Breathable Roofing Underlayments for Use in Steep-slope Applications

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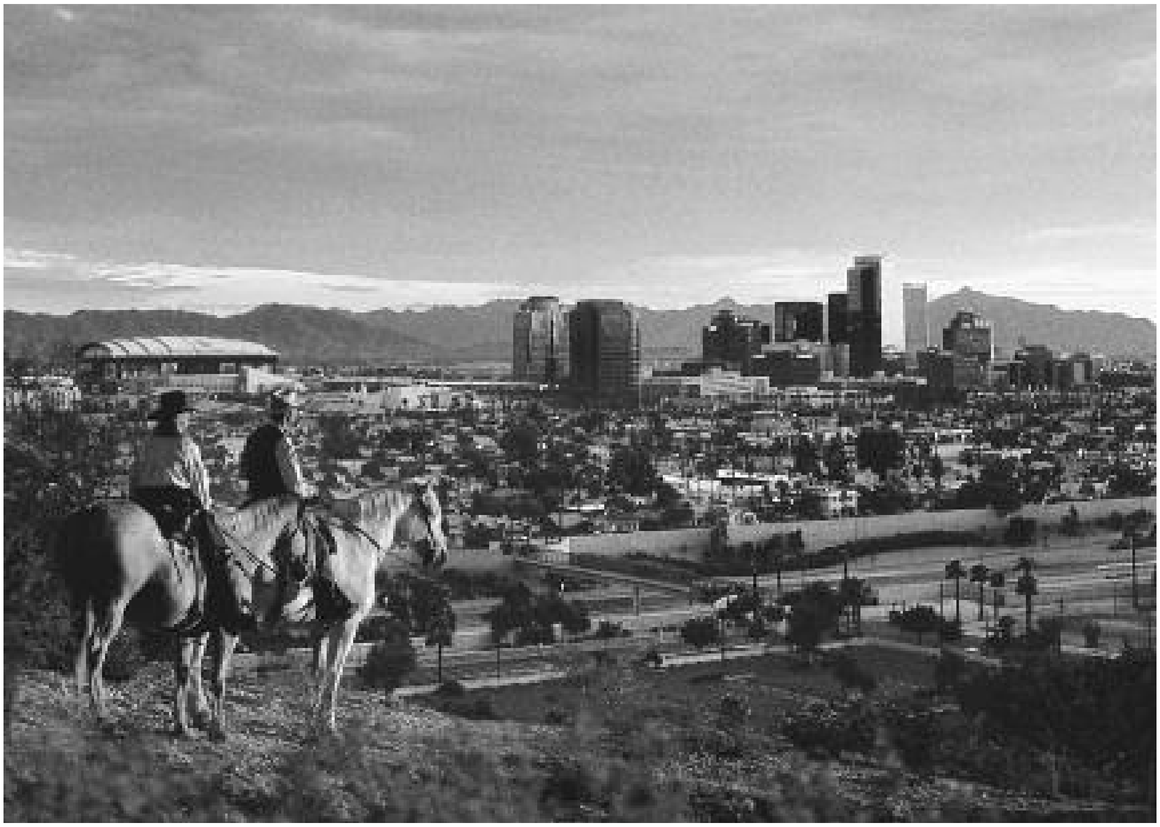


Roof Consultants Institute

ABSTRACT

One potential area of concern in the building industry is the adequate removal of moist air from attic spaces. Without proper ventilation, the risk of condensation of moist air traveling through the ceiling can become significant. As construction practices change and more attic area is used as living space, the need for proper ventilation will become even more critical.

Ventilation at the eaves and ridge vents has typically been used to minimize this problem, but the effectiveness of this solution can be severely limited if the ducts become partially blocked. One potential solution is the use of breathable films as underlayments.

Breathable films are currently being used as housewraps to control the water vapor permeation through the walls of a home. While these films typically have not been used in the United States as roofing underlayments, they have been a part of European construction practices for some time.

This paper will focus on the attributes of breathable films and the potential advantages of their use as underlayments.

SPEAKER

DR. DAVID BLAND is director of new technology, and **CHRISTOPHER FAUST** is director of new business development for Clopay Plastic Products of Mason, Ohio. Both men have over 16 years of experience in the field of plastic films and breathable film technology. They also have extensive knowledge in the area of heat and mass transfer.

