KNIFE- VERSUS ABRASIVE-PLANED WOOD: QUALITY OF ADHESIVE BONDS

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ABSTRACT

Glueline strength and durability were determined for abrasive- versus knife-planed wood surfaces. Laminated beam sections were made, 16 each of southern pine and Douglas-fir, using 4 surfacing treatments prior to laminating. The four treatments were knife planing, and abrasive planing with 36, 60, and 80 grit. Comparisons were made of resistance to glueline separation after accelerated aging, of bond shear strength, and of percentage wood failure within a species group.

Under microscopic examination, abrasive planing showed crushing and tearing of the wood surface, whereas knife planing showed a clean-cut surface. Gluelines with abrasive-planed surfaces were similar to the knife-planed in shear strength, were higher in percentage of wood failure, and lower in resistance to glueline separation upon accelerated aging.

Keywords: Bond quality, durability, gluelines, planing, surfacing.

INTRODUCTION

Abrasive planing of wood surfaces has been used extensively in certain parts of the wood industry for several years. Its advantages over knife planing are reported to include removal of less stock to obtain accurate surfacing. Also, less chipping and tearing of the grain occurs around knots and localized grain deviations.

However, little information is available on the effect of abrasive planing upon gluebond quality. Until more is known about this aspect of abrasive planing, certain industries are reluctant to consider it where high bond strength and durability are basic requirements.

Bond quality differences have already been noted between knife- and abrasive-planed laminated material in related studies. B. H. River of the U.S. Forest Products Laboratory (FPL) noted higher average wood failures in block shear with abrasive-planed as compared to similar knife-planed material. Also, Thomas Brassell of the American Institute of Timber Construction (AITC) reported more checking in and near the glueline of abrasive-planed laminated members after exposure to accelerated aging.

Neither River nor Brassell did sufficient research on the subject to warrant publication of definite conclusions. However, their work suggested the need for this study, which has been undertaken at FPL with support from the AITC.

This study compares the strength and durability of bondlines using abrasive- and knife-planed wood surfaces. Its primary objective has been to determine if a difference exists in shear strength, wood failure, and

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resistance to accelerated aging of knife-planed versus abrasive-planed laminations of Douglas-fir and southern pine lumber. A secondary objective has been to determine the effect of the grit size used in abrasive planing upon these bond properties.

MATERIALS AND METHODS

General

The study consisted of laminating six plies of ¾-inch lumber into beam sections of approximately 6 by 4½ by 48 inches from abrasive-planed material, some of Douglas-fir and some of southern pine. Then their shear strength, wood failure, and resistance to glueline separation were compared with similar beam sections from knife-planed material.

A total of 16 beams were laminated for each species, 4 with knife-planed surfaces and 4 each that had been surfaced with 36-, 60-, and 80-grit abrasives.

Selection and preparation of material

The Douglas-fir and southern pine were selected to be average or higher in density, straight-grained, free of strength-reducing defects, and as nearly as possible flat-grained.

The lumber, received from the AITC, was crosscut into 48-inch lengths in such a way as to remove defects that could have interfered with test results. The 48-inch lengths were then presized to a constant thickness of ⅞ inch using a freshly sharpened knife planer. Piece numbers were assigned to each lamina as they were crosscut from the original boards. A computer generated a list of lamina numbers and randomly assigned lamina to beams and positions within the beams. The beams were mechanically assigned to treatments (that is, beam 1 was knife planed, beam 2 surfaced with 36 grit, beam 3 with 60 grit, beam 4 with 80 grit, and so on).

Then the material was stored in conditions of 80 F and 65% relative humidity until equilibrium was reached.

Surfacing of lamina

Final surfacing was done just before gluing. Knife planing was done on a planer that had just been sharpened, with the feed rate set to give 20 knife marks per inch of stock. The material was inspected before planing so as to feed it into the machine with the grain, thereby reducing torn and chipped grain as much as possible. The pieces were fed through the planer twice, removing 1/16 inch per pass and reducing the ⅞-inch thickness to ¾ inch. The pieces thus machined were preassembled into beams and wrapped in plastic to retard moisture changes.

The material was abrasively planed as follows: About 1/16 of an inch was removed from all pieces in two passes using 36 grit. That which was to be finished with 36 grit was passed through the abrasive planer twice more to get down to the final thickness of ¾ inch. The material to be finished using 60-grit and 80-grit abrasives was passed through the machine four more times to get down to the final ¾-inch thickness. All of this was done in the same manner for both species.

