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Barrier EIFS Clad Walls: Results from a Moisture Engineering Study

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ABSTRACT: This paper presents the results of work performed to enhance understanding of water penetration and moisture characteristics of barrier Exterior Insulation Finish Systems (EIFS) clad walls. The investigation was prompted by recent failures of barrier EIFS clad walls on houses in the Wilmington, North Carolina area. The objective was to determine the cause of the problem and gain a better understanding of water penetration and moisture transport in these systems.

The study included a field investigation, laboratory experiments, and computer simulation. The experimental results indicate that barrier EIFS clad walls are prone to leak in areas around penetrations and allow water to enter into the wall cavity. A drainage cavity wall was also tested, and observed to perform well, managing water around penetrations and preventing leakage into the wall cavity. The computer simulation indicates that barrier EIFS clad walls in Wilmington have low moisture tolerance due to slow drying rates.

In conclusion, barrier EIFS clad walls do not provide effective management of rain penetration. As such, in-service performance is unpredictable and unreliable. In contrast to barrier EIFS clad walls, walls using a drained cavity approach were shown to provide good control of rain penetration.

KEY WORDS: barrier EIFS, deterioration, drained cavity design, drying potential, exterior wall systems, moisture damage, moisture transport, water penetration, wood structure.

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INTRODUCTION

THIS PAPER PRESENTS the results of work performed to enhance understanding of water penetration and moisture characteristics of barrier Exterior Insulation Finish Systems (EIFS) clad walls. The study was conducted by a team of researchers from the National Research Council Canada (NRCC) and the United States Gypsum Company (USG). The Institute for Research in Construction of NRCC is an internationally recognized research laboratory with particular expertise in the performance of exterior building envelopes. USG is a large building material manufacturer that markets exterior cladding systems.

The investigation was prompted by recent failures of barrier EIFS clad walls on houses in the Wilmington, North Carolina area. Moisture related damage to wood frame structural components was observed in many instances. This study was undertaken to determine the cause of the problem and gain a better understanding of water penetration and moisture transport in these systems. The research approach and results of this investigation are presented along with conclusions and recommendations for future actions.

FIELD INVESTIGATION

Wilmington is located on the mid-Atlantic seacoast where summer climatic conditions are hot and humid. The ASHRAE Handbook of Fundamentals lists 2.5% summer design conditions as 33°C (91°F) dry bulb and 26°C (79°F) coincident wet bulb temperatures which corresponds to a 58% design relative humidity. The 2.5% winter design temperature is -3°C (27°F).

A field investigation of selected EIFS clad houses in Wilmington and New Hanover County, NC was conducted in the late fall of 1995. The purpose of the fieldwork was to observe and inspect houses identified as having moisture related problems. Visual inspections were coupled with moisture readings taken inside wall assemblies using handheld moisture probes. At one site, tests were conducted around windows using a portable spray rack and blower door fan to simulate wind-driven rain conditions and observe water intrusion paths.

Walls inspected in Wilmington were designed as barrier EIFS clad walls. A section through a typical wall is shown in Figure 1. Barrier EIFS clad walls are designed as face sealed systems with the intent that water is prevented from entering the wall assembly. No design provisions are made for the drainage or management of water that may intrude the wall.

The walls are wood frame with drywall on the interior face, a six mil polyethylene vapour retarder on the interior of the studs, and glass fiber insulation in the stud cavity. Oriented Strand Board (OSB) or plywood struc-

formed to enhance understanding of characteristics of barrier walls. The study was conducted by the National Research Council Canada (USG). The Institute for Building Research is a nationally recognized research organization that provides information and assistance to building manufacturers that markets

features of barrier EIFS clad walls in the field. Moisture related problems were observed in many cases and the cause of the problem was not clear. The results of this investigation are being used to provide recommendations for future actions.

Near the coast where summer climate is hot and humid. ASHRAE Handbook of Fundamentals lists a design dry bulb temperature of 33°C (91°F) which corresponds to a design temperature of 38°C (100°F).

