A comparison of cladding materials sponsored by:
U.S. Department of Housing and Urban Development
U.S. Department of Agriculture’s Forest Products Laboratory
Brick Industry Association

Study performed at the NAHB Research Center
Study Summary
Over the course of a one-year period, a moisture performance comparison study was conducted at an independent test facility. In the study, brick veneer wall assemblies were compared to seven wall assemblies constructed of popular siding materials. The study was designed to determine the average humidity level in the wall cavities of each wall assembly. Humidity levels were monitored and recorded repeatedly throughout each day of the study, encompassing a full four-season range of weather. Humidity levels were determined by measuring the moisture content of studs and sheathing in each assembly. Low wall cavity humidity levels are desirable for a number of reasons, including maintaining the structural integrity of wood and wood products used in the wall assembly, and inhibiting the development of mold.

The study revealed that the brick veneer wall assembly outperformed all others and was consistently the driest assembly.

Why is a Moisture Study Important?
What Home Owners Should Know
Most home owners understand that a flood can damage a home. However, few home owners are aware that moisture buildup between the exterior siding (cladding) on a home and its structural components can result in damage over time that could lead to expensive repairs or loss in value.

In recent years, consumers have been repeatedly exposed to stories in the media about severe storms, hurricanes, flooding and other natural disasters that can lead to extreme damage to private residences. The average home owner has learned that it’s not just the storm or hurricane that may cause extensive damage; the residual water left behind may lead to rot, decay or mold in a home. Today, there is likely no word more feared by a home owner than “mold.” It not only can cause serious health issues, it can also reduce the value of a home or hinder the sale of a home in the future.

In this study, the ability of prominent residential cladding materials to best keep dry the structural wall elements of a home was measured. Behind each cladding, readings for moisture, temperature and relative humidity were recorded over time for the wall elements that contained wood, like sheathing and studs. This study helps home owners understand that the exterior siding they choose can also affect the structural integrity and long-term value of a home.

What Builders Should Know
Builders faced with home buyer fears about mold, rot and insect infestation can rest assured that there are choices for exterior siding that actually help reduce the incidence of damage that can result from these compromising factors. The sidings a builder chooses or recommends to home buyers can lead to greater buyer peace of mind and ongoing structural integrity, and may result in greater value at resale.

Armed with the information in this study, builders can help home owners feel confident that they have chosen an exterior siding that not only helps maintain the structural integrity of homes, but also can actually enhance the value of their homes.
Moisture Performance Study

A yearlong field moisture comparison study of typical residential wall assemblies was conducted at a nationally recognized, independent third-party building products laboratory. The study was sponsored by the U.S. Department of Housing and Urban Development, the U.S. Department of Agriculture’s Forest Products Laboratory and the Brick Industry Association (BIA), and focuses on the performance of eight different wall assemblies.

Study Objective
The study compares eight popular and commonly used sidings in a mixed-humid climate to determine which wall assemblies perform best, from the perspective of minimizing the moisture content of the wood sheathing and studs and the humidity within the wood stud wall cavity (where batt insulation is typically placed).

Since it is possible for moisture in the wood stud wall cavity to lead to mold, rot, structural damage and insect infestation, siding products that yield a lower humidity level on a consistent basis are more desirable in residential construction. This study shows which siding products, when installed correctly, provide a consistently lower humidity level in the wood stud wall cavity. In the study, factors that affect the performance of each of these wall assemblies were monitored and measured, including:

- Natural external factors, such as temperature, wind, rain and other ambient weather phenomena
- Interior humidity
- Temperature of the wood stud wall cavity
- Controlled injection of water to simulate leaks

* See the full Moisture Performance Comparison of Typical Residential Wall Assemblies study prepared by the NAHBRC at www.boralbricks.com.
Testing Factors

Exterior Cladding Materials Tested
Test structures were built for the moisture comparison study which included the following exterior siding materials:
• Vinyl siding
• Manufactured stone
• Fiber cement siding
• Brick veneer
• Four variations of stucco installation

Location of Test Structures
The comparison study took place in Upper Marlboro, Maryland at an independent third-party test facility approximately 20 miles east of Washington, D.C. This geographic area is described as having a mixed-humid climate, which is defined as a region that experiences in excess of 20" of rain and/or snow per year and has an average monthly winter temperature below 45°F, resulting in fewer than 5,400 heating degree days annually.

Time Period of Study
The moisture comparison study was conducted between November 2008 and November 2009. Weather conditions during this period were close to 30-year historical average conditions for the region. The one-year study period allowed the test structure to experience a full range of exposure to ambient, natural, four-season weather phenomena.

ElementsMeasured
A broad cross-section of elements was monitored and measured throughout the 12-month study period. The measurements chosen to be recorded were taken to determine which factors influence the moisture content of wood elements in the walls and the relative humidity of the wood stud wall cavities of the eight wall assemblies tested.