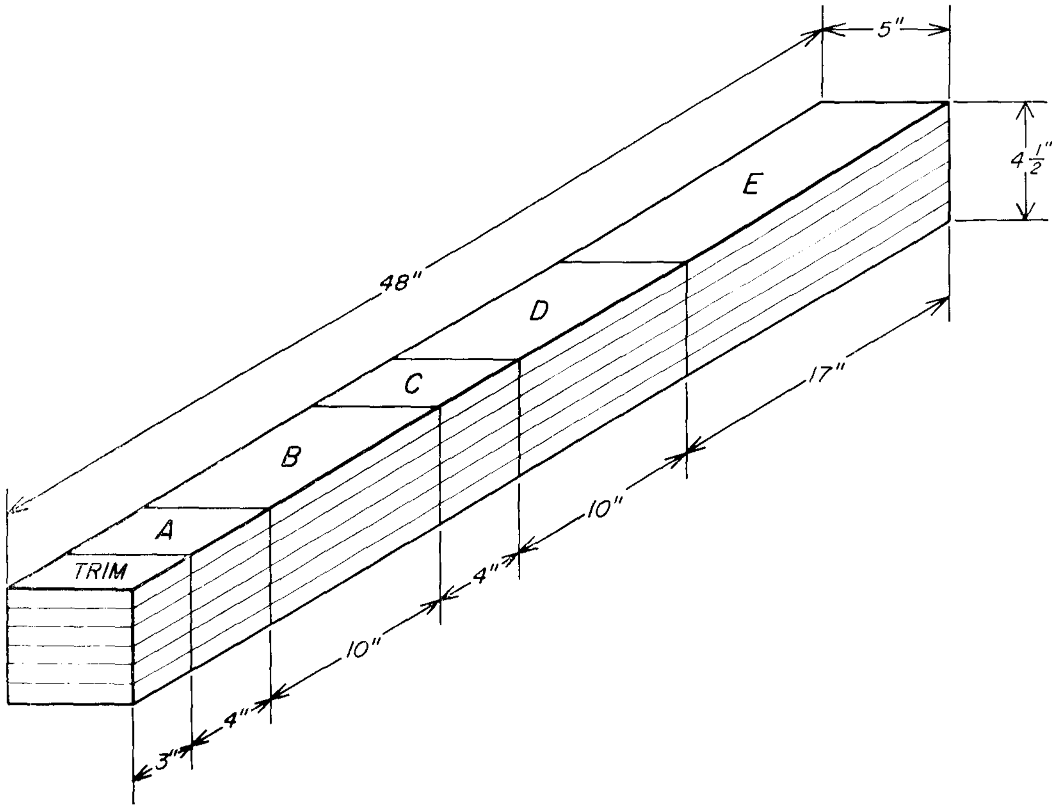
After machining, the material was separated into beam assemblies and wrapped in plastic to reduce moisture changes and possible surface contaminations. It should be added that the surfaces were lightly brushed as they came from the machine, but the brushing was sufficient to remove only the finer dust particles.

The abrasives used were all open coat aluminum oxide, and all belts were new at the beginning of the study.

Laminating test beams

Before laminating, the beams were laid up dry in the sequence dictated by the computer, and a final check was made of the material going into each beam.

The adhesive used in the study was a commercially available room-temperature-curing phenol-resorcinol. It was applied at the rate of 60 pounds per thousand square feet of glueline using a ribbon or extruder-



M 143 994

FIG. 1.—Laminated test beam, showing location of cuts to obtain test specimens: (A) and (C) are location of "stair step" shear blocks; (B) and (D) were each cut into three cross sections for accelerated aging; and (E) was reserved for further testing, if needed.
(M 143 994)

type spreader. The temperature in the gluing area was between 75 and 80 F during gluing. The assembly time was 30 min closed; there was essentially no open assembly time. A gluing pressure of 150 pounds per square inch (psi) was applied using Dosker or rocker head clamps and a torque wrench.

The beams were kept under pressure for about 20 h. They were then removed from the clamps and returned to conditions of 80 F and 65% relative humidity for a 7-day postcuring period.

