Results of key building performance goals for energy efficiency, temperature control and moisture control in mixed, coastal, hot, humid, Zone 3 climates.
EI\(^\text{2}\)S Performs: Excellent Choice in Mixed, Coastal, Hot, Humid Climate for Energy Efficiency, Temperature and Moisture Control

In this era of sustainable, green building, energy efficiency has once again become the most widely publicized and used benchmark by which successful building design and operation is measured. Control of thermal energy flow and moisture by the building envelope is key to energy conservation, preservation of the construction and its contents, and occupant satisfaction. The choice of exterior cladding and how well that cladding is installed is critical to achieving two principal goals that drive the design, construction, operation, and maintenance of U.S. homes and commercial buildings:

- Energy efficiency
- Moisture and temperature control

Up to now, what has been lacking is a full understanding of the hygrothermal (temperature and moisture control) performance of all types of wall systems for typical climactic effect, such as wind driven rain, rainwater penetration, condensation, solar and night sky radiation, wind speed, and site/wall orientation. This lack of understanding stems from insufficient real-world data and has resulted in misinterpretations of how wall systems as a whole perform.

The results of a new landmark study provide for the first time ample real-world data demonstrating that EIFS clad wall assemblies with drainage (EI\(^\text{2}\)S) outperform other typical U.S. exterior claddings (Brick, Stucco and Cementitious Fiberboard Siding) during most of the year. The results also demonstrate that EIFS is an excellent exterior cladding choice for achieving key building performance goals in a hot and humid climate, specifically a mixed, coastal, Zone 3 climate.\(^1\)

The US Department of Energy (DOE), through the Office of Energy Efficiency and Renewable Energy’s (EERE) Building Technologies Program, and the EIFS Industry Members Association (EIMA), sponsored the study, which was conducted by researchers at the Oak Ridge National Laboratory (ORNL). A building was constructed near Charleston in Hollywood, South Carolina, featuring panels with various wall claddings and assemblies. Each of the wall panels in which the claddings had been incorporated contained sensors that provided a full profile of temperature, heat flux, relative humidity, and moisture content. These sensors collected data 24 hours a day, 7 days a week, and transmitted the data to the ORNL research facility in Oak Ridge, Tennessee for analysis (see Measuring Wall Systems Performance below for more information about the building, wall panels, and sensors).

One of the strengths of this study is that it considered the building envelope in its entirety, along with studying isolated materials or components of the exterior claddings. The other strength is that the wall was exposed to real climactic loads. This study allowed the researchers to gather real-world data over a 30-month period (Phase I January 2005 - May 2006 and Phase II June 2006 - June 2007). Phase II continued Phase I conditions except a design “flaw” was created in specific specimens to introduce water into them. The following summarizes the key findings of this study, all of which are applicable to a mixed, coastal, Zone 3 climate:

- In Phase II, one of the best performing wall system configurations was comprised of EIFS that included a liquid applied water-resistive barrier coating and four (4) inches of expanded polystyrene insulation board. In addition, all of the thermal insulation was placed outbound of the sheathing (no stud cavity insulation). This EIFS wall configuration performed better than brick. Brick had the lowest thermal and moisture performance among the claddings and wall configurations studied, followed by stucco (both 3-coat and 1-coat) (Fig. 1).

- EIFS walls maintained a consistent, acceptable level of moisture (average monthly relative humidity below 80 percent, as defined by ASHRAE SPC 160P, Design Criteria for Moisture Control in Buildings), within the cladding despite varying outdoor conditions when appropriate interior vapor retarders were used. Brick and stucco tended to accumulate slightly more moisture during both Phase I and Phase II of the project and retained moisture longer than EIFS (see Fig. 2 which represents the measured relative humidity on the face of the exterior sheathing).

- EIFS and a liquid applied water-resistive barrier coating readily dispersed moisture introduced by flaws (installed in Phase II) in the building envelope, as compared with brick, which retained more water (see Fig. 3 which represents the measured moisture content on the face of the exterior sheathing).

- Liquid applied water-resistive barrier coatings, in certain instances as described later on in this report, outperformed other water-resistive barriers in this study. In addition, EIFS with water-resistive barrier coatings performed significantly better than other EIFS claddings that used building paper or spun-bonded polyolefin membranes. The results also indicated that building wraps permit greater vapor transport inward in mixed climates (see Fig. 4 which provides recorded relative humidity on the inside face [stud cavity side] of the exterior sheathing).

