WATER PENETRATION TESTING OF STUCCO ON CONCRETE MASONRY CONSTRUCTION

for
Florida Concrete & Products Association
and
NCMA Education and Research Foundation

Conducted by: Masonry Information Technologists
Jim Gulde, President

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Florida Concrete and Products Association	Robert Sitter, President
• Providing Promotional and Technical Services to Architects, Engineers, Contractors, The Design and Construction Industry of Florida	
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1.0—INTRODUCTION

This project was jointly funded through NCMA's Education and Research Foundation in cooperation with The Florida Concrete and Products Association and their members. Jim Gulde of Masonry Information Technologists, Inc. served as the Principal Researcher.

Stucco on block is a very popular finish representing 20% of the block sales in the USA. It provides the plain gray block a whole new look - a very economical and attractive finish. Stucco has done much to promote concrete masonry and improve its image.

The hurricanes that inundated Central Florida in 2004 caused significant damage to residential construction due to water intrusion, mainly to houses built after 2001. All building components typical of this type of construction came under severe scrutiny. This created the motivating factor for the development of this project, as CBS (concrete block-stucco) residential construction represents about 85% of the homes in Florida.

While it is assumed that stucco increases the resistance to water penetration of concrete masonry, a review of the literature has found no comprehensive tests on this subject. This research was undertaken to provide some information as to how effective stucco is in preventing water intrusion through the CBS wall system.

Coincidentally, the Florida Building Code 2001 Edition (ref. 2) introduced a new term of "*Decorative Cementitious Coating(DCC) ",* defined as "*a skim coat as defined in ASTM C 926, of Portland cement based plaster applied to concrete or masonry surfaces intended for cosmetic purposes*". as an alternate to traditional Portland cement-based stucco. Following the adoption of the 2001 code, many builders began using a DCC (which has no thickness requirements) in lieu of the standard stucco and stucco thicknesses required by ASTM C 926, *Standard Specification for Application of Portland Cement-Based Plaster* (ref. 5).

ASTM C926 is the national standard for application of stucco, and is referenced in the building code (refs. 2 & 3). ASTM C 926 Table 1* defines required thicknesses of stucco over various substrates which is based on empirical historical performance. For stucco applied directly to concrete masonry units, the required thickness is ½ in. (13 mm) for 2 coat work and ⅝ in. (16 mm) for three-coat work.

However, to date, little is known about the relative resistance to water intrusion based on varying thicknesses of stucco. The effectiveness of a "skim coat at ⅛ in. (3mm) thickness" to resist water penetration was added to the research project.

*Table 1 Stucco Thickness. It should be noted that the thicknesses shown in the Table are "Nominal" Thickness. Nominal is defined here as a dimension to which variations are to be anticipated and expected. However, care was exercised to assure that the thickness of the stucco application on these laboratory walls was the thickness indicated in the report.

1. Project Objectives:

A. To develop elementary data on water intrusion through various thicknesses of stucco applications applied on Concrete Block Walls.

B. To determine if thicknesses less than those required in ASTM C 926 can function adequately compared to the required thickness.

C. To assist in the continuing of the marketing of the Concrete Block Stucco (CBS) walls throughout the United States.

2. Project Description:

The purpose was to test for water penetration resistance of concrete masonry walls with varying thicknesses of stucco and various levels of workmanship of both the masonry and the stucco. This involved testing wall samples that were built 4 ft (1.2 m) wide and 6 ft (1.8 m) tall using the ASTM E 514 (ref. 6) protocol. The project was broken into two phases utilizing different wind pressures:

1. Phase I utilizing pressures representative of 62 and 110 mph (100 and 177 kph) winds
2. Phase II utilizing pressures representative of 155 and 180 mph (249 and 290 kph) winds

2.0—WALL CONSTRUCTION

The NCMA Research and Development Laboratories, under the direction of Bob Thomas and Jeff Greenwald conducted basic research on the water integrity of stuccoed masonry walls. The walls were built in the NCMA lab in the late fall of '05. Steve French, a stucco applicator from Florida, traveled with a trailer to NCMA the week of 14 November and applied the stucco to the walls.

Thirteen (13) walls were built to be tested in accordance with ASTM E514 *Standard Test Method for Water Penetration and Leakage Through Masonry* (ref. 6) as described in Table 1. The ½ in. (13 mm) stucco was applied in accordance with ASTM C926, *Standard Specification for Application of Portland Cement-Based Plaster* (ref. 5), which allows this thickness to be applied in a "double-up" method where the second coat is applied as soon as the first coat can hold the second coat. The other stucco thicknesses were applied in a single coat.