Inspections in Wilmington and New York City in 1995. The purpose of the study was to identify construction practices identified as having potential for moisture problems coupled with moisture held moisture probes. At the time of the study a portable spray rack was used to create conditions and observe

the performance of barrier EIFS clad walls. Figure 1. Barrier EIFS clad wall section. The intent is that water is not to penetrate the wall. Design provisions are made to prevent water from intruding the wall.

On the interior face, a six mil vapor barrier, studs, and glass fiber insulation (OSB) or plywood struc-

FIGURE 1. Typical barrier EIFS clad wall section.

tural sheathing is nailed on the outside of the studs. Expanded polystyrene (EPS) foam is adhesively bonded to the sheathing. The foam is coated with a polymer modified cementitious basecoat with a mesh embedded in the basecoat. Following mesh embedment, a "double back" coating of basecoat is applied. An acrylic synthetic stucco finish is then applied. EIFS manufacturers typically recommend that joints at window and door penetrations be sealed using a closed cell foam backer rod and appropriate caulking compound.

Several observations were made from the fieldwork. Water was found to be intruding into the exterior walls near window assemblies, doorways, hose bibs, and roof eaves. There was little evidence that water was penetrating through the field of the EIFS cladding. In particular, vinyl combination windows (two or more units field joined by a vinyl mullion) were problematic. Flashing and sealing specifications recommended by EIFS manufacturers were typically not followed.

Information gained from the field inspections was used to develop a laboratory program to measure water intrusion rates in wall assemblies typical of Wilmington construction practices and determine relative drying rates for those walls. A final step was to develop modified wall designs with improved moisture performance that better accommodate water infiltration.

LABORATORY CHARACTERIZATION OF WATER PENETRATION

The objective of the laboratory phase of the research was to determine the

airtightness and water penetration characteristics of full-scale wall test specimens under controlled laboratory conditions. Specific data on water intrusion rates for assemblies tested under known water exposure and wind pressure conditions would be used later in computer simulation models to predict wall drying rates and assess the potential for damage to moisture sensitive wall components. Four wall designs were tested:

- Specimen 1: Two EIFS clad walls without penetrations. The walls were tested with different basecoat thicknesses (Figure 2).
Specimen 2: An EIFS clad wall with a vinyl combination window sealed with backer rod and caulk (Figure 3).
Specimen 3: An EIFS clad wall with a vinyl combination window without the backer rod detail (Figure 4).
Specimen 4: A drainage cavity wall design using a direct applied (DEFS) cement board system (Figure 5).

For these specimens, EIFS materials and cement board were provided by USG. OSB sheathing and vinyl windows were purchased in North Carolina and shipped to NRCC. Wood studs were obtained in Canada.

Experimental Procedure

All experimental work was conducted at the NRCC laboratory in Ottawa, Canada. Air and water penetration tests on full scale wall assemblies were conducted using the NRCC Dynamic Wall Test Facility (DWTF). This facility accepts a 2440 mm $\times$ 2440 mm (8' $\times$ 8') test specimen. The specimens

FIGURE 2. Specimen 1: EIFS clad walls without penetrations.

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FIGURE 3. Specimen 2: EIFS clad wall with a vinyl combination window sealed with backer rod and caulk.

FIGURE 4. Specimen 3: EIFS clad wall with a vinyl combination window without the backer rod detail.

were mounted in a steel test frame and the test frame was mounted to the DWTF. A typical test specimen is shown in Photo 1. The specimens were sealed to the steel frame with backer rods and silicone sealant in a single stage joint. The interior face of the specimens was exposed to the laboratory which allowed for observation of the stud cavities during testing.

Airtightness characteristics were evaluated by applying a static air pressure difference of 500 Pa (10.4 psf) across the specimen and measuring the air flow rate with and without the face of the specimen sealed. The difference between the two measurements represented the airtightness of the specimens. The test pressure difference was chosen because previous NRCC experience with similar specimens had demonstrated that they were relatively airtight and a pressure difference of 500 Pa (10.4 psf) produced a measurable air leakage rate. This air pressure difference corresponds to a wind speed of 42 m/s (64 mph).

