

Evaluation of the Moisture Performance of EIFS Walls Without Interior Vapor Barriers

The importance of location of the proper air barriers, vapor barriers and water-resistive barriers on the wall and the roles they play in high-performing EIFS

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INTRODUCTION

In the last few years more specifications are being written to include the requirements for air barriers, vapor barriers and water-resistive barriers. Some of these emerging specification requirements are a result of mandates by local building codes while others are a result of promising building science and research.

To better understand the differences between air barriers, vapor barriers and water-resistive barriers, this article is intended to help identify that the placement of one or more of these barriers within a wall assembly can impact the performance of that wall in terms of drying capability, particularly if the wrong type of barrier is installed or if it is improperly located. Because it is the responsibility of the building designer to properly locate the barrier for its intended purpose, these issues are of critical importance.

We'll start by making certain we understand the core principals. The three types of barriers are defined as follows:

Air Barrier: An air barrier is defined as a material that controls the unintended movement of air into and out of a building enclosure. Air barriers provide a resistance to the pressure differences across the two sides of the air barrier material. The fundamental material property characterizing the air barrier is air permeability.

Even today, air barriers are the least understood among the three types of barriers; even the characterization of the performance attributes are confusing. There are performance characteristics that are associated with the air barrier at the material level, and then at the system or full assembly level. In terms of purpose of the air barriers, the important value is that of the system or full assembly level. At the same time in order for an air barrier system to be effective, **it must be continuous** and the air resistance uniformly distributed.

Vapor Barrier: A vapor barrier is designed to retard the movement of water by vapor diffusion. A vapor barrier is also commonly referred to as a vapor retarder. The fundamental material property characterizing the vapor barrier is vapor permeance (perm).

Vapor barriers have recently been redefined into three categories by the 2009 International Building Code and International Residential Code based on a material's permeability (the ability for moisture to pass through a material in a gaseous state). The three classes are as follows:

- Class I: 0.1 perm or less (Sheet polyethylene, non-perforated aluminum foil)
- Class II: greater than 0.1 perm and ≤ 1.0 perm (kraft faced fiberglass batts or low perm paint)
- Class III: greater than 1.0 perm and ≤ 10.0 perms (latex or enamel paint)

The differences between a vapor barrier and an air barrier is that a vapor barrier does not have to be continuous, does not have to be free of holes, and does not have to be lapped or sealed. A void in a vapor barrier simply means that additional vapor diffusion will exist at a

given area as compared to other areas that are free of voids. Another important aspect is that many vapor retarders have different performances at low and high relative humidities. It is not uncommon for many asphaltic building papers to have vapor permeance.

Water-Resistive Barrier: A water-resistive barrier is designed to keep liquid water from entering a building enclosure. While the purpose of the water-resistive barrier primarily is to resist water entering through the material, a secondary function many times neglected to be identified is to promote vertical drainage. This makes the characterization of the fundamental property of the water resistive barrier 2- or even 3-dimensional.

Water-resistive barriers are commonly used in building construction as a means of protecting the wall assembly from water penetration should a leak develop in the primary enclosure. Water-resistive barriers are available in both liquid applied membranes and sheet membranes. They must be used in combination with flashing material to direct water that bypasses the primary layer to the exterior.

STUDY METHODOLOGY

This article addresses the impact of the choice of vapor barrier use on the moisture performance of two EIFS (Exterior Insulation and Finish System) wall configurations.

The first EIFS wall (wall 1) includes an exterior finish, base coat, two (2) inches of expanded polystyrene insulation, a liquid applied water-resistive barrier, ½ inch GP Dens-Glass Gold® sheathing, four (4)-inch steel stud framing, no stud cavity insulation, a vapor retarder, interior gypsum wallboard, and a coat of latex primer and latex paint.

The second wall (wall 2) is the same as wall 1, except that the exterior insulation is four (4) inches of expanded polystyrene rather than the two (2) inches.