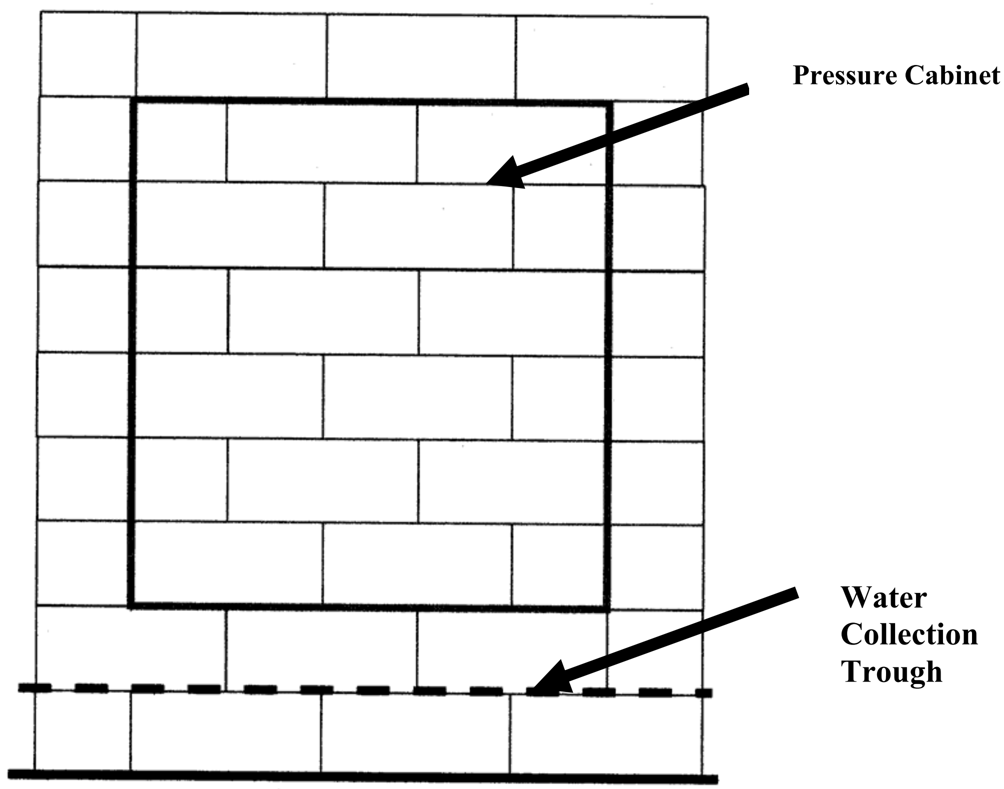


Figure 1—All Walls were 8 in. (203 mm) Nominal Thickness, 3-½ Units Wide and 9 Courses High

Table 1—Wall Specimens and Stucco Thicknesses

Stucco Thickness	Number of Walls	Description
None	1	Control wall – no stucco
⅛ in. (3 mm)	4	Skim coat of stucco material
¼ in. (6 mm)	4	½ the code required thickness
½ in. (13mm)	4	ASTM C926 required thickness
Total	**13**	

Mortar Joint Strategy:

This project was developed for the sole purpose of testing the "stucco coating", not the block or mortar joints. However, it is found upon occasion that the workmanship on mortar joints leaves something to be desired. Therefore one wall of each stucco thickness was constructed with "flawed" mortar joints as described in Table 2.

Table 2—Flawed Mortar Joint Strategy

Head joints – 12 available on each side of wall within pressure cabinet area. 8 of the 12 head joints to be "flawed" 4 of the 12 head joints to have no flaw.	
"Flawed" technique as follows:	Number of "flawed" joints per wall
H1: No mortar; butt CMU head joints tight –	2
H2: Mortar; 1 in. (25 mm) wide; full mortar joint -	2
H3: Mortar; 1 in. (25 mm) wide; ½ full mortar joint -	2
H4: Mortar; ⅜ in. (10 mm) wide; ½ full mortar joint -	2
Total "flawed" head joints per wall	8
Bed joints – 5 available on each side of wall B1: Missing along 3 ft (0.9 m), four 2-in. (51 mm) long no mortar -33 percent B2: Correct – along 3 ft (0.9 m), full mortar joint – 33 percent B3: Incorrect – along 3 ft (0.9 m), ½ full mortar joint – 33 percent	