Moisture Content Levels
It’s important to understand the definition of “dry” when considering the various factors measured in this study. Dry conditions for wood are typically defined as conditions that result in a moisture content (MC) of 19 percent or less. The accepted MC for engineered wood products (EWP) is 16 percent or less. Wood and wood products, such as studs and sheathing, which may be either plywood or oriented strand board (OSB), can begin to exhibit signs of decay or deterioration of structural integrity typically when the moisture content of these products approaches 30 percent.
Wall Assemblies

While each wall assembly included a different exterior cladding product or represented a different installation process for the cladding product, there were common components to each assembly:

- Nominal 2” x 4” wood studs
- Sheathing (OSB or plywood)
- Fiberglass batt Insulation
- Water-resistive barrier (WRB)
- 1/2” dry wall

<table>
<thead>
<tr>
<th>Panel #</th>
<th>Test Structure</th>
<th>Sheathing</th>
<th>WRB</th>
<th>Exterior Finish</th>
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<tr>
<td>1</td>
<td>1</td>
<td>7/16&quot; OSB</td>
<td>Spun-bonded polyolefin WRB</td>
<td>Vinyl siding</td>
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<td>1 layer No.15 felt</td>
<td>Stucco</td>
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<td>WRB 3/8&quot; air gap No.15 felt</td>
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<tr>
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<td>2 layers No.15 felt</td>
<td>Manufactured stone</td>
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<td>Spun-bonded polyolefin WRB</td>
<td>Fiber cement siding</td>
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<tr>
<td>7</td>
<td>2</td>
<td>1/2&quot; plywood</td>
<td>2 layers No.15 felt</td>
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<tr>
<td>8</td>
<td>2</td>
<td>7/16&quot; OSB</td>
<td>Spun-bonded polyolefin WRB</td>
<td>Brick with 1&quot; air space</td>
</tr>
</tbody>
</table>

Description of Wall Assemblies

Two structures were designed and built specifically for the purposes of conducting moisture performance studies. Siding products were installed based on manufacturer recommendations. If instructions from the manufacturer were not available, products were installed in accordance with current local building codes.

Each structure included five pairs of 8’ x 9’ test panels, resulting in a nominal footprint of 8’ x 48’ for each structure. A northern and southern exposure panel was tested for each type of siding. Test structures included a window on the west-facing side and a door on the east-facing side. With minimal roof overhang and 4” gutters, each structure experienced significant exposure to ambient weather phenomena.

Since interior temperature can contribute to changes in humidity levels in the wall cavity, interior conditions were controlled throughout the test period. Portable air conditioners were used in each structure to ensure that summer temperatures did not exceed 78°F. The winter indoor temperature was maintained at 70°F, with a humidifier used to keep indoor humidity between 25 and 30 percent. Slight deviations in interior temperatures were consistent in both structures.
PanEl 1: Vinyl-Sided Wall
Unbacked vinyl siding was installed over a single layer of Tyvek® HomeWrap® (spun-bonded polyolefin WRB) in compliance with provisions in Table R703.4 of the 2006 International Residential Construction (IRC) code.

PanEl 2: Stucco-Clad Wall – One Layer of Felt
In a construction configuration that is no longer permitted under the 2006 IRC, a Portland cement-based material (scratch coat and finish coat) was applied as cladding over a single layer of WRB. This installation was included in the study because this type of application was common prior to the adoption of the 2006 IRC and was still accepted in the county where the study took place at the time the test structure was erected.

PanEl 3: Stucco-Clad Wall – Two Layers of Felt
In line with a prevailing construction practice in the region of the test location, a Portland cement-based stucco assembly was constructed that included two layers of No.15 felt paper (WRB). In this type of assembly, the stucco scratch coat bonds to the outer WRB, essentially constricting its role as a drainage plane. However, the second inner layer of WRB, as assembled, is able to function as a drainage plane.

PanEl 4: Stucco-Clad Wall with Vented Cladding
The third stucco wall system incorporated a recommended technique that creates an air gap between the stucco cladding and the structural wall. This vented installation enhances the drying process. The air gap was created by applying 1-1/2" wide by 3/8" thick plywood furring strips over a spun-bonded polyolefin WRB. A single layer of No.15 felt was applied to the furring strips, with lath and stucco applied over the felt.

PanEl 5: Wall Clad with Manufactured Stone
Manufactured cast concrete stone was applied over two layers of No.15 felt paper (WRB). As with natural stone, thickness varies in manufactured stone, with product used in this installation varying between 1" and 2-5/8" thick. A scratch coat of Type S mortar mix was applied, with the same mortar mix used as grout.

PanEl 6: Stucco Wall with Plywood Sheathing
Plywood sheathing of 1/2" was substituted for OSB in this panel, which otherwise was identical in construction to panel 3.

PanEl 7: Fiber Cement Siding Wall
Fiber cement siding was installed in this panel over a spun-bonded polyolefin WRB. The siding was finished with a light color exterior latex paint.