- Insulation located on the exterior (outside of the stud cavity) is more effective since it maintains the sheathing and insulation at drier levels. This has important implications for preventing material degradation (see Fig. 5 which provides the measured relative humidity on the face of the exterior sheathing).

- The results of this study validate that vertical ribbons of adhesive provide an effective means of drainage within an EIFS clad wall assembly (see Fig. 9).

\(^1\) 2006 International Energy Conservation Code
FIG 1  
Comparison of Heat Flux Sensor on inside face of interior gypsum wall board in Brick, EIFS and Stucco assemblies

Brick Panel 15  
Brick ties over 1 layer of grade D 60 minute Heat Flux Sensor

EIFS Panel 5  
4” EPS without batts in stud cavity Heat Flux Sensor

Stucco Panel 12  
Metal lath over 2 layers grade D 60 minute Heat Flux Sensor
FIG 2
Comparison of Relative Humidity Sensor 3 (RH3) behind Water Resistive Barrier in Brick, EIFS and Stucco Assemblies

**Brick Panel 15**
- Brick ties over 1 layer of grade D
- 60 minute
- Sensor RH 3

**EIFS Panel 5**
- 4" EPS without batts in stud cavity
- Sensor RH 3

**Stucco Panel 12**
- Metal lath over 2 layers grade D
- 60 minute
- Sensor RH 3
FIG 3
Comparison of Moisture Content Sensor 1 (MCR1) of wood sheathing behind Water-Resistive Barrier in Brick, EIFS and Stucco Assemblies

Brick Panel 15
Brick ties over 1 layer of grade D 60 minute Sensor MCR 1

EIFS Panel 5
4" EPS without batts in stud cavity Sensor MCR 1

Stucco Panel 12
Metal lath over 2 layers grade D 60 minute Sensor MCR 1
FIG 4
Comparison of Relative Humidity Sensor 5 (RH5) at inside face of sheathing in EIFS, Stucco and Brick Assemblies

EIFS Panel 2
1.5" EPS plus batts in stud cavity
Sensor RH 5

EIFS Panel 9
1.5" EPS plus batts in stud cavity
Sensor RH 5

Stucco Panel 12
Metal lath over 2 layers grade D 60 minute
Sensor RH 5

Brick Panel 15
Brick ties over 1 layer of grade D 60 minute
Sensor RH 5
FIG 5
Comparison of Relative Humidity Sensor 3 (RH3) at inside face of sheathing behind Water-Resistive Barrier in 1.5" and 4" EIFS Assemblies

EIFS Panel 2
1.5" EPS plus batts in stud cavity
Sensor RH 3

EIFS Panel 5
4" EPS without batts in stud cavity
Sensor RH 3
FIG 6
Comparison of Relative Humidity Sensor 5 (RH5) at inside face of sheathing in EIFS and Stucco Assemblies

EIFS Panel 2
Vented - Vertical adhesive ribbons over liquid applied WRB plus batts in stud cavity
Sensor RH 5

EIFS Panel 9
Vented - Drainage mat over SBPO WRB plus batts in stud cavity
Sensor RH 5

EIFS Panel 10
Ventilated - Lath over liquid applied WRB plus batts in stud cavity
Sensor RH 5
Measuring Wall System Performance

The researchers in consultation with the EIFS Industry Members Association (EIMA) designed and built a test facility in Hollywood, South Carolina near Charleston, a location that is typical of a mixed, coastal, Zone 3 climate, as prescribed in the 2006 International Energy Conservation Building Code. The building’s flexible design allowed researchers to change the wall panels with ease and to control conditions inside the building by creating two zones within the building’s interior (Figure 7). Interior temperature and relative humidity conditions were selected based on the proposed ASHRAE SPC 160P standard. Building orientation and placement of the wall panels were determined based on a comprehensive study of historical weather patterns, including prevailing wind and precipitation direction.

This research uses multiple assemblies of materials suitable for both field exposure testing and computer modeling. Tested assemblies include both configurations with material properties typical of commercially available systems and configurations not currently available. A manufacturer or supplier should be contacted for commercially available assemblies. The data were collected in two phases. Refer to Table 1 for wall configurations that were evaluated in Phase I, and to Table 2 (page 12) for wall configurations evaluated in Phase II of this study.