Water penetration characteristics were evaluated by applying a static or dynamic air pressure difference across the specimen while spraying water on the face of the specimen at a rate of 4.2 L/min/m² [6.2 gal/hr/ft²]. Electrical

FIGURE 5. Specimen 4: Drainage cavity wall.

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PHOTO 1. Test specimen mounted in the DWTF and instrumented for water penetration tests.

resistance moisture pins were designed and installed to sense the presence of moisture at various locations in the EPS. In groups of three, pins were located near the basecoat, at the center of the EPS, and near the OSB. Water entry paths were determined through visual observation. The rate of water intrusion was determined by collecting water on the sill of the rough window opening and the bottom of all stud cavities. For Specimen 4, water was also collected at the base of the drainage cavity. The dimensional lumber in the specimens was sealed to prevent water from being absorbed into the wood. For Specimens 2 and 3 the moisture content of the OSB and EBS was determined from samples taken after the tests were completed.

EIFS Wall without a Penetration

The first series of tests evaluated airtightness and water penetration in the field of the EIFS cladding without any windows or penetrations. The effect of basecoat thickness on water penetration was also studied in Specimen 1.

Two 1220 mm × 2440 mm (4' × 8') sections were tested side-by-side in the DWTF as illustrated in Figure 2. The basecoat thickness of Specimen 1-A was measured to be 3.8 mm (0.15"). The basecoat thickness of Specimen 1-B was measured to be 3.1 mm (0.12"). Both specimens were constructed on a 38 mm × 89 mm (2" × 4") wood stud frame with studs located at 406 mm (16") on center, with double top and single bottom plates and with OSB sheathing nailed to the outside. EPS was adhered to the OSB, covered with basecoat and mesh, and finished with a coat of synthetic stucco (Class PB).

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The air leakage test indicated that both sections were relatively airtight. A static water penetration test conducted for three hours with an air pressure difference across the specimens of 300 Pa [6.3 psf] for the first hour and 500 Pa [10.4 psf] for the next two hours. This corresponds to 33 m/s (50 mph) and 42 m/s (64 mph), respectively. Neither section experienced water penetration into the wall cavity. This result agreed with site observations that water entry was occurring at interfaces between the EIFS cladding and other exterior components.

EIFS Walls with Vinyl Combination Windows

The second series of tests involved EIFS clad walls with vinyl combination windows. One wall was built using a backer rod and sealant detail around the window perimeter (Specimen 2). The other wall eliminated the backer rod detail to simulate typical Wilmington construction practices (Specimen 3).

The test specimens were 2440 mm $\times$ 2440 mm (8' $\times$ 8'). The field of Specimens 2 and 3 was constructed in the same manner as described for Specimen 1-A above. Combination vinyl windows, which consisted of two single-hung window units mulled together, were installed in each specimen. The units were joined with a pair of vinyl mullion strips supplied by the window manufacturer. All window units were labeled as meeting American Architectural Manufacturers Association (AAMA) water penetration standards.

Specimen 2 was installed with a backer rod and sealant detail consistent with typical manufacturer's specifications. Figure 3 is a section showing details around the window. Specimen 3 was constructed with the EIFS installed flush against the window frame. This detail did not use a backer rod and caulk to seal at the joint between EIFS and the window frame. A fillet bead of caulk was applied where the EIFS architectural band returned to the window frame. This was a common detail observed in houses in Wilmington. Figure 4 is a section showing this detail.

For the tests, each window was separately sealed with polyethylene and the mullion joint taped. As the windows were rated as meeting AAMA water penetration standards, it was considered appropriate to exclude window leakage from the evaluation of water penetration characteristics of the wall.