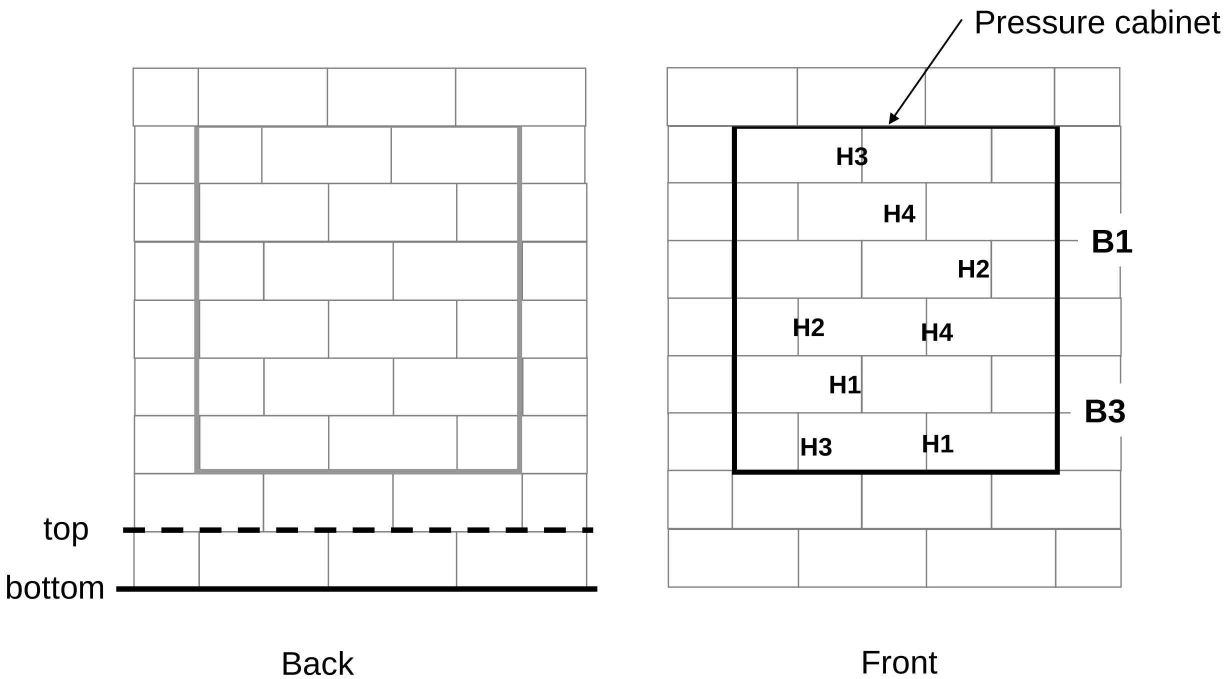


Figure 2—Wall 1 Assembly Faces

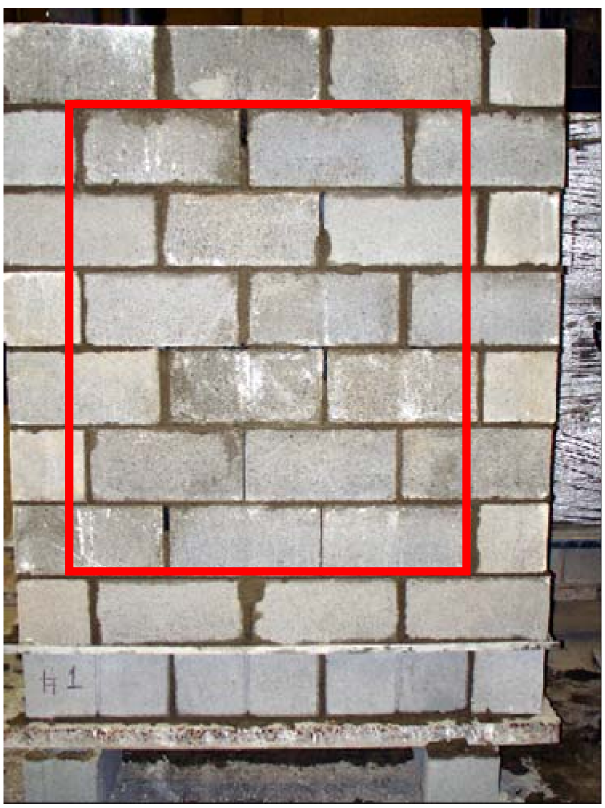


Figure 3—Wall 1 Photo Front Face

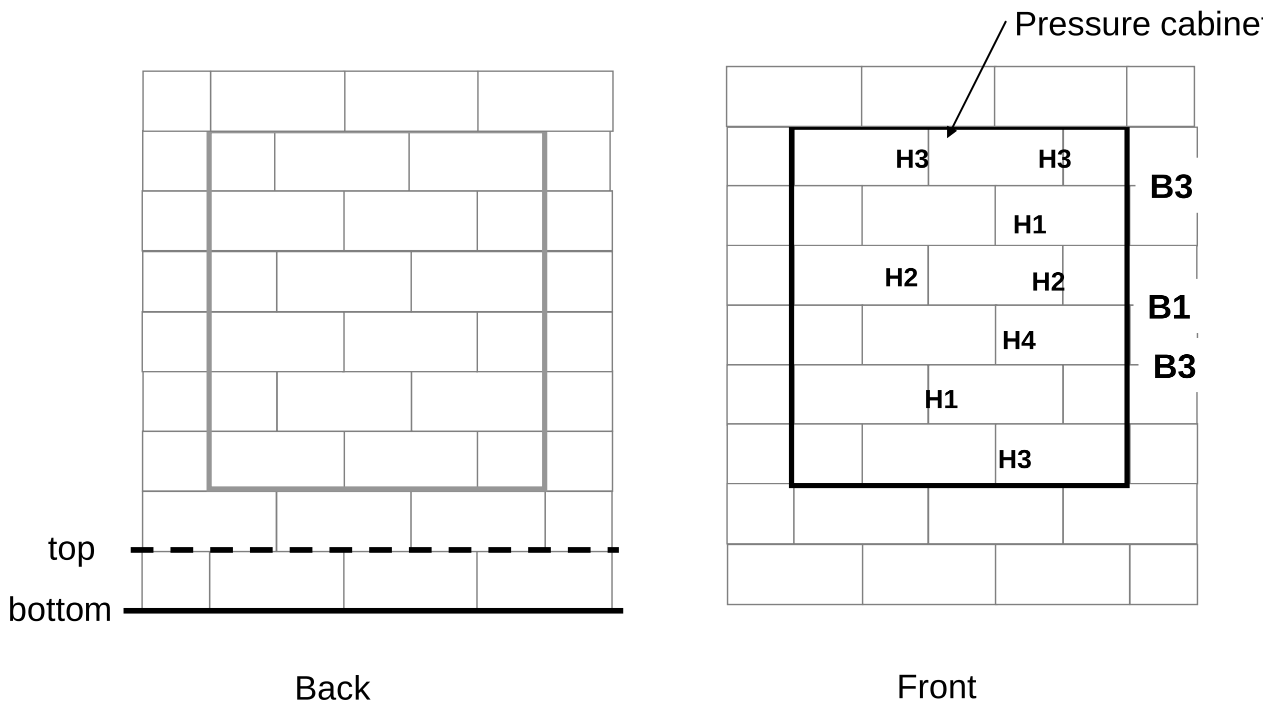


Figure 4—Wall 2 Assembly Faces

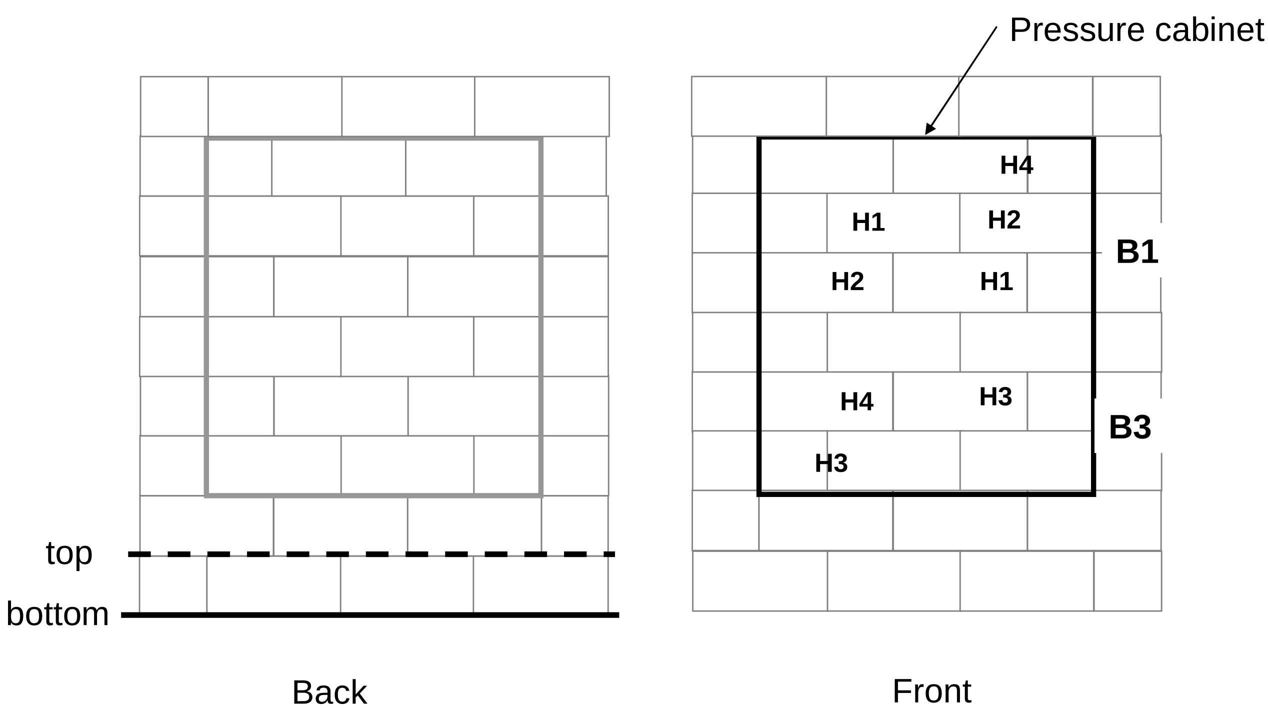


Figure 5—Wall 3 Assembly Faces

Figure 6— The final step in the building of the walls - the application of the stucco to the block.

The walls were generally built to meet the standards of *Building Requirements for Masonry Structures* (ACI 530/ASCE 5/TMS 402) and *Specification for Masonry Structures* (ACI 530.1/ASCE 6/TMS 602) (MSJC) (refs. 2 & 3) using type S masonry cement. Since this project was developed to test the "stucco", not the block or mortar, one wall of each stucco thickness was constructed with "flawed" mortar joints. The "flawed" joints were inserted to determine if stucco would perform even with some reduced quality in the masonry.

3.0—PHASE I - INITIAL TESTING
WIND SPEEDS OF 62 AND 110 MPH (100 AND 177 KPH)

Phase I testing consisted of testing 6 walls described as follows:
6 Walls were tested as follows (See Table 2 for "flawed" construction description):

- Wall 1: Good block construction – Control Wall with no stucco. (Blank Wall)
- Wall 2: Good block construction - ⅛ in. (3 mm)skim coat,
- Wall 3: Good block construction - ½ in. (13 mm) stucco,
- Wall 4: Flawed construction - ⅛ in. (3 mm) skim coat,
- Wall 5: Flawed construction - ¼ in. (6 mm) skim coat,
- Wall 6: Flawed construction - ½ in. (13 mm) stucco.

Figure 6—Phase I Test Walls
(Photo taken: December 19, 2005)

The walls in Phase I were tested at two pressures. Round one was tested at ASTM E514 prescribed water flow and pressure of 40.8 gallons per hour and 10 lbs per square foot (0.47 kPa) (2 in. (51 mm) of water) where wind velocity, V = approximately 62 mph (100 kph). Round two was tested at ASTM E514 prescribed water flow and 31 lbs per square foot (1.5 kPa) (6 in. (13 mm) of water) pressure. The higher pressure was calculated from the equation: $p = 0.00256(V)^2$ with V = 110 mph (177 kph) wind speed.

Phase I Test Results And Observations

