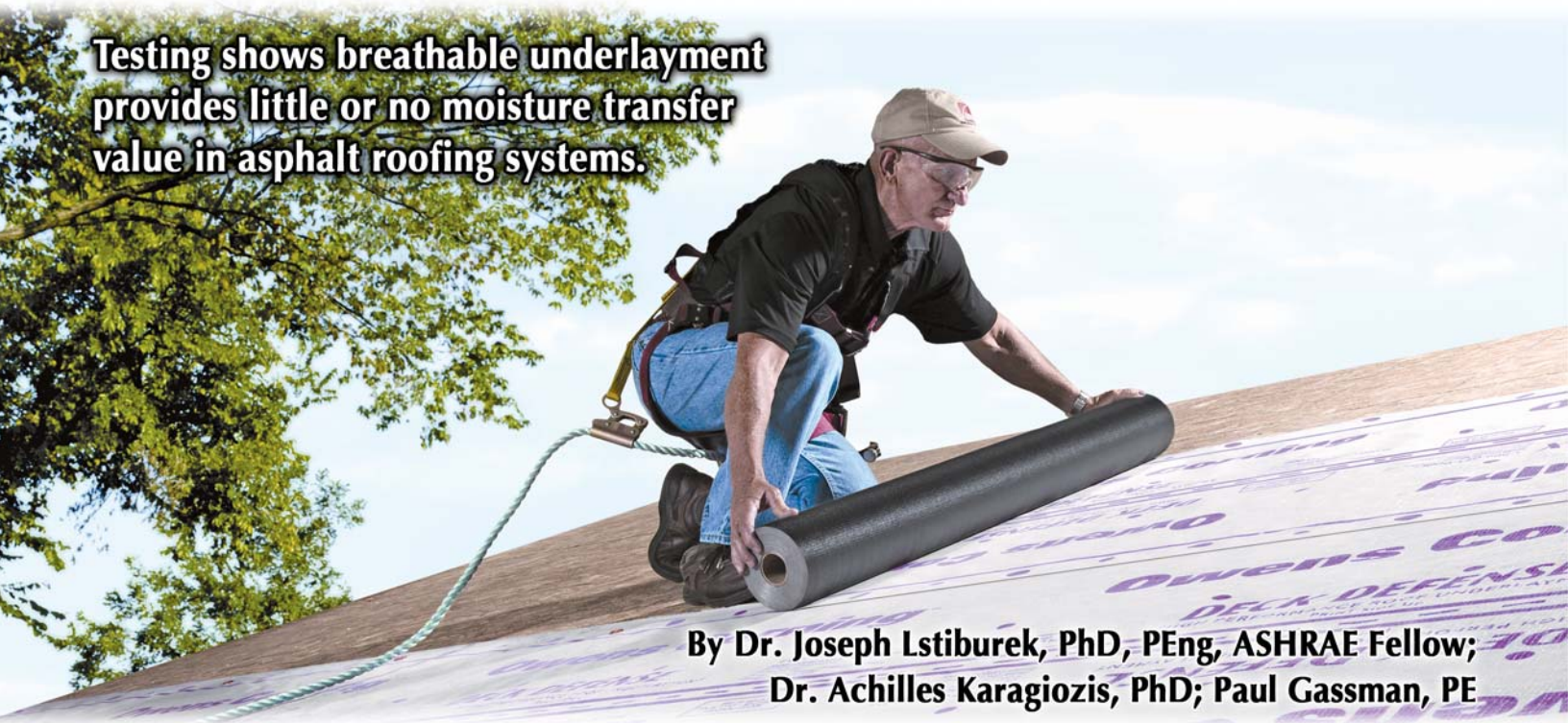


VAPOR PERMEABILITY PROVIDES NO PERFORMANCE BENEFIT FOR ROOFING UNDERLAYMENTS IN VENTILATED ATTICS

Testing shows breathable underlayment provides little or no moisture transfer value in asphalt roofing systems.



By Dr. Joseph Lstiburek, PhD, PEng, ASHRAE Fellow;
Dr. Achilles Karagiozis, PhD; Paul Gassman, PE

Figure 1 - Typical underlayment installation.

