Delamination of Southern Pine Plywood During Three Years Of Exterior Exposure

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Abstract

Plywood was made from eight loblolly pine trees selected to exhibit a range of specific gravity and growth rate. Three-ply, 3/8-inch specimens were exposed outdoors for 3 years in central Louisiana; percentage of delamination was measured annually. Rings per inch and tightness of peel had minor effects. A low gluespread resulted in rapid delamination, particularly with high-density veneer or long assembly time. Of glues having a low percentage of resin solids, those extended solely with wheat flour resisted delamination. Glues extended with blood suffered more severe delamination, even when percentage of resin solids was high. High specific gravity wood delaminated more rapidly than low specific gravity wood, particularly if gluespread was low or assembly time long. Plywood given a long assembly time tended to delaminate, and dense veneer or light gluespread accelerated the effect. Rate of delamination decreased after the first year, but general conclusions about the primary variables were the same after 3 years as after 6 months. An 11-factor equation explained 35 percent of the variation in terms of wood properties and results of a standard shear test.

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THIS PAPER is the last of a series of six on properties of southern pine plywood manufactured with phenolic glue for exterior service. It examines the interactions of seven variables as they affected rate of delamination over a period of 3 years. It also evaluates percentage of wood failure and several other parameters as predictors of durability. Background data will be found in the five previous papers (2, 3, 4, 5, 6).

Procedure

Veneer of eight loblolly pine trees was glued into three-ply panels 12 inches square and 3/8-inch thick. Half the panels were made from veneer peeled cold and loose (10 lathe checks per inch averaging 0.09 inch deep) with a roller nosebar; the other half, from veneer peeled hot and tight (14 lathe checks per inch averaging 0.05 inch deep) with a fixed nosebar. In all, 576 panels were manufactured — 72 from each tree.

The seven variables were:

1) Specific gravity (ovendry weight and green volume): either under 0.5 or over 0.5.
2) Rings per inch: either less than 6 or more than 6.
3) Peel: cut cold and loose or cut hot and tight.
4) Resin level: percent of resin solids in wet mixed adhesives, 26 or 21.
5) Secondary extension: wheat flour plus blood, wheat flour only, or no secondary extender.
6) Gluespread in pounds per 1,000 square feet of core (half on each side of core): 65 or 75.
7) Assembly time before hot pressing, minutes (before prepress, prepress, after prepress): 5 + 5 + 3 = 13, 16 + 5 + 3 = 24, 14 + 5 + 13 = 32.

Veneer was cut 0.130 inch thick and dried at 300°F. to 3 percent moisture content. Panels were pressed two to the opening for 6.5 minutes at 285°F., with a specific pressure of 175 psi. The glue was a phenol formaldehyde formulation containing 40 percent resin solids (Reichhold Chemicals, Inc., 22-398 Plyophen).

Procedures for tree selection, veneer manufacturing, panel assembly, glue mixing, glue spreading, assembly, and pressing are all described in the initial paper of the series (2). Percentage of wood failure and strength in wet rolling shear were measured by the American Plywood Association's vacuum-pressure-soak method; 16 specimens were evaluated from each panel. Modulus of elasticity and compressive strength were determined at 11 percent moisture content by loading the samples parallel to the grain of the face and back plys.

Two 1 by 3-1/4 inch specimens were cut from each panel (a total of 1,152 specimens) and were subjected to exterior exposure by fixing each specimen with a machine screw 3/4 inch above the surface of a 45°, south facing exposure deck located in Pineville, La. Delamination in both gluelines of each specimen was measured twice during the first year and then at 12-month intervals, and expressed as a percentage of each total glueline area.

Results from Analysis Of Variance

Delamination of the 2,304 gluelines averaged 3.3, 5.0, and 6.1 percent after 12, 24, and 36 months of exposure.

After 3 years, gluelines nearest the sun had delaminated significantly less than those on the shady side, all specimens considered:

Exposure	Delamination (%)
Sunny	5.7
Shady	6.8

Each three-ply specimen necessarily contained one loose-to-loose and one loose-to-tight glueline. After 3 years, loose-to-loose gluelines had delaminated significantly less than loose-to-tight gluelines:

Loose-to-loose	5.4
Loose-to-tight	6.7

The effect of the seven factors on delamination during each of the 12-month periods was studied by analysis of variance. All significant effects and interactions (0.01 level) are illustrated in Figure 1. The rate of delamination was not linear, but decreased with time.

Rings per Inch

By analysis of variance, growth rate as measured by rings per inch was not related to delamination, nor did it interact with any other primary factor.

Peel

Type of peel (cut cold and loose or cut hot and tight) was not related to delamination. Neither did it interact with any other primary factor.

Gluespread

Plywood made with the 65-pound gluespread delaminated faster than that made with the 75-pound spread. With the low spread, delamination was severe unless assembly time was kept short (Fig. 1,A). The effect was most noticeable on wood of high specific gravity (Fig. 1,D); the 65-pound spread was more effective on wood of low specific gravity than the 75-pound spread was on wood of high gravity.