In testing the blank (control) wall, the water and pressure commensurate with the 62 mph (100 kph) wind speed were maintained for 4 hours. Visible water was observed in the wall cores and the wall face within ½ hour. In addition, approximately 20 gallons of water penetrated the wall face under pressure and approximately 0.1 gallons migrated through the wall cross section. It is estimated that water flow rates of 5 gallons per hour and 0.03 gallons per hour would be attained for the wall face and wall cross section, respectively.

Table 3—Control Wall Performance, Phase I

Observation Time (hr)	Control wall at 62 mph (100 kph) wind speed
0.5	
1.0	
1.5	

Observation Time (hr)	Control wall at 62 mph (100 kph) wind speed
2.0	
2.5	
3.0	
4.0	

In testing the 5 stuccoed walls: two at ⅛ in. (3 mm) skim coat, one at ¼ (6 mm) skim coat and two at ½ in. (13 mm) stucco, the water and pressure were maintained for 4 hours for the 62 (100 kph) wind speed followed by another 24 hours at 110 mph (177 kph). In both rounds of testing, no visible water was observed in any of the wall cores or on the leeward wall face.

Table 4—Flawed Wall with ⅛ in. (3 mm) Skim Coat Performance, Phase I

	
Flawed wall with ⅛ in. (3 mm) skim coat after 4 hours at 62 mph (100 kph)	Flawed wall with ⅛ in. (3 mm) skim coat after 4 hours at 62 mph (100 kph) plus 24 hours at 110 mph (177 kph)

Table 5—Test Results - Area of Dampness on Leeward Wall Surface, percent

Wall Specimen	Length of Exposure, hours												
	0	4	4.5	5	5.5	6	6.5	7	7.5	8	12	22	28
Wall 1-Control	0	45	Stopped after 4 hours										
Wall 2 (⅛)	0	0	0	0	0	0	0	0	0	0	0	0	0
Wall 3 (½)	0	0	0	0	0	0	0	0	0	0	0	0	0
Wall 4 (⅛F)	0	0	0	0	0	0	0	0	0	0	0	0	0
Wall 5 (¼F)	0	0	0	0	0	0	0	0	0	0	0	0	0
Wall 6 (½F)	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 6—Test Results – Water Collected on Through-Wall Flashing, lbs. (kg)

Wall Specimen	Length of Exposure, hours												
	0	4	4.5	5	5.5	6	6.5	7	7.5	8	12	22	28
Wall 1-Control	0	20 (9.0)											
Wall 2 (⅛)	0	0	0	0	0	0	0	0	0	0	0	0	0
Wall 3 (½)	0	0	0	0	0	0	0	0	0	0	0	0	0
Wall 4 (⅛F)	0	0	0	0	0	0	0	0	0	0	0	0	0
Wall 5 (¼F)	0	0	0	0	0	0	0	0	0	0	0	0	0
Wall 6 (½F)	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 5—Area of Dampness on Leeward Wall Surface, percent