Air leakage tests on both specimens indicated that the field of the specimen was relatively airtight, but that significant leakage occurred through the wall/window interface and through the frame of the window. Inspection of the window units revealed that air leakage through the frame appeared to enter at drainage holes on the exterior face and exit through welded joints on

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Static water penetration tests were conducted as the "as-built" specimens and on the specimens with three different defects introduced into the window or the wall/window interface. This resulted in Specimens 2 and 3 being tested under the following four conditions:

- *as built*—the specimens constructed as described above in which appropriate care and caution were exercised in construction
- *mullion exposed*—the tape sealing the mullion strip between the window units was removed
- *mullion defect*—field inspection in Wilmington indicated that vinyl windows were installed with mullion strips that did not cover the entire joint between window units; this defect was simulated by removing 9 mm (3/16") from the bottom of the mullion strip
- *sealant defect*—field inspection in Wilmington indicated that windows had defects (from adhesion/cohesion failure) in the window/EIFS sealant; such defects were simulated by creating a 75 mm (3") long opening in the fillet seal between the architectural band and the windowsill

Water was initially applied with pressure difference of 137 Pa (2.86 psf) for fifteen minutes and then 300 Pa (6.27 psf) for a period of one hour for all but two variations of both specimens. These air pressure differences correspond to wind speeds of 22 m/s (34 mph) and 33 m/s (50 mph), respectively. For the "as built" variation of Specimen 2, the 300 Pa (6.27 psf) pressure was applied for two hours because water didn't appear in the specimen until fifty-two minutes into the test. For the "mullion defect" variation of Specimen 3, it was applied for only twenty-five minutes because a very large quantity of water, to a depth of 19 mm (3/4"), accumulated on the sill of the rough opening.

Measured water penetration rates for Specimens 2 and 3 are shown in Figures 6 and 7, respectively. For Specimen 2 in the "as-built" variation, the water weeped through the OSB approximately fifty minutes after appearing at the windowsill or 100 minutes of total test time. For Specimen 3 in the "as-built" variation, the water wept through the OSB at the same time as water appeared at the windowsill or approximately twenty minutes into the test. Photo 2 shows Specimen 3 with water weeping into the stud cavity on the interior face of the OSB. The arrows denote points where a water leak started. A similar pattern was observed on Specimen 2.

In addition to determining the water penetration rates, the testing resulted in several other key findings. First, water did not pass through the field of the EIFS. In both specimens, about half the moisture pins located in the EPS near the basecoat indicated the presence of moisture shortly after the

* NOTE: Test duration of 2 hours at 300 Pa (6.24 psf)

FIGURE 6. Measured water penetration rates into Specimen 2 window with backer rod and caulk.

* NOTE: Test stopped after 26 minutes at 300 Pa (6.24 psf)

FIGURE 7. Measured water penetration rates into Specimen 3 window without backer rod.

PHOTO 2. Specimen 2 with water weeping into the interior of the study cavity after testing.

application of water; however, the lack of any indication of moisture near the OSB away from windows strongly suggested that water does not penetrate the field of the EIFS cladding.

Another key finding was that water passed around and through the window assembly. As Figures 6 and 7 illustrate, a significant amount of water passed through the sills of the windows in both test specimens. Water also moved through the wall layers around and under the windows. In both specimens, water was observed to be weeping from the face of the OSB into the stud cavities about 300 mm (12") below the windowsills in all variations.

Defects typical of those observed in Wilmington increased the amount of water that entered the wall in a given time period. The amount of water measured in the "mullion defect" and "sealant defect" tests was considerably more than that measured in the "as-built" variations in both specimens. Defects around the window penetration also reduced the time required for water to enter the cavity. In some cases, when defects were introduced in the specimens, the weeping through the OSB appeared within the first seven minutes into the test.

The presence of a backer rod and sealant around the window reduced the water intrusion rate, but did not prevent it. Measured water passing through Specimen 3, the window without backer rod and caulk, was three times greater than that measured for Specimen 2. Some of this difference is likely due to an observed difference in leakage through the windows themselves, but a significant portion is attributable to the presence of the backer rod and caulk. It was also observed in Specimen 2 that sealant integrity can be

weakened by water penetration. Post-test examination of the backer rod and sealant below and to the side of the window indicated that a water entry path has been created by adhesion failure of the bond between the basecoat and the sealant. Closer examination determined that the failure was a consequence of water penetrating to the area and wetting the basecoat and sealant.

Finally, significant water can be retained by the OSB and EPS. Two 100 mm (4") diameter samples were removed after the final test for both specimens at a location about 300 mm (12") below the window. The OSB and EPS contained between 20% and 32% moisture content by weight whereas samples removed from the tops of the specimens above the window were dry at 5% moisture content.