Resin Solids and Extender

Surprisingly, a low percentage of resin solids (21 percent) in combination with wheat flour extender resulted in the glue bond that suffered least delamination (Fig. 1,B). Substantial delamination was observed in plywood made with glue having either low or high resin solids in combination with an extender containing blood as well as wheat flour. All other combinations tested were intermediate (Fig. 1,B).

Specific Gravity

Veneer cut from trees of low specific gravity made plywood that delaminated less rapidly than that made of high-gravity wood. Delamination of high-gravity wood was particularly rapid when assembly time was long (Fig. 1,C) or when gluespread was low (Fig. 1,D).

Assembly Time

From Figures 1,A and C, it is evident that plywood given a short assembly time delaminated less than that given a long assembly time. When assembly time was long, severe delamination occurred in wood of high gravity or with a low gluespread; a short assembly time, on the other hand, yielded plywood that resisted delamination even if wood specific gravity was high.

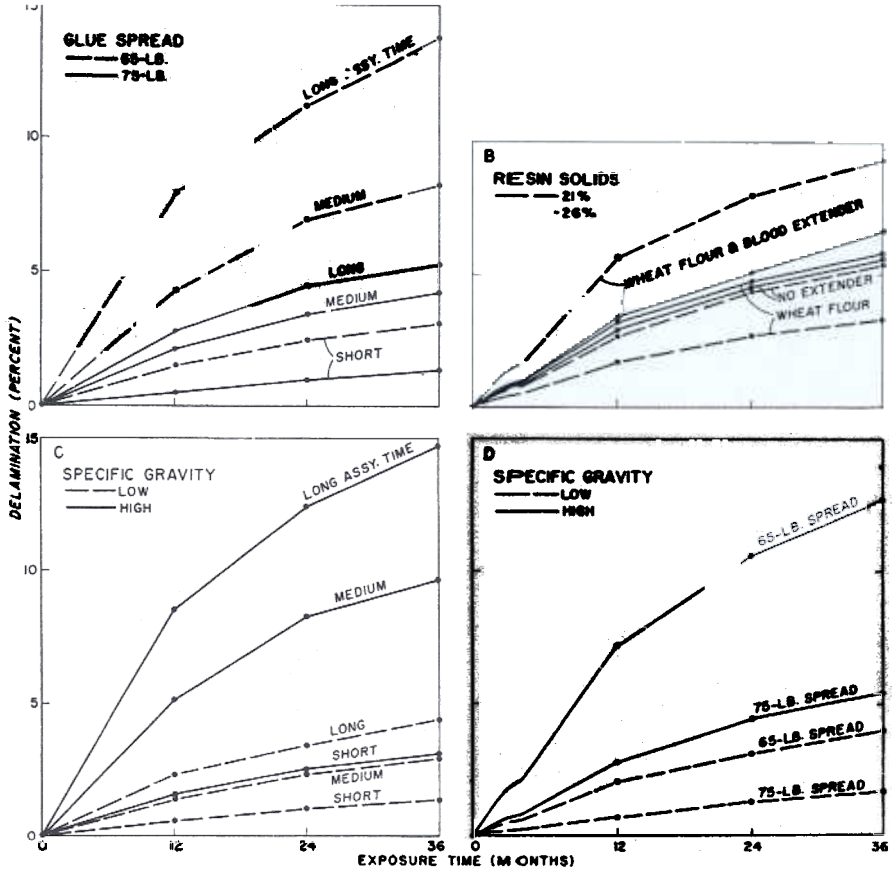

Figure 1. — Delamination of small specimens of southern pine plywood in exterior exposure (Pineville, La.) as affected by duration of exposure, wood specific gravity, gluespread, assembly time, extenders, and percentage of resin solids in the glue.

Results from Regression Analysis

Measurable characteristics of assembled plywood were related to percent of delamination observed after 3 years. Simple correlations (Table 1) were poor but might have been better if more specimens in each

Table 1. — RELATIONSHIP BETWEEN MEASURABLE CHARACTERISTICS OF ASSEMBLED PLYWOOD AND PERCENT DELAMINATION OBSERVED AFTER 3 YEARS.

Property Correlated with 36-month Delamination	Number of Specimens Evaluated per 12-inch-square Panel	
Percent of delamination after 36 months of exterior exposure (two gluelines per specimen)	2	-----
Percent of wood failure	16	—0.43
Specific gravity of plywood (based on volume of veneer at 11-percent moisture content and ovendry weight — no adhesive)	2	+ .29
Modulus of elasticity of dry plywood (loaded parallel to grain of face and back plys)	2	+ .15
Compression strength of dry plywood (loaded parallel to grain of face and back plys)	2	+ .11
Wet rolling shear strength of plywood	16	— .09
Check depth in core veneer ÷ checks per inch	1	+ .08
Dry rolling shear strength of plywood	1	+ .04
Rings per inch in core veneer	1	— .03

Coefficient	Independent Variable	Average Value	Approximate Range
			.....
		76.0	0-100
		6,146.7	
		227.4	0-400
— 0.0001251		55,185.0	
—153.5			
		0.539	0.3-0.8
+175.8		0.296	.....
— 0.0005813			
		7,930.2	4,000-12,000
+ 1.454			
		2.233	1.0-4.0
—145.1			
		0.00661	
— 0.09730		10.6	3-14
+ 0.002528			
		17,022.0	