Breathable Roofing Underlayments for Use in Steep-slope Applications

INTRODUCTION

One potential area of concern in regards to steep-slope roofing applications is the adequate removal of moist air from attic spaces. Without proper ventilation, the risk of condensation of moist air traveling through the ceiling can become significant. As construction practices change and more attic area is used as living space, the need for proper ventilation will become even more critical. Ventilation at the eaves and ridge vents has typically been used to minimize this problem, but the effectiveness of this solution can be severely limited if the ducts become partially blocked. One potential solution is the use of breathable films as underlayments. Breathable films are currently being used as housewraps to control the water vapor permeation through the walls of a home. While these films have not been typically used in the United States as roofing underlayments, they have been a part of European construction practices for some time. This paper will focus on the attributes of breathable films and the potential advantages of their use as underlayments in steep-slope applications.

BACKGROUND

Over the course of the past two decades, breakthroughs in polymer film technology have made it possible for small quantities of air and moisture to pass through tiny pores in polymer films. These breakthroughs have led to new and innovative applications for polymer film in a variety of industries. Once thought of as only a product for the hygiene and healthcare markets, microporous breathable films have now found their way into the building and construction market as well. As is evident in the housewrap market, breathable products have proven invaluable in protecting the exterior of a house against mold growth and harsh climates. The roofing market is no different; the structural integrity of a roofing system must be protected against the elements during construction.

A microporous breathable film product can be laid over the steep-slope roof deck to add protection during construction but also work to regulate moisture levels and reduce mold growth years into the future. Further advancements in microporous breathable technology have made it possible to regulate just how much moisture can pass through the tiny pores in the material. Over the next several years, microporous film technology will continue to evolve in order to make products more economical and customizable through high-speed manufacturing processes and unique material compositions to match specific applications.

How are Breathable Products Used Today?

Breathable products are currently used in the building and construction industry today as housewraps. The housewrap provides both moisture control and air resistance for wall structures. Both water resistance and moisture vapor transmission define moisture control in a building structure. When properly applied, the housewrap provides water resistance by both stopping and draining any liquid water that has penetrated the exterior finish.

While the main function of housewrap is as a water barrier, it is the breathability that allows moisture vapor to move freely through the material. This helps to prevent condensation build-up and reduces the likelihood of rot degradation in the home structure.

A second function of housewrap is to provide an air barrier to prevent airflow through the wall and enhance energy performance. Studies have shown that airflow through the walls can reduce the insulation value of a structure by as much 60%.

Similar type systems have been considered for roof underlayment. European construction has been using breathable underlayments for a number of years.[1] Differences in construction between North America and Europe have minimized the interest level in breathable underlayments in North America.

Moisture Control and Energy Efficiency

Moisture control and energy efficiency are also becoming important topics in roof systems. Ventilation is an effective means of controlling moisture but complicated roof designs and poor installation of insulation can limit its effectiveness. The current black felt roofing material is a good moisture barrier but tends to degrade rapidly when exposed to sunlight and water. The material also tends to hold water. The water-holding issues, combined with the low permeability of this material, prevent a wet roof from easily drying.

Metal roofs, in particular, may benefit from a breathable membrane. These structures are conducive to moisture condensing in the underlayment layer. A breathable membrane would limit condensation within the underlayment by allowing the moisture to escape and condense on the underside of the metal roof. The underlayment would then serve as a waterproof drainage surface by allowing the condensate from the metal structure to drip onto the underlayment and drain to the eave.

Energy concerns may also be an issue in the future. A U.S. DOE study indicated that the average house incurs about 1.1 complete air changes per hour and that about half of all energy used to heat and cool homes is used to heat or cool this infiltrated air. Air infiltration can come from the usual expected sources, such as doors and windows, but infiltration can also occur through the many seams and openings in the exterior walls. There is very little public data on how much air leakage is blocked by housewrap, but it is believed to be in the range of ten to fifty percent.[2]

Air infiltration has not been a concern in the past for roof systems, since the structure usually abutted an open, non-livable space. Changing building practices, such as cathedral ceilings and livable attic space, are making roof systems more like wall systems. Black felts generally are poor air barriers due to the width of the material, the inability the properly seal the edges, and the degradation of the felt over the course of a few years. With the changes in building structure, a breathable underlayment may supply the same energy advantages as those seen with housewrap.

