A COMPARISON OF TEST METHODS FOR EVALUATING SHEAR STRENGTH OF STRUCTURAL LUMBER

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ABSTRACT

Four different test methods that used full-size specimens to determine the parallel-to-grain shear strength of Douglas-fir structural lumber were compared: three-point bending, four-point bending, five-point bending, and torsion. A small, clear specimen test was also used to determine the parallel-to-grain shear strength of wood. There were 380 matched specimens for the five test methods (76 specimens for each test method). Analysis of variance indicated that at least one of the average shear strengths from the five different test methods was significantly different from the other (p-value = 0.00) at a 5 percent significance level. The Duncan multiple-comparison test showed that shear strengths from all test methods were significantly different from each other. The torsion test produced the highest shear strength and appeared to be the best test method for determining shear strength of structural lumber because this test is able to produce pure shear stress in the specimen. The three-point bending test was a good test method for determining shear strength of structural lumber because this test uses a simple set-up that approximates real life applications of lumber, and it produced the highest percentage of shear failure among the bending test methods.

The shear strength parallel to the grain of wood, based on small, clear specimens, is not considered to be representative of the shear strength of full-size, solid sawn, structural lumber. Recently, researchers (7,13) have given more attention to investigating the shear strength of lumber based on full-size specimen tests.

Soltis and Rammer (15) proposed a five-point bending test method to determine the shear strength of lumber based on full-size specimens. They reported that the test can consistently produce shear failure from a wide range of lumber sizes, and the lumber shear strength is related to shear strength of small, clear specimens. Further, they recommended the five-point bending test procedure as a standard test method to determine the shear strength of structural lumber based on full-size specimens.

There are two methods of determining the shear strength of lumber based on full-size specimens as described by the American Society for Testing and Materials (ASTM) (2): the four-point bending test and the torsion test. However, these tests have rarely been used to determine the shear strength of lumber. Several investigators (7-10,13) have used a variety of methods to examine the shear strength of lumber and reported that shear strength is affected by the size of the lumber.

The objective of this study was to investigate four different test methods for determining the shear strength of structural lumber based on full-size specimens: the three-point bending test, the four-point bending test, the five-point bending test, and the torsion test. A small, clear specimen test (1) was also used to determine the shear strength of clear wood. A secondary objective was to determine the relationship between the shear strength of the lumber based on full-size specimens, and the shear strength of wood based on small, clear specimens. Relationships between various strengths and modulus of elasticity (MOE) were also investigated.

MATERIALS AND METHODS

Seventy-six pieces of 12-foot-long, machine-stress-rated (1800- 1.6E), nominal 2- by 4-inch, Douglas-fir (Pseudotsuga menziesii) lumber were obtained from Frank Lumber Company in Mill City, Oreg. The pieces were selected to have similar MOE and specific gravity (SG). The lumber was stored in a controlled environment (73°F and 68% RH) for about 1 month to condition the lumber prior to testing. Each piece of lumber was then cut to produce five different specimens that were randomly assigned to the five test methods; therefore,
each test method had one specimen from each piece of lumber. All specimens were again stored in the conditioning room until the testing began.

**SAMPLE SIZE**

Based on the ASTM standard D 2915-94 (5) the sample size was equal to 36 specimens. The results of preliminary tests (average shear strength = 1,238 psi and coefficient of variation = 15%) were used in the calculation of sample size. Rammer et al. (13) reported that in the five-point bending test for 2- by 4-inch Douglas-fir lumber, approximately 50 percent of the specimens failed in shear. Therefore, the sample size was doubled with 4 extra pieces to make it 76 specimens for each test method.

**MEASUREMENTS**

Measurements included specimen size (length, width, and depth), weight, MOE, moisture content (MC), SG (dry weight/dry volume), maximum load or maximum torque at failure, and the time to failure. Width and depth were measured at three places (at the two ends and in the middle). MOE of the full-size (12-ft.) lumber was measured with an "E-computer" (Metriguard 340) before the lumber was cut into the specimens for each test method. MC and SG were determined with a small piece (about 1 in. long) cut from each specimen immediately after testing from the location close to the failure. MC was determined in accordance with ASTM D 4442, method A (6), and SG was determined in accordance with ASTM D 2395, method B (4). The failure mode was observed and sketched after failure.

