U.S. Department of Housing and Urban Development
Office of Policy Development and Research

WATER INTRUSION EVALUATION FOR CAULKLESS SIDING, WINDOW, AND DOOR SYSTEMS

WATER INTRUSION - LABORATORY TESTING RESULTS

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Prepared for

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by

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INTRODUCTION

Over time all exterior wall sealant systems, including caulk, leak. Caulks work from a few days to a few years, which makes it impossible to predict when and where maintenance will be required. Since wall siding systems vary in their reliance on sealants through proper system selection and design a caulkless wall system may be developed. A caulkless wall siding system would not require sealants, or caulk, thereby eliminating both the initial expense and the routine maintenance associated with caulk. The purpose of this research is to design, evaluate, install, and monitor wall siding systems that do not require caulk, either initially or during routine maintenance.

LABORATORY EVALUATION

Four wall systems were evaluated using vinyl and fiber cement siding materials. The evaluation was performed in a controlled laboratory environment to quantify the design options for robust, tolerant wall siding systems that require little maintenance.

The wall systems evaluated were:

- Vinyl Siding – Best practice (caulkless)
- Fiber Cement Siding – Best practice with caulk
- Fiber Cement Siding – Caulkless system
- Fiber Cement Siding – Caulkless system with a air-gap drainage plane

These siding systems were evaluated on their ability to eliminate wind-driven rain intrusion and to drain water that penetrates the system. Evaluations were made using sprayed water to simulate driving rain. Each test wall was separated into halves. The first half contained a 3’ wide by 5’ tall vinyl window and the second half was a clear wall area. The clear wall areas contained six intermediate seams in the vinyl specimen and eight in each of the fiber cement specimens. These seams were to simulate the conditions on a much longer wall span.

The laboratory evaluations were made using a calibrated spray chamber that applied five gallons of water per square foot of wall per hour. The wall specimens were tested in accordance with ASTM E 547-93 *Water Penetration of Exterior Windows, Curtain Walls, and Doors by Cyclic Static Air Pressure Differential*. The testing procedure consisted of two, 15-minute pressurized wetting periods separated by a one-hour period of depressurization and followed by a one-hour drip-dry period. The pressurized wetting cycle was conducted under a 2.5 pounds per square foot pressure differential from the exterior of the wall to the interior. The water used in the testing was dyed with a high concentration of dark red dye. This allowed for visual observations of water intrusion and movement behind the siding.

Water that penetrated the siding and ran down the weather barrier was collected and measured using a gutter system as shown in Figure 1. Water collected in the gutter system was weighed and converted to gallons. Figure 1 shows a detail of the gutter cross section. The gutter was sealed to the OSB sheathing and to the face of the bottom lap of siding.