ABSTRACT

Many manufacturers have introduced synthetic underlayments in the roofing market to serve as secondary water shedding barriers under roof shingles. Traditional organic asphalt felt has served this purpose for years, but durability has diminished over time, and the product is inferior to recently available synthetic products made with layers of composite polyolefin. While traditional felts are permeable, allowing moisture vapor transfer over time, newer synthetic materials are typically non-permeable, allowing very little moisture transport.

Recent testing and evaluation at Owens Corning demonstrates that “adding” breathability to synthetic underlayment provides no advantage to the building performance of an asphalt roof assembly.

A modified ASTM E96 “dry cup” testing method demonstrated that standard overlapping shingle construction creates its own vapor barrier system, preventing both the

transport of moisture from exterior weather elements and the escape of moisture vapor from the building interior. Moisture transfer through the roof cannot be achieved simply by making the underlayment material breathable. Because the experimental data indicate that the multi-layered shingle system creates a vapor barrier, a properly designed and installed attic ventilation system or a properly designed and installed unvented roof assembly¹ is necessary to protect the roof sheathing from moisture within the home.

The focus of this paper is to investigate the system performance of standard asphalt shingles and to evaluate the impact of installing nonbreathable underlayments between the shingle layer and the roof deck. The research performed indicates that nonbreathable underlayments may be installed below asphalt shingle roofing materials with comparable or better moisture performance.

INTRODUCTION

The roofing market has seen an onslaught of new synthetic underlayment products in the past ten years. These products bring many advantages to the installer: increased speed of installation, lighter weight, and significantly stronger physical characteristics, resulting in greater wind uplift performance than typical asphalt felt underlayments. As durable moisture barriers, these products also benefit homeowners by protecting their homes from the elements over an extended dry-in period during construction or reroofing.

Some synthetic products claim to improve performance of the roofing system by including “breathability” as an added feature. But does this feature truly add any benefit to a typical asphalt shingle roofing system?

In a standard installation, underlayment is sandwiched between the plywood or oriented strand board (OSB) roof deck and a covering layer of asphalt shingles. Does a

breathable underlayment allow attic moisture to escape? Does it allow a roof deck to breathe? These questions are addressed in this white paper.

DEFINING BREATHABILITY

The 2009 International Residential Code (IRC) defines a vapor-permeable membrane as “a material or covering having a permeance rating of 5 perms or greater when tested in accordance with the desiccant method with Procedure A of ASTM E96. A vapor-permeable material permits the passage of moisture vapor.”²

However, traditional convention within the building industry defines

- A material with a perm of less than 0.1 as vapor-impermeable,
- A material with a perm of between 0.1 and 1.0 as vapor-semi-impermeable,
- A material with a perm of between 1.0 and 10.0 as vapor-semipermeable, and
- A material with a perm of greater than 10 as vapor-permeable.

Additionally, a vapor barrier is defined as less than 0.1 perm, and a vapor retarder is defined as less than 1.0 perm. As such, some inconsistency exists between the IRC and traditional convention.

MEASURING PERMEABILITY

The industry standard test method for water vapor transmission, also known as permeance, is ASTM E96, *Standard Test Methods for Water Vapor Transmission of*