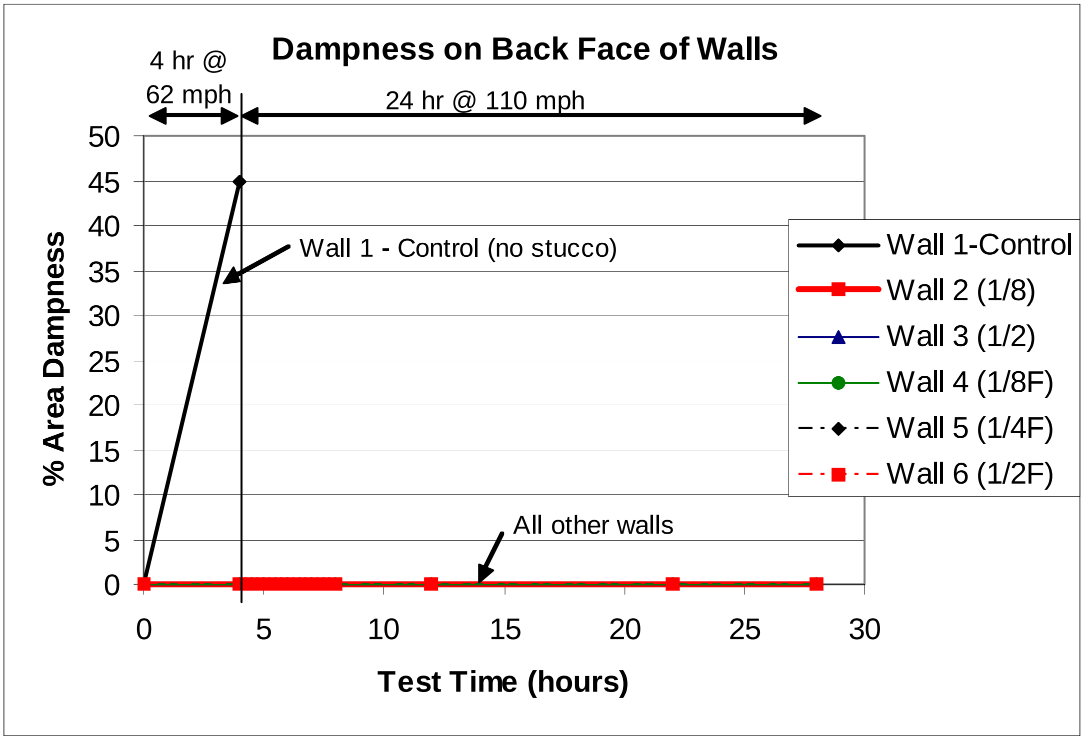
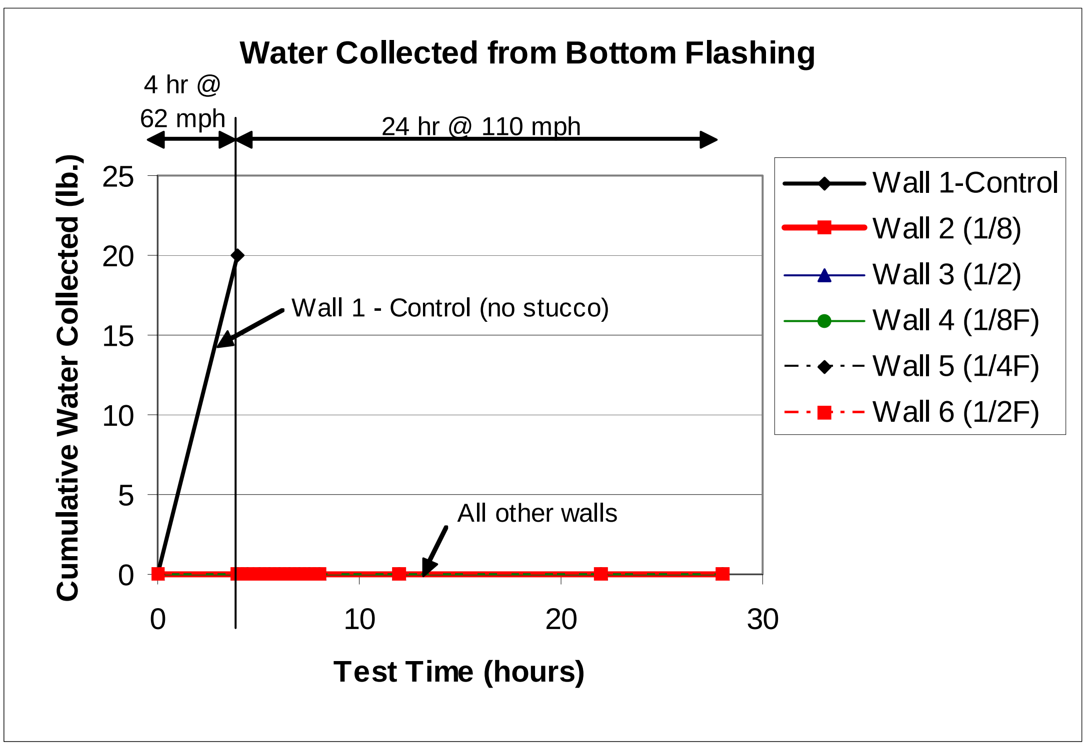


Figure 6—Test Results – Water Collected on Through-Wall Flashing, lbs.



Phase I Summary:

In the control wall (with no stucco) water was observed penetrating into the cores and dampness on the leeward wall face within 30 minutes at the 62 mph (100 kph) wind speed. The walls with ⅛ in. (3 mm) and ¼ in. (6 mm) skim coats and ½ in. (13 mm) stucco showed no evidence of water penetration during the four hours of 62 mph (100 kph) wind driven rain. Additionally, in the following 24 hours at 110 mph (177 kph) there was no trace of water entering the cores or dampness appearing on the leeward face of the wall. Each of the stucco material thicknesses had one wall with "flawed" mortar joints.

