RESPONSE OF EASTERN SPRUCE FINGER JOINTS TO VARIATION IN ASSEMBLY TIME AND MOISTURE CONTENT[1]

Craig E. Shuler

Associate Professor

Department of Forest and Wood Sciences, Colorado State University, Ft. Collins, CO 80523

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ABSTRACT

Eastern spruce finger joints that were manufactured at three wood moisture contents (8, 12, 14%) and three open assembly times (10, 20, 30 min) were tested in tension and static bending to evaluate the quality of the adhesive bonds. The adhesive used was room-temperature setting phenol-resorcinol. No appreciable differences were noted in bond performance at any of the assembly conditions, although the low MC group tended to show less wood failure in the tension tests. Maximum tensile stress and modulus of rupture values ranged from 62–88% of the respective handbook values for solid red spruce.

Keywords: Eastern spruce, finger joints, phenol-resorcinol, glue bond quality.

A recent study was conducted at the Forest Products Laboratory of the School of Forest Resources, University of Maine, concerning glue-laminated timbers with finger-jointed laminates of eastern spruce and eastern hemlock (Shuler et al. 1979). Obvious glueline failures (minimal wood failure) of the spruce finger joints were noted during testing. This follow-up study was consequently undertaken to observe two factors, moisture content and open assembly time, that may have caused those poor gluelines. As there is very little published information regarding the bonding of eastern spruce, this study also serves to explore whether or not there are some basic difficulties in forming satisfactory finger joints with this material. In this case, the levels of each factor were chosen so as to include the conditions originally experienced when manufacturing the beams.

PROCEDURE

Unseasoned eastern spruce 2 × 4's were obtained from a local stud mill and dried in the laboratory dry kiln at the School of Forest Resources. One-third of the charge was removed when kiln samples indicated a moisture content (MC) of 16%. Another third was removed at an estimated MC of 12%, and the final third was dried to 8% MC. After each portion was removed from the kiln, it was wrapped in plastic and allowed to cool; and then each board was measured with an electrical resistance moisture meter. The average MC's of the high (H), medium (M), and low (L) groups were 14, 12, and 8%, respectively. The H group was left at 14% since this corresponded to the average MC of the spruce material in the beam study mentioned above.

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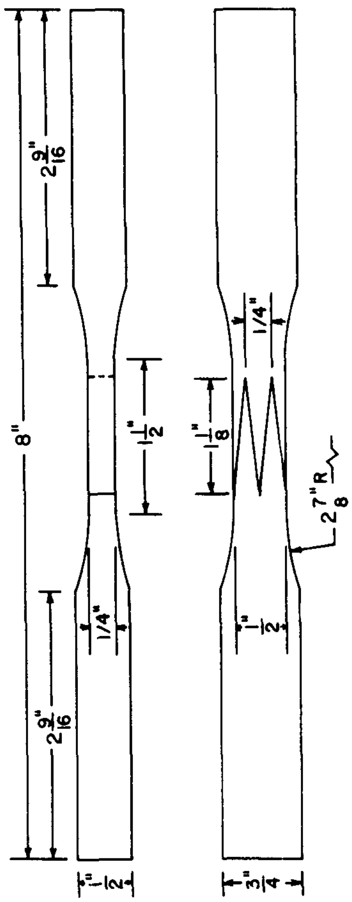

FIG. 1. Dimensions of finger joint tensile specimens.

The dried material was planed, and twenty-four 2-foot sections were cut for each MC group. These sections were relatively defect-free and had MC's that were within a half percent of the average MC for the group. This material was then wrapped in plastic, by MC group, until the finger jointing took place.

Finger joints were cut with a standard cutter head at a commercial wood-laminating plant. The joints were spread with a production mix phenol-resorcinol adhesive catalyzed to cure at room temperature (the same adhesive as used in the earlier beam study). Open assembly times of 10, 20, and 30 min were used. Four joints of each MC-assembly time combination were made. Thus, twelve joints were made in each MC group.

