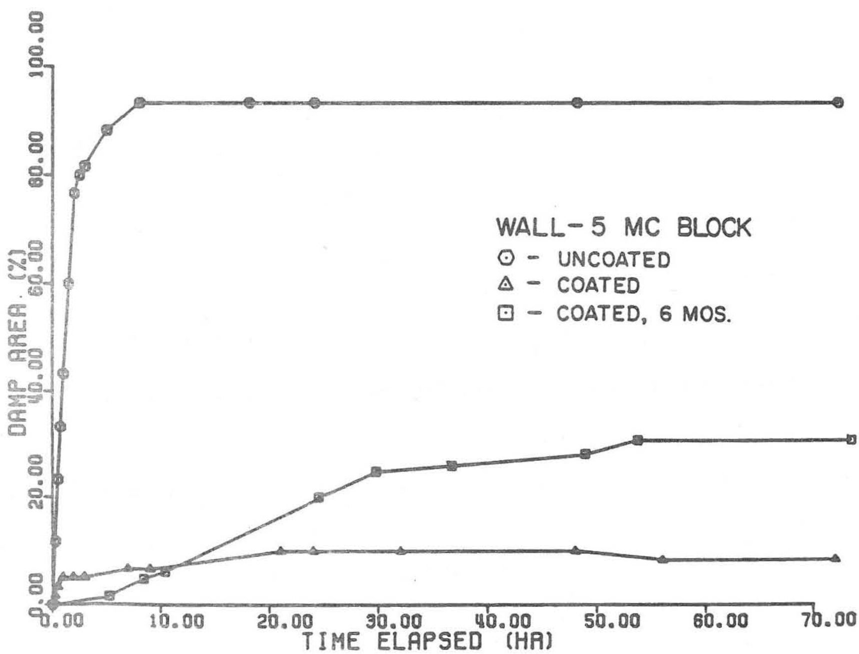

Fig. 7. Damp Area vs. Time - Wall No. 5