TECHNICAL NOTE

Water Vapor Permeance of Wood Structural Panels and Wood Wall Construction

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Controlling against moisture damage in structures depends upon proper system design, installation and maintenance. The structural system must be designed to control against leaks, the major source of moisture damage, as well as condensation that may cause excessive moisture. Good construction practices control condensation within the walls and influence the rate at which water vapor moves around and through wall system components, and mitigate the effects of humidity and temperature differentials between the inside and outside of the structure. For more information, see APA Technical Note, *Condensation Causes and Controls*, Form X485.

Wood, one of the most common building materials in North America, naturally contains some moisture within its cellular structure. The moisture content in wood changes as water vapor moves in and out of the wood in response to temperature and humidity changes in the surrounding environment. Moisture content in wood is also affected by direct contact with liquid water. Common sources of liquid-water intrusion include water leaks in the building envelope and leaks in water pipes. Absent sufficient drying potential, water leaks can be damaging if they lead to high moisture content in wood for a prolonged period of time. However, water leaks in the building envelope can be minimized through proper building design, construction and maintenance. More specific recommendations for minimizing water leaks through the proper design and construction of wood walls are presented in the *Builder's Guide Series*, available at www.EEBA.org.

Water may also accumulate within a wall in the form of water vapor. Water vapor is the result of air leaks allowing moisture-laden air into the wall cavity, or vapor diffusion through building components. Because moisture vapor can move through exterior wall systems, care must be taken with respect to the design of the wall to prevent excessive condensation. Condensation occurs when either water vapor becomes too high or a surface temperature too low, such that a surface temperature drops below the dew point. Although controlling condensation involves many design aspects beyond the scope of this document, the topics addressed here – the water vapor permeance of structural wood panels, vapor retarders and their role in wall-system design – require careful consideration during the building design phase.

The proper placement of vapor retarders within a wall system will help manage the diffusion of vapor through the wall system. To determine proper vapor retarder placement and minimize moisture-related problems, the building designer must consider the interior and exterior environments, as well as the wall's thermal and water vapor permeance characteristics (as discussed on the following pages).

MOISTURE MOVEMENT AND WATER VAPOR PERMEANCE

Water vapor permeance is the rate of moisture movement through a material as a function of the water vapor pressure gradient that can exist between two surfaces. The water vapor permeance of panels is measured using ASTM Method E 96. This method combines a controlled environment with either a desiccant (dry-cup) or water (wet-cup) to create a vapor pressure gradient. The resulting weight change over a specific time is used to calculate the permeance per area and per unit of the vapor gradient. Values are reported in perms (grains* per hour, per ft^2, per inch of mercury vapor pressure) or in kg per Pascal per second per $meter^2$. One perm is equal to 5.7×10^{-11} kg/Pa-s-m^2.

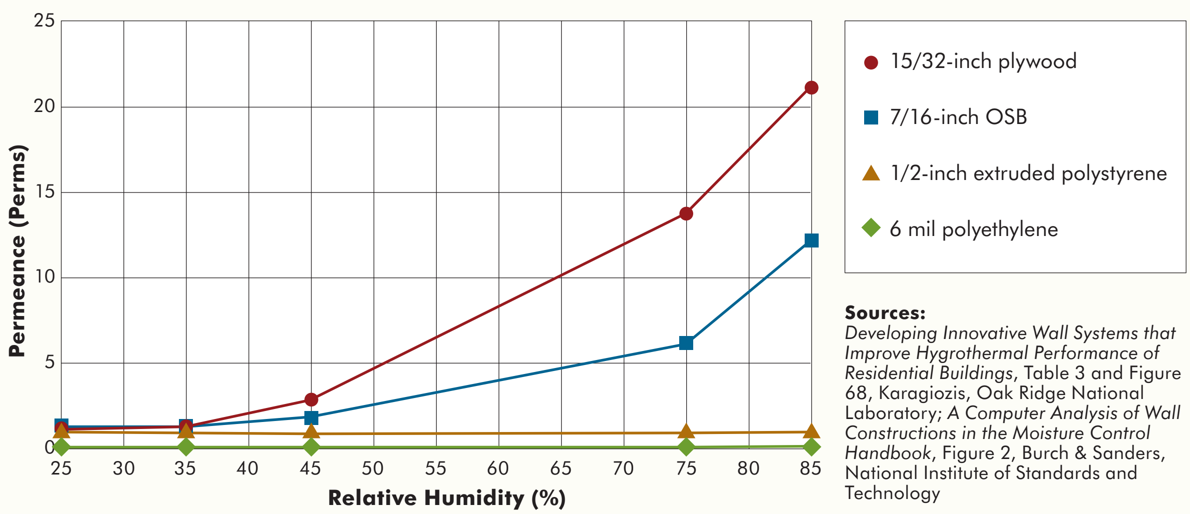
Vapor retarders limit the amount of water vapor that passes through a wall assembly. Section 202 of the 2007 Supplement to the International Building Code® (IBC®) and Section R202 of the 2007 Supplement to the International Residential Code® (IRC®) classify a membrane as a Class I vapor retarder when it has a permeance of 0.1 perm or less, a Class II vapor retarder when it has a permeance of greater than 0.1 up to 1.0 perms, and a Class III vapor retarder when it has a permeance of greater than 1.0 up to 10 perms, when tested in accordance with the desiccant method using Procedure A (dry-cup) of ASTM E 96. Materials with higher perm ratings allow greater passage of water vapor. A membrane with a permeance of 5 perms or more is classified as vapor permeable in accordance with the 2006 IBC and IRC. The permeance of a material is inversely proportional to its thickness; in other words, two layers of a material will have one half the permeance of a single layer of that material.