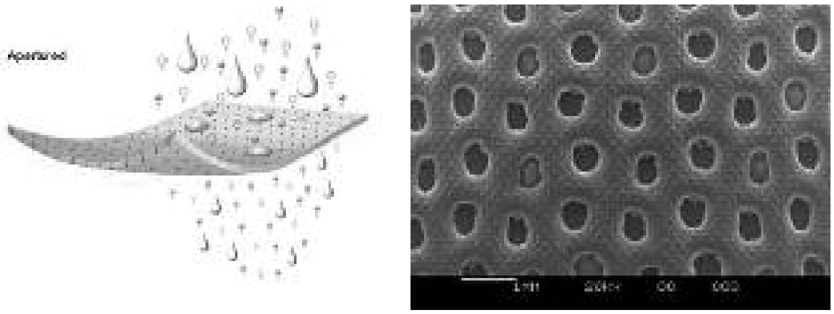
Types of Breathable Films

Breathability can be defined in a number of different ways, but the underlying principle is that air particles and moisture vapor must be able to pass through the material. For example, coffee filters, cloth, and leather are all considered breathable products because air is able to travel through these materials. When breathability was first highlighted as a valuable characteristic of a plastic film product, engineers struggled to find ways to make films breathable without compromising the structural integrity of the material.

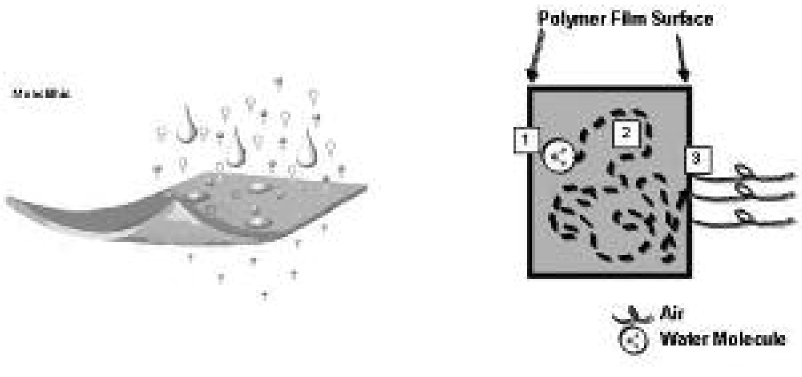
The first method discovered entails an obvious solution to a rather complex problem; by simply puncturing the material, the plastic will be able to breathe. These mechanically punched small holes are easily detected by the human eye and offer a great amount of breathability; however, the holes are big enough for water molecules to squeeze through as well. This method of perforating the film creates a problem because most plastic films are used to protect against the elements, and these small holes allow the elements to get through (*Figures 1A* and *1B*).

On the other extreme, another way to create a breathable membrane is with a monolithic film. Monolithic films chemically break down water molecules and allow some of the molecules to diffuse through in vapor form. Monolithic films are considered both waterproof and windproof, but are very expensive to produce. With this structure, airflow is very limited, and it is impossible for any water molecules to squeeze through the film (*Figures 2A* and *2B*).

The final way to create breathability in a film is by creating thousands of microscopic pores that connect to one another to form a tortuous path through

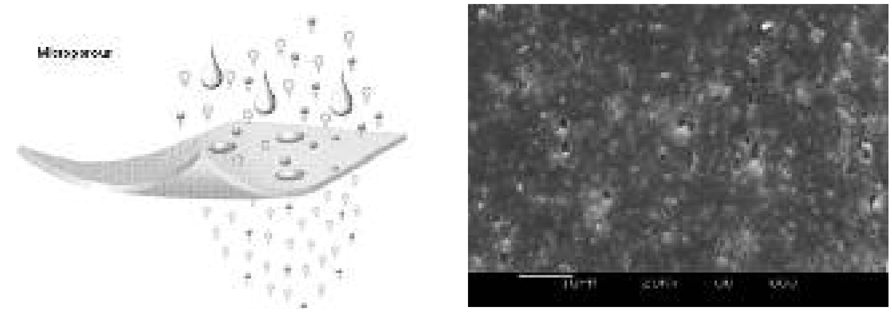


Figures 1A and 1B: Apertured film depiction and actual product at 200x magnification.



Figures 2A and 2B: Monolithic film depiction and diagram of diffusion process.

the material. This tortuous path is too small for a water molecule to fit through, but moisture vapor is able to find a path. This microporous breathable structure allows for moderate airflow and relatively little, if any, liquid flow. Microporous breathable structures have become very popular because they are relatively inexpensive to produce yet provide superior performance (*Figures 3A* and *3B*).



