STRENGTH TESTS OF SPLICED STUDS

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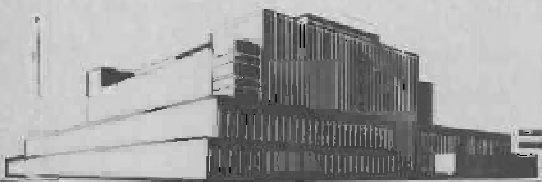

FOREST PRODUCTS LABORATORY
MADISON 5, WISCONSIN

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE

In Cooperation with the University of Wisconsin

STRENGTH TESTS OF SPLICED STUDS[1]

By

E. C. O. ERICKSON, Engineer

Forest Products Laboratory,[2] Forest Service
U. S. Department of Agriculture

Among developments proposed for the reduction of manufacturing waste, particularly short lengths of lumber, is the spliced stud. Spliced studs are made by joining short lengths of nominal 2 by 4's end to end by means of water-resistant glues in relatively short "fingered" joints. End-splicing not only affords an effective method of utilizing short pieces but provides a means of salvaging a relatively large quantity of high-quality material from stock containing large knots and other defects that seriously impair the strength and lower the grade. Obviously, the removal of such major defects will result in the production of relatively clear material. In spliced studs, the splices will be the governing factor in determining the grade.

Inasmuch as a certain degree of strength is required of studs in small house construction, the question arises as to what strength is developed in spliced studs and what the efficiency of the splice should be. Also raised is the question of the permanence of the splice and its ability to withstand adverse moisture conditions.

This report presents the results of two series of tests conducted to obtain specific information on the strength and efficiency of spliced studs. In one series, casein-glued splices were tested soon after manufacture. In the other, resin-glued splices were tested following natural weathering and regulated wetting-drying cycles, simulating the exposure to which studs may be subjected during storage and during erection of a structure.

The tests were made in 1940 and 1941, and results were first published in September 1941. New methods of making end joints have since been developed, and much progress has been made in glues and gluing techniques, particularly with respect to glue-line durability. The results presented in this report, however, are an appraisal of studs spliced and evaluated under the specific conditions described.

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[1]Original report dated September 1941.

[2]Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

Type of Splice Tested

Obviously there is a wide choice of varieties and types of spliced joints. The particular type of splice or joint tested consisted of one short and three long, tapered fingers in each piece as seen on the edge of the stud (fig. 1). The serrates or notched fingers are made on nominal 2- by 4-inch stock and the joint is glued before dressing the stud to size. The tapered fingers are so designed that lateral pressure results during assembly, when the adjoining parts are forced together with end pressure. No face pressure or clamping is used while the glue is setting.

Test Material

Material for the first series of tests consisted of 30 Douglas-fir studs, 8 feet long, each of which had been made by cutting a clear 2 by 4 in two and rejoining the parts in their original relative position in a fingered joint by means of casein glue.

Material for the second series consisted of 60 Douglas-fir studs, 8 feet long, each with from one to three cold-press, urea-resin-glued joints. This group also differed from the first group in that short lengths of unrelated pieces had been joined without regard to their origin or to any differences in density, rate of growth, or other characteristics.

Conditioning of Studs Before Testing

In order to investigate the behavior of the joints when exposed for limited periods to adverse moisture conditions, the 60 resin-glued studs were divided into three similar groups of 20 studs each (similar with respect to number of joints in each stud) and conditioned as follows:

Group No. 1 consisted of casein-glued studs kiln dried at the Laboratory to an average moisture content of 12 percent; Group No. 2 consisted of resin-glued studs subjected to three cycles of alternate soaking and drying. The first cycle consisted of soaking in water at room temperature for 1 week, followed by drying for 5 weeks in 30 percent relative humidity at a temperature of 80° F. The second and third cycles were the same as the first except that the drying period was shortened to 3 weeks; Group No. 3 consisted of resin-glued studs exposed to the weather for 14 weeks from July 27 to November 4, 1940; Group No. 4 consisted of resin-glued studs subjected to two cycles of alternate high and low humidities. The first cycle consisted of exposure to 97 percent relative humidity for 1 month, followed by exposure to 30 percent relative humidity for 1 month, both at a temperature of 80° F. The second cycle was the same as the first except that exposure to 30 percent relative humidity was shortened to 2 weeks. The studs were then stored in a room maintained at 65 percent relative humidity and 80° F., and conditioned to approximately 12 percent moisture content before testing. No exposures in these tests included temperatures high enough to demonstrate the now well-recognized limitations of urea-resin glues in resistance to heat.