The maximum loads were measured using a load cell, and the data were recorded in a computer. A Tinius Olsen universal testing machine (120,000-lb. capacity) was used for the three-point, four-point, and five-point bending tests. The small, clear specimens were tested with a smaller (60,000-lb. capacity) Tinius Olsen machine. The torsion test was conducted with a Tinius Olsen torsion machine (60,000-lb.-in. capacity).

**LENGTH OF SPECIMENS**

The shear span for each test method was 5d (17.5 in.), where d is the depth of the specimen. This was based on the shear span of the five-point bending test proposed by Soltis and Rammer (15). The shear span of the five-point bending test (Fig. 1) is defined as the distance between the two loading points, which is
equal to 5d; the total span is equal to 10d. The shear span of the three-point bending test (Fig. 2) is defined as the distance between the supports. The shear span of the four-point bending test (Fig. 3) is defined as the sum of the distances between the edge support and the nearest loading point on both sides. The specimen shown in Figure 3 meets all the requirements of the ASTM D 198 (2) test standard.

The shear span of 5d was maintained for the torsion test also. The overall length of the torsion test specimen was 35.5 inches (Fig. 4), which included 2d (7 in.) on each side of the shear span to exclude the end effects and 2 inches on each side for clamping. The specimen length also met the requirements of ASTM D 198 (2), which requires the length of the torsion test specimens to be at least eight times the larger cross-sectional dimension.

The shear block specimens were made in accordance with ASTM D 143 (1) shear block, except the thickness was 1.5 inches because the specimens were cut from nominal 2- by 4-inch lumber. The size of the shear block was 2 by 1.5 by 2.5 inches with a 2- by 2-inch shear plane.

**SIZE OF BEARING PLATES**

A large load is required to produce shear failure under the bending test with short-span beams. The loading and reaction points are critical points of high compressive stress perpendicular to the grain. To avoid compression perpendicular to the grain failure at these points, bearing plates were designed to distribute the stresses. The published value of compressive strength perpendicular to the grain for Douglas-fir is 800 psi (17). The sizes of the steel bearing plates (Figs. 1, 2, and 3) were based on presumed uniform bearing stress and the maximum load from preliminary tests. The plates were 1/2 inch thick and 4 inches wide, which helped provide lateral stability to all specimens. The edges of the plates were rounded (not shown in the figures) to minimize wood crushing.

**TESTING PROCEDURES**

The four-point bending and torsion tests were conducted in accordance with the ASTM standard D 198 (2). The three-point bending test was also conducted by following the ASTM D 198 procedure because no standard test method is available to test full-size specimens under three-point bending to determine shear strength. The five-point bending test was conducted in accordance with the method proposed by Soltis and Rammer (14). The small, clear specimen tests were conducted in accordance with the ASTM standard D 143 (1).

**Stress calculations**

The failure stress of a beam was taken as either shear or bending strength de-
pending upon the type of failure in the beam. Shear or bending strength was based on the maximum torque or load in the beam. Although combined stresses are present in the test specimens, only one type of stress was used as the failure stress depending upon the failure mode. Shear and bending strengths for the bending tests were determined with beam theory (12). The shear strength in the torsion test was determined based on the equation given in ASTM D 198 (2). Maximum stress at the middle of the wide face was taken as the shear strength of the specimens. The maximum compressive stress perpendicular to the grain was calculated as maximum load divided by the contact area between the bearing plate and the beam. The shear strength, bending strength, and MOE in this report were adjusted to the shear strength at 12 percent MC with equations recommended by ASTM D 1990 (3).

**Statistical methods**

A completely randomized design was used in this study. The 5 different test methods were the treatments, and the 76 specimens used in each test method were the replications. One-way classification analysis of variance with 5 percent significance level was performed in order to analyze mean differences among the test methods. Since no test method could be designated as a control in this study, the Duncan multiple-comparison analysis was conducted to compare all possible pairwise combinations among the means of the treatments. Simple linear regression analyses were employed to determine the relationship between the shear strengths from the full-size specimens and the shear strength from the small, clear specimen test.

**Results and discussion**

The average MC for each test method was 13 percent with a coefficient of variation (COV) of 6 percent. The average SG for each test method was 0.49 with a COV of 8 percent.

