

U. S. FOREST SERVICE RESEARCH NOTE

FPL-051

May 1964

IMPROVING THE GLUING CHARACTERISTICS OF PLYWOOD SURFACES BY SANDING¹

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The condition of wood surfaces at the time of gluing has an important influence on the strength of glue joints. Even with the best of woodworking glues and careful gluing technique, strong glue bonds will not result unless the wood surfaces have been well prepared and are free from contaminating substances and certain physical conditions that may interfere with adhesion of glues.

The preparation of satisfactory gluing surfaces on lumber products is not difficult because such materials can usually be planed or otherwise machined. Fresh wood surfaces that are smooth, uniform, and free from crushed fibers are generally most satisfactory for gluing purposes. Glue joints that develop the full strength of the wood can usually be made on well-planed wood surfaces with acceptable woodworking glues and gluing techniques. Sanding, tooth planing, or other methods of roughening well-planed wood surfaces are unnecessary and inadvisable, and may even decrease joint strength.

In contrast to well-planed normal wood surfaces, plywood sometimes presents more difficult gluing problems although, normally, it can be glued satisfactorily. Surface conditions that may develop during veneer and plywood manufacture and may be accentuated by the techniques used in aircraft assembly gluing are believed responsible for these occasional difficulties.

Some of the surface changes that occur in plywood manufacture and may interfere with the adhesion of glue in secondary gluing are readily recognized. Serious glazing of the surfaces during hot-pressing is usually recognized as undesirable. Heavy bleed-through of glues and similar deposits on the faces of plywood may also interfere to some extent with glue adhesion. Wax deposits from cauls constitute another type of surface condition that is known to affect the quality of glue joints seriously. Excessive squeeze-out of glue during edge-gluing, of course, also interferes with formation of good joints. Such surface conditions can be largely avoided by changes in manufacturing practices.

¹This is a reprint of Forest Products Laboratory Report 1351 of the same title, originally issued in 1943.

In addition to these recognizable surface conditions that interfere with adhesion of glues, however, there appear to be others that are not so easily detected and of which the cause is not yet known. A number of examples of plywood of this type have been received from aircraft fabricators who had experienced difficulty in bonding them strongly together with cold-setting glues in assembly gluing operations. Numerous gluing tests have been made on this material at the Forest Products Laboratory and, in many cases, the experience of aircraft fabricators with the plywood in question has been verified. Plywood so tested had been produced by several manufacturers with veneer from different sources. This difficulty has been encountered in yellow birch, sweetgum, Douglas-fir, and yellow-poplar, and most often, though not exclusively, in the heartwoods of these species. The plywood was generally of good quality, and its appearance gave no indication that trouble would be experienced in making satisfactory secondary glue joints to the surfaces. The nature of these unfavorable surface conditions, which probably develop during plywood manufacture, has not been satisfactorily determined, but it is important that corrective measures be available when the problem is encountered.

Light sanding of the plywood surfaces to be glued is the most effective and practical means thus far found for correcting such unfavorable surface conditions. Various other methods, such as moistening with water, the use of wetting agents, and treatment with chemicals, have been tried but none of them has been found as reliable or as generally effective as light sanding.

In investigating the efficacy of light sanding for improving the gluing characteristics of plywood with which difficulty had been experienced, a number of studies were made. The studies included gluing tests on sanded and unsanded plywood; tests with three different grades of garnet paper; and measurements on the thickness reductions produced by light, medium, and heavy hand sanding.

Some of the plywood used in these studies, although it had given difficulty in factory assembly gluing, showed no evidence of surface conditions that would suggest difficulty in secondary gluing, whereas other samples showed glaze, bleed-through, or wax on the faces.

In one series of experiments, Sitka spruce cap strips were glued with cold-setting, urea-resin glues by means of nail gluing to strips of plywood that had given trouble. One-half of the plywood strips were lightly sanded with 3-0 garnet paper before gluing and the rest were left in their original condition. Shear specimens were cut from these samples and the quality of the glue joints was determined by shear tests on the type of assembly and shear specimen shown in figure 1.

The results of these tests are summarized in table 1. They show that, in every instance, light sanding effected a material improvement in the quality of the glue joints. The improvement was greater in some cases than in others, but the results indicate that this type of surface treatment largely removed whatever interfering substances or surface conditions were present.