The group exposed to the elements showed the usual weathered appearance at the end of the period, and those exposed to alternate wet and dry conditions showed characteristic checking patterns. No marked change was observed in the appearance of the glue joints. Checking was most severe on the upper edges of the pieces of rapid growth in the group exposed to the sun. Here, some checking followed along the glue lines of the joint fingers, but as much or more occurred at the root of the fingers (fig. 2).

Scope and Method of Test

A total of 198 strength tests were made. The tests were static bending (both edgewise and flatwise) and compression parallel to grain. For the most part, tests were made on each stud with the joint at the center of the span or at the center of the length of a compression specimen, followed by a test of the same type on an adjacent unjointed portion selected as a control. Control tests were made on that portion of the spliced stud which showed the greatest amount of wood failure at the joint. The various tests are summarized in table 1.

Results of tests of the various joints and controls are given in tables 2 and 3.

Test Procedure

Detailed procedure of both flatwise and edgewise bending tests conformed closely to standards of the American Society for Testing Materials. A typical edgewise bending test made over a span of 45 inches with center load is shown in figure 3.

In the edgewise bending tests of the studs in Group 3, the uppermost edge, which had been exposed to the sun, was placed at the bottom or tension side.

In some of the edgewise bending tests of studs with two or three joints each, a 75-inch span with third-point loading was used. When but one splice fell between the load points, it was placed close to the center of the span. When there were two splices in this portion, they were placed equidistant from the center.

In general, testing was not carried to complete failure, but was stopped when the load had decreased to about one-half of the maximum.

Test Data

Data from individual tests of the studs in each exposure group were averaged for each particular type of test and summarized in tables 2 and 3.

These tests supplied the values necessary for the determination of joint efficiency. The efficiency is taken as the value for the spliced stud divided by the value for the unspliced control and expressed as a percentage. Inasmuch as it was desired to express efficiencies of joints as ratios to clear material, strength efficiencies were computed for spliced specimens only in those instances in which the maximum load carried by the corresponding control specimen was uninfluenced by defects.

Similarly the reported maximum load and modulus of rupture values resulting from the edgewise bending tests on resin-glued studs with two or three joints between the supports of a 75-inch span (table 3) do not include the data from the few specimens which failed through natural defects before the full strength of the joint was developed.

Results of Tests

Average results for the various groups in each of the particular tests (tables 2 and 3) showed substantially the same behavior. The performance and efficiency of the conditioned resin-glued joints was practically the same as that obtained with the casein-glued joints that had not been subject to any adverse moisture conditions. This indicated that the urea-resin adhesive used in the manufacture of the studs tested was resistant to the adverse moisture conditions for the limited period of the exposure.

No definite glue failures were noted in any of the joints tested. Although some of the failures followed the glue lines very closely in part, most of these showed principally wood failure. In the edgewise bending tests, the failures were, in general, a splintering of fingers in tension or fracture at the root of fingers, followed by splitting along or near the neutral axis (fig. 3).

Analysis of the data from the strength standpoint presents the following facts: The average efficiency in edgewise bending was 59 percent (range 49 to 79 percent), in flatwise bending 33 percent (range 23 to 42 percent), and in compression parallel to grain 89 percent (range 80 to 100 percent). These splice efficiencies are expressed as a precentage of the strength properties of clear material.