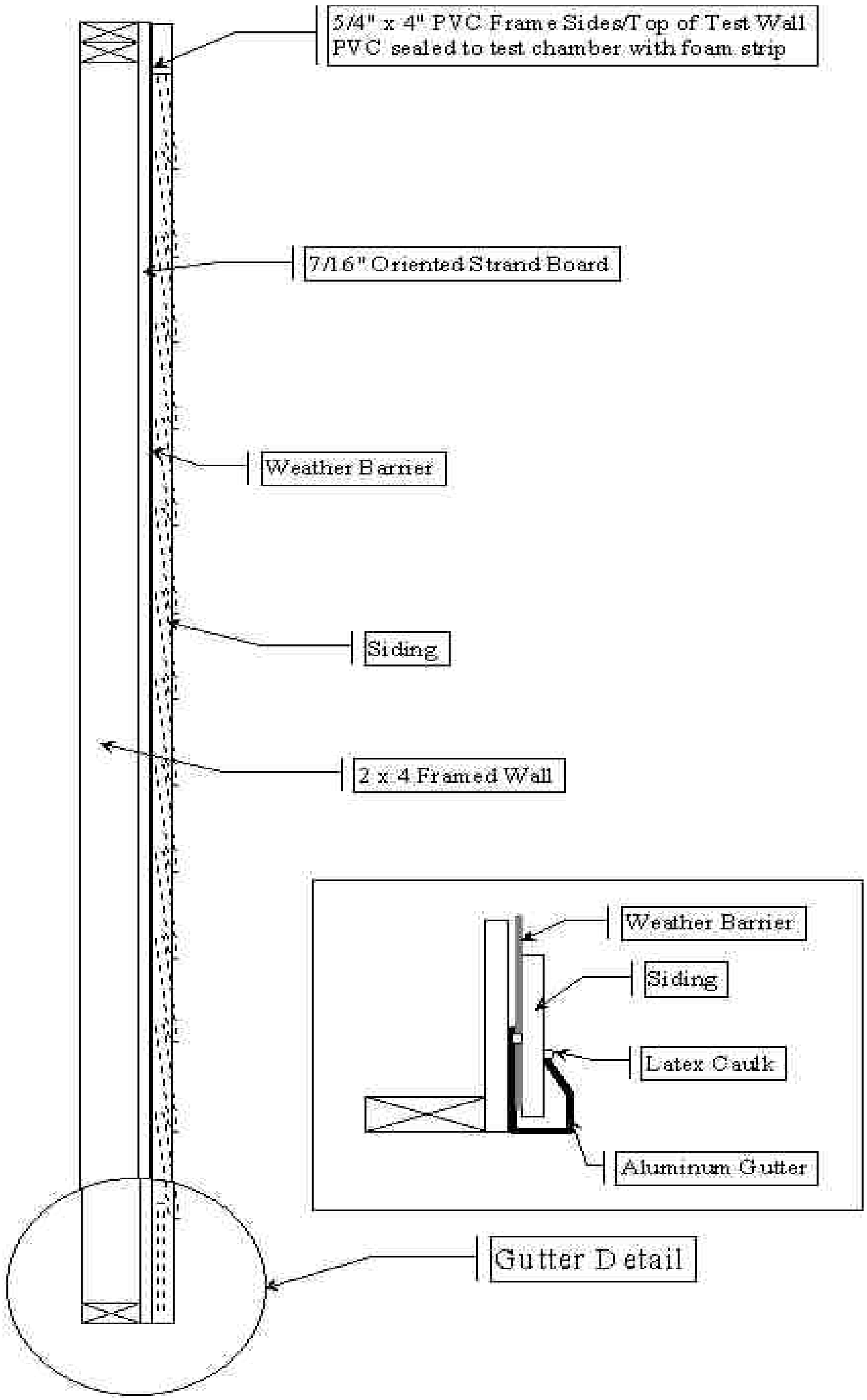


Figure 1
Specimen/Gutter Cross Section

The moisture content of the sheathing was measured in 39 locations on the wall cavity side of the sheathing and framing before and after the testing (see Figure 2). After the water exposure sequence, the test walls remained sealed to the chamber overnight and moisture readings were taken the next morning. The measurements were taken with a two-pin solid state moisture meter (Delmhorst model RC-1C). The accuracy of the meter is ±5 percent of the reading when moisture levels are between 5 and 12 percent by weight.