**Failure modes**

The failure modes of the specimens for each test method were observed and recorded throughout the testing. Three different types of failure modes were observed during the testing: shear failure, bending failure, and combined shear and bending failures. Figure 5 shows shear failures for the three- and five-point bending tests and the torsion test. Clearly there are no other failure modes other than shear failure (including no tension perpendicular to the grain failure). Other types of failure modes for all tests are given in Riyanto (14). Generally, shear failure begins as a crack in the beam when the torque or load in the beam is at the maximum. Plastic deformations begin to occur only after the beam has failed in shear. Since failure stress was determined at the maximum applied torque or load, no measures were necessary to account for the large plastic deformations in the beams. Table 1 shows the percentage of the failure modes for each test method.

**Three-point bending test.** — The three-point bending test produced 33 shear failures (44%), 33 bending failures (44%), and 10 combined shear and bending failures (13%). The shear plane was parallel to the grain near the neutral axis of the beam. The shear failures typically started under the loading point and then propagated towards either one or both ends of the specimens.

The shear failures occurred mostly in the clear portion of the specimens. If a shear crack came across a knot, it either stopped or went around the knot. This may be an indication that tight knots do not reduce the shear strength of wood. Distorted grain around the knot resists shear stress that tends to shear the wood parallel to the grain. The shear failure was along the transition layer between the latewood of one growth ring and the earlywood of the adjacent growth ring, which is the weakest layer because the density of wood changes abruptly. This phenomenon was observed in the specimens that had growth rings parallel or nearly parallel to the thickness (1.5 in.) of the specimen (quartersawn lumber).

Bending failure typically occurred in the middle of the span under the loading point. The failure was usually initiated by either tension failure at the bottom or compression failure at the top of the specimen. Specimens with knots, particularly those that had knots in the middle area, failed in bending more often than in other failure modes. The presence of pith, cluster knots, and insect holes also caused bending failure in the specimens.

**Four-point bending test.** — The four-point bending test produced 6 shear failures (8%), 68 bending failures (89%), and 2 combined shear and bending failures (3%). Typically, the shear failure occurred between one of the loading points and the nearest support. Shear failure in the four-point bending test also occurred in the clear portion of the wood, and most of the specimens that failed in shear had growth rings parallel or nearly parallel to the thickness.

Bending failure in the four-point bending test commonly occurred between the load points because bending stress was maximum and shear stress is minimum in this range. The bending failure was always initiated by either compression failure at the top of the specimen or tension failure at the bottom of the specimen.

**Five-point bending test.** — The five-point bending test produced 21 shear failures (28%), 27 bending failures (35%), and 16 combined shear and bending failures (21%). Twelve other specimens (16%) had lateral stability problems before reaching the maximum load. The tests were stopped because conditions were not safe, and the specimens were not retested.

Failures in the five-point bending test were always initiated by compressive damage at the loading points and at the middle support. Some specimens were severely damaged in compression perpendicular to the grain before failure.

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**Table 1. — The percentage of failure modes for each test method.**

<table>
<thead>
<tr>
<th>Test method</th>
<th>No. of specimens</th>
<th>Percentage of specimens failed in</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Shear</td>
<td>Bending</td>
</tr>
<tr>
<td>Three-point bending</td>
<td>76</td>
<td>44</td>
</tr>
<tr>
<td>Four-point bending</td>
<td>76</td>
<td>8</td>
</tr>
<tr>
<td>Five-point bending</td>
<td>76</td>
<td>28</td>
</tr>
<tr>
<td>Torsion</td>
<td>76</td>
<td>100</td>
</tr>
<tr>
<td>Small, clear specimen</td>
<td>76</td>
<td>100</td>
</tr>
</tbody>
</table>

a S&B = combined shear and bending failures.
b Tests stopped due to lateral stability problem.
The shear failure typically occurred in between the middle support and one of the loading points, and it never occurred on both sides of the middle support. Also, the shear cracks did not continue over the middle support because of high compressive stress at the middle support.

The bending failure typically occurred either above the middle support or between the middle support and the edge support under the loading point. The bending failure was always initiated by tension failure either at the top of the specimen above the middle support or at the bottom of the specimen under the loading points.

The combined shear and bending failures occurred either on the same side of the middle support or on each one on both sides of the middle support. The maximum loads from these tests were included in the analysis of the shear strength.