It may be pointed out that on the basis of the largest knot admitted in 2 by 4's, the efficiency of the Standard Grade of Coast-type Douglas-fir in edgewise bending is about 20 percent. A 2 by 4 in this grade admits a 2-inch knot, which may reduce the effective depth to 1-5/8 inches. Since strength in bending is proportional to the square of the effective depth the strength of a minimum Standard-grade 2 by 4 is approximately $\left(\frac{3\text{-}5/8 - 2}{3\text{-}5/8}\right)^2$ or 20 percent as great as that of a clear piece. The corresponding figure for a 2 by 4 in the Construction grade, which admits a 1-1/2-inch knot, is 34 percent. In comparison, the lowest efficiency in edgewise bending found in this series of tests of resin-glued spliced studs following exposure to the weather and to large moisture changes was 49 percent.

Control tests could not be made of the resin-glued studs that were tested edgewise with two or three joints between the 75-inch span; hence, specific efficiency values are not available. Strength values from these studs, however, indicate an efficiency of about 54 percent when compared with the corresponding control values for the specimens that were tested over a span of 45 inches.

The conclusion from these tests is that, except for bending in the flatwise direction, the effect of the splices on the strength of the spliced studs as manufactured is less than the effect of knots ordinarily permitted in material for this use. It may be noted that the spliced studs are in general lower in stiffness than unspliced studs, the deficiency being greater in the flatwise than in the edgewise bending tests. The deficiency in strength and stiffness flatwise does not appear to be especially significant, because studs are ordinarily well braced against bending in this direction.

The data indicate that joints of this type when used in Douglas fir and well bonded with urea-resin glue, can be expected to retain their strength when exposed for limited periods to adverse moisture conditions that may be encountered during storing and handling at the building site. The limited exposure periods used in these tests do not permit judgment of the behavior of the joints in long-time service of studs in buildings.

Since the strength of such splices is dependent not only on the kind of glue used, but also on gluing technique, it would appear that the product will require careful control in its manufacture (because adequacy of the joint cannot be determined by visual inspection) and provision for testing of samples when deemed necessary. Hence, a specification covering the manufacturing technique, as well as some simple method of evaluating the strength of spliced studs, will likely be necessary.

It is to be expected that joints with the same dimensions of parts, if used in members of other sizes, or oriented differently with respect to wide and narrow faces, and manufactured under different gluing conditions, would show efficiencies differing from those found in the present tests.

Joists and rafters present more critical requirements than do studs, because they are subjected to greater and more continuous bending stresses, and because there is greater hazard and danger in the possible failure of a single member. Therefore, it appears that even if spliced dimension should prove to be suitable for studs, its use for joists and rafters may be questionable under present conditions.

Table 1.--Types and number of tests conducted on spliced studs

Group number	Type of glue in joints	Number of tests					
		Static bending				Compression parallel to grain	
		Edgewise		Flatwise			
		Joint	Control	Joint	Control	Joint	Control
1	Casein	16	16	8	8	6	6
2	Resin	[1]20	10	5	5	3	3
3	Resin	[1]20	10	5	5	3	3
4	Resin	[1]20	10	5	5	3	3

[1]Ten of the resin glued studs in each of Groups 2, 3, and 4, having from 2 to 3 joints each, were tested in edgewise bending over a span of 75 inches with third-point loading, for which no control tests were possible.

Table 2.--Results of tests on short specimens of spliced studs[1]