In Phase I, 15 exterior cladding configurations were integrated into one side of the building (southeastern exposure), with the goal of having all the claddings exposed to similar weather conditions for a full weather year (15 months from January 2005 through May 2006) (Figure 8). In addition, the hygrothermal performance of three innovative EIFS features (liquid applied water-resistive barrier coatings, smart vapor retarder systems, and exterior cladding ventilation) were evaluated. Table 1 lists the configurations of these 15 wall panels.

### TABLE 1
Phase I Configuration of the Exterior Wall Assemblies Investigated

<table>
<thead>
<tr>
<th>Panel / System</th>
<th>EPS</th>
<th>Attachment</th>
<th>Drainage / Air Space</th>
<th>Weather Barrier</th>
<th>Sheathing</th>
<th>Framing</th>
<th>Cavity Insulation</th>
<th>Vapor Barrier</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panel 1 EIFS</td>
<td>1-1/2’ Flat</td>
<td>Ribbon &amp; Dab</td>
<td>NA</td>
<td>NA</td>
<td>None</td>
<td>CMU</td>
<td>None</td>
<td>Note 1</td>
</tr>
<tr>
<td>Panel 2 EIFS</td>
<td>1-1/2’ Flat</td>
<td>Notched Trowel</td>
<td>Vertical Ribbons</td>
<td>Liquid</td>
<td>Plywood</td>
<td>2 x 4@16’</td>
<td>R-11 Unfaced</td>
<td>None</td>
</tr>
<tr>
<td>Panel 3 EIFS</td>
<td>1-1/2’ Flat</td>
<td>Notched Trowel</td>
<td>Vertical Ribbons</td>
<td>Liquid</td>
<td>Plywood</td>
<td>2 x 4@16’</td>
<td>R-11 Unfaced</td>
<td>smart vapor retarder</td>
</tr>
<tr>
<td>Panel 4 EIFS</td>
<td>1-1/2’ Flat</td>
<td>Notched Trowel</td>
<td>Vertical Ribbons</td>
<td>Liquid</td>
<td>Plywood</td>
<td>2 x 4@16’</td>
<td>R-11 Unfaced</td>
<td>None</td>
</tr>
<tr>
<td>Panel 5 EIFS</td>
<td>4’ Flat</td>
<td>Notched Trowel</td>
<td>Vertical Ribbons</td>
<td>Liquid</td>
<td>Plywood</td>
<td>2 x 4@16’</td>
<td>R-11 Unfaced</td>
<td>Yes</td>
</tr>
<tr>
<td>Panel 6 EIFS</td>
<td>1-1/2’ Flat</td>
<td>Notched Trowel</td>
<td>Vertical Ribbons</td>
<td>Liquid</td>
<td>Plywood</td>
<td>18 ga @16’</td>
<td>R-11 Unfaced</td>
<td>None</td>
</tr>
<tr>
<td>Panel 7 EIFS</td>
<td>1-1/2’</td>
<td>Mech. Fastened</td>
<td>Grooved EPS</td>
<td>House wrap</td>
<td>Plywood</td>
<td>2 x 4@16’</td>
<td>R-11 Unfaced</td>
<td>None</td>
</tr>
<tr>
<td>Panel 8 EIFS</td>
<td>1-1/2’</td>
<td>Mech. Fastened</td>
<td>Grooved EPS</td>
<td>House wrap</td>
<td>Plywood</td>
<td>2 x 4@16’</td>
<td>R-11 Unfaced</td>
<td>6 mil Poly</td>
</tr>
<tr>
<td>Panel 9 EIFS</td>
<td>1-1/2’ Flat</td>
<td>Mech. Fastened</td>
<td>Mat</td>
<td>House wrap</td>
<td>OSB</td>
<td>2 x 4@16’</td>
<td>R-11 Unfaced</td>
<td>None</td>
</tr>
<tr>
<td>Panel 10 EIFS</td>
<td>1-1/2’ Flat</td>
<td>Adhesive</td>
<td>Lath</td>
<td>Liquid</td>
<td>ASTM C1177 Gyp. Board</td>
<td>18 ga @16’</td>
<td>R-11 Unfaced</td>
<td>None</td>
</tr>
<tr>
<td>Panel 11 EIFS Commercial</td>
<td>1-1/2’ Flat</td>
<td>Notched Trowel</td>
<td>Vertical Ribbons</td>
<td>Liquid</td>
<td>ASTM C1177 Gyp. Board</td>
<td>18 ga @16’</td>
<td>R-11 Unfaced</td>
<td>None</td>
</tr>
<tr>
<td>Panel 12 3-Coat Portland Cement Plaster (Stucco)</td>
<td>None</td>
<td>Mech. Fastened Note 2</td>
<td>3.4 Metal Lath</td>
<td>2 Layers Grade D 60 Minute</td>
<td>OSB</td>
<td>2 x 4@16’</td>
<td>R-11 Unfaced</td>
<td>None</td>
</tr>
<tr>
<td>Panel 13 1-Coat Portland Cement Plaster (Stucco)</td>
<td>1’ Flat</td>
<td>Paint - later date Note 2</td>
<td>Woven Wire Plaster Base 1 x 20 ga.</td>
<td>1 Layer Grade D 60 Minute (behind foam)</td>
<td>OSB</td>
<td>2 x 4@16’</td>
<td>R-11 Unfaced</td>
<td>None</td>
</tr>
<tr>
<td>Panel 14 Brick</td>
<td>None</td>
<td>Brick Ties</td>
<td>Air Cavity 1”</td>
<td>1 Layer Grade D 60 Minute</td>
<td>OSB</td>
<td>2 x 4@16’</td>
<td>R-11 Unfaced</td>
<td>None</td>
</tr>
<tr>
<td>Panel 15 Cementitious Fiberboard Siding</td>
<td>1/2’ XPS</td>
<td>Mech. Fastened</td>
<td>NA</td>
<td>1 Layer Grade D 60 Minute</td>
<td>OSB</td>
<td>2 x 4@16’</td>
<td>R-11 Unfaced</td>
<td>None</td>
</tr>
</tbody>
</table>