Water Managed Wall Using a Drainage Cavity

Specimen 4 was designed to evaluate the effect of a drainage cavity on the air leakage and water penetration characteristics of an exterior wall system. This design contains a drainage path for water which gets past the cladding or wall/window interface weather seals. Figure 5 is a section through the "as-built" variation of Specimen 4 at the windowsill.

In constructing Specimen 4, building paper was stapled to the OSB and a 12 mm (1/2") deep drained and flashed cavity was created by attaching DUROCK® cement board panels over 50 mm (2") wide by 12 mm (1/2") thick DUROCK® furring strips. The furring strips were screwed to the sheathing 406 mm (16") on center. The cement board panels were 1220 mm x 2440 mm (4' x 8') by 12 mm (1/2") thick. DUROCK® cement board, made by USG, is an aggregated portland cement board reinforced with a polymer coated woven glass fiber mesh on both front and back. Photo 3 illustrates Specimen 4 with the furring strips in place and the cement board panels being installed. The panels were then covered with exterior basecoat and finish coat.

The plane of airtightness for the specimen was established by covering the interior face of the studs with 9 mm (3/8") Plexiglas. Plexiglas was used to allow the cavity to be observed during testing. Air leakage tests indicated that the field of the specimen was relatively airtight, but that significant air leakage occurred through the wall/window interface and through the frame of the window. The values were about the same as those for Specimen 3.

The plane of airtightness of the wall was joined to that of the window in order to maintain continuity of the air barrier system over the entire wall. This was achieved, at the sill, by extending the Plexiglas to the sill of the window (see Figure 5) and at the jam and head by taping between the Plexiglas and window frame. (Note that the Plexiglas was joined high on the windowsill in order to cover known leaks at the corners of the windowsill.)

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PHOTO 3. Specimen 3 under construction showing the furring strips and drained cavity.

The same air barrier effect could be achieved in typical construction with gypsum drywall, window trim details, caulk, and paint.

Static and dynamic water penetration tests were conducted on the "as-built" specimen and on the specimen with the various defects installed. For the static water penetration tests, water was initially applied with a pressure difference of 137 Pa (2.86 psf) for fifteen minutes and then with a pressure difference of 300 Pa (6.27 psf) for a period of one hour. For the dynamic water penetration tests, water was applied with a 0.5 Hz sinusoidal pressure difference of 200 Pa (4.18 psf) superimposed on a static pressure difference of 300 Pa (6.27 psf) for a period of one hour.

The measured water penetration into Specimen 4 is summarized in Figure 8. A number of observations was drawn from this series of tests. A drained cavity design manages water penetration. In both the static and dynamic tests, no water was evident in the OSB or the stud cavities for any of the test conditions even though there was considerably more water behind the cladding in Specimen 4 than Specimens 2 or 3. Water passed through defects typical of those observed in Wilmington. The amount of water measured to drain through the drainage cavity in the "sealant defect" test was considerably more than that measured in the "as-built" test. However, the drainage cavity directed all of the water that entered through the defect out of the wall through the drainage cavity.

Implications of Barrier EIFS and Drained Cavity Test Results

The test results led to the conclusion that the field of the barrier EIFS is relatively watertight, but water can enter the wall assembly under wind-

FIGURE 8a. Measured water drainage rates through Specimen 4 with static air pressure.

driven rain conditions at wall/window interfaces. Under conditions typical of those seen in-service, barrier EIFS clad walls are not completely water tight. Specimens 2 and 3 demonstrated that a barrier design could not properly manage water which entered through penetrations such as those associated with windows. Water was observed to enter the wall through the combination windows in both specimens, through the individual window unit sills, and the mulled joint between the two units. Considerable water was also observed to enter the wall through defects in the wall/window interface. In all cases, the water accumulated on the sill of the rough opening and drained into the specimens below the window, saturated the OSB and EPS, and entered the stud cavities.

FIGURE 8b. Measured water drainage rates through Specimen 4 with dynamic pressure.

Figure 4 with static air pressure.