Group number	Average moisture content at test[2]	Average specific gravity[2]	Strength: Average maximum load: Splice	Strength: Average maximum load: Control[4]	Strength: Efficiency of splice[3]: Average	Strength: Efficiency of splice[3]: Maximum	Strength: Efficiency of splice[3]: Minimum	Stiffness: Average load at 0.1-inch deflection: Splice	Stiffness: Average load at 0.1-inch deflection: Control[4]	Stiffness: Efficiency of splice[3]: Average	Stiffness: Efficiency of splice[3]: Maximum	Stiffness: Efficiency of splice[3]: Minimum
1	2	3	4	5	6	7	8	9	10	11	12	13
	Percent		Pounds	Pounds	Percent	Percent	Percent	Pounds	Pounds	Percent	Percent	Percent
BENDING ON EDGE. 45-INCH SPAN, CENTER LOAD[4]												
1	12.7	0.51	2,050	3,550	58.2	76.0	51.5	585	593	98.7	108.0	88.2
2	11.1	.49	1,780	3,080	58.7	79.3	48.7	482	522	93.2	112.3	79.6
3	12.2	.48	1.825	3,015	60.9	69.4	51.9	494	504	99.8	122.3	81.9
4	12.2	.50	1,765	3,005	58.2	65.1	49.1	529	543	99.1	126.2	79.8
BENDING FLATWISE. 24-INCH SPAN CENTER LOAD[4]												
1	12.9	.49	1,110	3,295	34.0	39.9	28.6	761	848	89.8	98.7	85.4
2	11.3	.54	1,055	3,550	29.8	34.8	26.5	719	896	80.5	89.0	67.9
3	12.0	.51	1,200	3,150	35.0	42.4	30.8	721	804	89.7	95.6	85.4
4	11.9	.49	1,070	3,295	32.3	39.6	23.2	643	786	81.8	87.5	76.7
COMPRESSION PARALLEL TO GRAIN.[4] SPECIMENS 8 INCHES LONG												
1	12.7	.47	36,080	41,705	86.7	93.2	82.3					
2	11.6	.46	34,900	38,600	91.0	94.1	85.0					
3	11.8	.50	35,500	42,055	84.6	88.6	79.6					
4	11.6	.48	34,760	37,220	94.2	100.5	88.4					

[1]Studs as supplied were 8 feet long and consisted of two to four short lengths spliced with glued finger joints. Average true cross section was 1.58 by 3.54 inches.

[2]One moisture and one specific gravity determination were made on each control portion tested. Specific gravity based on weight and volume when ovendry.

[3]Value for spliced stud divided by value for control.

[4]A test on each stud with a splice at the center of the span, or at the center of the length of a compression specimen, was followed by a test of the same type on an adjacent, unspliced portion (that portion which showed the most wood failure at the joint).

Table 3.--Results of edgewise bending tests on spliced studs over a 75-inch span under third-point loading

Group number	Maximum load			Modulus of rupture		
	Average	Maximum	Minimum	Average	Maximum	Minimum
	Lb.	Lb.	Lb.	P.s.i.	P.s.i.	P.s.i.
2	1,600	1,850	1,355	6,050	7,000	5,070
3	1,520	1,830	1,180	5,580	6,980	4,415
4	1,465	1,680	975	6,315	6,315	3,730