Figures 3A and 3B: Microporous film depiction and actual stretched film at 200x magnification.

Breathable Performance By Type				
Types of Breathable	**Air Flow**	**Liquid Flow**	**Moisture Absorption**	**Cost**
Apertured/perforated	Easy	Easy	Little to none	Low
Microporous	Moderate	None to difficult	Little to none	Low to moderate
Monolithic	Difficult	None	Significant	High

Table 1

Table 1 shows a comparison between the different film structures and their performance.

Methods to Make a Microporous Breathable Film

All microporous breathable films start out the same way. When the plastic resin is melted to begin the extrusion process, tiny particles of $CaCO_3$ (Calcium Carbonate) or $BaSO_4$ (Barium Sulfate) are mixed in with the melted resin to create a filled film. From here, the breathability characteristics can be created in a variety of different ways: machine direction orientation (MDO), tentering, or incremental stretching.

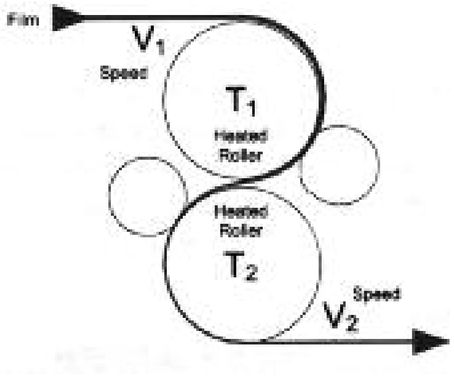


Figure 4

In the MDO process, this filled film is rolled between two pairs of rollers moving at different speeds to stretch the film in the machine direction. In this process, the film is stretched but the fillers ($CaCO_3$ or $BaSO_4$) stay the same size, creating microscopic pores in the material. The speed of these two pairs of rollers can be altered to control the amount of breathability in the product. *Figure 4* illustrates the MDO method, which is very inexpensive and the product can be produced very quickly; however, the end-product is very weak in cross direction strength.

The tentering method involves pulling the edges of the film to stretch the material in the cross direction. The tentering method is the easiest way to create a microporous breathable film, but it has a very limited use and often results in uneven stretching due to the fact that the film is only pulled from its edges. *Figure 5* illustrates the tentering method.

Finally, the incremental stretching method combines the benefits of MDO and tentering by running the film through a set of interlocking "teeth" to stretch the film at set intervals. This method allows for stretching in the machine direction, cross direction, or both, and produces holes that are

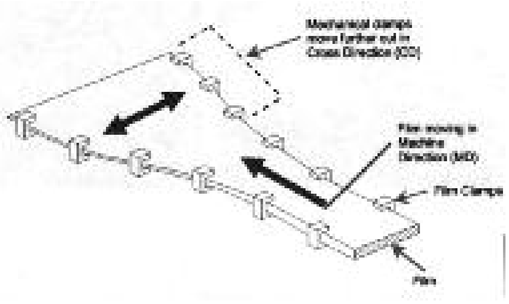


Figure 5

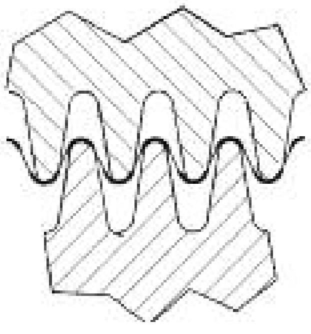


Figure 6

smaller and rounder than those produced by the MDO method. *Figure 6* represents the incremental stretching, or intermeshed method.

Although this method does not allow as much stretching capability as the MDO method, the pore size can be controlled with much greater accuracy and with greater consistency across the width of the film. *Figure 7* shows a comparison between the MDO and incremental stretching (intermeshed) products. Both of these films have the same MVTR but the intermeshed clearly has smaller pores.