Light sanding is obviously hard to define. The danger of over-sanding and consequent reduction in strength has been the principal objection to sanding aircraft plywood. In order to determine the reduction in thickness of face plies produced by various amounts of sanding, a test was made on four woods. This plywood was of uniform thickness and the face plies were 0.020 inch thick. The sanding was all done across the grain of the face plies with 3-0 garnet paper attached to a sanding block. Three types of sanding, designated as light, medium, and heavy, were used. Light sanding consisted of 10 single strokes across the face ply, medium sanding of 20 strokes, and heavy sanding of 40 strokes. The reductions in face-ply thickness are shown in table 2.

It is evident from these results that the same type of sanding reduced the thickness of face plies of wood varying in density to different degrees. Light sanding did not, however, reduce face-ply thickness by more than 0.002 inch, or 10 percent, for any of the species tested. Medium and heavy sanding, on the other hand, produced greater reductions in thickness, which were possibly sufficient to cause significant strength decreases.

Another test was made with different grades of garnet paper, and the reductions in thickness caused by each were measured. The face plies were lightly sanded across the grain by 10 strokes. The reductions in thickness of face plies produced by three types of garnet paper are shown in table 3. It is evident from these results that the danger of over-sanding and seriously reducing face-ply thickness decreases with the finer grades of paper. The thickness reductions with 4-0 garnet paper were hard to detect for birch and averaged about 5 percent for the softer species.

There is some question whether sanding should be done with or across the grain of the face plies. In sanding the areas to be glued in aircraft plywood, it is usually difficult or impossible to sand with the grain. The tests summarized in table 4 were made to determine whether the same type of sanding would reduce face-ply thickness to a greater extent when done across the grain, at an angle of 45° to the grain, or when sanded with the grain direction. With one possible exception, there was no significant difference in reduction in thickness of face plies sanded in the three different directions.

In an attempt to determine the amount of sanding required to produce satisfactory gluing surfaces on plywood that could not be well glued without some face treatment, the experiment summarized in table 5 was made. The faces of the plywood used were first given a thin coating of floor wax to produce an extremely unfavorable gluing condition. Such surfaces would rarely, if ever, be met on aircraft plywood but they afforded a good test medium. Sanding was done with 3-0 garnet paper and reductions in face-ply thickness by the three types of sanding practices, light, medium, and heavy, were in the range of those given in table 2. The results in table 5 show that light sanding produced great improvement in every case and was generally about as effective and produced about as

favorable gluing surfaces as did medium or heavy sanding. These results are in line with those obtained in other tests on plywood having surfaces that were not readily glued. The results for yellow-poplar in table 5 indicate some improvement for medium sanding as compared with light sanding. This may have resulted from deeper penetration of the wax in the yellow-poplar and its better removal by the additional sanding.

Table 6 compares the effects produced by different amounts of sanding with several grades of garnet paper on the gluing characteristics of plywood that had been found difficult to glue without some surface treatment. The sweetgum heartwood used in these tests had what appeared to be normal surfaces and the mahogany had heavy bleed-through of glue or other materials over its entire surface. All sanding was done across the grain. The plywood was nail-glued to spruce cap strips with cold-setting, urea-resin glue. The results of these tests corroborate those given above and indicate that light sanding, with 4-0 or 3-0 garnet paper, is as effective and produces as great an improvement in gluing characteristics of plywood that is normally hard to glue as does heavy sanding with the same grade of paper or with coarser papers.

In all the sanding studies reported here, the sander dust was removed with a clean cloth or brush. No special effort was made to remove sander dust from the pores and no interference with adhesion of glues was observed.

Summary

Light hand-sanding of plywood surfaces has been found very beneficial in correcting surface conditions that interfere with the adhesion of cold-setting glues in aircraft-assembly operations. Light sanding should not be considered a cure-all but a useful aid in correcting the gluing characteristics of plywood otherwise difficult to glue. The danger of over-sanding can be reduced by specifying the use of sandpaper no coarser than 3-0 garnet on species of high density and no coarser than 4-0 garnet on species of low density. Reductions in face-ply thickness should never exceed 10 percent and whenever possible should be limited to 0.001 inch. Frequent thickness measurements are advisable when hand sanding is practiced. In order to be of the maximum value, light sanding should follow masking and sealing operations.