Figure 1 displays the water vapor permeance of select building materials tested by the National Institute of Science and Technology (NIST) and Oak Ridge National Laboratory (ORNL). The results show that the water vapor permeance of plywood and oriented strand board (OSB) is sensitive to relative humidity gradients. For example, at 50 percent humidity, the water vapor permeance of 7/16-inch OSB sheathing is approximately 2 perms, but the water vapor permeance may be increased to 12 perms when the humidity is increased to about 85 percent. Both 15/32-inch plywood and 7/16-inch OSB are regarded as semi-permeable materials under the 2006 IBC and IRC. For comparison, the water vapor permeance of polyethylene and some extruded polystyrene products are very low and are generally insensitive to relative humidity gradients.

*A “grain” is 1/7000 of a pound

FIGURE 1

WATER VAPOR PERMEANCE FOR BUILDING MATERIALS AS A FUNCTION OF RELATIVE HUMIDITY



Sources:
Developing Innovative Wall Systems that Improve Hygrothermal Performance of Residential Buildings, Table 3 and Figure 68, Karagiozis, Oak Ridge National Laboratory; *A Computer Analysis of Wall Constructions in the Moisture Control Handbook*, Figure 2, Burch & Sanders, National Institute of Standards and Technology

BASIC VAPOR MANAGEMENT DESIGN CONSIDERATIONS

The water vapor permeance of materials is just one consideration when conducting a full analysis of exterior wall assemblies. Such an analysis is beyond the scope of this document; however, the following basic principles regarding water vapor permeance should be considered by the building designer:

- Water vapor moves from high concentrations to low concentrations.
- In cold climates with heated indoor air, vapor will generally flow from indoors to outdoors.
- In warm, humid climates, vapor will generally flow from outdoors to indoors.
- In some mixed climates, the flow of vapor may reverse from winter to summer.
- Section R318.1 of the 2006 IRC and Section 502.5 of the 2006 International Energy Conservation Code® (IECC®) require an approved vapor retarder of 1.0 perms or less on the warm-in-winter side of the wall in all climates except states in the southern U.S. However, it should be noted that code requirements for vapor retarders have been subject to intense scrutiny and frequent changes. In the 2009 IRC, for example, revisions have been made to vapor retarder definitions, classifications (vapor retarders are classified according to their permeabilities: Class I, Class II or Class III) and placement requirements. Refer to the pertinent codes adopted by the local jurisdiction for the applicable requirements.

A more thorough discussion of vapor management considerations is available in some of the documents included in the list of references on page 5.

PLYWOOD AND OSB ARE "SMART VAPOR RETARDERS"

Managing water-vapor migration is an important consideration. In cold climates and/or during periods of low exterior humidity, exterior sheathings with high permeability permit water vapor to escape a wall cavity to the outside. In warm and dry climates, exterior sheathings with low permeability inhibit warm and humid air from coming into contact with the cool, air-conditioned surfaces of interior walls. Figure 1 shows that some materials, such as polyethylene and vinyl sheeting tested by the NIST and ORNL, have very low vapor permeance. In many climates, it would be desirable to have a low permeance barrier on one side of a wall and then, in a different season, have a low permeance barrier on the other side of the wall. Fortunately, this complicated aspect of wall construction can be resolved through the use of *smart vapor retarders*, such as plywood and OSB. The permeance of smart vapor retarders is low when the relative humidity is low and increases as the relative humidity increases. The increased permeance when the wall humidity is elevated allows for greater vapor movement and faster drying of the wall. As shown in Figure 1, the water vapor permeance of 7/16-inch OSB is approximately 2 perms at 50 percent relative humidity, but that permeance may be increased by a factor of 6 (i.e., 12 perms) when the humidity is increased to 85 percent.