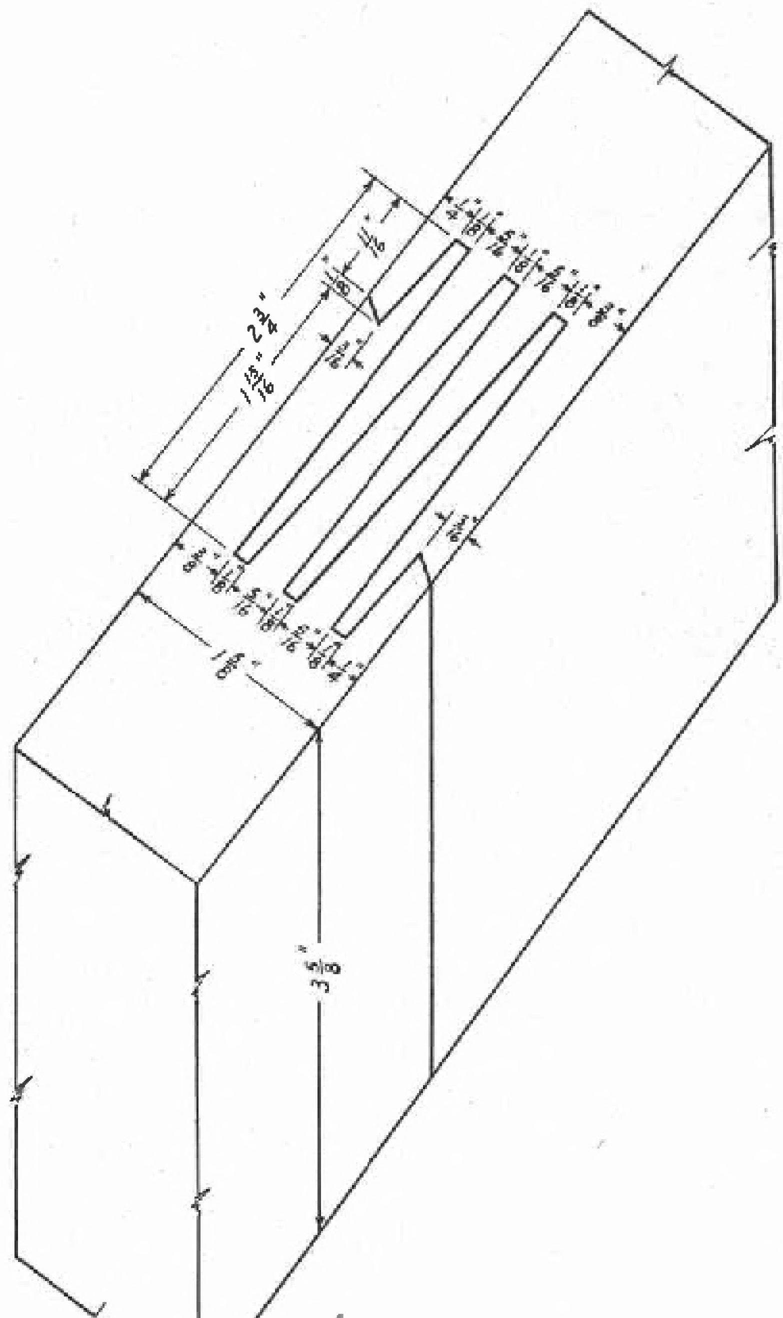

Figure 1. --Approximate details of finger-joint splice tested.