PanEl 8: Brick Veneer
Per a typical brick veneer assembly, brick was applied using Type N masonry cement mortar with a nominal 1" air space between the cladding and the structural wall. Nominal 4" bed-depth brick was laid with flashing under the first course. Immediately above the flashing, open head-joint weep holes were installed at 24" on center. The air space was designed to vent into the attic via a 1/2" slot at the top of the installation.
Over the course of 12 months, data was gathered for the eight wall assemblies at the test site. Weather conditions during the study were near 30-year historical average conditions for the area, with the exception of a somewhat milder summer and rainfall over the course of the test period that was 5 percent lower than historical average. As a result of higher levels of radiation experienced by south-facing walls, higher stud wall cavity temperatures, lower stud wall cavity relative humidity and lower wood moisture levels were recorded than for north-facing walls.
Source of the Moisture Measured

Natural elements, such as temperature, precipitation and wind-driven rain, were measured during the test period. Indoor temperature and humidity were also measured.

The wall assemblies were also subjected to bulk moisture experiments. Since leaks due to faulty window and WRB installation can allow water to enter a structure between the cladding and the sheathing, bulk moisture experiments were used to simulate leak conditions. In general, the brick veneer installations with a 1" air space were able to dissipate moisture quickly and were effective in maintaining a dry wall assembly.

Systems of Measurement and Monitoring

Wall Sensors and Data Collection

Forty-four sensors designed to read moisture content, relative humidity and temperature were affixed to wood framing or sheathing in each wall section. Readings were transmitted by the sensors every 30 minutes throughout the one-year testing period. Since readings can vary considerably when taken from different locations within the structure (cooler near the floor, warmer near the roofline) sensors were positioned in numerous locations, as shown in the illustration, to ensure that all areas were measured accurately.

Indoor Temperature and Humidity Monitoring

An additional system was used to collect information from the interior of the test structures. The system both monitored and controlled the indoor temperature and relative humidity. Data was gathered every five seconds and averaged every 30 minutes throughout the yearlong test period.
Moisture Content (MC) of Studs
Throughout the test period, moisture content fluctuated to a certain degree in the studs in all wall assemblies. However, studs in all wall cavities remained below a moisture content of 12 percent. Throughout the study, the MC of the studs was lowest in the brick wall assemblies, with the studs 16 percent drier than unvented stucco walls during winter months. A comparison of MC for studs in each wall assembly can be seen in these charts.
Moisture Content of Sheathing

The south-facing brick veneer wall assembly had the lowest sheathing MC when compared to all other wall assemblies. The sheathing was consistently drier than any other wall assembly throughout the test period. In the north-facing wall assemblies, the MC of the sheathing was similar for brick and vinyl siding. The charts below show the variations in MC throughout the test period.
Wood Stud Wall Cavity Temperature
The temperature of the wall cavity between the wood studs can affect humidity levels in the cavity by enhancing the drying process during warm weather. However, it can also increase the damaging effects of humidity during cooler months.

Remarkably, throughout the test period, temperatures were similar among all assemblies, regardless of the type of siding installed, with the exception of the brick veneer installation. The wood stud wall cavity temperature for January of the brick veneer installation was 11°F warmer than the coldest wall assembly. The wood stud wall cavity temperature in the brick veneer wall assembly remained the highest throughout the test period.
Wood Stud Wall Cavity Relative Humidity
The relative humidity of the wall cavity between the wood studs corresponds, in general, to the MC of the sheathing, which can be seen by comparing the following charts below to the “Moisture Content – Sheathing: North” and “Moisture Content – Sheathing: South” charts. Throughout the test period, the brick veneer assembly maintained the lowest or second-lowest wood stud wall cavity relative humidity.
Of the wall assemblies studied, the brick veneer wall assemblies were the most consistently dry wall assemblies and met the “Conditions Necessary to Minimize Mold Growth” of ASHRAE Standard 160.

The two factors that affected the MC of wood-based sheathing in wall assemblies more than all other factors were air circulation and wall temperature. Typical brick veneer residential construction contains a nominal 1" air space behind the brick. As shown by this study, such construction consistently produced a wood stud wall cavity with lower humidity. Darker claddings, such as brick and darker-colored manufactured stone, maintained the highest wood stud wall cavity temperature. The wall assemblies with higher wood stud wall cavity temperatures tended to have lower sheathing MC.

North-facing manufactured stone walls and north- and south-facing stucco-clad walls with plywood sheathing exhibited the poorest performance from the perspective of highest initial moisture content. The wall cavities for these two assemblies were the slowest to dry.
Benefits of Dry Wall Assemblies
Maintaining a consistently dry wall assembly provides certain advantages:

• Lower humidity can inhibit mold development.

• Over time, high wood stud wall cavity humidity levels can compromise the performance of wood and wood products, such as studs and sheathing. Wood stud wall cavities with consistently low humidity can minimize damage to wood and wood products, and help maintain structural integrity.

• Damp wood and wood products provide an ideal breeding ground for bacterial growth and insect infestation. Wall assemblies that include a nominal 1” air space like brick veneer can provide rapid drying, which can hamper bacterial growth and insect infestation.

To download a complete copy of this report, go to www.boralbricks.com.
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