Phase I Conclusions

Stucco material applications of ⅛ in. (3 mm), ¼ in. (6 mm) and ½ in. (13 mm) thicknesses dramatically increase the water penetration resistance of plain, gray, 8-in. (203 mm) concrete masonry walls. No water penetrated into the cores or to the leeward face of the test walls after 62 mph (100 kph) of wind driven rain for four hours followed by 110 mph (177 kph) wind driven rain for 24 hours in when tested in accordance with ASTM E514.

4.0—PHASE TWO - EXTREME HURRICANE CONDITION WIND SPEEDS OF 155 AND 180 MPH (249 AND 290 KPH)

Phase II Testing

Due to the excellent performance at 62 and 110 mph (100 and 177 kph) during Phase I of the flawed ⅛ in. (3 mm) skim coat walls, no further testing was conducted on ¼ in. (6 mm) skim coated walls during Phase II. Phase II testing was conducted utilizing the following walls under higher pressures representing hurricane conditions of 155 and 180 mph (249 and 290 kph) wind speeds:

- 4 walls with ⅛ in. (3 mm) skim coat- one of these with "flawed" mortar joints
- 4 walls with ½ in. (13 mm) stucco- one of these with "flawed" mortar joints

After 4 hours of testing at 155 mph (249 kph) no moisture was observed in any of the cores or leakage on the leeward face in any of the test specimens. In view of this, there was little reason to continue the test to 24 hours since the object was to determine the difference in performance between walls. The pressure was then increased to that of a 180 mph (290 kph) wind. Almost immediately moisture appeared in the cores of the ⅛-in. (3 mm) coated walls. Therefore the test at 180 mph (290 kph) was continued for full 24 hours. Moisture in some form appeared on the back surface on three of the four walls. See photos in Table 5 and 6.

The ½ in. (13 mm) stucco walls were then tested at the same regimen as the ⅛-in. (3 mm) skim coat for comparison, i.e. 4 hrs at 155 mph (249 kph) followed by 24 hrs at 180 mph (290 kph). Again, there was no moisture observed in the first four hours at the lower wind pressure. Under the increased rate of 180 mph (290 kph), moisture was observed in the cores of these walls as well as moisture on the leeward face in some form on all four walls but in lesser overall amounts than for the ⅛-in. (3 mm) skim coat. See photos in Table 5 and 6.

While there was variation between the walls in each set of 4, the dampness on the leeward face results was very similar between the ⅛ in. (3 mm) skim coat and the ½ in. (13 mm) stucco. However, there was a marked difference in the amount of water collected on the flashing, with a better overall performance of the ½ in. (13 mm) stucco at the higher wind speeds. Only one wall of the ½ in (13 mm) stucco collected water on the flashing in the bottom of the cells - and that was a small amount only at the final reading (final 4 hours of the 28-hour test). Two of the four ⅛ in. (3 mm) skim coat walls collected water - both of which occurred much earlier in the test – at the 12 hour mark in the 28 hour test. One of these could have been slightly influenced by moisture entering the flashing from the front side as a result of leakage around the seal for the chamber under the elevated pressure. However, this same wall had the greatest amount of dampness penetrating to the leeward face confirming that it was the worst performing wall tested. It was also noted that Wall ½-2 which is the only ½ in. (13 mm) stucco specimen that accumulated any water on the flashing had dampening on the lower 3 courses above the flashing only whereas the others that were damp had damp spots throughout the test area.

Table 7—Walls After 4 Hours at 155 mph (249 kph) then 4 hours at 180 mph (290 kph), Phase II, Organized from Best to Worst Performing at Test Conclusion

⅛ in. (3 mm) skim coat		½ in. (13 mm) stucco	
Wall S-A Flawed Mortar Joints		Wall ½-1	
Wall S-3		Wall ½-2	
Wall S-2		Wall ½-B Flawed Mortar Joints	
Wall S-1		Wall ½-3	

Table 8—Walls After 4 Hours at 155 mph (249 kph) then 24 hours at 180 mph (290 kph), Phase II, Organized from Best to Worst Performing at Test Conclusion

⅛ in. (3 mm) skim coat		½ in. (13 mm) stucco	
Wall S-A Flawed Mortar Joints		Wall ½-1	
Wall S-3		Wall ½-2	
Wall S-2		Wall ½-B Flawed Mortar Joints	
Wall S-1		Wall ½-3	

Table 9—Test Results - Area of Dampness on Leeward Wall Surface, percent

Wall Specimen	Length of Exposure, hours												
	0	4	4.5	5	5.5	6	6.5	7	7.5	8	12	22	28
½ - B	0	0	0	0	0	0.2	0.5	0.8	0.8	0.8	3.2	5.2	6.1
½ - 1	0	0	0	0	0	0	0	0	0	0	0	0.2	0.3
½ - 2	0	0	0	0.6	0.7	0.8	0.9	1	1.05	1.1	1.9	4.7	6.1
½ - 3	0	0	0	0	0	0	0	0	0	0	0.7	8.9	13.5
S - A	0	0	0	0	0	0	0	0	0	0	0	0	0
S - 1	0	0	1.1	1.3	1.3	1.5	1.5	1.5	1.5	1.5	1.6	15.2	24.9
S - 2	0	0	0	0	0	0	0	0	0	0	0	1.5	4.5
S - 3	0	0	0	0	0	0	0	0	0	0	0	0.3	1.8

Table 10—Test Results – Water Collected on Through-Wall Flashing, lbs. (kg)

Wall Specimen	Length of Exposure, hours												
	0	4	4.5	5	5.5	6	6.5	7	7.5	8	12	22	28
½ - B	0	0	0	0	0	0	0	0	0	0	0	0	0
½ - 1	0	0	0	0	0	0	0	0	0	0	0	0	0
½ - 2	0	0	0	0	0	0	0	0	0	0	0	0	0.5
½ - 3	0	0	0	0	0	0	0	0	0	0	0	0	0
S - A	0	0	0	0	0	0	0	0	0	0	0.34 (.19)	3 (1.4)	5.79 (2.6)
S - 1	0	0	0	0	0	0	0	0	0	0	0.75 (.34)	8 (3.6)	18.7 (8.5)
S - 2	0	0	0	0	0	0	0	0	0	0	0	0	0
S - 3	0	0	0	0	0	0	0	0	0	0	0	0	0