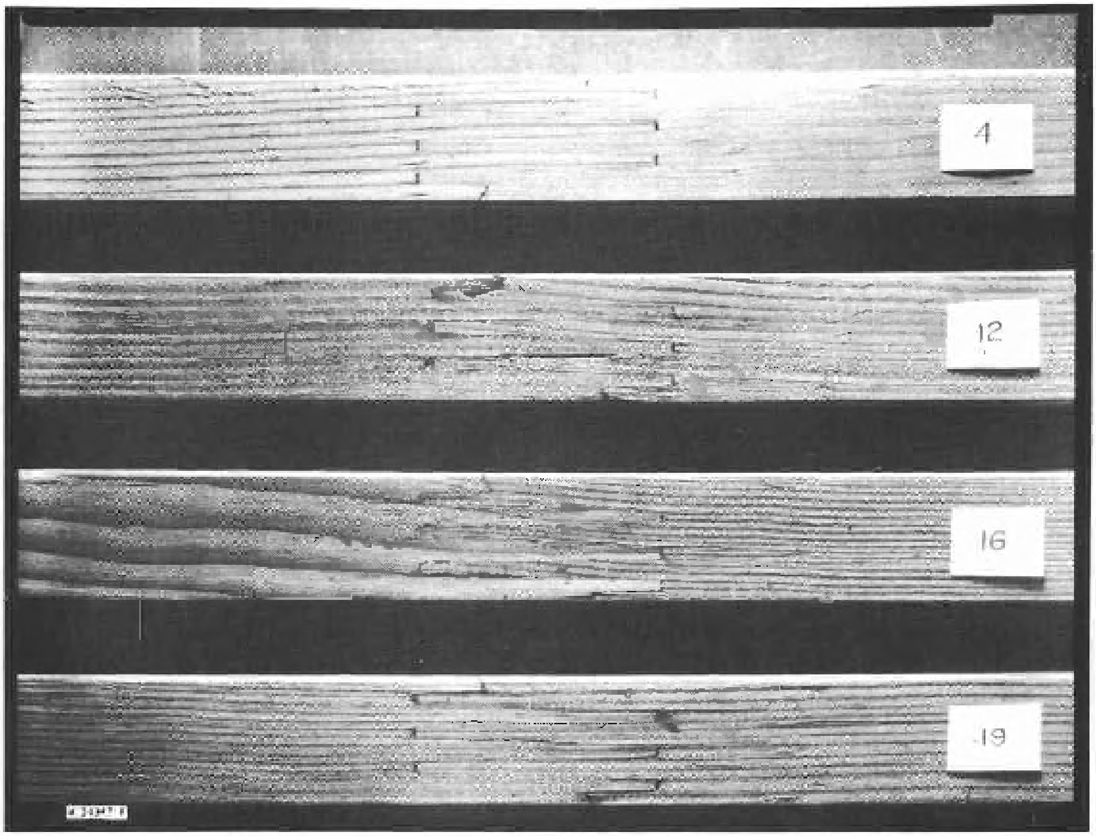

Figure 2. --Weathered edges of representative joints after exposure to the elements for 14 weeks (July to November at Madison, Wis.).

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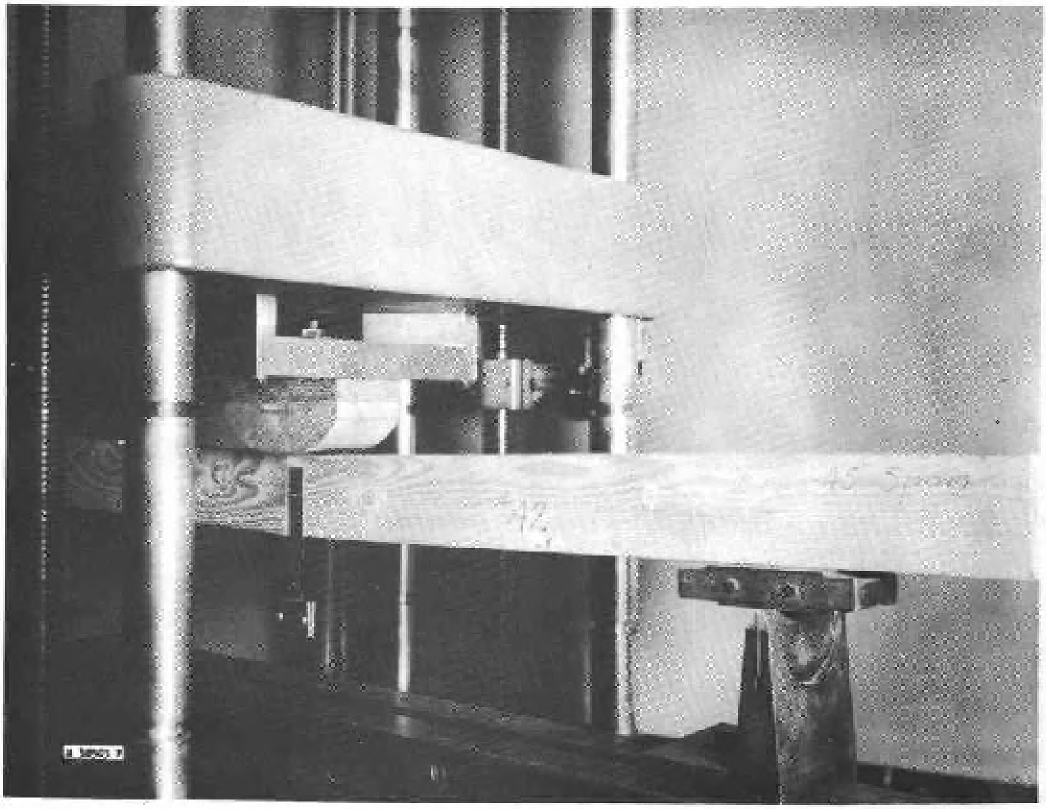

Figure 3. --Apparatus and arrangement for testing specimens in edgewise bending over a span of 45 inches with splice and load at center of span.

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