Each joint was then cut into three tensile test specimens and a bending specimen. The tensile specimens were originally intended to be of rectangular shape similar to the standard specimen specified for finger joint evaluation by the American Institute of Timber Construction (Test 106). But initial testing resulted in failure outside the joint area by crushing the specimen in the test grips. Since the intent of this study was to observe glue bond behavior rather than establish

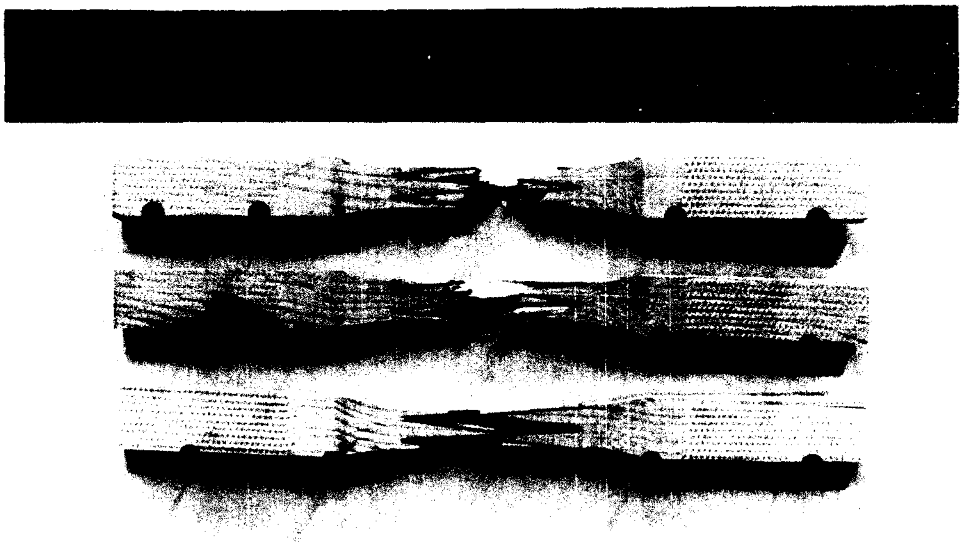

FIG. 2. Typical failures of eastern spruce finger joints tested in tension.

finger joint strength, a nonstandard, necked-down specimen was considered suitable for use. This tensile specimen is depicted in Fig. 1. The bending specimens were 1 inch wide, $1\frac{3}{8}$ inches deep, and 28 inches long. All specimens were stored in a conditioning room (68 F and 65% RH) for approximately one month before testing.

Tensile tests were conducted at a rate of loading of 0.1 inch/min crosshead speed. Maximum tensile stress (MTS) was calculated from the failure load, and percent wood failure was estimated by examining the failed specimens.

Bending specimens were subjected to a two-point load to produce a constant moment through the finger joint region. Total span was 26 inches, and the load points were $10\frac{7}{16}$ inches from each reaction point. Rate of loading was 0.1 inch/min of crosshead travel. From the load-deformation data obtained, modulus of rupture (MOR) and modulus of elasticity (MOE) were calculated.

RESULTS AND DISCUSSION

Table 1 shows the average values of MTS, percent wood failure (in tension), and static bending MOR and MOE. The primary intent of the study was to observe the quality of the adhesive bonding, so the actual stress values are considered of secondary importance. Consequently, the data were not corrected for testing moisture content or specific gravity differences. As a point of interest, however, an analysis of variance was run on the uncorrected data for each property. Moisture content was indicated as being a significant factor in all cases except MOE. Subsequent "t" tests showed that the L group performed less

TABLE 1. *Average values for maximum tensile stress, wood failure in tension, MOR and MOE of eastern spruce finger joints.*

Moisture content and assembly time[a]	Test MC[b] (%)	SG[b]	Tension[b] MTS (psi)	Tension[b] Wood failure (%)	Static bending[c] MOR (psi)	Static bending[c] MOE (10^6 psi)
L—10	11.2	0.43	7,510	90	7,009	1.748
L—20	12.4	0.40	6,836	92	6,548	1.621
L—30	12.0	0.42	6,921	94	6,433	1.500
M—10	12.6	0.44	7,720	98	7,481	1.675
M—20	12.5	0.44	8,734	97	8,061	1.736
M—30	12.0	0.44	6,974	94	7,803	1.782
H—10	13.5	0.46	8,995	95	7,754	1.736
H—20	13.6	0.45	8,693	96	8,133	1.602
H—30	14.3	0.46	7,887	98	7,846	1.606

[a] L, M, H, designate 8, 12, 14% MC respectively; 10, 20, 30 refer to minutes of open assembly time.
[b] Each value shown is the average of 12 samples.
[c] Each value shown is the average of 4 samples.

favorably than the M or H group. It is possible that this difference might disappear, however, if moisture content and specific gravity were considered. In no case did either assembly time or the MC-assembly time interaction show significance.