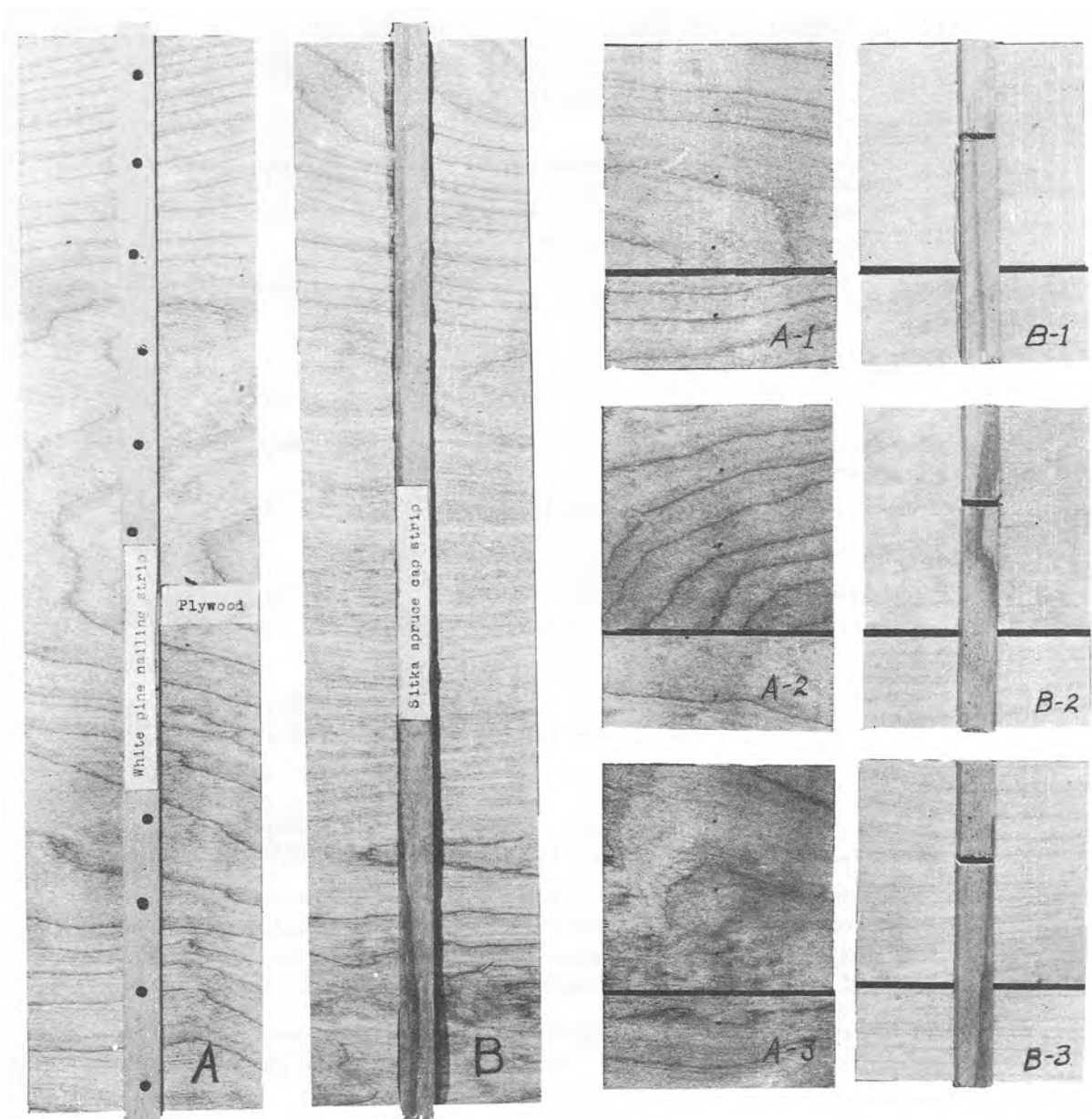


Figure 1.--Rail-gluing assemblies. A, top view of assembly with nailing strip in place; B, bottom view of assembly showing spruce cap strip; A-1, A-2, and A-3, top view of shear specimens cut from assemblies such as A and B; B-1, B-2, and B-3, bottom view of similar shear specimens.

Table 1.--Results of shear tests on sanded and unsanded plywood nail-glued to Sitka spruce cap strips with a cold-setting, urea resin glue.¹

Plywood species	Appearance of surfaces	Surface treatment	Breaking strength	Wood failure
			<u>Pounds per square inch</u>	<u>Percent</u>
Yellow birch	Normal	None	364	28
Do.....	.....do.....	Light sanding	520	99
Sweetgum (heartwood)	.....do.....	None	340	45
Do.....	.....do.....	Light sanding	628	98
Sweetgum (heartwood)	.....do.....	None	420	63
Do.....	.....do.....	Light sanding	500	100
Mahogany	Heavy bleed-through	None	389	30
Do.....	.....do.....	Light sanding	519	99
Mahogany	Wax on the faces	None	186	0
Do.....	.....do.....	Light sanding	445	53

¹ Comparisons are between sanded and unsanded samples of the same lot and not between species or lots because the plywood panels were of different thicknesses and constructions.