Under conditions typical of barrier EIFS design could not propagate water through the wall through the individual window units. Considerable water effects in the wall/window interface. The sill of the rough opening was saturated the OSB and

Figure 5 with dynamic pressure.

In contrast to barrier EIFS, the drained cavity wall did manage water effectively. Water entered this specimen in a manner similar to that observed in the barrier design specimens. However, it was successfully drained out through the drainage cavity. No water appeared in the OSB or stud cavities. Note that effective design requires that the wall-window interface also be designed using a drained cavity approach. Design details that serve to direct water from the sill and jamb area out to the drainage cavity are required. Openings around penetrations must be wrapped and flashed so that any water that gets behind the cladding is drained back to the exterior. Figure 5 illustrates such details, including a sill wedge, a sill wrapped with self-adhesive flashing membrane, metal flashing, and a drainage cavity.

CHARACTERIZATION OF WALL DRYING POTENTIAL USING MODELING

This task was designed to evaluate and characterize the drying potential of barrier EIFS clad walls typical of those constructed in Wilmington. The specific objective was to determine, through modeling, the net annual accumulation in such walls under several different conditions. One set of simulations was designed to evaluate different interior vapour permeance levels and their effect on wall drying rates. A second set of simulations was designed to determine moisture levels in wall component materials under typical Wilmington weather conditions and to assess the potential for moisture related damage.

Simulation Procedure

LATENITE, a combined heat, air, and moisture transport simulation program developed by NRCC, was used for the simulations. Moisture performance was simulated on an hourly basis for a period of three years. Hourly weather data for Wilmington, which was obtained from the National Climatic Center for the years 1989–1991, were used as exterior boundary conditions. The data included ambient temperature and relative humidity, solar radiation, wind speed and direction, and precipitation rates. Water penetration rates at the wall/window interface were determined by scaling the amounts measured in the experimental program to the wind-induced pressure difference and rainfall rate. Material properties used in the simulations were determined by direct measurement in the NRCC laboratory, or were obtained from the LATENITE material property database. Interior conditions were based on a review of house operational features and on discussions with USC.

Effect of Interior Vapour Permeance on Wall Drying Potential

The effect of interior water vapour permeance on the drying potential of

FIGURE 9. Schematic of computational domain model without window.

EIFS clad walls in the Wilmington area was investigated in four simulations. Figure 9 provides a schematic of the computational domain. Two different water vapour permeance rates, representing "poor" and "good" quality paint, were evaluated for painted gypsum board. A summary of the parameters evaluated in the various simulations is contained in Figure 10.

For these simulations, the OSB sheathing was initially assigned a relative humidity of 98% (moisture content of $0.21 \text{ kg}_w/\text{kg}_d$), while all other materials were assigned a relative humidity of 80%. These initial moisture conditions were intended to represent a situation where either water penetration has occurred or construction moisture is present. Moisture transport through the wall was restricted to vapour diffusion only. This was consistent with observations from the field and from laboratory tests on EIFS clad walls without penetrations.

The simulation with the polyethylene vapour retarder and unpainted interior drywall (Model 1) dried the slowest. Removal of the polyethylene resulted in the highest drying rate (Model 2). Drying performance on

Simulation	Interior Water Vapour Permeance		Window Water Leakage
	Polyethylene Film	Painted Drywall	
Model 1	Yes	No paint	No leak
Model 2	No	No paint	No leak
Model 3	No	High WVP ¹	No leak
Model 4	No	Low WVP ²	No leak

¹Paint/gypsum board with water vapour permeance of $210 \text{ ng}/(\text{Pa}\cdot\text{s}\cdot\text{m}^2)$ [3.7 perms].

²Paint/gypsum board with water vapour permeance of $30 \text{ ng}/(\text{Pa}\cdot\text{s}\cdot\text{m}^2)$ [0.5 perms].

FIGURE 10. Simulation parameters for barrier EIFS clad walls without penetration.