Preparation and testing of specimens

Figure 1 indicates where cuts were made in the beams to obtain the required test specimens. Sections of the beam marked A and C were the location of the "stair step" shear blocks; two were taken from each section. The sections marked B and D were each cut into three cross sections and subjected to accelerated aging to determine glueline separation. The remaining section, marked E, was held in reserve in case further study was felt necessary.

The "stair step" shear blocks were tested

TABLE 1.—*Treatment means and tests of significance among means*

Criterion	Test of knife vs. abrasive planing[a]	Paired comparison[b]				Standard error of the mean
		DOUGLAS-FIR				
Shear (psi)	N.S.	36	80	60	K	
		1205	1269	1323	1355	28.28
Wood failure (%)	*	K	60	80	36	
		92.0	94.3	95.4	96.9	0.81
Glueline separation (in.)	*	36	80	60	K	
		45.08	36.53	26.81	13.03	1.76
		SOUTHERN PINE				
Shear (psi)	N.S.	80	36	60	K	
		1619	1605	1545	1541	23.76
Wood failure (%)	*	K	60	36	80	
		72.0	87.8	88.3	89.2	2.12
Glueline separation (in.)	*	36	80	60	K	
		48.82	30.15	11.88	9.44	1.54

[a] Significance at the 0.05 level of probability is shown by *. N.S. indicates nonsignificant at the 0.05 level.

[b] Pairwise comparisons were made at the 0.05 level using Scheffe's Test. Two means not underscored by the same line are significantly different.

dry in accordance with the procedure described in ASTM D 905. The load at failure and the estimated percent wood failure were recorded for each glueline.

The glueline separation test consisted of subjecting six pieces from each beam to a three-cycle accelerated aging exposure and measuring the separations that occurred on the end grain surface as a result of the exposure. Each piece was a full cross section of the beam with a length of 3 inches along the grain. The procedure was as follows:

Cycle 1.—Place specimens in autoclave. Admit water at temperature of 65 to 80 F until specimens are submerged. Draw vacuum of at least 25 inches Hg and hold for 5 min. Release vacuum and apply pressure of 75 ± 2 psi for 1 h. Repeat vacuum-pressure cycle a second time. Remove specimens and place in an oven at a temperature of 150 F ± 3.6 F and relative humidity of 15% or less, for a period of 21 to 22 hr. Maintain air speed across end grain of specimens at 500 ± 50 ft per min.

Cycle 2.—Return specimens to autoclave and admit steam at 212 F for 1½ h, after which specimens are submerged in water at 65 to 80 F and a pressure is applied of 75 ± 2 psi for a period of 40 min. Dry specimens in oven as in Cycle 1.

Cycle 3.—Repeat Cycle 1.

At the completion of the third cycle, the separations in and within 0.1 inch of the glueline were measured, totaled, and figured as a percentage of total end grain glueline length. (A more detailed description

