APA – The Engineered Wood Association

APA Report T94-12

Physical Properties of Structural Panels

Technical Services Division

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PHYSICAL PROPERTIES OF STRUCTURAL PANELS

INTRODUCTION

The successful utilization of structural panels often requires information on certain of their physical properties. Structural capabilities of structural panels is discussed in other reports by APA. This paper presents information on key nonstructural properties of structural panels.

The APA is a nonprofit trade association that represents structural panel manufacturers in North America. It's primary function is to expand the successful use of structural wood panels through the development of standards, auditing of quality and the education of end users. The APA has evaluated physical properties of panels that influence performance in construction applications. Properties that have been evaluated include:

- Panel density
- Response to humidity and direct wetting
- Panel dimensional response to moisture
- Water vapor permeance
- Thermal properties

PANEL TYPES

For the purpose of this report, structural panel types include plywood and oriented strand board (OSB). Structural panels are used in sheathing applications for roofs, walls and floors. The panels are evaluated for the specific application under APA's Performance Standard, which that assesses structural performance, dimensional stability and glue bond durability.

DENSITY

Density influences many of the physical properties of structural panels. The density of plywood is closely related to the specific gravity of the wood species used in the panel. The density of OSB panels is a function of both the species used and the degree of compaction that occurs during the pressing operation.

The following table presents results of a study conducted by APA in 1989 which structural panels were evaluated for density at each of APA's regional auditing laboratories. Density was measured on 3x3-inch specimens. Density was based on oven-dry weight and dimensions measured at the moisture content as received (approximately 2 to 4% for OSB and 4 to 8% for plywood).

Table 1. Density of Structural Panels

Panel Type	No. Tested	Avg. Density		COV (%)
		(pcf)	(g/cm^3)	
Douglas-fir plywood	1504	31.5	.51	8.0
Western softwood plywood	246	26.0	.42	9.9
Southern pine/hardwood plywood	1146	35.6	.57	8.5
OSB	1295	40.6	.65	8.8

MOISTURE RELATIONS

Wood structural panels are hygroscopic. Panel moisture content is a function of relative humidity (and temperature to a very slight degree) when not exposed to direct wetting. In construction applications such as roofs, walls and floors, the panels in service are protected from wetting so the panel moisture content is primarily a function of humidity.

Panels may be exposed to direct wetting during construction, and during the service life for some applications. When exposed to direct wetting, the moisture content is influenced by wetting time and by panel variables that affect capillarity such as veneer species of plywood and wax additives of OSB.

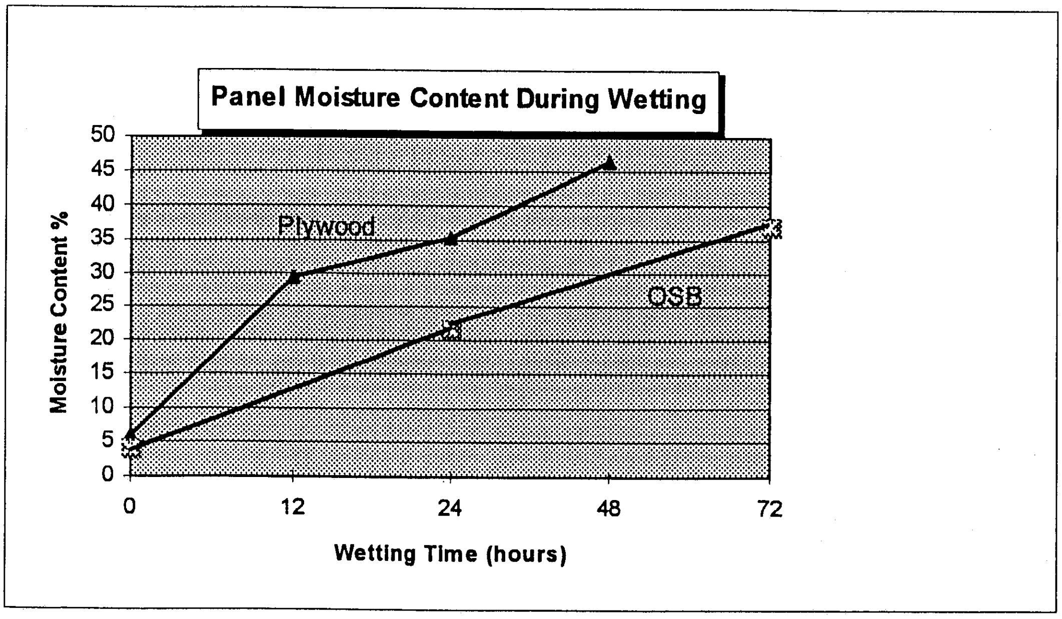
An APA study evaluated the equilibrium moisture content of structural panels. Results indicated that the moisture content of plywood and OSB at a given relative humidity is lower than the published values for solid wood. The APA data below is based on an absorption cycle at a temperature of approximately 70°F.