Two vapor retarder strategies were investigated; one with a 4-mil poly vapor retarder installed between the cavity and the interior gypsum wallboard, and the second one without the polyethylene vapor retarder. Three diverse climatic locations were selected for analysis: Boston, MA, Seattle, WA and Minneapolis, MN.

The analysis performed developed a moisture performance statement on the use of a permeable interior vapor retarder strategy versus the use of a vapor tight system (1 Perm or less) for both 2 inch and 4 inch exterior insulation wall systems and the three climatic locations.

A number of activities were performed prior to executing this state-of-the-art hygrothermal analysis. Nearly all essential hygrothermal material properties (vapor permeability, sorption isotherms, suction isotherms, liquid diffusivity as a function of relative humidity or moisture content) used in the analysis were measured at the Oak Ridge National Laboratory. The information presented provides the basis for the development of the basic understanding of the transient heat and moisture performance of the EIFS wall system.

THE USE OF VAPOR RETARDERS

Interior vapor control strategies (vapor barrier/vapor retarders) were introduced to reduce the flow of interior space water vapor moisture into the concealed wall cavity. The original intent was to reduce the inflow of moisture due to moisture generation from the interior of the building. In the 1940's, American construction materials and wall systems were much different than the ones used today. There has been a lot of speculation and confusion among building envelope practitioners on the use of vapor barriers in constructions, such as the deployment of a sheet of polyethylene or asphalt coated kraft paper for interior vapor control.

PAST RESEARCH

There has been considerable discussion about what needs to be done to control moisture vapor movement in walls of U.S. buildings. Indeed, guidance in the selection of vapor retarders becomes even more critical for highly insulated walls that are being proposed for the future zero-net energy buildings. EIFS walls fall into the category of highly energy efficient wall systems. In 2003, the U.S. Department of Energy (DOE) contributed research that led to the development of a series of recommendations to propose changes to the energy codes. Initial proposals met with some resistance, in large part because there was a perceived lack of scientific backing to the proposals. The Oak Ridge National Laboratory (ORNL), working in close collaboration with Building Science Corporation (BSC), developed a plan to perform a series of advanced hygrothermal computer simulations using the WUFI [Karagiozis et al, 2001] and the MOISTURE-EXPERT [Karagiozis, 2001] software simulations. These simulations validated previous understandings, and provided additional insight on some of the complex interactions present in building envelopes.

They also included the impact of one (1) percent water penetration on the sheathing membrane (ASHRAE Standard SPC 160) as an additional load, as well as the impact of air conditioning during the summer months. These results became the scientific backbone for the recommended code vapor retarder changes submitted in 2006-2007 to the International Energy Conservation Code (IECC) and International Residential Code (IRC). Those changes were formally adopted as part of the 2009 International Building Code (IBC) and International Residential Code (IRC).

Additionally, another DOE co-sponsored project with EIMA (EIFS Industry Members Association) on Exterior Insulation and Finish Systems was recently completed that demonstrated the viability of EIFS walls without cavity insulation, and without interior vapor barriers, in mixed hot and humid climates as found in the Southeastern portion of the country (Charleston SC). That study included instrumented EIFS walls as well as other cladding configurations, measuring the hourly thermal and moisture performance. The study ultimately concluded that an EIFS wall with a liquid-applied water-resistive barrier out-performed all other tested wall configurations.

INTERNATIONAL BUILDING CODE (IBC) AND INTERNATIONAL RESIDENTIAL CODE (IRC)

In section 1405.3.2 of the IBC and 601.3.2 of the IRC the description of **material vapor retarder class** is as follows: The vapor retarder class shall be based on the manufacturer's certified testing or a tested assembly.

The following classes were specified:

1405.3 Vapor retarders. Class I or II vapor retarders shall be provided on the interior side of frame walls in Zones 5, 6, 7, 8 and Marine 4.

Exceptions:

1. Basement walls.
2. Below-grade portion of any wall.
3. Construction where moisture or its freezing will not damage the materials.