Torsion test. — The torsion test produced only shear failures (100%). The shear plane was parallel to the grain. Typically, shear cracks started from the midspan and propagated toward the ends of the specimen. As in the bending tests, the shear failure in the torsion test also occurred mostly in the clear portion of the specimen. Similar to the bending tests, if a shear crack came across a knot, it either stopped or went around the knot.

Specimens with high slope of grain usually failed at a lower torque and in a shorter time than did the specimens with straight grain. This is because the specimens with high slope of grain have less area between two rings to resist the horizontal slip. Specimens with growth ring orientation parallel to the thickness (quartersawn lumber) also failed at lower torque. This is because the specimen consisted of several weak layers parallel to the thickness.

**Shear strength analysis**

The shear strength analysis in this section is based on the shear strengths from the specimens that failed in shear and in combined shear and bending. The average shear strengths among test methods (Table 2) varied from 934 psi for the four-point bending test to 1,834 psi for the torsion test. The published value of shear strength parallel to the grain for dry Douglas-fir is 1,130 psi (17). As expected, the results of this study show that the shear strength from the small, clear specimen test (1,151 psi) is the closest to the published value.

The coefficient of variation provides an indication of how consistently the test method determines the shear strength of lumber. The coefficients of variation among these test methods varied from 15 percent for the small, clear specimen test to 28 percent for the four-point bending test. The small, clear specimen test had the lowest COV because the shear block specimens were made from the clear part of the lumber, which was free of any defects. Therefore, the specimens for the small, clear specimen test were more homogeneous than were the specimens for the full-size test methods.

Among the test methods that used full-size specimens, the three-point bending test, torsion test, and five-point bending test had very similar coefficients of variation (16%, 18%, and 18%, respectively). The four-point bending test had the largest COV (28%). Based on the COV values, the three-point test was most consistent and the four-point test was least consistent in determining the shear strength of lumber.

Completely randomized design was used to analyze differences among the average shear strength of each test method. Initially, each test method had an equal number of replications (76 specimens), but because the number of shear failures differed among these test methods, the shear strengths were analyzed by completely randomized design with unequal replications. The statistical analyses were done with the Statgraphics program (16).

Analysis of variance was performed to examine differences among the average shear strengths from these test methods. The results indicate that there is a significant difference among the average shear strengths (p-value = 0.00) at the 5 percent significance level. Thus, each test method gave a different shear strength value for the same lumber. This result agrees with Keenan's (8) statement that the shear strength of lumber is not a constant value but is related to the method of shear strength determination, even when all of the factors that normally affect the mechanical properties of wood are controlled.

Since analysis of variance showed that each test method gave a different value of shear strength, the results were further analyzed using the Duncan multiple-comparisons test. The results are shown in Table 3. The pairwise comparisons in Table 3 indicate that the average shear strengths from the five different test methods were significantly different.

### Table 2. — The average of shear strength from each test method.

<table>
<thead>
<tr>
<th>Test method</th>
<th>No. of specimens</th>
<th>Average (psi)</th>
<th>COV (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Three-point bending</td>
<td>43</td>
<td>1,315</td>
<td>16</td>
</tr>
<tr>
<td>Four-point bending</td>
<td>8</td>
<td>934</td>
<td>28</td>
</tr>
<tr>
<td>Five-point bending</td>
<td>37</td>
<td>1,608</td>
<td>18</td>
</tr>
<tr>
<td>Torsion</td>
<td>76</td>
<td>1,834</td>
<td>15</td>
</tr>
<tr>
<td>Small, clear specimen</td>
<td>76</td>
<td>1,151</td>
<td>15</td>
</tr>
</tbody>
</table>

*a COV = coefficient of variation.

### Table 3. — Multiple-comparison analysis (Duncan test) of average shear strengths.

<table>
<thead>
<tr>
<th>Test method</th>
<th>Average shear strength</th>
<th>SE</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Four-point bending</td>
<td>934</td>
<td>93</td>
<td>A</td>
</tr>
<tr>
<td>Small, clear specimen</td>
<td>1,151</td>
<td>20</td>
<td>B</td>
</tr>
<tr>
<td>Three-point bending</td>
<td>1,315</td>
<td>33</td>
<td>C</td>
</tr>
<tr>
<td>Five-point bending</td>
<td>1,608</td>
<td>47</td>
<td>D</td>
</tr>
<tr>
<td>Torsion</td>
<td>1,834</td>
<td>37</td>
<td>E</td>
</tr>
</tbody>
</table>

SA = standard error.