Table 2. Equilibrium moisture content of solid wood and structural panels at 70°F (21°C)

	Moisture Content (%)		
Relative Humidity	Solid Wood[1]	Plywood	OSB
10	2.5	1.2	0.8
20	4.5	2.8	1.0
30	6.2	4.6	2.0
40	7.7	5.8	3.6
50	9.2	7.0	5.2
60	11.0	8.4	6.3
70	13.1	11.1	8.9
80	16.0	15.3	13.1
90	20.5	19.4	17.2

1) From Agriculture Handbook No. 72 by U.S. Forest Products Laboratory

A standardized wetting cycle was developed by APA and has subsequently been accepted in various performance and manufacturing standards. The method wets the exposed surface only with a water spray system; the back side is exposed to the resultant high humidity. The procedure designed to simulate a panel exposed to weather such as when wetted during construction. The wetting cycle is used to evaluate dimensional stability and is used prior to structural tests of sheathing panels. The following figure relates wetting time and panel moisture content for 7/16" OSB and 1/2" plywood.



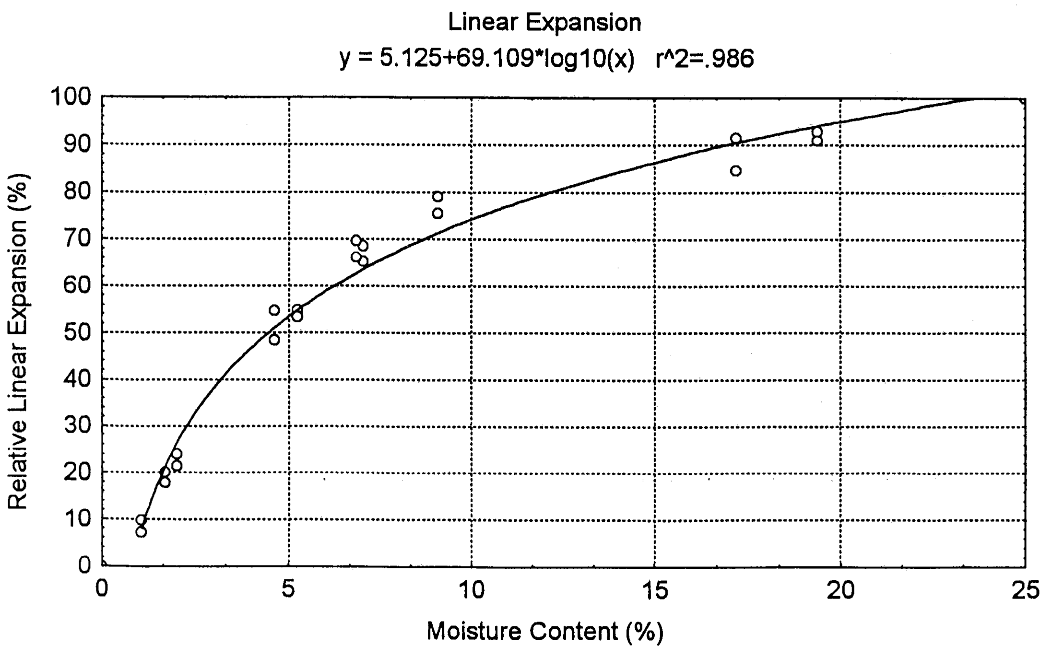
DIMENSIONAL STABILITY

The moisture content of structural panels is generally 2 to 8% when manufactured. When exposed to elevated humidity or wetting after manufacture, the resultant increase in moisture content leads to dimensional increase in thickness, length and width. The increase in length or width is reported as linear expansion. The thickness increase is called thickness swell.