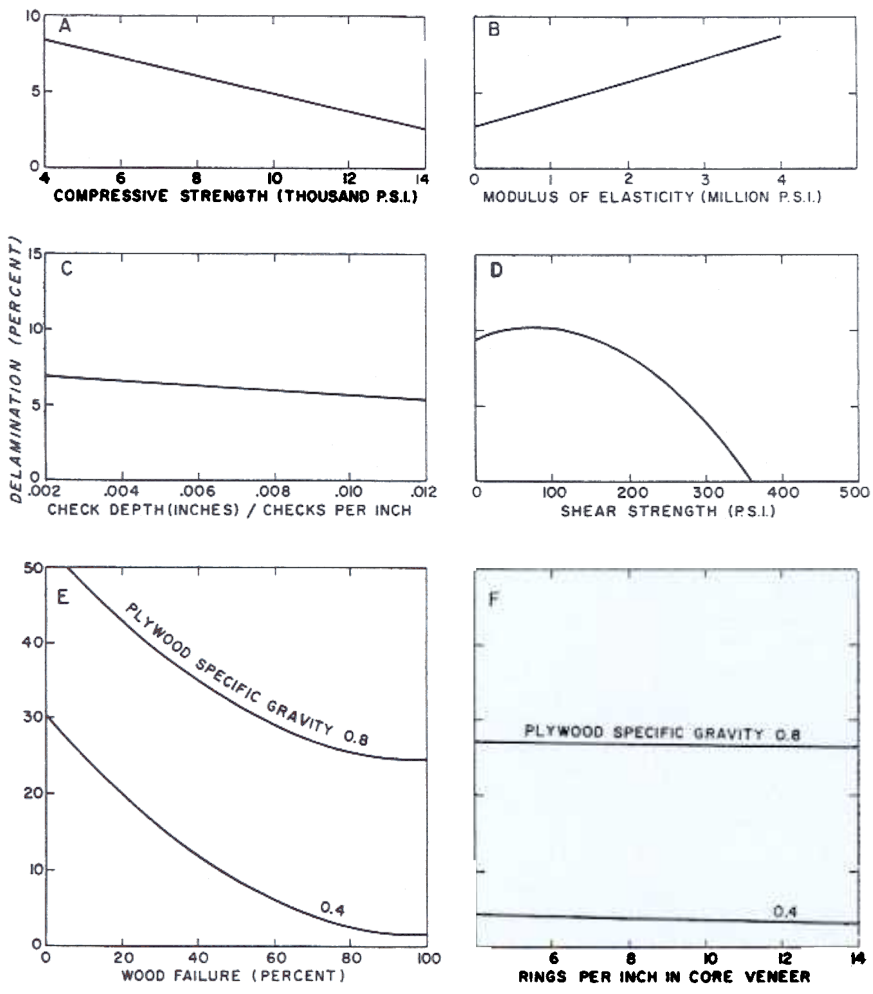

Figure 2. — Delamination after 36 months as related to wood properties and to percent of wood failure and wet rolling shear strength in standard APA vacuum pressure-soak test.

panel had been available for analysis of each property.

An effort was made to predict percent of delamination solely from wood properties and results of the standard vacuum-pressure-soak shear test; glue variables of resin level, extension, spread, and assembly time were not considered. A multiple regression expression selected through use of the Rex program (1) provides considerable guidance to choice of optimum conditions for resistance to delamination.

According to the equation, percent of delamination after 36 months can be predicted by summing the products of the coefficients and independent variables listed in Table 2. The listing shows the average value of each variable and the range within which the equation is applicable (average percent of delamination was 6.08). The range of values for the variable check depth ÷ checks per inch is not available, but check depth averaged 0.07 inch (approximate range from 0.05 to 0.09), and check frequency averaged 11.6 per inch (approximate range from 9.5 to 13.5).

The equation accounted for 35 percent of the variation in percentage of delamination; standard error of the estimate was 8-percent delamination.

In Figure 2, effects found significant from the regression expression have been illustrated. The curves were constructed by holding all independent variables at their mean values except the ones of interest, which were allowed to vary within their observed ranges.

It can be seen that the plywood tended to delaminate most rapidly if it was of high specific gravity and had a high modulus of elasticity. Specimens resisted delamination if the plywood had a high percentage of wood failure in the usual quality-control test, and high strength in wet rolling shear. The equation also indicates, albeit weakly, that plywood containing slow-grown core veneer resisted delamination.

When considered in combination with all the other factors in the regression equation, a high compression strength parallel to the grain and a high ratio of check depth to check frequency also enhanced resistance to delamination.

Researchers interested in accelerated tests of adhesives for exterior southern pine plywood will observe that general conclusions concerning the effects of the primary variables on delamination after 36 months of exposure are the same as those reported (6) after 6 and 12 months of observation. While rate of delamination during the first 12 months was nearly linear with time, it decreased with each succeeding period of exposure.

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