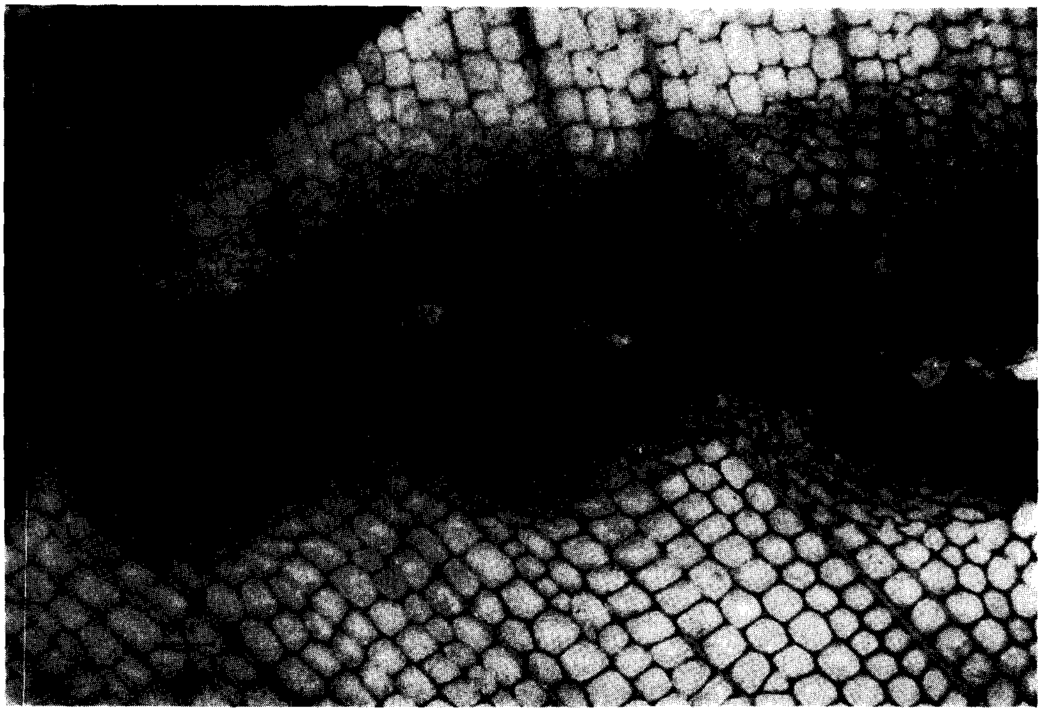


FIG. 2.—Photomicrograph of glueline in Douglas-fir abrasively planed with 36-grit open coat aluminum oxide (170×). Crushing and distortion of cells are evident near glueline. (M 144 038)

of the procedure can be found in sections 12 and 13 of ASTM D 2559.)

RESULTS

The data analysis consisted of one-way analysis-of-variance tests, keeping the Douglas-fir and southern pine data separate. The dependent variables measured for the four surface treatments were shear strength, percentage wood failure, and amount of glueline separation. In addition to the overall analysis, tests were made of the difference between knife planing and the average of all abrasive-planing treatments and between all possible pairs of treatments. The results of these tests, summarized in Table 1, indicate that, for percent wood failure and amount of glueline separation, knife-planing values were significantly lower for both species. The analysis of the shear strength values indicated no significant difference due to surface treatments.

Note that for the test criteria used in this study, abrasive planing with 60 grit always gave results closest to those of knife planing. Except for shear and percent wood failure in southern pine, the results from 36 grit were farthest from those of knife planing. In most cases, abrasive planing with 80 grit gave results in between those obtained with 36 and 60 grit.

Microscopic examination of the material indicated that the surface of the wood and the material immediately below the abrasive-planed surface were crushed and torn. The damage was primarily in the earlywood and was more apparent in material surfaced with 36-grit abrasives (Fig. 2). By comparison, the knife-planed material was clean-cut, with little evidence of crushing or tearing of the wood cells (Fig. 3).