Linear Expansion

Linear expansion of structural panels is generally evaluated by measuring length increase due to a change in moisture condition. A steady state moisture condition can be achieved by oven drying, humidity exposure, or vacuum soaking. Linear expansion can also be measured following exposure to moisture such as a one-sided water spray to simulate wetting typical of construction site exposure.

Linear expansion by humidity exposure is typically conducted by using standardized initial and ending humidities such as 50 and 90% humidities. Since humidity exposure in actual applications can vary, APA undertook a study to evaluate the relative expansion of structural panels across interim moisture conditions from oven dry to complete saturation. The relative linear expansion and thickness swell was determined at various equilibrium moisture contents by exposure to various humidities. The relative linear expansion at each moisture content was determined as a percentage of total expansion from oven dry to complete saturation by a vacuum-soak cycle. The relation is shown below.



The relative linear expansion is a function of moisture content as expressed below:

$$RLE = 5.125 + 69.109\ LOG_{10}\ (MC)$$

Where:

RLE = relative linear expansion at reference moisture content as percent of total from oven dry to saturated (%)

MC = reference moisture content (%)

The above relation can be used to estimate actual expansion when the linear expansion from oven drying to saturation is known. Approximate moisture content of panels after manufacturing is 2 to 4% for OSB and 5 to 8% for plywood. Some acclimation to ambient humidity conditions may occur during transit. The following provides information on linear expansion from oven dry to saturation (i.e., vacuum soak). The oven dry/vacuum soak cycle represents the extreme amount of potential expansion which may occur. It is not representative of expansion which normally occurs in-service.

Table 3. Linear expansion from oven dry to vacuum soak.

Panel Type	No. Tested	Along Direction		Across Direction	
		Avg	COV (%)	Avg	COV (%)
OSB					
7/16"	734	.23	25.7	.38	20.0
23/32"	499	.22	25.6	.38	21.1
Plywood					
3/8" - 1/2"	203	NT		.34	44.4
19/32" - 3/4"	187	NT		.31	35.1

NT = not tested
Along direction refers to 8-foot direction
Across direction refers to 4-foot direction

The effect of linear expansion of structural panels may lead to buckling of panels after being nailed to supports. The buckling potential has been studied by APA and reported in Research Report 144 and Research Report 149. This research has led to development of a stability index which relates panel structural properties and dimensional stability to the relative potential for buckling. The stability index is based upon Euler's equation for column buckling and considers dimensional buckling analogous to column buckling. These techniques are able to identify panels with high dimensional buckling. However, buckling is an unstable event which eludes accurate prediction using these techniques.

APA's use recommendations recognize potential for expansion of structural panels. Gapping of panel edges provides room for panel expansion prior to developing axial compression which can lead to buckling. Techniques to minimize buckling are addressed in APA use recommendations and technical notes.

Thickness Swell

Thickness swell of structural panels is evaluated by techniques similar to those for testing linear expansion. Thickness swell can be evaluated using steady state humidity cycles or direct wetting. Unlike linear expansion, thickness swell is sensitive along panel edges since the end grain of the fiber increases capillarity. For that reason, thickness swell measurements are typically focused on the swell near the panel edge. In addition to the above moisture cycles, thickness swell is frequently measured using the 24-hour soak specified in ASTM Standard D1037.

The thickness swell of plywood is primarily related to the radial expansion of the wood species with some increase expected from release of compression set that occurs during pressing. The thickness swell of OSB is generally greater than wood due to release of compaction stress created during pressing.

APA undertook a study to evaluate the relative thickness swell of structural panels across interim moisture conditions from the oven-dried condition to complete saturation. The relative thickness swell was determined at various equilibrium moisture contents by exposure to various humidities. Unlike linear expansion, thickness swell increases uniformly as a function of moisture content. The relative thickness swell can be expressed as below:

$$RTS = 4.0 * MC$$

Where:

RTS = relative thickness swell at reference moisture content as of total from oven dried to saturated (%)

MC = reference moisture (%)