Typical Interior Finishing - 1/2” drywall, primed and painted (1 coat acrylic paint)
Note 1: Finished with furred (with 1X2 treated) 1/2” drywall, primed and painted (1 coat acrylic paint)
Note 2: Painted white initially, Plywood = 1/2”, OSB = 1/2”, Lath = G 60
FIG 7
Interior of NET Facility

FIG 8
Exterior of Southeast Wall NET Facility (Phase 1)
The three innovative EIFS features evaluated in this study are described below:

- **Liquid applied water-resistive barrier coatings.** These water-resistive barrier coatings are innovative due to the hygrothermal properties they impart and their application characteristics. These materials may be further engineered to provide gravity-assisted flow by modifying the surface tension characteristics of the exterior sheathing, thus water drains more readily. (Figure 9).

- **Synchronous exterior and interior wall element moisture management.** This technology engineers several elements of wall materials and sub-systems to minimize moisture in EIFS walls. This is achieved by using the most appropriate water vapor transmission, sorption, suction and liquid transport properties for each material in the envelope. In some instances, they are an assembly of materials, or subset of an envelope, that optimize the thermal and moisture transport, which results in high drying potential of the walls (Figure 10).

- **Ventilated exterior claddings.** In these systems, the exterior cladding is intentionally ventilated (open at top and bottom) and drained using one of two options: directly using integrated systems or channelled foam systems, or indirectly using adhesive channels, such as notched trowel, vertical ribbons. A variation of these systems was included in this study to assess unvented, vented (open at the bottom only) and ventilated systems (open at the top and bottom), (not commercially available). Vented systems moderate the air pressure across the exterior cladding, reducing the pressure difference across the cladding, which can reduce exterior air and water from entering the wall system. Ventilation allows air to move freely behind the cladding, which increases the drying potential of walls (Figure 11).
In Phase II, simulated building envelope defects were introduced into some of the wall panels, which included newly constructed wall panels as well as some of the 20-month aged wall panels from Phase I. The goal was to assess the performance of cladding assemblies to water penetration, as well as the impact on the performance of wall systems from wall orientation on moisture infiltration, the type of water-resistive barriers used (sheet membranes versus liquid applied) and different exterior cladding systems (EIFS and brick). In Phase II, wall panels were placed on both the southeast and northwest sides of the building (Figure 12). Table 2 (page 12) lists the configurations of the wall systems studied in Phase II, including on which side of the building the panels were placed. Data were collected from May 2006 to June 2007.
Each of the wall panels contained an array of sensors that recorded a full, constant profile of temperature, heat flux, relative humidity, and moisture content. Because of a limited availability of heat flux sensors, the sensors were strategically placed among some of the walls to demonstrate the importance of the rate of heat transfer of exterior insulated wall systems (see “Study Results Underscore Importance of Balance” on page 14 for more information). Table 2 notes which panels had heat flux sensors (HFS).