CONSIDERATIONS

The selection of exterior wall sheathing material is just one of many issues that must be taken into account in the design of durable exterior wall assemblies. All such considerations should be carefully evaluated by the building designer to ensure that moisture-related problems are minimized. This document provides the building designer with water vapor permeance information for plywood and OSB, as well as several related considerations:

a. Bulk water intrusion is the most common source of potentially damaging liquid water within walls. Exercise great care in detailing flashings around all doors, windows, roofs, walls and chimneys. All intersections between horizontal surfaces and vertical surfaces must be designed and installed to shed liquid water to the outside of the walls. For more information, refer to the APA publication *Build a Better Home: Walls*, Form A530, or visit www.buildabetterhome.org.

b. Designers and builders should consider the water vapor permeance ratings of any sheathing product before incorporating it into an exterior wall assembly.

c. Some exterior wall sheathing products are nearly impermeable, even at high relative humidities. For example, limited permeability testing recently conducted by APA on a rigid foam sheathing product recognized as a wall bracing panel determined a permeance range of 0.5 to 1.2 perms. When used in conjunction with interior-side vapor retarders, impermeable exterior wall sheathings can inhibit water that has entered the wall through leaks from exiting the wall system. The simultaneous use of impermeable barriers on both the interior and exterior walls is referred to as a *double vapor retarder* and should be avoided.

d. Wood structural panels are semi-permeable, and are smart vapor retarders because their permeability is low when the relative humidity is low and increases as the relative humidity increases. By increasing permeability when the wall humidity is elevated, wood structural panels help aid water vapor diffusion through exteriors walls, mitigating moisture buildup in concealed spaces. This characteristic makes wood structural panels an important component of a properly designed durable exterior wall assembly.

e. Always design wall systems to encourage drying mechanisms. Check local building codes for exterior wall system design requirements.

REFERENCES

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Permeance results of LP OSB coated with Flameblock.

Surface Coating	Pan condition	Side of specimen facing up in the pan	Initial Specimen Weight (g)	Perm (inch-pound) 75% R.H. [(a)]	
				individual	Set average
None (Control)	Wet (water)	OSB screen side	122.94	5.96	5.33
		OSB smooth side	133.61	4.33	
		OSB screen side	136.68	5.29	
		OSB smooth side	125.15	5.75	
1 side with Flameblock	Wet (water)	OSB screen side	183.32	6.12	4.68
		Coated side up	182.37	3.48	
		OSB screen side	176.06	5.20	
		Coated side up	173.14	3.92	
Both sides with Flameblock	Wet (water)	n.a.	234.14	4.23	4.63
		n.a.	220.49	5.53	
		n.a.	227.19	4.06	
		n.a.	224.25	4.68	
Surface Coating	Pan condition	Side of specimen facing up in the pan	Initial Specimen Weight (g)	Perm (inch-pound) 25% R.H. [(b)]	
				individual	Set average
None (Control)	Dry (dessicant)	OSB screen side	138.5	1.51	1.78
		OSB smooth side	138.81	1.87	
		OSB screen side	135.61	1.83	
		OSB smooth side	130.7	1.90	
1 side with Flameblock	Dry (dessicant)	OSB screen side	202.38	0.66	1.11
		Coated side up	191.48	1.25	
		OSB screen side	183.67	1.01	
		Coated side up	180.11	1.54	
Both sides with Flameblock	Dry (dessicant)	n.a.	223.64	0.66	0.68
		n.a.	234.51	0.50	
		n.a.	210.97	0.97	
		n.a.	234.58	0.58	

[(a)] Assumed relative humidity of 100% inside wet cup and 23°C 50% RH in environmental cabinet, therefore specimen RH of 75%.

[(b)] Assumed relative humidity of 0% inside dry cup and 23°C 50% RH in environmental cabinet, therefore specimen RH of 25%.

Reported by:

Aaron Kjeld

AARON J. KJELD
Staff Scientist
Technical Services Division