Indicates that the average shear strengths from the five different test methods are all significantly different from each other.
from each other. Although each test setup used the same shear span (5d), different types of stresses with differing magnitudes were produced. Besides producing different magnitudes of shear stress, the bending test setup also produced different magnitudes of bending stresses and compressive stresses perpendicular to the grain. The presence of the other stresses with varying magnitudes might affect the shear stress at failure for the specimens.

In bending tests, three different types of stress were present in the specimens: shear stress, bending stress, and compressive stress perpendicular to the grain. Table 4 shows the magnitude of the stresses in the beam at the time of failure.

The four-point bending test produced the lowest shear stress (934 psi) and high bending strength (12,938 psi). Published values of shear strength and bending strength for Douglas-fir are 1,130 psi and 12,400 psi, respectively. The shear strength produced by the four-point bending test never reached the average shear strength of lumber. Therefore, the specimens under the four-point bending test failed in bending more often than in shear. Based on these results and the previous discussion on failure modes, the four-point bending test appears to be a poor test method for determining the shear strength of lumber based on full-size specimens.

Table 4 shows that the five-point bending test produced the highest shear strength (1,608 psi) among the bending tests, but also produced the highest compressive stress at the loading points (899 psi) and very high at the middle support (927 psi). Mandery (11) investigated the relationship between maximum shear stress at failure and compressive stress perpendicular to the grain of wood. He concluded that increasing compressive stress perpendicular to the grain significantly increases the shear stress at failure in the wood. Therefore, when deciding which test method should be used in determining the shear strength of full-size lumber, researchers should take this fact into account. In the five-point bending test, the high shear stress occurred in the same area with the high compressive stress perpendicular to the grain. The area is in the range between the middle support and the loading points.

As far as failure modes are concerned, the three-point bending test produced shear cracks in the area between the loading point and the end of the beam. In the five-point bending test, the shear crack occurred in the area between the loading points and the middle support. In real-life applications of wood as a structural component, shear failure commonly occurs at the ends of the beam. Therefore, the three-point bending test would appear to be closer to most real-life situations than the five-point bending test for determining the shear strength of lumber.

**Relationship between shear strengths**

The results of the simple linear regression analyses between various shear strengths from full-size specimens and the corresponding shear strengths from small, clear specimens are shown in Table 5. The p-values in Table 5 indicate that the shear strength from the torsion test, three-point bending test, and five-point bending test had significant relationships with the shear strength from the small, clear specimen test. Based on the $r^2$ values (Table 5), the percentage of variation explained by the linear model was highest for the torsion test, followed by the three-point bending test and the five-point bending test.

The shear strength from the torsion test had a better relationship with the shear strength from the small, clear specimen test because there was minimum effect of other stresses in these two methods. The relationship between the shear strength from the three-point bending test and the shear strength from the small, clear specimen test was better than that between the five-point bending and small, clear specimen tests, probably because compressive stresses (perpendicular to the grain) were smaller in the three-point bending test than in the five-point bending test.

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**Table 4. Average stresses in the beam during testing.**

<table>
<thead>
<tr>
<th>Test methods</th>
<th>No. of specimens</th>
<th>Shear stress</th>
<th>Bending stress</th>
<th>Compressive stress$^a$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Loading point</td>
</tr>
<tr>
<td>Three-point bending</td>
<td>43</td>
<td>1,315</td>
<td>13,283</td>
<td>759</td>
</tr>
<tr>
<td>Four-point bending</td>
<td>8</td>
<td>934</td>
<td>12,938</td>
<td>371</td>
</tr>
<tr>
<td>Five-point bending</td>
<td>37</td>
<td>1,608</td>
<td>8,854</td>
<td>899</td>
</tr>
<tr>
<td>Torsion</td>
<td>76</td>
<td>1,834</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Small, clear specimen</td>
<td>76</td>
<td>1,151</td>
<td>--</td>
<td>--</td>
</tr>
</tbody>
</table>

$a$ Compressive stress perpendicular to the grain.