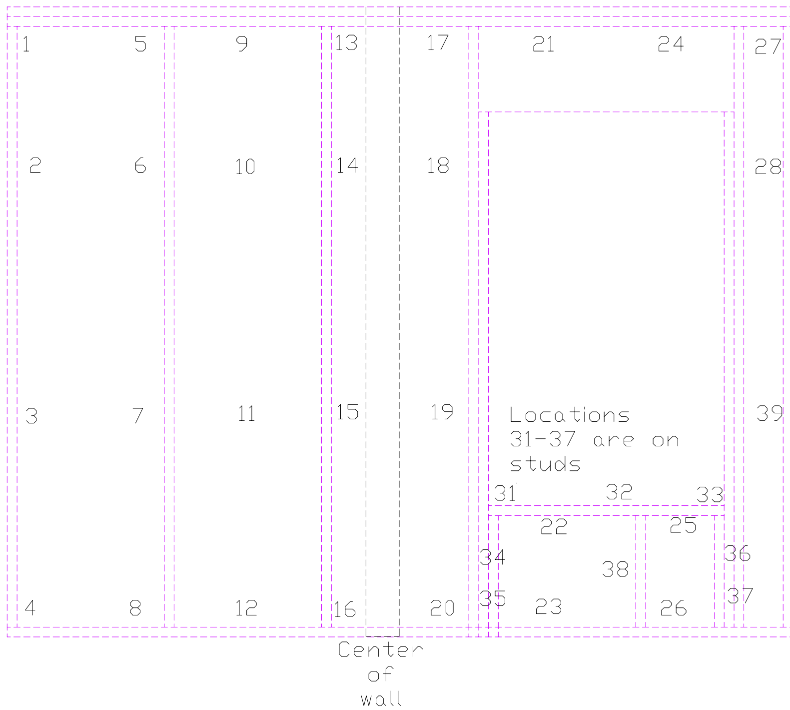


Figure 2
Moisture Reading Locations

TEST WALLS

The test walls were 8 feet high by 10 feet wide. Each wall contained a single 3’ by 5’ window as shown in Figure 2. Each wall was subdivided into two segments using a standard end treatment trim. Rate of water intrusion and leakage paths can be observed for each exposure type: in the field of a siding system, around an opening (window), and at trim interfaces. Each half of the wall specimen was drained separately to allow the primary siding leakage in a typical field and around a window to be measured independently.

Test walls were constructed using best construction practices; studs on 24-inch centers, 7/16-inch oriented strand board (OSB) sheathing, exterior weather barrier and flange-mounted welded vinyl windows equipped with integral j-channels. Careful attention was paid to head, sill, and side flashing details. This was accomplished with 10-inch wide strips of 30-pound building felt attached with button-cap nails (see Figure 3). The bottom flashing was installed before the window so that the framing could be protected. Next, the window was installed. The window flanges were set in 100 percent silicon caulk. The side flashing was then installed so that it covered the window flange and overlapped the bottom flashing. Finally, a slit was cut in the weather barrier above the window. The felt flashing was inserted under the weather barrier and over the top window flange and side flashings. With the exception of the caulkless fiber cement test wall, the siding was installed as per manufacturer specifications.

Figure 3
Flashing Detail

The vinyl and conventional fiber cement siding were installed in accordance with manufacturer specifications. Primed wood trim (5/4 inch) was installed around the window for the conventional fiber cement wall to conceal the integral j-channel in the window. After the siding was installed it was caulked with a latex caulk at all butt joints and where the siding butted the primed wood trim. The fiber cement siding specimens were finished with two coats of semi-gloss exterior latex paint, applied with a 7-inch cloth roller. No insulation or interior wallboards were installed to allow access to measure the sheathing moisture content.

The caulkless fiber cement test walls utilized wood fiber/plastic composite corner posts and j-channels. These components are dimensionally and functionally very similar to vinyl siding corners and j-channel (Figure 4). When fiber cement manufacturers were consulted as to the feasibility of the caulkless system, they had several concerns. Their primary concerns were that the siding would absorb water through unprimed end cuts within the corner posts or j-channel. To address these concerns, several of the cut ends were protected with snap-on vinyl end treatments (Figure 5). Several other ends were not protected so that a comparison could be made.