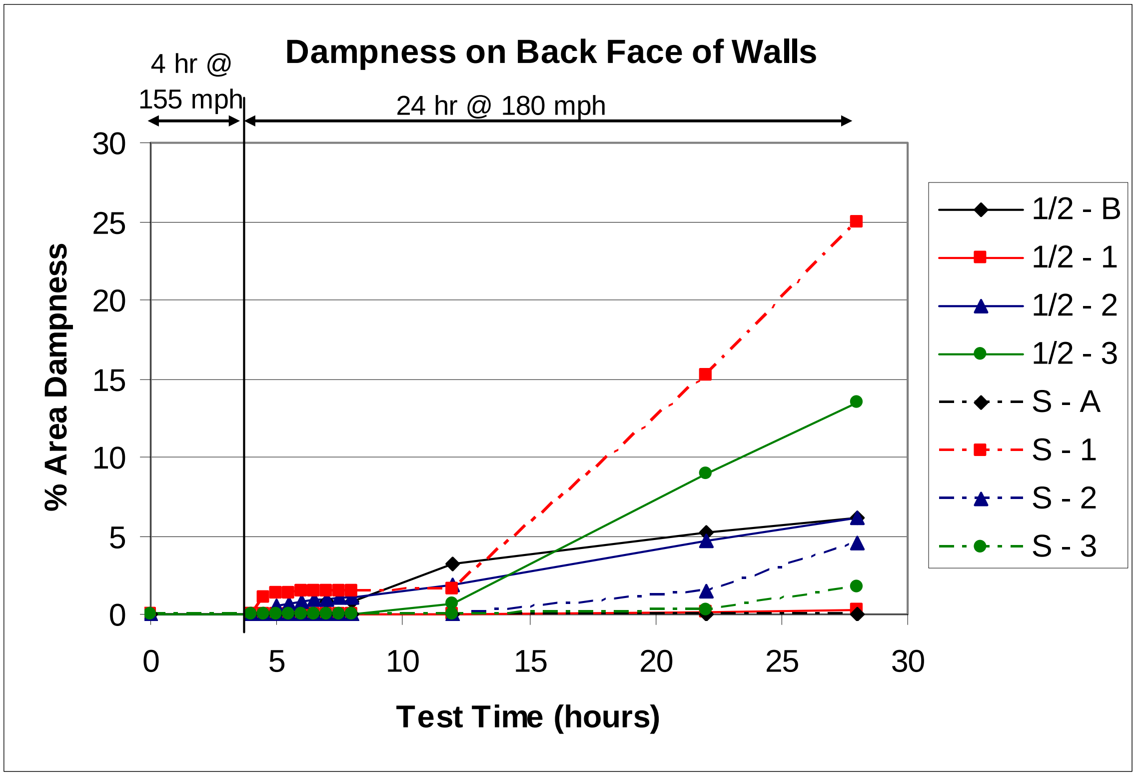


Figure 7—Area of Dampness on Leeward Wall Surface, percent

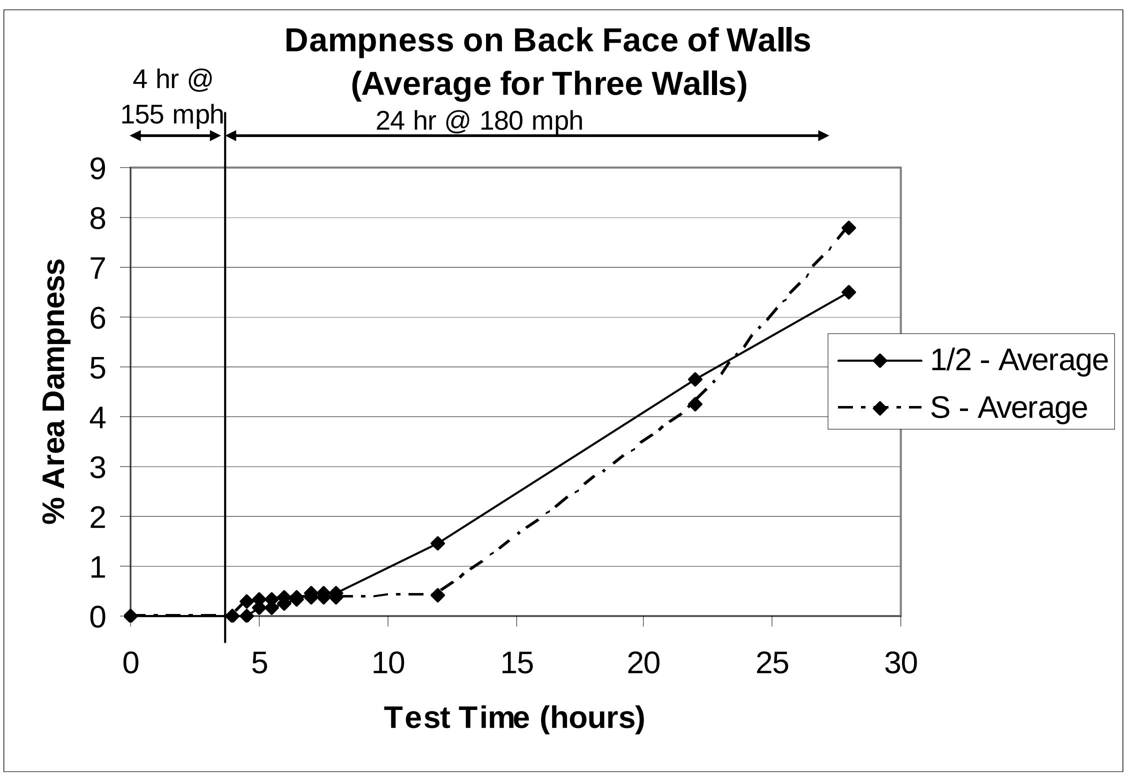


Figure 8—Test Results: Dampness ⅛ in. (3 mm) Skim Coat vs. ½ in. (13 mm) Stucco

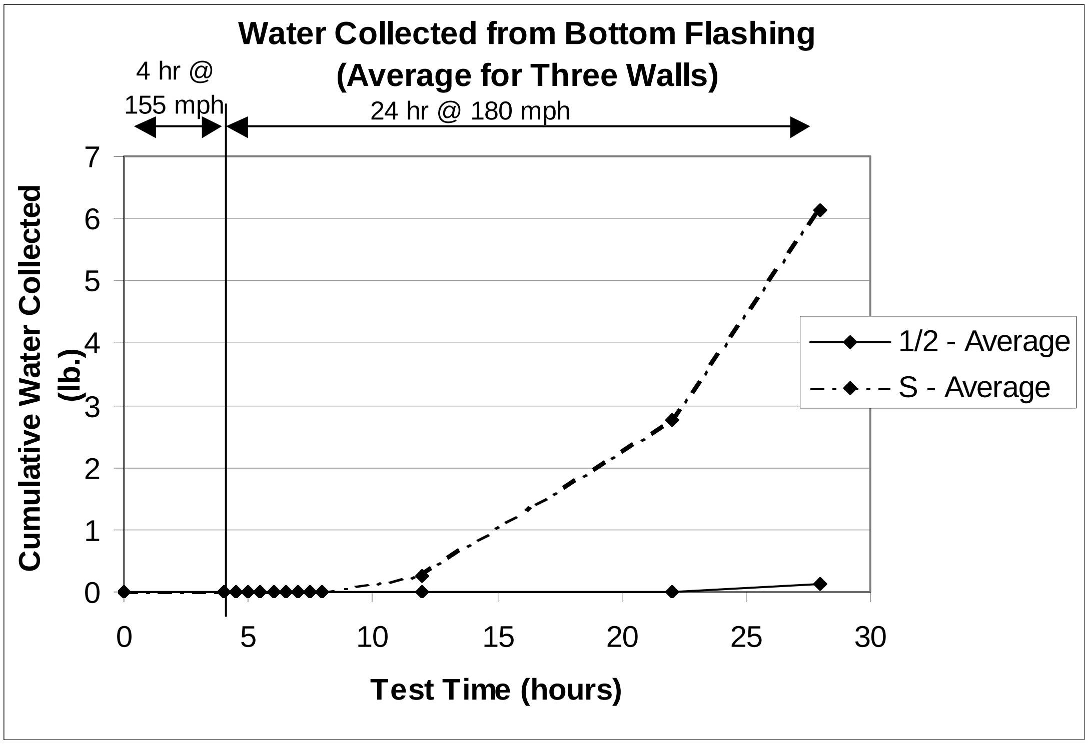


Figure 9—Test Results – Water Collected on Flashing
⅛ in. (3 mm) Skim Coat vs. ½ in. (13 mm) Stucco.

<u>Phase II Observation Summary</u>

At 155 mph (249 kph) for four hours, the four ⅛ in. (3 mm) skim coat walls and the four ½ in. (13 mm) stuccoed walls showed no visible water on the leeward face and no water in the cores.

At 180 mph (290 kph) for 24 hours, the walls with ⅛ in. (3 mm) skim coat and the walls with ½ in. (13 mm) stucco passed water into the cores and to the opposite face. Although data above and the charts show some differences, the results for the amount of water collected on the flashing for the ⅛ in. (3 mm) skim coat and the ½ in. (13 mm) stucco were dramatically different at the higher pressure as shown in Figure 9. Also the time at which water began collecting on the flashing was much earlier for the ⅛ in. (3 mm) skim coat than for the ½ in. (13 mm) stucco.

5.0—SUMMARY AND CONCLUSIONS

This two phase testing program found that:

A. At wind speeds of 110 mph (177 kph), all the coated walls resisted water penetration regardless of stucco material thickness; while the walls with no stucco material failed early in the testing at the much lower wind speed of 62 mph (100 kph).
B. At wind speeds exceeding 155 mph (249 kph), traditional ½ in. (13 mm) stucco as produced in Florida, and in accordance with ASTM C 926 provided excellent resistance to moisture penetration.
C. At wind speeds of 180 mph (290 kph), the amount of dampness appearing on the leeward side of the wall was similar for both stucco material thicknesses. However, ½ in. (13 mm) stucco displayed a dramatic difference as compared to the ⅛ in. (3 mm) skim coat for the extended time and pressure in regard to the amount of water collected at the bottom of the cells on the flashing.