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**Table 5. Simple linear regression analysis between shear strengths of full-size specimens and small, clear specimens.**

<table>
<thead>
<tr>
<th>Regression ($Y = a + bx$)</th>
<th>No. of specimens</th>
<th>$r^2$</th>
<th>p-value</th>
<th>Significance (5% level)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Three-point bending</td>
<td>Small specimens</td>
<td>43</td>
<td>0.21</td>
<td>0.00</td>
</tr>
<tr>
<td>Five-point bending</td>
<td>Small specimens</td>
<td>37</td>
<td>0.13</td>
<td>0.03</td>
</tr>
<tr>
<td>Torsion</td>
<td>Small specimens</td>
<td>76</td>
<td>0.26</td>
<td>0.00</td>
</tr>
</tbody>
</table>

$p^2 = coefficient of determination.
TABLE 6. — Simple linear regression analysis between shear strength and MOE.

<table>
<thead>
<tr>
<th>Test method</th>
<th>Shear</th>
<th>MOE</th>
<th>n</th>
<th>( r^2 )</th>
<th>p-value</th>
<th>Significance (5% level)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Three-point bending</td>
<td>Shear</td>
<td>MOE</td>
<td>43</td>
<td>0.00</td>
<td>0.87</td>
<td>No</td>
</tr>
<tr>
<td>Five-point bending</td>
<td>Shear</td>
<td>MOE</td>
<td>37</td>
<td>0.01</td>
<td>0.66</td>
<td>No</td>
</tr>
<tr>
<td>Torsion</td>
<td>Shear</td>
<td>MOE</td>
<td>76</td>
<td>0.01</td>
<td>0.36</td>
<td>No</td>
</tr>
<tr>
<td>Small, clear specimen</td>
<td>Shear</td>
<td>MOE</td>
<td>76</td>
<td>0.01</td>
<td>0.46</td>
<td>No</td>
</tr>
</tbody>
</table>

\( n \) = number of specimens.
\( r^2 \) = coefficient of determination.

Relational between shear strength and MOE

The results of the regression analyses (Table 6) between the shear strength from each test method and MOE show no significant relationships. This indicates that MOE was not a good variable for estimating the shear strength of lumber regardless of the test method used for determining the shear strength. These results are similar to the results reported in previous studies (7,15). These researchers also concluded that there is no significant relationship between the shear strength and the bending strength of lumber.

Comparison of test methods

The comparison of test methods is shown in Table 7. The torsion test always produced shear failure and also produced the state of stress that was pure shear. Therefore, the shear value was a better representation of the shear strength of lumber. The torsion test also showed low variability in shear strengths, which indicates that this test gives consistent results. The shear strength from the torsion test was significantly related to the shear strength of the small, clear specimens. This is important because most of the available data on shear strength of various species were based on the small, clear specimen test. Also, it is very easy to conduct a torsion test if a torsion machine is available.

Among the test methods that used a bending set-up, the three-point bending test appears to be a better test method than either the five-point or the four-point bending tests. This is because the three-point bending test produced the highest percentage of shear failures and the lowest coefficient of variation. The compressive stress that occurred in the three-point bending test was smaller than the compressive stress in the five-point bending test; also the mode of shear failure in the specimen is closer to real-life failure of lumber in structural applications. Therefore, if the objective is to determine the shear strength of wood as a material, the torsion test is the appropriate test method, because this test is able to produce pure shear stress in the specimens. However, if the objective is to determine the shear strength of wood as a structural component, the three-point bending test is an appropriate test method because the three-point bending test uses a bending set-up that closely approximates real-life applications of wood as a structural component.

Conclusions

Based on the results of this study, the following conclusions can be stated:

1. There was a significant difference among the average shear strengths determined using the five different test methods mainly because different test set-ups produced different distributions of combined stresses in the specimens.

2. Among the test methods that used full-size specimens, the torsion test always produced shear failure (100%); the three-point, five-point, and four-point bending tests produced shear failure among 44, 28, and 8 percent of the specimens, respectively.

3. The torsion test may be a good test method for determining the shear strength of solid wood as a material because it produces pure shear stresses in the specimens, and the three-point bending test may be an appropriate test method for determining the shear strength of lumber as a structural component because it produces a failure mode similar to the one found in real-life situations.

4. There was a significant linear relationship between the shear strengths from the torsion test, three-point bending test, and five-point test and the shear strength from the small, clear specimen test. This is an important result because the vast data set on shear strength from small, clear specimen tests can be used to determine the shear strength of full-scale structural lumber.

5. MOE did not have a linear relationship with the shear strength of lumber regardless of the test method used for determining the shear strength.

Literature cited