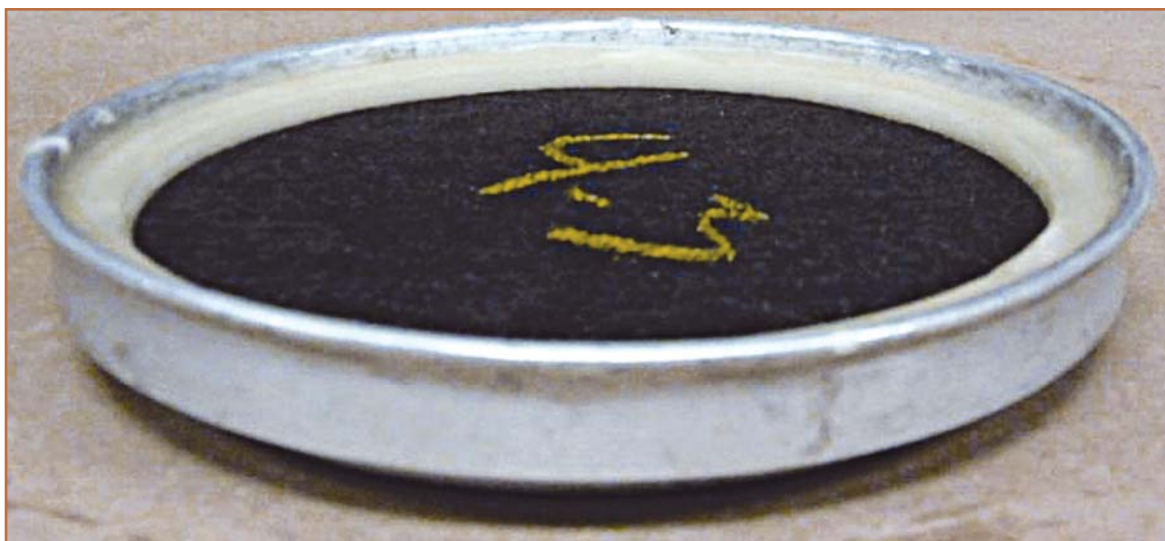


Figure 2 – #15 felt underlayment sample from ASTM E96, 6-in.-diameter “dry cup” test.

*Materials.*³ Because the IRC recommends the “dry cup” process defined as Procedure A, and with consideration of the sample size required to examine the overall system effectively, the dry or desiccant method was used for the shingle roofing system testing in this study (Figure 2).

The test is relatively straightforward. Test material is sealed over a container of desiccant and placed in a humidity- and temperature-controlled chamber. Over time, the desiccant will draw moisture from the ambient air in the chamber through the test material, which is then trapped in the desiccant. Measuring the water weight gain in the sealed container over time gives a value for permeance, which measures the time rate of water vapor transmission through the test material.

INDIVIDUAL COMPONENT TESTING

ASTM E96 enables the measurement of individual materials

as well as the assembled system. Individual material testing was accomplished using 6-in. cups, with a wax seal ring around the perimeter to close the sample cup. Table 1 provides a baseline understanding of the roofing system materials.

SHINGLE INSTALLATION INSTRUCTIONS

Owens Corning™ Classic® 3-tab shingles were used in all testing. Application instructions for these shingles include a 5-in. vertical exposure on the 12-in.-high shingle and a 6-in. offset on the horizontal dimension for shingle lapping. This is the industry standard practice for shingle installation.

TEST MATERIAL	PERMEANCE RATING
Asphalt shingles – individual	0.9
#15 felt	7.0
Breathable synthetic	9.5
Nonbreathable synthetic	0.1
7/16-in. OSB decking	1.0

Table 1 – Typical single-component testing.⁴

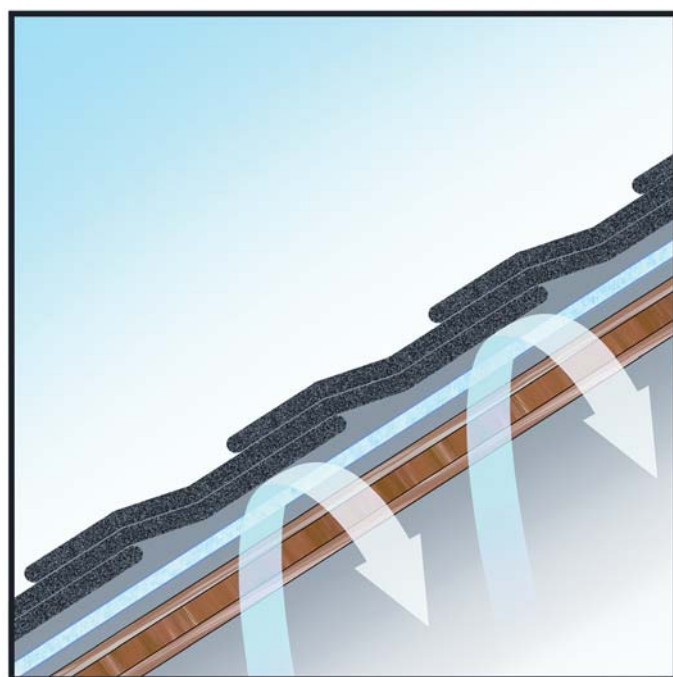


Figure 3 – Overlapping shingle construction.