FACE

AND FINISH
YSTYRENE
LL CONSTRUCTION
ITY INSULATION
VAPOR RETARDER
ARD
OOD
OOD CONSTRUCTION
SPACE
0.4
0.5

model without window.

igated in four simulations. onal domain. Two different " and "good" quality paint, ummary of the parameters in Figure 10.

initially assigned a relative (kg_w/kg_d) , while all other 0%. These initial moisture where either water pene- resent. Moisture transport n only. This was consistent oratory tests on EIFS clad

retarder and unpainted removal of the polyethylene Drying performance on

	Window Water Leakage
rywall	
at	No leak
it	No leak
VP ¹	No leak
VP ²	No leak

¹) 13.7 permsl.

²) 10.5 permsl.

d walls without penetration.

DRYING FACTOR

FIGURE 11. Relative drying times of OSB under different interior vapour permeance conditions.

the walls with painted drywall was much lower than unpainted drywall, but above that of the wall with the polyethylene vapour retarder (Models 3 and 4).

Figure 11 illustrates the relative drying rates predicted by the computer model. Note that a wall without any warm side vapour retarder has a drying rate that is twenty-five times that of one with a vapour retarder like 6 mil polyethylene. However, in the practical case of a painted drywall finish, removal of the polyethylene results in a maximum eight-fold improvement in drying rate. For Wilmington construction with interior polyethylene vapour control, drying times were excessively long.

Effect of Leakage on Wall Drying Potential

Figure 12 is a schematic showing the computational domain for simulations with window water leakage. Figure 13 is a summary of parameters evaluated in Models 5, 6, and 7. A net yearly increase of the total moisture content was observed in the simulation with a high water penetration rate and a polyethylene vapour retarder with painted gypsum board (Model 5). However, in the simulation with a high water penetration rate, but without a polyethylene vapour retarder (Model 6), a gradual reduction in the total moisture content was observed. Close examination of the moisture content in the OSB, however, showed that high localized moisture content conditions persisted below the window, even with the general drying trend. The simulation with a low water penetration rate and polyethylene vapour retarder with painted gypsum board (Model 7) also showed a gradual reduction in the total moisture, with high localized moisture content conditions persisting below the window.

FIGURE 12. Schematic of computational domain model with window.

Discussion of Simulations Results

For barrier EIFS clad walls in Wilmington, the moisture performance can be strongly affected by the water vapour permeance of the interior finish. It was observed that an interior finish with low water vapour permeance, such as a polyethylene vapour retarder or gypsum wallboard with a high quality paint, inhibited drying of the wall. In contrast, a wall with untreated gypsum wallboard on the interior face was observed to dry quickly. In general, barrier EIFS clad walls in Wilmington, which typically used a low vapour permeance material on the interior finish, had low drying potential. This can create conditions in moisture sensitive components like OSB and dimensional lumber that promote rot and decay.

The simulations predict that a barrier EIFS wall with high moisture intrusion around a window will never completely dry over the three-year time period modeled. This high moisture intrusion rate corresponds to a window without backer rod, with EIFS cladding flush against the window with a fillet bead of caulk. This was a common detail observed in Wilmington.

Simulation	Interior Water Vapour Permeance		Window Water Leakage
	Polyethylene Film	Painted/Gypsum Board	
Model 5	Yes	Low WVP	High ¹
Model 6	No	Low WVP	High
Model 7	Yes	Low WVP	Low ²

¹Window with high water penetration rate (leakage scaled from Specimen 3).

²Window with low water penetration rate (leakage scaled from Specimen 2).

FIGURE 13. Simulation parameters for barrier EIFS clad walls with a window.

n model with window.

Results

moisture performance can be affected by the interior finish. It is important to consider vapour permeance, such as sheathing board with a high quality gyp wall with untreated gyp to dry quickly. In general, walls typically used a low vapour drying potential. This can be affected by materials like OSB and dimen-

l with high moisture intrusion over the three-year time period corresponds to a window leakage against the window with a leakage observed in Wilmington.

Sheathing Board	Window Water Leakage
VP	High ¹
VP	High
VP	Low ²

men 3).
men 2).

clad walls with a window.

Windows simulated with a lower moisture intrusion rate, typical of detail with backer rod and caulk around the window, did show a gradual moisture reduction over the simulated period. However, overall wall moisture tolerance was still quite low and localized areas of high moisture content were seen under windows.