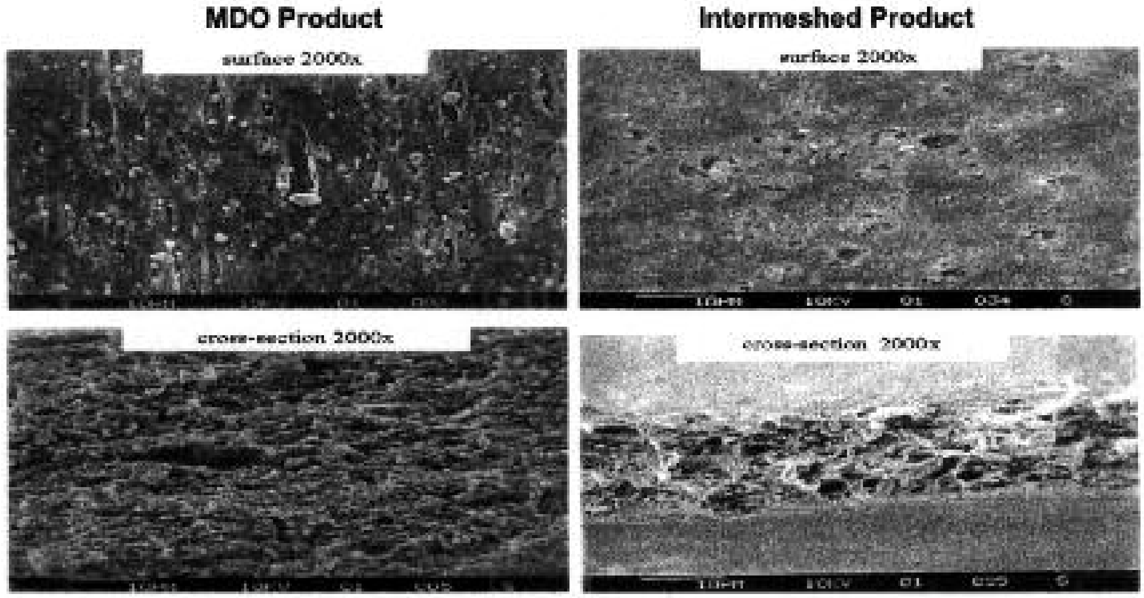


Figure 7

Now take a look at *Figure 8*. This shows the difference in leakage performance between the MDO process and incremental stretching method at the same MVTR. Clearly, the incremental stretching method results in smaller pore size; and therefore, no leakage vs. MDO's larger pore size distribution with leakage.

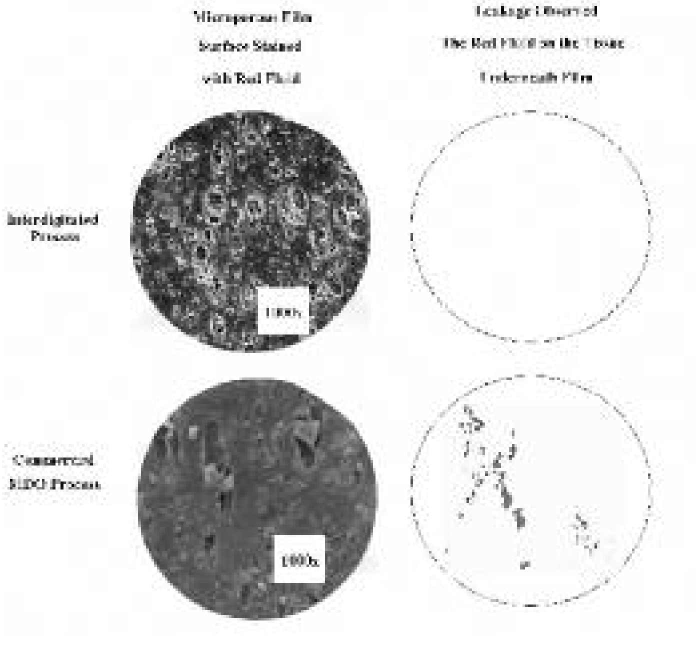


Figure 8

The combination of water resistance, moisture vapor transmission, and air barrier can be directly related to the pore size and porosity of the material. The housewrap products on the market today offer a wide range of moisture vapor transmission rates usually defined in terms of perms and water resistance, which are typically described by the hydrohead values of the materials. Structures having high porosity and small pore size would be expected to provide superior breathability while maintaining high water resistance.

The evolution of microporous film has focused on customizing and optimizing properties such as pore size distribution as a means of controlling the airflow, moisture permeation, and hydrohead. *Figures 9* and *10* show examples of how pore size and airflow can be controlled through the use of coextrusion technology.