² Each average is for 9 or more shear specimens cut from 3 or more nail-glued assemblies of the type shown in figure 1.

Table 2.--Reduction in face-ply thickness produced by sanding 0.020-inch faces of plywood with 3-0 garnet paper¹

Species	Reduction in face-ply thickness					
	Light sanding		Medium sanding		Heavy sanding	
	(10 strokes)		(20 strokes)		(40 strokes)	
	Inch	Percent	Inch	Percent	Inch	Percent
Yellow birch	0.0005	4	0.002	10	0.004	20
Sweetgum	.001	5	.002	10	.006	30
Yellow-poplar	.002	10	.004	20	.007	35
Douglas-fir	.002	10	.004	20	.005	25

¹Each value is an average of thickness measurements on 5 plywood strips of the type used in nail-gluing tests (fig. 1). Sanding was done by hand, across the grain.

Table 3.--Reduction in face-ply thickness produced by lightly sanding 0.020-inch faces of plywood with different grades of garnet paper¹

Species	Grade of garnet paper					
	4-0		3-0		2-0	
	Inch	Percent	Inch	Percent	Inch	Percent
Yellow birch	0.00	0	0.001	5	0.002	10
Sweetgum	.001	5	.002	10	.003	15
Yellow-poplar	.001	5	.002	10	.003	15
Douglas-fir	.001	5	.001	5	.004	20

¹Each value is an average of thickness measurements on 5 plywood strips of the type used in nail-gluing tests (fig. 1). Sanding was done by hand, across the grain.

Table 4.- Reduction in thickness of face plies of plywood with faces 0.020-inch thick by sanding with, at right angles to, and at 45° to the grain; all sanding done with 3-0 garnet paper and by light sanding -- 10 strokes across the face.¹

Species	Reduction in face thickness by sanding					
	With grain		90° to grain		45° to grain	
	Inch	Percent	Inch	Percent	Inch	Percent
Yellow birch	0.001	5	0.001	5	0.001	5
Sweetgum	.001	5	.002	10	.002	10
Yellow-poplar	.002	10	.002	10	.002	10
Douglas-fir	.001	5	.001	5	.001	5

¹Each set of values is an average of thickness measurements on 5 plywood strips of the type used in nail-gluing tests (fig. 1).

Table 5.--Effectiveness of light, medium, and heavy sanding in improving the quality of glue joints made on wax-coated plywood. Sanding done with 3-0 garnet paper.

Species	Sanding	Joint strengths and wood failures obtained with 2 types of glues ¹			
		Cold-setting urea- resin glue		Casein glue	
		Joint strength	Wood failure	Joint strength	Wood failure
		<u>Lb. per sq. in.</u>	<u>Percent</u>	<u>Lb. per sq. in.</u>	<u>Percent</u>
Yellow birch	None	0	0	0	0
Do.....	Light	606	67	600	48
Do.....	Medium	534	72	574	33
Do.....	Heavy	576	97	596	100
Sweetgum	None	0	0	0	0
Do.....	Light	516	83	526	93
Do.....	Medium	514	100	560	95
Do.....	Heavy	466	67	574	75
Yellow-poplar	None	116	0	66	0
Do.....	Light	454	38	396	50
Do.....	Medium	576	93	510	82
Do.....	Heavy	510	63	526	97
Douglas-fir	None	0	0	136	0
Do.....	Light	504	43	556	43
Do.....	Medium	504	77	430	92
Do.....	Heavy	520	100	586	83

¹Each value is the average for 9 or more shear specimens cut from 3 or more nail-gluing assemblies of the type shown in figure 1.

Table 6.--Effect of light and heavy sanding with different grades of garnet paper on the quality of glue joints made on sweetgum heartwood plywood and mahogany plywood with a cold-setting, urea-resin glue.

Kind of plywood	Grade of garnet paper	Type of sanding	Reduction in face-ply thickness	Joint strength	Wood failure
			Percent	Lb. per sq. in. ¹	Percent
Sweetgum heartwood plywood	4-0	Light	4.0	707	77
	4-0	Heavy	12.0	643	55
	3-0	Light	4.0	615	72
	3-0	Heavy	17.0	661	85
	2-0	Light	9.0	638	98
	2-0	Heavy	30.0	628	98
	Control	None	None	442	23
	Mahogany Plywood with heavy bleed-through	4-0	Light	5.0	666	98
3-0		do....	4.0	660	97
2-0		do....	8.0	710	100
Control		None	None	400	50

¹ Each average based on 12 shear specimens cut from 4 assemblies of the type shown in figure 1.