Figure 4
Drainage Plane

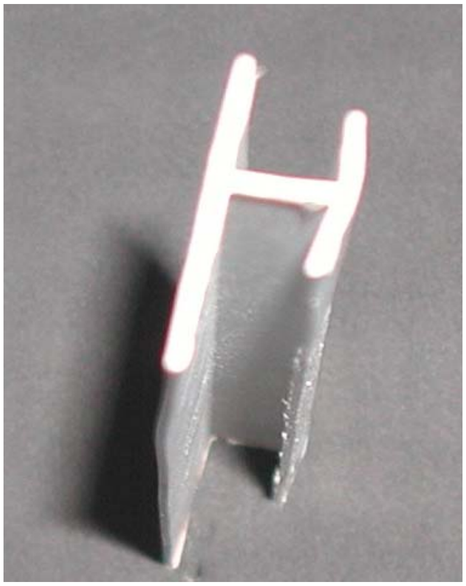


Figure 5
Vinyl Edge Protector

Two, 2-inch wide strips of fiberglass composition roofing shingles, fastened with roofing nails, were used to form a 1/4-inch deep drainage plane (see Figure 4) for the fiber cement caulkless system with an airgap.

Once constructed, the test walls were inserted in the test chamber using a foam gasket to prevent leakage during the evaluation period (Figure 6).

Figure 6
Wall Secured in Test Chamber

TEST RESULTS

The water intrusion results are presented in Table 1. Both the vinyl and fiber cement caulkless systems performed as expected, allowing a significant amount of water to penetrate the siding system. The conventional, caulked fiber cement wall system allowed much less water to penetrate, however, given that this type of system is not designed to allow water to penetrate, the amount of water was significant. Virtually no visible signs of water penetration were detected through the weather barrier and flashing system installed behind each of the siding systems. Only some minor spot staining was detected where fasteners penetrated the weather barrier. It is important to note that water collected in the gutter is a function of many factors. Although water intrusion is always undesirable, more important is the ability of a siding system to allow water to move freely out of the system before being absorbed.

TABLE 1
WATER INTRUSION RESULTS

WATER COLLECTED IN GUTTER SYSTEM (U.S. GALLONS)				
	Window Side		Clear Wall	
	1st Cycle*	2nd Cycle	1st Cycle	2nd Cycle
Vinyl	2.876	3.335	2.125	3.163
Fiber Cement - Caulked	0.496	0.610	0.606	0.631
Fiber Cement - Caulkless	2.369	2.809	1.500	1.994
Fiber Cement - Caulkless w/Drainage Plane	2.513	3.148	2.929	2.692

*Cycle = 15-minute exposure to 5 gallon/ft^2-hr water spray at 2.5 lbs/ft^2 air pressure.

Table 2 presents the moisture readings before and after the testing. The negative changes recorded were most likely the result of areas that did not get wet during testing drying out overnight. Figure 7 provides a summary of the elevated moisture readings. The total increased moisture readings include all elevated moisture readings. The readings above .5 percent were separated to exclude those readings within the error potential for the measuring equipment. The vast majority of the readings showed no elevation in moisture levels. By referring to Table 2 and Figure 2, it can be determined that about a third of the elevated moisture readings occurred near the window opening and well over half occurred on the bottom half of the specimen. However, the number of elevated readings and their degree suggest the flashing systems performed adequately. This reinforces the fact that windows and other penetrations are the most susceptible to water intrusion and absorption.