The important information to be drawn from these data is that the finger joints all performed well. Even though there are some differences, it appears that satisfactory bonding did occur at the conditions included in this study. This is supported by the following:

1. Although the percent wood failure figures are somewhat subjective and of little value numerically, they do indicate that extensive glueline failures were absent. The joints typically contained considerable wood tension failure rather than a shear-type failure along the glue line (Fig. 2).
2. There was no indication of slippage in the joints since the MOE results exceeded the Wood Handbook (U.S. Forest Products Laboratory 1974) value for solid eastern spruce (red spruce, 1.52×10^6 psi) by approximately 10%. [NOTE: Eastern spruce is the group name for black spruce (*Picea mariana*), red spruce (*Picea rubens*), and white spruce (*Picea glauca*); and the wood of these three species is indistinguishable once the bark has been removed. Red spruce values for comparison were arbitrarily selected on the basis of the abundance of this species in the area where the research material was obtained.]
3. In general, finger joints are reported to provide 45–90% of the strength of solid wood (Selbo 1975; Sunley and Dawe 1963). The mean MOR values shown in Table 1 range from 62–80% of the Wood Handbook values (10,200 psi) for red spruce (U.S. Forest Products Laboratory 1974). The mean MTS values range from 67–88% of this same value.

An interesting observation made while examining the failed tension samples was that extensive areas of exposed latewood were present in the fifteen cases where wood failure was estimated to be less than 90%. This may indicate a failure of the adhesive to wet the latewood, reducing the quality of the bond. If this is a critical factor, it would have a greater effect in these small necked-down samples than in a full-sized joint. This is because the slope of the fingers and the relatively narrow latewood zone of eastern spruce would tend to produce only a small percentage of glueline area of just latewood.

For the bending tests, the fingers were oriented in the same direction as they were cut, i.e. horizontally. Also in this study the specimens were not surfaced; consequently, failures were initiated most commonly by release of the short outer finger on the tension face. The decision to not surface plane and to orient the fingers horizontally was made in order to provide the least favorable testing conditions and because this duplicated the conditions in the original beam study.

It is impossible to compare these results directly with the values obtained in the original beam study since the stress distributions are quite different in each case. In fact it should be emphasized that this follow-up study was intended only to evaluate bonding characteristics rather than establish stress capability. Small bending specimens are expected to exhibit higher strength values than larger members. But it should be noted that the average stress values obtained in this study are appreciably greater (30–100%) than the average values obtained with the large, laminated beams (Shuler et al. 1979). And the fact that none of the finger joints showed extensive glueline failure would indicate that neither MC nor assembly time was responsible for the poor performance of the finger joints observed in the laminated beams.

When the failed sections of the laminated beams were reinspected, numerous longitudinal cracks originating at the inner tips of the female portion of the joints were noted. One possible explanation for this is excessive clamping pressure which may have 1) produced a starved glue joint by forcing the adhesive away from the glueline and 2) mechanically weakened the joint. This underscores the problem of manufacturing wood products under conditions developed for other species and the need to study optimum finger joint parameters (i.e., finger length, pitch, clamping pressure, etc.) for eastern spruce.

CONCLUSIONS

1. At all conditions used in this study, which are in the range of typical bonding conditions, the quality of the finger joints was considered satisfactory as determined by appearance, mode of failure, amount of wood failure, and comparison with solid wood static bending stress values.

2. Statistical analysis of the uncorrected data indicated: a) the low moisture content (8%) samples were shown to have less wood failure, lower MTS, and lower MOR than the other two MC groups (however, this group still exhibited MOR values which averaged 65% of published solid wood values); and b) neither assembly time nor the interaction between assembly time and MC contributed significantly to the differences observed.

3. The factors examined in this study do not explain the poor performance of eastern spruce finger joints observed in a previous study, and additional investigations should be made into the physical parameters of spruce finger jointing (e.g., finger geometry and clamping pressure).

4. Although this factor was not evaluated, it was observed that the amount of

latewood exposed on the glueline may influence the quality of eastern spruce glue bonds.

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