Breathable Products

While we have discussed types of breathable films, in most cases they need to be combined with another substrate for added strength. This is typically with a nonwoven or scrim product. Both perforated and non-perforated materials are currently being used as breathable products in building and construction. Perforated structures tend to be a woven product produced by weaving highly oriented polypropylene or polyethylene tapes on a textile loom. The tapes are coated with a film and then perforated to create the breathable structure.

These products are inexpensive and offer excellent strength and tear properties but the perforation techniques used to create the breathability lead to large holes in the structure, thus minimizing the effectiveness at water holdout. The pore structure of these materials is about 0.15 microns in diameter.

Nonwovens and laminates of nonwovens with breathable films make up the non-perforated materials used as housewrap. These materials are unique in that both breathability and excellent moisture control characteristics can be achieved with a single product.

There are many different forms of non-perforated products. One method is a fine fiber nonwoven web produced via a flash-spun process. Varying the lay-down speed and bonding conditions controls the moisture vapor transmission rate. The structure provides both high moisture vapor transmission rates and excellent hydrohead.

Properties similar to those of the flash-spun material can also be achieved with spunbond nonwovens that are coated with either a breathable monolithic film or a microporous breathable film. The monolithic films provide complete resistance of water penetration through the material but the products tend to be more expensive. Microporous breathable films provide a more economical alternative to monolithic films. These films are produced by stretching a filled polyolefin via tentering, machine direction orientation (MDO), or intermeshing.

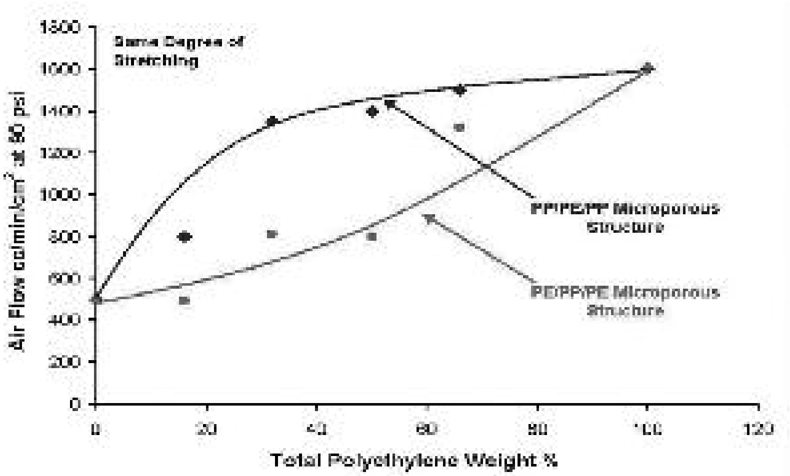


Figure 9

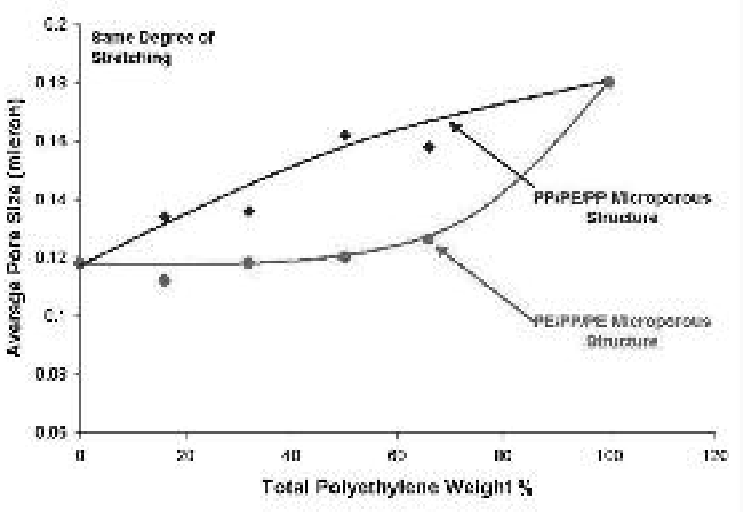


Figure 10

Material Comparison

It was stated earlier that the combination of water resistance (hydrohead), moisture vapor transmission (MVTR), and air barrier can be directly related to the pore size and porosity of the material. A study was performed in comparing the pore size, moisture vapor transmission rate, and hydrohead for a series of different housewraps. The moisture vapor transmission rates and hydrohead were measured according to the ASTM E 96 desiccant method and AATCC-127 method respectively. Both are standard tests used in the industry.