TABLE 2
MOISTURE READINGS

WALL MOISTURE READINGS (PERCENT MOISTURE CONTENT)												
Wall Location	**Vinyl**			**Fiber Cement (Conventional)**			**Fiber Cement (Caulkless)**			**Fiber Cement (Drainage Plane)**		
	Before	After	**Change**	Before	After	**Change**	Before	After	**Change**	Before	After	**Change**
1	8.75	9.00	**0.25**	9.75	9.75	**0.00**	9.00	9.00	**0.00**	8.25	8.25	**0.00**
2	8.50	8.75	**0.25**	9.25	9.50	**0.25**	8.75	8.75	**0.00**	9.25	8.25	**-1.00**
3	8.50	9.00	**0.50**	9.25	9.25	**0.00**	8.75	8.75	**0.00**	9.00	8.25	**-0.75**
4	9.25	9.25	**0.00**	10.00	9.25	**-0.75**	9.00	9.00	**0.00**	9.00	8.25	**-0.75**
5	8.75	9.00	**0.25**	9.75	9.50	**-0.25**	9.00	9.00	**0.00**	8.25	8.50	**0.25**
6	8.75	9.25	**0.50**	9.25	9.75	**0.50**	8.25	8.25	**0.00**	9.25	8.25	**-1.00**
7	8.75	9.26	**0.51**	9.25	10.00	**0.75**	8.25	9.25	**1.00**	8.75	8.25	**-0.50**
8	9.25	9.50	**0.25**	9.25	9.25	**0.00**	9.00	9.00	**0.00**	9.25	8.50	**-0.75**
9	8.50	9.00	**0.50**	9.00	9.25	**0.25**	8.75	8.75	**0.00**	8.25	8.50	**0.25**
10	8.75	8.25	**-0.50**	9.25	9.25	**0.00**	9.00	9.00	**0.00**	9.00	8.50	**-0.50**
11	8.75	9.00	**0.25**	9.25	9.25	**0.00**	8.50	8.75	**0.25**	8.75	8.00	**-0.75**
12	8.75	8.50	**-0.25**	9.00	10.00	**1.00**	9.75	9.75	**0.00**	9.25	8.50	**-0.75**
13	8.75	8.25	**-0.50**	9.25	9.25	**0.00**	9.25	9.25	**0.00**	8.00	8.00	**0.00**
14	8.75	9.00	**0.25**	9.75	9.50	**-0.25**	8.50	8.50	**0.00**	8.50	8.00	**-0.50**
15	8.75	8.50	**-0.25**	9.50	9.05	**-0.45**	9.25	9.25	**0.00**	9.00	8.25	**-0.75**
16	8.75	8.75	**0.00**	9.50	11.00	**1.50**	9.50	10.00	**0.50**	8.75	8.50	**-0.25**
17	8.75	8.25	**-0.50**	9.25	9.25	**0.00**	9.00	9.00	**0.00**	8.25	8.50	**0.25**
18	8.50	8.50	**0.00**	9.50	9.50	**0.00**	8.50	9.25	**0.75**	9.00	8.25	**-0.75**
19	8.50	9.00	**0.50**	9.25	9.25	**0.00**	8.75	8.75	**0.00**	9.25	8.25	**-1.00**
20	8.75	8.75	**0.00**	10.00	9.50	**-0.50**	9.25	9.25	**0.00**	9.25	8.50	**-0.75**
21	9.00	9.00	**0.00**	9.25	9.00	**-0.25**	8.50	9.00	**0.50**	8.50	8.25	**-0.25**
22	8.50	8.50	**0.00**	9.25	9.00	**-0.25**	9.00	9.00	**0.00**	8.00	8.25	**0.25**
23	8.50	8.75	**0.25**	9.00	8.50	**-0.50**	9.50	9.50	**0.00**	9.00	8.00	**-1.00**
24	8.50	8.75	**0.25**	9.50	9.50	**0.00**	8.50	8.75	**0.25**	8.25	8.00	**-0.25**
25	8.25	8.75	**0.50**	9.50	9.00	**-0.50**	9.25	9.25	**0.00**	8.75	8.00	**-0.75**
26	8.75	9.25	**0.50**	10.00	10.00	**0.00**	9.75	9.50	**-0.25**	9.00	8.00	**-1.00**
27	8.75	9.25	**0.50**	9.25	9.25	**0.00**	8.75	9.00	**0.25**	8.25	8.25	**0.00**
28	8.25	8.25	**0.00**	9.25	10.25	**1.00**	8.25	8.50	**0.25**	8.00	8.00	**0.00**
29	8.50	8.75	**0.25**	9.25	9.75	**0.50**	8.50	9.00	**0.50**	8.50	8.00	**-0.50**
30	8.50	8.25	**-0.25**	10.00	10.25	**0.25**	9.25	8.75	**-0.50**	10.00	8.50	**-1.50**
31	8.50	8.25	**-0.25**	9.75	9.75	**0.00**	9.25	9.00	**-0.25**	9.50	8.50	**-1.00**
32	7.75	9.00	**1.25**	10.00	9.50	**-0.50**	8.25	8.25	**0.00**	9.25	8.25	**-1.00**
33	8.75	8.75	**0.00**	10.50	10.25	**-0.25**	8.75	8.75	**0.00**	9.00	8.00	**-1.00**
34	8.75	9.00	**0.25**	12.00	12.00	**0.00**	9.25	9.75	**0.50**	10.00	9.00	**-1.00**
35	9.25	9.25	**0.00**	12.50	12.50	**0.00**	9.75	9.75	**0.00**	9.75	8.75	**-1.00**
36	8.75	8.50	**-0.25**	10.00	9.50	**-0.50**	9.50	9.50	**0.00**	9.50	8.50	**-1.00**
37	10.00	9.75	**-0.25**	10.00	9.25	**-0.75**	9.75	9.50	**-0.25**	9.25	8.25	**-1.00**
38	10.00	10.00	**0.00**	10.75	10.00	**-0.75**	9.50	9.50	**0.00**	9.50	8.50	**-1.00**
39	10.00	10.00	**0.00**	9.50	9.75	**0.25**	8.75	8.50	**-0.25**	9.00	8.00	**-1.00**