1405.3.1 Class III vapor retarders. Class III vapor retarders shall be permitted where any one of the conditions in Table 1405.3.1 is met:

**TABLE 1405.3.1
CLASS III VAPOR RETARDERS**

ZONE	CLASS III VAPOR RETARDERS PERMITTED FOR ¹
Marine 4	Vented cladding over OSB; Vented cladding over plywood; Vented cladding over fiberboard; Vented cladding over gypsum; Insulated sheathing with R-value \geq R2.5 over 2x4 wall; Insulated sheathing with R-value \geq R3.75 over 2x6 wall
5	Vented cladding over OSB; Vented cladding over plywood; Vented cladding over fiberboard; Vented cladding over gypsum; Insulated sheathing with R-value \geq R5 over 2x4 wall; Insulated sheathing with R-value \geq R7.5 over 2x6 wall
6	Vented cladding over fiberboard; Vented cladding over gypsum; Insulated sheathing with R-value \geq R7.5 over 2x4 wall; Insulated sheathing with R-value \geq R11.25 over 2x6 wall
7 and 8	Insulated sheathing with R-value \geq R10 over 2x4 wall; Insulated sheathing with R-value \geq R15 over 2x6 wall

From the 2009 IBC section 1405.3 and Section 601.3 of the IRC, Class I or II vapor retarders are required on the interior side of frame walls in Zones 5, 6, 7, 8 and Marine 4.

However, an exception is provided for in 1405.3.1 of the IBC (601.3.1 of the IRC) for class III vapor retarders. Class III vapor retarders shall be permitted where any one of the conditions in Table 1405.3.1 of the IBC (601.3.1 of the IRC) are met. EIFS walls with cavity insulation are appropriately characterized in Tables 1402.5.3.1 and 601.3.1 as insulated sheathing with an R-value > 5 for a 2x4 inch wall and R-value > 7.5 for a 2x6 inch wall for Zone 5 (Boston, MA); R-value > 2.5 for a 2x4 inch wall and R-value > 3.75 for a 2x6 inch wall for Zone 4 Marine (Seattle, WA); and R-value > 7.5 for a 2x4 inch wall and R-value > 11.25 for a 2x6 inch wall for Zone 6 Marine (Minneapolis, MN).

In all cases, the use of a vapor permeable vapor retarder (such as latex paint coating) is permitted for of the three cities used in the study. As for the particular case of EIFS walls without cavity insulation, the IBC and IRC do not explicitly address the use of vapor retarders. It is the purpose of this study to develop the necessary vapor control guidance for EIFS walls without stud cavity insulation.

**TABLE R601.3.1
CLASS III VAPOR RETARDERS**

ZONE	CLASS III VAPOR RETARDERS PERMITTED FOR ¹
Marine 4	Vented cladding over OSB; Vented cladding over plywood; Vented cladding over fiberboard; Vented cladding over gypsum; Insulated sheathing with R-value \geq R2.5 over 2x4 wall; Insulated sheathing with R-value \geq R3.75 over 2x6 wall
5	Vented cladding over OSB; Vented cladding over plywood; Vented cladding over fiberboard; Vented cladding over gypsum; Insulated sheathing with R-value \geq R5 over 2x4 wall; Insulated sheathing with R-value \geq R7.5 over 2x6 wall
6	Vented cladding over fiberboard; Vented cladding over gypsum; Insulated sheathing with R-value \geq R7.5 over 2x4 wall; Insulated sheathing with R-value \geq R11.25 over 2x6 wall
7 and 8	Insulated sheathing with R-value \geq R10 over 2x4 wall; Insulated sheathing with R-value \geq R15 over 2x6 wall

APPROACH

The performance of the EIFS walls with or without a polyethylene vapor retarder were investigated using the state-of-the-art heat, air and moisture transport simulation model WUFI-ORNL or WUFI-Pro [Kuenzel [1996], Karagiozis et al [2001]. To analyze the simultaneous transport of heat and moisture occurring in these walls systems, a number of key physical transport phenomena are required.