The sensor placements were identical for all the wall panels (Figure 13), except for relative humidity sensors on panels with absorptive cladding systems (brick and stucco) and non-absorptive cladding systems (EIFS), which were embedded into the exterior cladding on those panels with non-absorptive claddings (Figure 14).

### TABLE 2

**Phase II Configuration of the Exterior Wall Assemblies Investigated**

<table>
<thead>
<tr>
<th>Panel / Orientation / System / Heat Flux Sensor (HFS)</th>
<th>EPS</th>
<th>Attachment</th>
<th>Drainage / Air Space</th>
<th>Weather Barrier</th>
<th>Sheathing</th>
<th>Framing</th>
<th>Cavity Insulation</th>
<th>Vapor Barrier</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panel 2, SE, EIFS</td>
<td>1-1/2&quot; Flat</td>
<td>Notched Trowel</td>
<td>Vertical Ribbons</td>
<td>Liquid</td>
<td>Plywood</td>
<td>2 x 4@16&quot;</td>
<td>R-11 Unfaced</td>
<td>None</td>
</tr>
<tr>
<td>Panel 3, SE With Flaw, HFS EIFS</td>
<td>1-1/2&quot; Flat</td>
<td>Notched Trowel</td>
<td>Vertical Ribbons</td>
<td>Liquid</td>
<td>Plywood</td>
<td>2 x 4@16&quot;</td>
<td>R-11 Unfaced</td>
<td>None</td>
</tr>
<tr>
<td>Panel 4, SE, EIFS</td>
<td>1-1/2&quot; Flat</td>
<td>Notched Trowel</td>
<td>Vertical Ribbons</td>
<td>Liquid</td>
<td>Plywood</td>
<td>2 x 4@16&quot;</td>
<td>R-11 Unfaced</td>
<td>6-mil Poly</td>
</tr>
<tr>
<td>Panel 5, SE, HFS EIFS</td>
<td>4&quot; Flat</td>
<td>Notched Trowel</td>
<td>Vertical Ribbons</td>
<td>Liquid</td>
<td>Plywood</td>
<td>2 x 4@16&quot;</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Panel 6, SE, HFS EIFS</td>
<td>1-1/2&quot; Flat</td>
<td>Notched Trowel</td>
<td>Vertical Ribbons</td>
<td>Liquid</td>
<td>Plywood</td>
<td>18 ga @16&quot;</td>
<td>R-11 Unfaced</td>
<td>None</td>
</tr>
<tr>
<td>Panel 7, SE, With Flaw, HFS EIFS</td>
<td>1-1/2&quot;</td>
<td>Notched Trowel</td>
<td>Vertical Ribbons</td>
<td>Liquid</td>
<td>Plywood</td>
<td>2 x 4@16&quot;</td>
<td>R-11 Unfaced</td>
<td>6-mil Poly</td>
</tr>
<tr>
<td>Panel 9, SE, HFS EIFS</td>
<td>1-1/2&quot; Flat</td>
<td>Mech. Fastened</td>
<td>Mech. Fastened</td>
<td>Mat</td>
<td>OSB</td>
<td>2 x 4@16&quot;</td>
<td>R-11 Unfaced</td>
<td>None</td>
</tr>
<tr>
<td>Panel 10, SE Ventilated, HFS</td>
<td>1-1/2&quot; Flat</td>
<td>Adhesive</td>
<td>Lath</td>
<td>Liquid</td>
<td>Plywood</td>
<td>2 x 4@16&quot;</td>
<td>R-11 Unfaced</td>
<td>None</td>
</tr>
<tr>
<td>Panel 12, 3-Coat Portland Cement Plaster (Stucco) SE, HFS</td>
<td>None</td>
<td>Mechanically Fastened</td>
<td>3.4 Metal Lath</td>
<td>2 Layers Grade D 60 Minute</td>
<td>OSB</td>
<td>2 x 4@16&quot;</td>
<td>R-11 Unfaced</td>
<td>None</td>
</tr>
<tr>
<td>Panel 14, SE, HFS Brick With Flaw</td>
<td>None</td>
<td>Brick Ties</td>
<td>Air Cavity 1&quot;</td>
<td>1 Layer Grade D 60 Minute</td>
<td>OSB</td>
<td>2 x 4@16&quot;</td>
<td>R-11 Unfaced</td>
<td>None</td>
</tr>
<tr>
<td>Panel 15, SE, HFS Brick</td>
<td>None</td>
<td>Brick Ties</td>
<td>Air Cavity 1&quot;</td>
<td>1 Layer Grade D 60 Minute</td>
<td>OSB</td>
<td>2 x 4@16&quot;</td>
<td>R-11 Unfaced</td>
<td>None</td>
</tr>
<tr>
<td>Panel 16, NW, EIFS</td>
<td>1-1/2&quot; Flat</td>
<td>Notched Trowel</td>
<td>Vertical Ribbons</td>
<td>Liquid</td>
<td>Plywood</td>
<td>2 x 4@16&quot;</td>
<td>R-11 Unfaced</td>
<td>6-mil Poly</td>
</tr>
<tr>
<td>Panel 17, NW, EIFS</td>
<td>1-1/2&quot; Flat</td>
<td>Notched Trowel</td>
<td>Vertical Ribbons</td>
<td>Liquid</td>
<td>Plywood</td>
<td>2 x 4@16&quot;</td>
<td>R-11 Unfaced</td>
<td>None</td>
</tr>
<tr>
<td>Panel 18, NW, With Flaw, HFS EIFS</td>
<td>1-1/2&quot; Flat</td>
<td>Notched Trowel</td>
<td>Vertical Ribbons</td>
<td>Liquid</td>
<td>Plywood</td>
<td>2 x 4@16&quot;</td>
<td>R-11 Unfaced</td>
<td>None</td>
</tr>
<tr>
<td>Panel 26, NW, Ventilated, HFS EIFS</td>
<td>1-1/2&quot; Flat</td>
<td>Adhesive</td>
<td>Lath</td>
<td>Liquid</td>
<td>Plywood</td>
<td>2 x 4@16&quot;</td>
<td>R-11 Unfaced</td>
<td>None</td>
</tr>
</tbody>
</table>