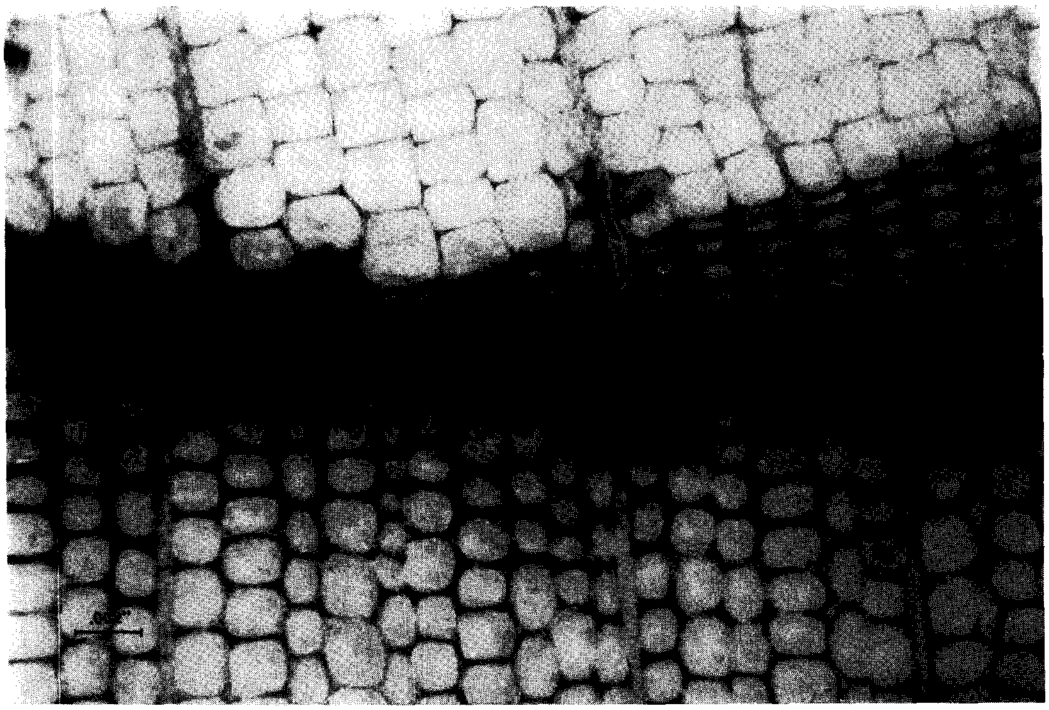


FIG. 3.—Photomicrograph of glueline in knife-planed and laminated Douglas-fir (290×). Cells near glueline are clean-cut, with little crushing or distortion.
(M 144 037)

DISCUSSION

A difference was definitely found in the response of laminated material which has been abrasive planed as compared to that which has been knife planed. The abrasive-planed material in this study had good dry shear strength, and average wood failure was generally higher than that found on the knife-planed material. Normally then, one would expect good performance from this material under exterior or accelerated aging exposures, but this was not the case.

Examination of the material after accelerated exposure indicated that separations occurring in and parallel to the glueline were much more numerous in abrasive-planed material and seemed to indicate damage to the wood surface. Inspection of samples of the material under a microscope showed this to be the case. The cells in the area of the glueline on knife-planed material were clean-cut, and very little crushing or distortion was evident. The material that had been abrasively planed, however, showed considerable damage to the wood cells for some distance below the surface. The damage was primarily to the earlywood, crushing and tearing the cells and compressing the dense latewood down into the underlying earlywood. In many respects it resembles what happens when a dull or improperly adjusted knife planer is used to surface wood. In this study the coarser the grit, the more extensive the damage appeared to be (Fig. 2).

The damage results from the high cutting forces and the direction of the cutting force components which are associated with a grinding process such as abrasive planing. Power and force to abrasively plane at stock removal rates required for surfacing stock for laminating are approximately six times greater than for knife planing at the same stock removal rate.

Further, abrasive planing is in some respects similar to knife cutting with a negative rake angle, and in other respects is similar to a hardness test where a three-dimensional tool (the grit) is embedded into the wood. A much higher force component normal to the workpiece surface is developed by abrasive planing than by knife planing. As a result of embedding the grit into the surface and applying a high normal force component, tearing of fibers at the surface and crushing below the surface are extensive.

When this material is subjected to soaking, the cells try to recover their original shape. In doing so, they will swell more than the undamaged cells, and high internal stresses will be developed. Because there are undoubtedly planes of weakness in the cells due to crushing, they pull themselves apart rapidly, and after several soak and dry cycles obvious checks appear in the damaged area.

If one looks only at the results of the shear tests, it would be very easy to be misled into believing that one had a good, durable bond. Obviously, this is not the case. The damage that occurred during surfacing with the abrasive planer is not detected by the standard block shear test. Possibly a test that placed the stresses perpendicular to the glueline rather than parallel to the glueline would make the damage due to surfacing more obvious, even without cyclic exposure.

Sixty-grit surfaced material performed better during the study than either the 36- or 80-grit surfaced material. Just why this happened is open to speculation. It may have been that the combination of gluing variables selected were more nearly optimum for 60-grit surfaced material than for the other two, or that an interaction of several variables exists. In any case, it is impossible to state at this time why it happened.

CONCLUSIONS

The following conclusions can be drawn:

1. Abrasive planing has little effect on the dry shear strength of laminated Douglas-fir or southern pine.
2. The estimates of wood failure in the block shear specimens tended to be higher for the abrasive-planed and laminated Douglas-fir and southern pine than for the similar knife-planed and laminated material. The higher wood failures are undoubtedly due to the damage to the earlywood as a result of abrasive planing.
3. Separations in and around the glueline after accelerated aging are more prevalent in abrasive-planed, laminated Douglas-fir and southern pine than in similar knife-planed material.
4. In this study the increased glueline separation in abrasive-planed material appears to have been the result of damage to the surface fibers or to fibers below the surface during machining. Damage to the surface and subsurface fibers was not evident to nearly the same degree in knife-planed Douglas-fir or southern pine.
5. Because of the damage to the surface and subsurface fibers and the apparent tendency to check excessively in these areas during cyclic wetting and drying, the exterior durability of abrasive-planed and laminated Douglas-fir and southern pine is questionable.