PARAMETRIC MODELING ANALYSIS

A modeling analysis of the combined, heat and moisture (hygrothermal) performance was required to quantify and characterize the impact of the use of two interior vapor retarder strategies and climate for the two EIFS walls (2-inch EPS and 4-inch EPS). A series of simulations (combination of 1-D and higher) were performed and these are summarized below:

EIFS with 2 inch EPS and no interior cavity insulation

- Inclusion of water penetration on WRB (Backstop® NT – Dryvit liquid-applied barrier)
- Effect of exterior environment (Seattle, Minneapolis and Boston)
- Impact of 4-mil/6-mil vapor barrier.
- Impact of 10-Perm interior drywall coating as a vapor retarder

EIFS with 4 inch EPS and no interior cavity insulation

- Inclusion of water penetration on WRB (Backstop NT)
- Effect of exterior environment (Seattle, Minneapolis and Boston)
- Impact of 4-mil/6-mil vapor barrier.
- Impact of 10-Perm interior drywall coating as a vapor retarder

OBSERVATIONS OF APPROACH

The hygrothermal simulations were performed for the three cities (Boston, Seattle and Minneapolis) with and without a polyethylene vapor retarder. The moisture conditions in the exterior sheathing (GP Dens-Glass Gold) and in the interior drywall were investigated. The results clearly show that the walls without the 4-mil polyethylene vapor retarder dry faster and the conditions are more balanced throughout the year. It is also clear that the vapor retarder is not needed to prevent water condensation in the wall cavity. This is due to the fact that the monolithic exterior insulation keeps the interior wall cavity warm even in the coldest months, thus preventing the possibility for condensation in the exterior sheathing.

CONCLUSION

This study evaluated framed walls clad with EIFS without stud cavity insulation. For the climates investigated, results of the hygrothermal analyses indicate that use of a vapor permeable (IBC and IRC Class III) retarder outperforms the use of polyethylene (IBC and IRC Class I) retarder for diffusion control.

This finding supports the requirements listed in Table 1405.3.1 of the 2009 International Building Code (IBC) and Table 601.3.1 of the 2009 International Residential Code (IRC) indicating that the use of a Class III vapor retarder is acceptable for use with EIFS.

REFERENCES:

Künzel, H.M., Karagiozis, A.N. and Holm A. 2001., WUFI-ORNL/IBP A- Hygrothermal Design Tool for Architects and Engineers, Chapter ASTM Manual 40 in Moisture Analysis of Buildings.

Karagiozis, A. and Kuenzel, H., WUFI-ORNL/IBP – A North American Hygrothermal Model, ASHRAE Proceedings for the Performance of Exterior Envelopes of Whole Buildings VIII: Integration of Building Envelopes, pp. 547 – 554, December 2001.

Künzel H.M.: Simultaneous Heat and Moisture Transport in Building Components. - One- and two dimensional calculation using simple parameters. PhD Thesis, IRB Verlag (1995).

EXCERPT FROM THE 2009 INTERNATIONAL BUILDING CODE, and 2009 International Residential Code
International Code Council

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Achilles Karagiozis is a distinguished research and development engineer at the Oak Ridge National Laboratory. He is in charge of research performed at ORNL in heat, air and moisture performance of buildings. Dr. Karagiozis is one of the leading building scientists in North America. He has been performing building science research for the past 16 years, trained more than 600 professionals in moisture design, championed and assisted in the development of innovative material systems and concepts. Research activities have been concentrated in energy efficiency, healthy, durable and sustainable building designs, housing integration issues, wireless route sensing, whole building performance applications, heating, ventilating and air conditioning of buildings and hygrothermal performance of envelopes. He is the US representative for IEA Annex 41 that deals with Moisture in Buildings, and is actively involved in a number of ASTM E06 technical committees and ASHRAE TC 4.4, and SPC 160. Achilles has also developed three or four of the world's most advanced hygrothermal models worldwide (WUFI, MOISTUREEXPERT, LATENITE and family). As an expert in the area of Moisture Engineering, he has solved many hygrothermal designs and retrofit challenges, and has developed multiple design guidelines for various envelope systems. Dr. Karagiozis is the author of more than 120 technical papers and reports related to moisture in buildings.

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