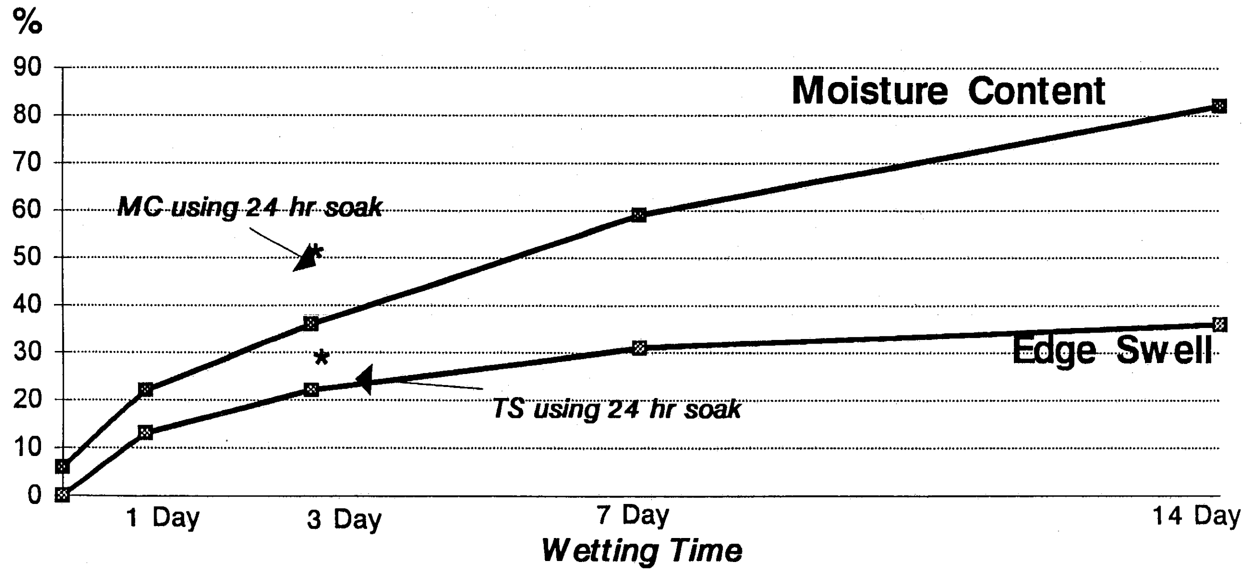
The above relation can be used to estimate actual thickness swell when the thickness swelling from oven drying to saturation is known. The following table provides information on thickness swell for structural panels when measured using the oven-dry-to-saturation cycle.

Table 4. Thickness swell from oven dry to vacuum soak

		Thickness Swell OD-VS (%)	
Panel	(No. Tested)	Average	COV
Plywood:			
3/8" - 1/2"	203	9.4	19.3
19/32" - 3/4"	187	8.8	18.0
OSB:			
7/16"	154	32.9	17.1
23/32"	61	28.9	15.1

Since thickness swelling is especially sensitive to one-sided wetting such as during construction, other methods such as the 24-hour soak or water spray methods are also used to test thickness swelling as applicable to construction applications. The following figure presents the relation between wetting time and thickness swell of OSB sheathing panels.

OSB Sheathing Response to One-Sided Wetting



WATER VAPOR PERMEANCE

Water vapor permeance of structural panels refers to the rate of moisture transmission through the panel as a function of the water vapor pressure gradient that can exist between the two faces. Water vapor transmission is measured using ASTM Method E96. This uses either a desiccant or water to create a vapor pressure gradient. The boundary conditions of the two methods differ since the humidity source can be the environment surrounding the specimen pan or the environment inside the specimen pan itself. In either method, the weight change over a specific time is used to calculate the permeance. Values are reported in perms (grains per ft^2-hr-in. HG vapor pressure). A grain is 1/7000 lb. (0.065 g).

Research by at the National Institute of Science and Technology has shown that the water vapor permeance is very sensitive to the relative humidity gradients. For example, at 50% humidity the water vapor permeance of plywood is approximately 1 perm but the water vapor permeance is increased by a factor of 10 when the humidity is increased to 90%. Similar results are reported shown for an OSB siding product which had been coated with a latex paint.

Water vapor permeance of structural panels has been evaluated by APA using the dry cup method. Plywood species selected to be representative of the industry were evaluated in the 1970's. The table below presents results for various species of 3/8-inch Exterior plywood.