Figure 4 – Shingle layer on OSB frame with large slotted windows.

This method provides an overlapping “watershedding” construction necessary to keep rainwater out (*Figure 3*). The same principle greatly increases the travel path or flow length for air movement through the same assembly. This resistance to airflow is likely the greatest contributing factor in creating the vapor resistance that this testing demonstrates.

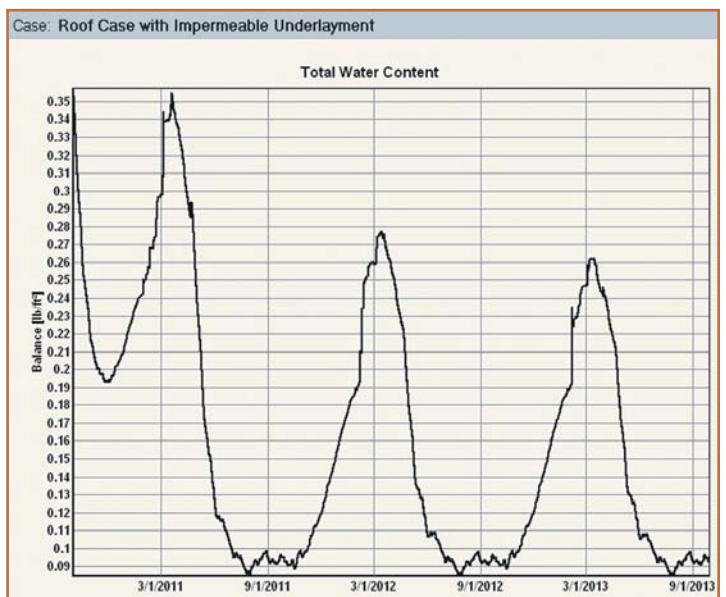
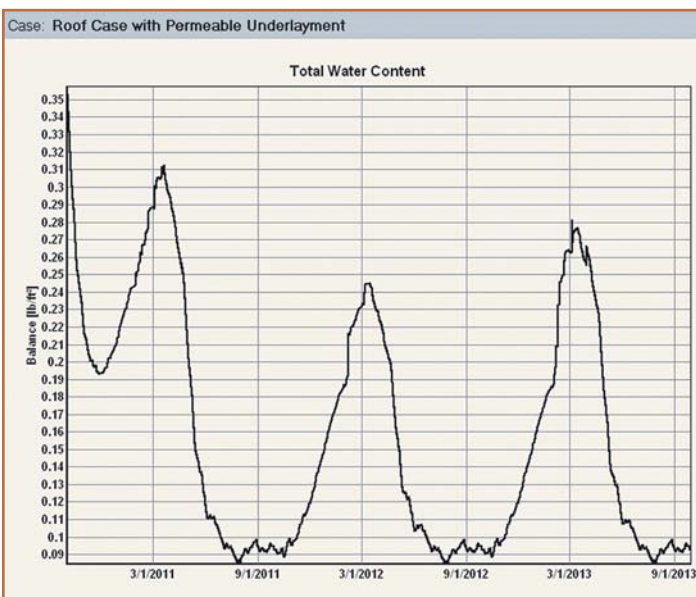
With a 12-in. height and a 5-in. exposure on the individual shingles, the overlapping system results in an air path that always has a double layer of shingles and a triple layer of material at each vertical intersection through which air and moisture vapor may migrate. The 36-in. width of the shingles also introduces a complicated path for any air and moisture vapor to travel through in the horizontal or lateral direction. Additionally, shingles are relatively heavy and flat and have a rough surface; all three of these physical characteristics increase the resistance to airflow in the roofing system.