Typical Interior Finishing - 1/2” drywall, primed and painted (1 coat acrylic paint)
SE = Southeast Face
NW = Northwest Face
FIG 13
Placement of Sensors in Panels

Placement of sensors on interior side for all wall assemblies

Placement of sensors on exterior side of EIFS wall assemblies

Placement of sensors on exterior side of brick and stucco wall assemblies

FIG 14
Placement of Relative Humidity Sensors in Brick and Stucco Panels

Placement of RH sensors on the exterior side of brick wall assembly

Placement of RH sensors on exterior side of stucco wall assembly
Study Results Underscore Importance of Balance

When designed and operating properly, the building envelope responds to both interior and exterior conditions. In an ideal building, the average rate of heat flux (or movement of energy) across the wall system should remain constant around a value of zero on the interior surface. Likewise, the relative humidity within the wall system should remain low, and temperature within the wall cavity also should remain constant. The closer the heat flux is to zero, the smaller the HVAC equipment will need to be to maintain comfortable interior conditions. The following discusses the study results and their implications within the context of the principal performance goals cited above: energy efficiency, moisture and temperature control.

Energy Efficiency

As noted, an ideal energy efficient building would feature a building envelope and wall system that perfectly balances outdoor and indoor air pressures, airflows, and heat and moisture loads. All too often however, problems occur when there is an imbalance. For example, too much heat entering the wall system (positive heat flux) requires a higher cooling load while too much heat leaving the wall system (negative heat flux) has the opposite effect and increases the heating load. As a result, the HVAC system has to work harder and use more energy.

The presence of excess moisture within the building envelope system can also affect energy efficiency. For example, as moisture accumulates, thermal conductivity may increase by a factor of up to three for polystyrene foam insulation, four for high-density fiberglass insulation, and two for red brick (IEA 1996, Dechow and Epstein 1982). Other studies have also demonstrated that moisture infiltration can decrease energy efficiency due to the local evaporation and condensation, while increasing the energy transfer (positive heat flux) across the building envelope by 5 percent to 150 percent of that occurring under dry conditions. Likewise, the relative humidity within the wall system should remain low, and temperature within the wall cavity also should remain constant. The closer the heat flux is to zero, the smaller the HVAC equipment will need to be to maintain comfortable interior conditions. The following discusses the study results and their implications within the context of the principal performance goals cited above: energy efficiency, moisture and temperature control.