	Water Vapor Permeance	
	Perms	($g/hr-m^2-mmHg$)
3/8" Plywood		
Doug-fir, coast	0.78	.021
Doug-fir, north interior	0.53	.015
Southern pine	1.43	.039
Western larch	0.63	.017
Western hemlock	0.89	.024
True fir, western	0.88	.024
Western white pine	0.45	.012
3/8" MDO plywood		
One side MDO	0.3	.008
Two side MDO	0.2	.006

When adjusted for the relative volume use of the various species, a water vapor permeance value of 0.8 perms is appropriate for 3/8-inch Exterior type plywood or plywood with exterior glue (Exposure 1). Use of overlays significantly impacted the water vapor permeance.

The following table presents similar results for OSB panels.

	Water Vapor Permeance	
	Perms	($g/hr\text{-}m^2\text{-}mmHg$)
7/16" OSB	0.91	.025
15/32", 1/2" OSB	0.70	.019
19/32", 5/8" OSB	0.72	.020
23/32", 3/4" OSB	0.49	.013

THERMAL PROPERTIES

Thermal Conductivity

Thermal conductivity of building materials is important for resisting heat transfer through structures. Thermal conductivity of wood products is generally related to density and moisture content as follows:

$$k = S\,(1.39 + 0.028\,MC) + 0.165$$

where:

k = conductivity (Btu-in./hr-sq ft-deg F)
S= specific gravity
MC= moisture content (%)

Although this relation works well for solid wood products such as lumber, research has indicated that the conductivity of structural panels is generally lower than would be predicted by the equation. A review of thermal properties of wood and wood panel products was reported by Tenwolde of the U.S. Forest Products Laboratory. Additionally, specific data on wood-based panels was developed by Kamke. The following presents test data for thermal conductivity of structural panels.

		Thermal Conductivity	
Panel	Specific Gravity	(Btu-in./hr-sq. ft.-°F)	(kcal/hr-m - °C)
7/16" OSB	.66	0.57	.07
23/32" OSB	.65	0.60	.07
3/8" plywood	.53	0.45	.06
3/4" MDO plywood	.50	0.66	.08

Thermal Expansion

The coefficient of expansion for wood products is very low relative to moisture induced expansion and contraction. For products with 60% of the fiber running in the longitudinal panel direction, the value for thermal conductivity is 0.0000034 inch/inch per °F (0.0000061 mm/mm/°C).

SELECTED REFERENCES

1. American Plywood Association. 1994. Design Capacities for APA Structural-Use Panels. T94-10.
2. American Plywood Association. 1994. Performance Standards and Policies for Structural-Use Panels. PRP-108.
3. American Plywood Association. 1992. Performance Standard for Wood-Based Structural-Use Panels. PS 2-92.
4. Bengelsdorf, M. F. 1981. Linear Expansion and Thickness Swell of Wood-Based Panel Products After One Side Wetting. American Plywood Association. PT81-25.
5. Zylkowski, S. C. 1986. Dimensional Stability of Structural-Use Panels. American Plywood Association. R&D86L-43.
6. O'Halloran, M. R. 1975. Plywood In Hostile Environments. American Plywood Association. Research Report 132.
7. Burch, D. M., W. C. Thomas and A. H. Fanney. 1992. Water Vapor Permeability Measurements of Common Building Materials. ASHRAE Transactions. Vol. 98 Part 2.
8. Richards, R. F., D. M. Burch and W. C. Thomas. 1992. Water Vapor Sorption Measurements of Common Building Materials. ASHRAE Transactions. Vol. 98 Part 2.
9. Kamke, F. A. and Zylkowski, S. C. 1988. Effects of wood-based panel characteristics on thermal conductivity. Forest Products Journal. Vol. 39. No. 5.
10. Tenwolde, A., J. D. McNatt and L. Krahn. 1988. Thermal Properties of Wood and Wood Panel Products For Use In Buildings. U.S. Forest Products Laboratory, USDA.
11. H. R. Trechsel and M. Bomberg. 1989. Water Vapor Transmission Through Building Materials and Systems: Mechanisms and Measurements. American Society for Testing and Materials. STP 1039.
12. U.S. Forest Products Laboratory, USDA. 1987. Wood handbook: Wood as an Engineering Material. Agriculture Handbook 72.
13. O'Halloran, M. R. 1980. Predicting Buckling Performance of Plywood Composite Panels for Roofs and Floors. American Plywood Association. Research Report 144.
14. Zylkowski, S. C. 1986. Dimensional Performance of Wood-Based Siding. American Plywood Association. Research Report 149.