The pore size within the materials was measured using a liquid porosimeter from Porous Materials Inc. This test utilizes a controlled air pressure to empty "through" pores, which had been filled with a wetting liquid. A simple relationship between the pressure, the properties of the wetting liquid, and the diameter of an ideal circular pore allows the calculation of the equivalent pore diameter. This relationship is shown in *Equation 1.*

$$d = (4\sigma \cos \theta) / P$$

Where d = equivalent pore diameter, mm
σ = surface tension of the liquid, N/m
θ = contact angle between liquid and pore wall
P = pressure, Pa

Equation 1

The bubble point recorded in *Table 2* is a measure of the largest "through" pore in the material. Since this is a measure of the diameter of a hole that extends through the material, it is believed to be directly related to the hydrohead. It can be seen from *Equation 1* that the smaller the pore size, the greater the pressure required to push liquid through the material.

Table 2 shows a comparison of the different products discussed above.

	Bubble Point Pore Size (microns)	Hydrohead (cm)	MVTR (perms)
Perforated	150	13	15
Nonperforated			
Monolithic	0	NA	7 - 10
Microporous (intermeshed)	0.7	865	7 - 50
Microporous (MDO)	0.25	250	7 - 50
Flashspun	4	210	20 - 50

Table 2

Perforated wovens provide excellent strength and have some degree of breathability but, as seen in *Table 2*, the relatively large pore size results in a very low hydrohead. This makes products of this type vulnerable to water penetration.

Breathability and water resistance are best achieved through non-perforated structures. *Table 2* shows a range of breathability can be achieved with any of these structures. The mean pore size of a material is related to the method of manufacture and stays relatively constant. Variation in breathability is achieved through changes in the basis weight and porosity.

A distinguishing trait among these materials is the water resistance or hydrohead. The hydrohead is strongly related to the maximum pore size in a material.

Table 2 shows that increasing pore size results in a decrease in the hydrohead. All of these materials pass the current code specification for housewrap.

Recently, there has been a concern with water resistance performance in systems exposed to surfactants and cedar and redwood siding. Surfactants are a typical ingredient of soap and can reduce the water repellency by changing the surface tension of the water. The reduction of surface tension can reduce the water resistance. The tannins in cedar and redwood also can act as surfactants and reduce the effectiveness of housewrap as a moisture barrier.[3] One study has shown that the hydrohead could be reduced by about 10% when using a surfactant system.[4] Minimizing the pore size in the product can minimize this problem.

What Construction Material Should I Use?

Typically, the breathable film by itself will not be able to meet the requirements of the roofing market. This could be due to tensile strength, puncture resistance, too slippery, etc. The benefit in using a breathable film is the flexibility in material construction. Based on the attributes a company may seek for sales and marketing differentiation, they can vary the materials used to create a softer/stiffer, thicker/thinner, tougher, anti-slip, etc.

Various types of material construction could be (*Figure 11*):

1. Extrusion coating - Film/nonwoven
2. Two sided coating - Film/nonwoven/film
3. Adhesive lamination Nonwoven/film/nonwoven or Nonwoven/film/scrim/nonwoven

There are also many variations available. For example, different scrims could be used for tear resistance, film additives could be used for extended UV resistance, and anti-slip coatings could be used for safety. Working closely with your film supplier will enable you to develop a product that meets the code requirements and your company's functional requirements.

CONCLUSION

Moisture control is becoming a major force in the design criteria for home structures. As construction techniques and energy requirements continue to change, it is apparent that roof systems are becoming more like wall

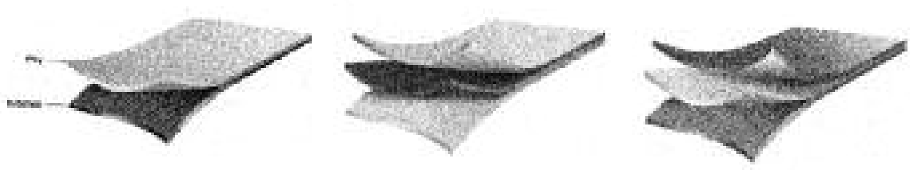


Figure 11

structures. Given these changes, it is possible that breathable membranes may play a large roll in roof design in the near future.

Given this possible scenario, we can use the experience gained in the housewrap market and apply this to the roofing market. The roofing product may look different than the housewrap product in order to meet the code / functional requirements of the market, but a synthetic, breathable film technology fills the needs of the roofing market today and more importantly, tomorrow.

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