D. The thickness of the stucco material, as constructed and tested in this environment; and, utilizing this test method does not appear to be a significant factor in resisting water penetration at low wind speeds.
E. The quality of workmanship regarding the mortar joints appears to have little influence on the watertightness of stuccoed masonry walls with the stucco material apparently able to fill and bridge the gaps and holes in the mortar. However, even though this may have produce acceptable results for water penetration resistance, head and bed joints for the full thickness of the face shell are required by the building codes (refs. 1, 2, & 3) for structural purposes.

Conclusions

Stucco applied in accordance with ASTM C 926 ½ in. (13 mm) stucco and the "skim coat" of ⅛ in. (3 mm) thickness did provide comparable resistance to water penetration at low wind speeds. The ½ in. (13 mm) stucco did allow much less water into the cells, however, and delayed the entry for a much longer time than did the ⅛ in. (3 mm) skim coat at the higher wind speeds.

However, it should be noted that these tests were conducted in a laboratory environment, and the walls and stucco material were cured as a condition of the test method. There were no instances of masonry or stucco material cracking observed in these test panels. Performance of masonry walls constructed in the field not adhering to recommended practice and industry standards, more than likely will experience a performance different than was experienced in this research project.

There are many characteristics and conditions in the materials and construction practices of stucco that have determined the thickness requirements in ASTM C926. They include the tolerance criteria of the concrete masonry unit as well as the tolerance criteria in the construction of masonry walls. It is not the intention of this report to suggest that a "skim coat" or reduced stucco material thickness is being recommended as a replacement of the existing criteria in ASTM C926 (ref. 5) and the building codes (refs. 2, & 3).

6.0—REFERENCES

1. *Building Code Requirements for Masonry Structures*, ACI 530/ASCE 5/TMS 402. Masonry Standards Joint Committee, 2005.

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