ROOFING SHINGLE LAYER TESTING

A 24-in.-wide by 36-in.-long commercially available plastic pan was selected as the “test dish” for the ASTM E96 testing on large-scale system components. This size allowed for a typical asphalt shingle application with seven overlapping horizontal rows of shingles and three vertical butt joints between adjacent shingles. To simulate the shingle layer during application, an OSB frame was fabricated with large slotted windows to allow moisture vapor transfer through this layer with minimal interference from the OSB, while the OSB allowed the shingle attachment as per manufacturer’s instructions (*Figure 4*).

Repetitive testing on this application showed the multilayered asphalt shingle system—when installed per the manufacturer’s instructions—has an average moisture vapor transfer rate of 0.65 perms. Demonstrating a measured perm of less than 1.0

Figure 5 – Hygrothermal simulations validating the hypothesis.



Figures 6A and 6B – Initial system samples.

showed that moisture transfer through the multi-layer asphalt shingles is negligible.

This important fact begs the question: If the asphalt shingles act as a vapor retarder on the roof, then what value is added with the introduction of a breathable roof underlayment below it? Any moisture within the roof deck or the attic will not be able to move through the roofing system, regardless of the permeability of the roofing underlayment layer.

COMPUTER ANALYSIS

Using a state-of-the-art hygrothermal (combined heat and moisture transport) model developed by Karagiozis *et al.* (2001), two simulations were performed representing the impermeable and permeable underlayment (Figure 5). This model has been validated for a number of wall and roof systems, showing good agreement with field data by a number of organizations. These two simulations were performed to investigate the moisture storage differences between the two types of roof underlayment approaches. Figures 6A and 6B indicate that there is no apparent difference in the manner water vapor transport is managed across these two different underlayment systems. Follow-up simulations showed that if time-aged roof shingles deteriorated and water penetration occurred onto the underlayment, substantially higher moisture accumulation in the OSB occurred for the vapor-permeable underlayment.

VALIDATION

Initial testing used 1/8-in. OSB and Owens Corning™ Classic® 3-tab shingles on each sample, with three different underlayments: standard 15-lb. felt, Fiberglas™-reinforced felt, and a nonbreathable brand of synthetic underlayment, using three full-system boards for each test. This testing validated the initial computer model, but additionally, it drove further testing on the individual components. Part of this was the testing of the shingle overlap layer, which was discussed earlier, but it also validated the large-scale test specimen developed to facilitate the testing.

The second issue examined involved the impact of sample conditioning on the overall test results. Moisture within the individual components—especially a large mass element such as a 24- x 36- x 1/8-in. OSB—could impact the overall results of a permeability test if not properly accounted for. See Table 2.

TEST MATERIAL	PERMEANCE RATING
OSB, #15 felt, Classic® shingles	0.31
OSB, Fiberglas™-reinforced felt, Classic® shingles	0.32
OSB, nonbreathable, Classic® shingles	0.27

Table 2 – Initial system testing.

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TEST MATERIAL	PERMEANCE RATING
OSB, #15 felt, Classic® shingles	0.12
OSB, nonbreathable Classic® shingles	0.15

Table 3 – Validation testing of conditioned roofing system.

SYSTEM TESTING WITH EQUILIBRIUM CONDITIONING

As a follow-up to the original testing, a full secondary set of testing was conducted on system boards that were conditioned, before testing, in the controlled humidity and temperature chamber for 45 days to reach equilibrium within the components and the system layers. Care was also taken to be sure that equilibrium was reached during the weight-measuring phase of the testing.

Low levels of moisture transfer resulted in a total test time of 56 days, allowing sufficient moisture to be spread over time to accommodate the accuracy of the weight scale that was used.⁵ These verification

tests also showed a full vapor retarder presented both with the industry standard 15-lb. felt and with the nonbreathable synthetic underlayment. See *Table 3*.

ADDING A “DUMMY” SAMPLE SET

The “dummy” sample also gave some additional opportunities for the test method, but it also served to validate the initial system results. This sample set was built with a full vapor barrier, a ¼-in. sheet of standard Plexiglass® thermoplastic.