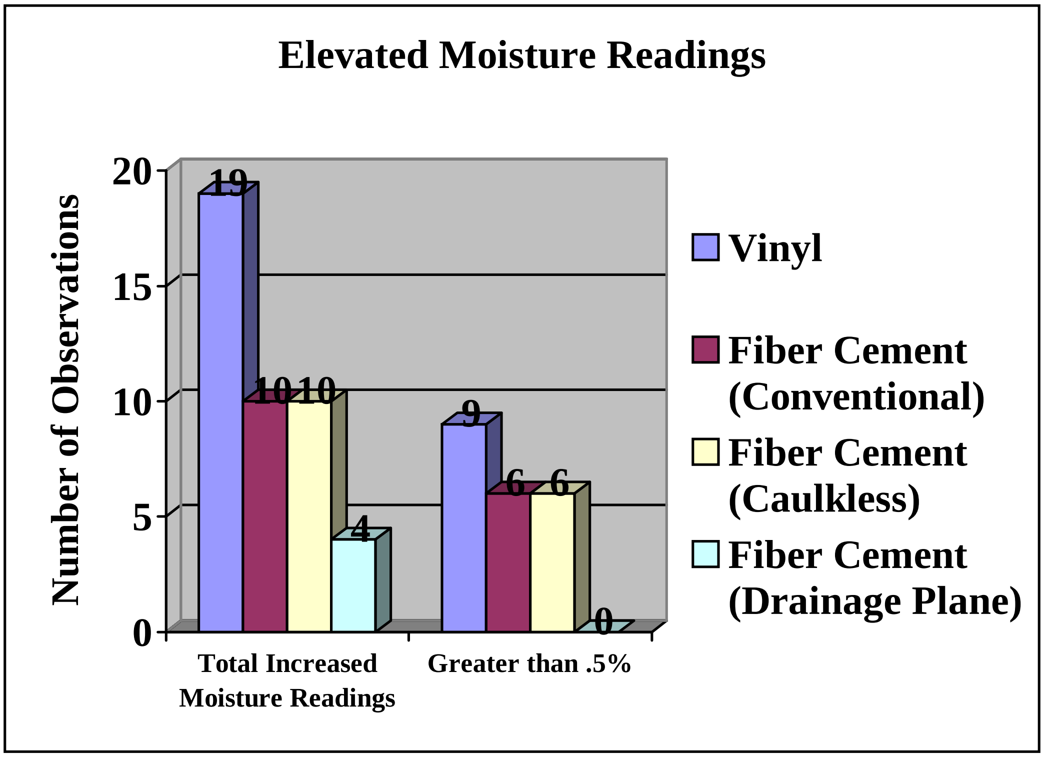
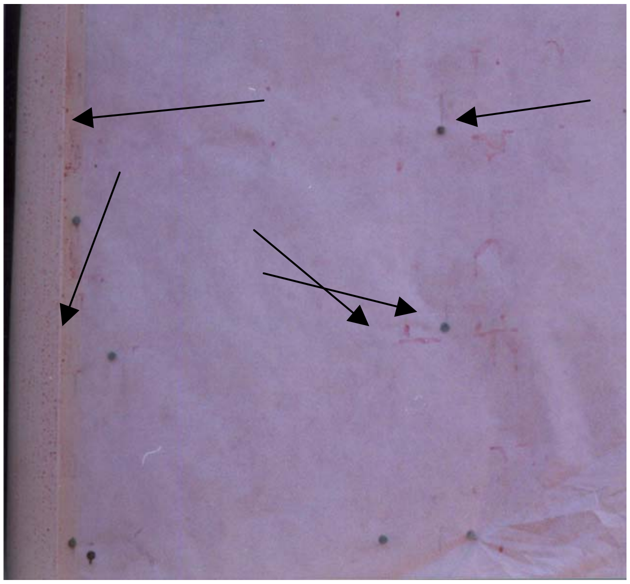