DISCUSSION AND CONCLUSIONS

The objective of this study was to develop an understanding of the moisture transport and water penetration characteristics of barrier EIFS clad walls. The study combined a field investigation with an extensive laboratory test program and state-of-the-art computer simulations.

During the initial site investigation in Wilmington, elevated moisture levels were found in the walls around penetrations in many barrier EIFS clad houses. In some cases, the elevated moisture levels were leading to premature structural deterioration of the sheathing and wood framing in the houses. Visual inspection, combined with the removal of cladding around selected windows indicated that many windows were installed without the specified backer rod and sealant details. Many windows were also observed to have significant cracking or damage in the caulk. Additionally, results from water spray rack testing indicated that large quantities of water could enter the wall in areas around penetrations and migrate into the cavity.

The objective of the laboratory experimental program was to identify water entry paths into barrier EIFS clad walls and to determine why this water could not get out. A second objective was to evaluate the water management capability of a drained cavity design. The results indicate that the field of the EIFS cladding away from penetrations is an effective air and water barrier. However, around penetrations, barrier EIFS clad walls are prone to leak and allow water to enter into the sheathing and wall cavity. Systems with backer rod and caulk take longer to fail than those without, but ultimately, under exposure to wind-driven rain, these systems will fail as well. In contrast, the drained cavity wall was also tested and was observed to manage water that entered the wall around penetrations, resulting in no water entry into the wall cavity.

The objective of the computer modeling work was to characterize the water removal, or drying potential, of walls typical of those constructed in Wilmington. The results indicate that the drying potential of barrier EIFS clad walls in Wilmington is strongly affected by the water vapour permeance of the interior finish. In general, the drying potential of barrier EIFS clad walls was low.

The effect of leakage around a penetration into the cavity was also simulated. The results indicate that for all cases modeled, OSB sheathing

was observed to have high localized moisture contents under the windows. In cases where a water penetration rate simulating a window without backer rod and caulk was used, together with an interior polyethylene vapour retarder, the wall experiences a net accumulation of moisture and never dries out. The slow drying rate, combined with water penetration around windows, create conditions likely to produce rot and deterioration in the wood frame structure of houses clad with barrier EIFS.

The results from the laboratory investigation and computer simulations were validated as the field investigation proceeded to the point where the EIFS cladding was being removed from houses in Wilmington. Photo 4 clearly illustrates the pattern of deterioration that occurred in the OSB sheathing under barrier EIFS. The house illustrated was one year old and had never been occupied. Note the dark, deteriorated sheathing under the windows and beneath roof/wall junctions. These field inspection results correspond directly to where the experimental program exhibited and the modeling predicted the high localized moisture contents would exist. Rot and deterioration of sheathing and structural members occurred under windows and in areas where flashing did not prevent water from entering under the EIFS lamina. Photo 5 is a close-up of deterioration in the OSB sheathing and wood structure under a window. This was and continues to be a recurring pattern in houses that are stripped of barrier EIFS in the Wilmington area.

In summary, it has been demonstrated that barrier EIFS clad, wood frame walls will not provide effective control or management of rain penetration. Such systems are not effective in locations where the local climate necessi-

PHOTO 4. Residential sheathing on a Wilmington House after barrier EIFS cladding had been stripped.

ents under the windows.
window without backer
or polyethylene vapour
moisture and never dries
penetration around win-
terioration in the wood

d computer simulations
to the point where the
n Wilmington. Photo 4
occurred in the OSB
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ter from entering under
on in the OSB sheathing
continues to be a recur-
EIFS in the Wilmington

EIFS clad, wood frame
ment of rain penetration.
ne local climate necessi-

PHOTO 5. Residential sheathing under a window on a Wilmington House after barrier EIFS cladding had been stripped.

tates adequate rain penetration control. These walls have low moisture tolerance due to slow drying rates. As such, in-service performance of barrier EIFS clad walls can be unpredictable and thereby unreliable.

Wall systems employing a drained cavity approach have been shown to provide good control and management of rain penetration. A drainage cavity approach is recommended as a viable approach for rain penetration control to improve performance reliability.

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