Moisture and Temperature Control

A consequence of excess water vapor within a wall assembly is the increased possibility of condensation on cool surfaces within the wall cavity. Moisture and/or liquid water also can enter the wall system through defects, poor design, and poor installation of interface materials. Uncontrolled moisture migration can result in significant material degradation if not adequately protected. One of the goals of this study was to determine which wall configurations performed best at managing moisture infiltration.

The results indicated that the highest relative humidities occurred near the exterior sheathing and wood framing during the winter months. This result was not unexpected, as insulation in the wall cavity will result in cooler temperatures at the exterior sheathing. In addition, relative humidity tends to increase as the temperature cools. The best performing wall configuration with respect to controlling relative humidity within the wall assembly was the EIFS panel with four inches of insulation (Panel 5) outbound of the sheathing. The wall stud cavity was not insulated and no vapor barrier was installed on the interior interface during the winter months (Figure 18, page 19). Interestingly, the EIFS wall panel that faced northwest (Panel 16) had up to 17 percent higher relative humidity at the exterior sheathing as compared with EIFS wall panels that faced southeast (Figure 19, page 20).
To determine how defects in the exterior cladding might affect relative humidity on the sheathing, the researchers introduced a simulated defect (“flaw”) into four of the panels. The “flaw” was a 2'-0” (610 mm) standard “K” gutter mounted above the panel that collected rainwater, which drained through a measurement device for deposition onto the water-resistive barrier in the wall assembly. The gutter length was sized 2'-0” in length to match the opening used in ASTM E2273 “Standard Test Method for Determining the Drainage Efficiency of Exterior Insulation and Finish System (EIFS) Clad Walls”. Each panel with a “flaw” had an identical corresponding panel without a flaw for comparative purposes. The panels with the “flaw” were:

- **Panel 3** (Corresponding Panel 2): EIFS with notched trowel, vertical adhesive ribbons, a liquid applied water-resistive barrier coating, no interior vapor barrier, southeast orientation (Figure 20, page 21, which represents the measured relative humidity on the face of the exterior sheathing).

- **Panel 7** (Corresponding Panel 4): EIFS with notched trowel, vertical ribbon, a liquid applied water-resistive barrier coating, and a 6-mil Poly vapor barrier, southeast orientation (Figure 21, page 22).

- **Panel 14** (Corresponding Panel 15): Brick, vented, southeast orientation (Figure 22, page 23, which represents the measured relative humidity on the face of the exterior sheathing).

- **Panel 18** (Corresponding Panel 17): EIFS with notched trowel, vertical adhesive ribbons, a liquid applied water-resistive barrier coating, no interior vapor barrier, northwest orientation (Figure 23, page 24).

The results showed that introducing the simulated flaw in the EIFS in the southeast and northwest orientations had a small effect on the sheathing relative humidity. Conversely, introducing the flaw in the brick vented system in the southeast orientation had a much larger effect on sheathing relative humidity. The implication is that EIFS layers comprised of vertical ribbons of adhesive and a liquid applied water-resistive barrier coating provided the most effective method for managing bulk water intrusion into the cladding cavity.

The EIFS walls that used a liquid applied water-resistive barrier coating performed better in this study than exterior claddings with sheet type membranes. In addition, EIFS walls with an exterior air space ventilation (that is, open at the top and bottom) performed better than walls with just venting (those open at the bottom only). The wall systems with highest sheathing relative humidity readings were stucco (both 3-coat and 2-coat), followed by brick and cementitious cladding. The results demonstrated that liquid applied water-resistive barrier coatings outperform the other membranes studied, including membranes covered with a mechanically fastened drainage mat.

The results also showed that using polyethylene vapor retarders increased the relative humidity by as much as 23 percent on the EIFS wall facing northwest (Panel 17) as compared with the EIFS wall panels facing southeast (Panel 7).
FIG 15
Comparison of Heat Flux Sensor at inside face of interior gypsum wall board in EIFS and Brick Assemblies

EIFS Panel 6
1.5” EPS plus batts in stud cavity
Heat Flux Sensor

EIFS Panel 9
1.5” EPS with mech. fasteners and drainage mat plus batts in stud cavity
Heat Flux Sensor

EIFS Panel 10
1.5” EPS lath ventilated plus batts in stud cavity
Heat Flux Sensor

Brick Panel 15
Brick ties over 1-layer grade D 60 minute
Heat Flux Sensor
FIG 16
Relative Humidity through the wall in Panel 5