Figure 7
Summary of Elevated Moisture Readings

VINYL SPECIMEN

The vinyl-sided specimen allowed significant water intrusion. The primary leakage area was around the end treatments. Significant streaking was noted on the interior portions of the j-channel and split-corner post as well as the window's integral j-channel (Figure 8). These visual observations are also supported by the results of the gutter collected water presented in Table 2. Significantly more water was collected on the window side of the wall. Some minor streaking was also noted at the intermediate splices in the siding on the clear wall side of the specimen (Figure 9).



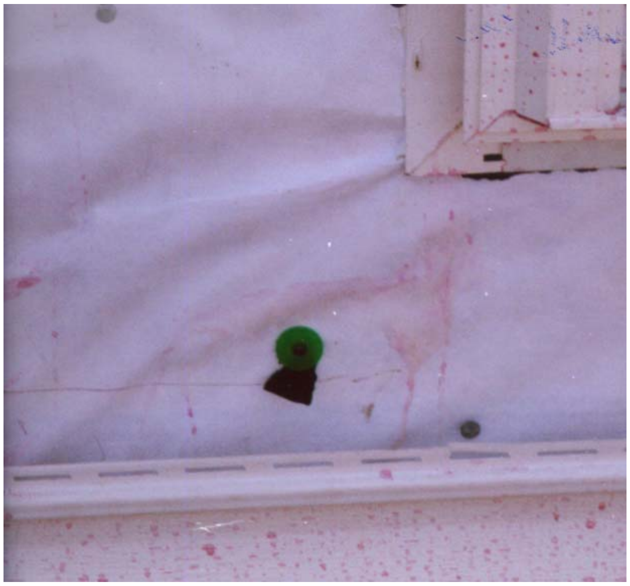


Figure 8
Vinyl Specimen - Window Corner

Figure 9
Vinyl Specimen

The majority of the streaking was almost completely vertical. This confirms that the vinyl siding provides an unobstructed drainage plain.

CONVENTIONAL FIBER CEMENT (CAULKED)

The conventional (caulked) fiber cement specimen experienced the least water intrusion. The amount of intrusion that did occur was unexpected. Since this system is more likely to take longer to dry out, the water intrusion was surprisingly high.

Visual inspection indicated that water penetrated to varying extents at the majority of the caulk joints. However, the majority of water intrusion appears to have occurred through the bottom of the laps of siding (Figures 10 and 11). This leakage path was more pronounced in this specimen when compared to either of the caulkless specimens (Figure 12). It is possible that the pressure difference between the front and backside of the siding was influenced by the caulk sealed areas. This could cause a greater pressure differential and concentration of air flow through less crack length areas. The high pressure difference and airflow rate could explain why water traveled up and over the siding laps. This would explain why this phenomenon did not occur on the caulkless systems.