TESTING SUMMARY


Each test procedure iteration, repeat testing, test component analysis, and roof system check consistently reinforced the

hypothesis that conventional system construction in accordance with manufacturers’ instructions creates a nonbreathable roofing system as a weather barrier for attic assemblies. In the same respect that rain-water and exterior elements are kept out of attics by the overlapping construction of the shingle system, interior moisture from within the home does not escape through the shingles. Incorporating a permeable underlayment layer into the roof system does not improve the system breathability of the roofing system.

MANAGING MOISTURE IN A ROOF DECK OR ATTIC

If a decking sheet or attic space contains moisture, and the roofing system is a vapor retarder or a vapor barrier, how does one manage that moisture?

The key is proper ventilation or protection of the underside of the roof deck with an appropriate unvented roof assembly. With the asphalt shingle layer acting as a vapor retarder, moisture should be vented to the building exterior through the space below or otherwise managed. With conventional vented attics, this reinforces the best practice of ventilation—both at the eave or soffit and the ridge of steep-slope roof constructions. Most building codes require a ratio of one to 300 (1:300) for net-free vent area to square feet of attic space. Emerging practices in attic design using “unvented attic space” must also account for the layered vapor barrier of asphalt shingles by introducing drainage and vapor planes below the shingles and above the unvented space.

Proper venting—and, in turn, proper airflow beneath the asphalt shingles and underlayment layers—will keep a roof deck and attic space dry and functioning as designed throughout the life of the roofing system, with or without a breathable underlayment below the shingles. 

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- A. Karagiozis, “Advanced Hygrothermal Models and Design Models,” The Canadian Conference on Building Simulation, Ottawa, International Building Performance Simulation



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A.N. Karagiozis, "Advanced Hygrothermal Modeling of Building Materials Using MOISTURE-EXPERT 1.0," Oak Ridge National Laboratory. *Proceedings of the International Particleboard/Composite Materials Symposium*, Owens Corning, pp. 39-47, 2001.

FOOTNOTES

1. For Owens Corning Roofing and Asphalt, LLC's position on unvented attics, see *Technical Services Bulletin*

RD-01012011. Request by phone: 1-419-248-6557 or e-mail: get-tech@owenscorning.com.

2. *International Residential Code for One- and Two-Family Dwellings*, first printing, March 2009, copyrighted 2009 by International Code Council, Inc., 4051 West Flossmoor Road, Country Club Hills, IL 60478-5795.
3. ASTM E96.
4. ASTM E96, Section 11, *Procedure of Desiccant Method*.
5. ASTM E96, Sect. 6.3, Balance and Weights.

Joseph Lstiburek, PhD, PEng, ASHRAE Fellow

Joseph Lstiburek is a principal of Building Science Corporation and is considered an authority on energy-efficient construction techniques in the areas of rain penetration, air barriers, vapor barriers, air quality, durability, and construction technology. He has conducted forensic investigations and served as an expert witness on building failures all over the U.S. Dr. Lstiburek has written numerous books and technical papers on building construction, indoor air quality, and durability, and has lectured extensively in building science. He attended the University of Toronto, where he earned an undergraduate degree in mechanical engineering, a master's degree in civil engineering, and a doctorate in building science.



Achilles Karagiozis, PhD



Achilles Karagiozis has more than 20 years of building science research experience. As the director of building science at Owens Corning, he is responsible for feeding Owens Corning's innovation pipeline with customer-inspired and building science-informed solutions. As an authority in the area of moisture engineering, he has solved many hygrothermal design and retrofit challenges and has developed multiple design guidelines for various envelope systems. He has also developed some of the world's most advanced hygrothermal models (WUFI, MOISTURE-EXPERT, and the LATENITE family). Dr. Karagiozis is the author of more than 120 technical papers and reports related to moisture in buildings.

Paul Gassman, PE

Paul Gassman is a product and process engineer with Owens Corning Roofing and Asphalt, LLC, with 18 years of experience in design, development, and manufacturing of building materials products. He holds a BS in civil engineering from Ohio State University and has been a registered professional engineer in the state of Ohio since 1990.



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