EIFS Panel 5
4” EPS without batts in stud cavity
Sensor RH 1

EIFS Panel 5
4” EPS without batts in stud cavity
Sensor RH 2

EIFS Panel 5
4” EPS without batts in stud cavity
Sensor RH 3

EIFS Panel 5
4” EPS without batts in stud cavity
Sensor RH 4

EIFS Panel 5
4” EPS without batts in stud cavity
Sensor RH 5
FIG 17
Relative Humidity through the wall in Panel 12

Stucco Panel 12
Metal lath over
2 layers grade D
60 minute
Sensor RH 1

Stucco Panel 12
Metal lath over
2 layers grade D
60 minute
Sensor RH 2

Stucco Panel 12
Metal lath over
2 layers grade D
60 minute
Sensor RH 3

Stucco Panel 12
Metal lath over
2 layers grade D
60 minute
Sensor RH 4

Stucco Panel 12
Metal lath over
2 layers grade D
60 minute
Sensor RH 5
FIG 18
Relative Humidity at interface of interior gypsum wall board and insulation in Stucco and Brick

Stucco Panel 12
Metal lath over 2 layers grade D 60 minute
Sensor RH 6

Brick Panel 15
Brick ties over 1 layer grade D 60 minute
Sensor RH 6
FIG 19
Comparison of Relative Humidity Sensor 3 for EIFS Panels 4 and 16 from the NW and SE sides of the facility. Panels constructed with a vapor barrier.

EIFS Panel 4
and Panel 16
1.5” EPS plus batts in stud cavity
Sensor RH 3
FIG 20
Comparison of Relative Humidity sensors (RH3) installed behind the liquid applied water-resistive barrier coating on EIFS panel 2 (without flaw) and EIFS panel 3 (with flaw)

EIFS Panel 2
1.5” EPS plus batts in stud cavity
without flaw

EIFS Panel 3
1.5” EPS plus batts in stud cavity
with flaw

“Flaw” - 2’ gutter catches rain water and drains, via a tip-bucket measuring device, onto the WRB
FIG 21
Comparison of Relative Humidity sensors (RH3) installed behind the liquid-applied water-resistant-barrier coating on EIFS panel 4 (without flaw) and EIFS panel 7 (with flaw). A 6-mil poly-vapor barrier is used on the interior.

EIFS Panel 4
1.5" EPS plus batts in stud cavity
without flaw

EIFS Panel 7
1.5" EPS plus batts in stud cavity
with flaw

“Flaw” - 2’ gutter catches rain water and drains, via a tip-bucket measuring device, onto the WRB

EIFS Panel 4
no flaw
Sensor RH 3

EIFS Panel 7
flaw
Sensor RH 3
FIG 22
Comparison of Relative Humidity sensors (RH3) installed behind 1 layer grade D, 60-minute water-resistive barrier on Brick panel 15 (without flaw) and Brick panel 14 (with flaw)

Brick Panel 15
Brick ties over 1-layer grade D
60 minute
without flaw

Brick Panel 14
Brick ties over 1-layer grade D
60 minute
with flaw

“Flaw” - 2’ gutter catches rain water and drains, via a tip-bucket measuring device, onto the WRB
FIG 23
Comparison of Relative Humidity sensors (RH3) installed behind the liquid applied water-resistant barrier coating on EIFS panel 17 (without flaw) and EIFS panel 18 (with flaw)

EIFS Panel 17
1.5" EPS plus batts in stud cavity without flaw

EIFS Panel 18
1.5" EPS plus batts in stud cavity with flaw

“Flaw” - 2’ gutter catches rain water and drains, via a tip-bucket measuring device, onto the WRB
EIFS an Excellent Choice for Mixed, Coastal Zone 3 Climates

The results of this study show that EIFS are capable of controlling temperature and moisture within the wall system and outperform other exterior claddings during the monitored year. In essence, EIFS have the ability to maintain an acceptable balance of moisture and temperature control that is indicative of a well-designed, properly operating energy efficient building without moisture problems.

All of the wall configurations evaluated in this study performed satisfactorily. This study convincingly proves that EIFS is an excellent choice for achieving key building performance goals, including energy efficiency, moisture and temperature control. EIFS absorbs less moisture and heat as does brick and stucco. These results clearly and convincingly demonstrate the superior performance of EIFS in a mixed, coastal, Zone 3 climate.

A complete report on both Phase I and Phase II is available at the Oak Ridge National Laboratory web site: http://www.ornl.gov/sci/roofs+walls/research/EIFS/eifs.htm

Citations