Figure 10
Conventional Fiber Cement Specimen - Window

Figure 11
Conventional Fiber Cement Specimen - Clear Wall

Figure 12
Fiber Cement - Staining on Back of Siding
(Extent of Staining is Outlined)

FIBER CEMENT CAULKLESS/CAULKLESS WITH DRAINAGE PLANE

Both of the caulkless fiber cement samples performed very similar to the vinyl sided specimen. As with the vinyl sample, the corner posts and j-channel had significant vertical streaking (Figures 13 and 14). The vertical streaking indicates an unimpeded flow of water out of the wall system. This was expected on the specimen with the drainage plane, but not necessarily of the specimen without the drainage plane. The 1/4-inch-thick composite cornerpost and j-channel appear to have created adequate separation at the edge details between the siding and weather barrier to allow the water to move freely.

Figure 13
Fiber Cement with Drainage Plane (Window)

Figure 14
Fiber Cement with Drainage Plane

Addressing the manufacturers concerns, the wetting of the unprotected cut edges of the siding within the J-channel was not significant. The vinyl edge protectors reduced the wetting, but they were difficult to install (Figure 15). Figure compares the wetting of the unprotected portions of the siding both in the samples with and without caulk. The wetting of the ends in the caulkless samples without the edge protectors appears minor.

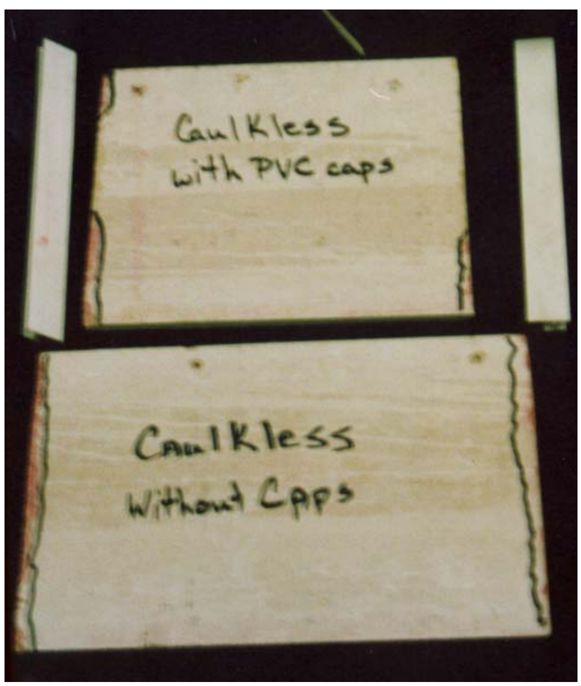


Figure 15
Edge Wetting (Staining Outlined)

NEXT STEPS - FIELD EVALUATION

The most important result of the testing had very little to do with the siding systems. Whatever the type of cladding used, the weather barrier and flashing system behind it is of the utmost importance. Many homes built today do not have a weather barrier or window flashing installed. In fact, the building codes do not require a weather barrier when exterior grade sheathing is used. Further laboratory testing should be conducted to gauge the performance of different combinations of weather barriers and flashing systems.

In addition to confirming the importance of weather barriers and flashing, the laboratory testing supports the feasibility of a caulkless fiber cement siding system. The caulkless system performed sufficiently well to merit further investigation through installation on the Marketable, Affordable, Durable, Entry-Level (MADE) demonstration homes. The caulkless system with a drainage plane will be installed on the first two MADE homes. Field monitoring and testing of one of these homes will provide valuable information on validating the leakage and moisture migration through the wall under normal weather conditions.

The field instrumentation will include embedded moisture sensors, a site weather station, and an instrumented wall gutter collection system similar to that used in the laboratory testing. In addition to the field instrumentation, small portions of the walls will be disassembled and visually inspected.