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# Bolt Bearing Behavior of Engineered Wood Composites

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# BOLT BEARING BEHAVIOR OF ENGINEERED WOOD COMPOSITES

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## *Abstract*

The goal of this research was to gain a better understanding of the bolt bearing behavior of engineered wood composites made from yellow poplar lumber. Lumber specimens included in this study were laminated veneer lumber, strand-based lumber, yellow poplar lumber, and Douglas-fir larch lumber. Testing followed the half-hole and full-hole configuration as set forth in ASTM Standard D5764 (1998).

In a previous study by Wilkinson (1991), a strong correlation was shown between bearing strength perpendicular to grain and bolt diameter. This study supports Wilkinson's finding for bearing strength perpendicular-to-grain based on the half hole test configuration. Other findings in this study indicate there may be a correlation between bolt diameter and bearing strength parallel-to-grain for the half-hole test configuration as well as a correlation between bolt diameter and bearing strength both perpendicular- and parallel-to-grain for the full-hole test configuration.

In general, half-hole tests resulted in a greater dowel-bearing strength than full-hole tests, especially for 12.7mm (½ in) diameter bolts. Also, engineered wood composites generally provided equivalent or greater dowel-bearing strength in the half-hole configuration and greater dowel-bearing strength in the full-hole configuration when compared to lumber from the same species.

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## *Introduction*

The scope of this study was specifically focused toward quantifying the bolt bearing strength ($F_e$) of lumber and wood-based products commonly used in wood-frame construction. Bolt sizes and grain orientation used for the half-hole (HH) test configuration are given in Table 1 and bolt sizes and grain orientation for the full-hole (FH) test configuration can be found in Table 2. Structural grade Douglas fir-larch lumber (DF), laminated veneer lumber (LVL), strand-based lumber (SBL), and yellow poplar lumber (YP) were selected for this study. The LVL and SBL specimens were fabricated entirely from YP material. The YP and DF lumber specimens were selected as a basis of reference. Physical testing was used to determine $F_e$ in accordance with the provisions of ASTM Standard D5764 (1998).

## *Testing Procedure*

The purpose of the HH configuration of the $F_e$ test was to determine the load resistance and displacement characteristics for fasteners in wood-based products. This was obtained through application of a force/load on a bolt placed in a drilled hole. Each rectangular wood specimen had a hole drilled in the 'width' face and was used to evaluate the resistance to fastener embedment in the hole without bending the fastener. Crushing strength of the wood under the fastener can be used to establish connection design values. The effects of bolt diameter, moisture content, specific gravity, and grain direction on $F_e$ can also be evaluated using these tests. 5% offset and maximum load of the specimen were determined from the test data.

The original intent of the FH configuration was to facilitate completion of the test for specimens that tend to fail prior to reaching the 5% offset load in the HH configuration. A goal of this study was to provide a direct comparison between the HH and FH tests configurations for lumber and engineered wood composite specimens.

Twelve replications were conducted for each wood product, angle to grain, and bolt size. The bolt sizes used in the HH tests were 12.7 mm (½ in), 19.05 mm (¾ in), and 25.4 mm (1 in) diameter. 12.7 mm (½ in) and 19.05 mm (¾ in) diameter bolts were used in the FH tests. Matched specimens were used for the FH and HH tests in this study.

## *Analysis of Results*

In evaluating the HH configuration, it is interesting to note that the engineered wood composites always exhibited higher $F_e$ values than the YP lumber for the perpendicular-to-grain loading orientation. However, for parallel-to-grain loading the results were mixed, with YP lumber sometimes exhibiting higher $F_e$ values than either LVL or SBL. In all cases, SBL had higher $F_e$ values than LVL. Specifically, SBL exhibited an 11% higher $F_e$ value for 12.7mm (½ in) diameter tests and a 15% higher $F_e$ value for 19.05mm (¾ in) diameter tests, versus LVL parallel-to-grain. Similarly, SBL $F_e$ values perpendicular-to-grain for the 12.7mm (½ in) diameter tests were 93% higher than LVL $F_e$ values, and were 43% higher for 19.05mm (¾ in) diameter tests of LVL. These $F_e$ values are shown in Table 1.

Diameter effects were observed for all products in both perpendicular and parallel-to-grain orientations. Wilkinson's (1991) study showed $F_e$ decreasing as bolt diameter increased for specimens loaded perpendicular-to-grain. However, the results of this study indicate somewhat of a "reverse effect", with $F_e$ increasing as the bolt diameter increased for LVL and YP lumber specimens loaded perpendicular-to-grain.

**Table 1. Average Dowel-Bearing Strengths for the HH Configuration, MPa (psi).**

| Bolt Diameter | | 12.7mm (½ in) | 12.7mm (½ in) | 19.05 mm (¾ in) | 19.05 mm (¾in) | 25.4 mm (1 in) |
|---|---|---|---|---|---|---|
| Grain Orientation | | Parallel | Perpendicular | Parallel | Perpendicular | Perpendicular |
| Material | Avg SG | MPa (psi) | MPa (psi) | MPa (psi) | MPa (psi) | MPa (psi) |
| DF | 0.498 | 50.5 (7322) | 20.5 (2985) | 36.1 (5234) | N/A | N/A |
| YP | 0.492 | 47.1 (6830) | 18.1 (2624) | 46.2 (6710) | 19.7 (2870) | 20.2 (2944) |
| LVL | 0.516 | 43.6 (6326) | 27.7 (3304) | 36.6 (5313) | 23.7 (3448) | N/A |
| SBL | 0.629 | 48.8 (7084) | 43.9 (6379) | 42.2 (6124) | 34.8 (5047) | 40.0 (5806) |

In evaluating the FH test, both LVL and SBL always exhibited higher $F_e$ values than the YP lumber, and SBL $F_e$ values were always greater than LVL. Specifically, SBL had a 1% higher $F_e$ than LVL and a 22% higher $F_e$ than YP lumber in the 12.7mm (½ in) parallel-to-grain test. In the 12.7mm (½ in) perpendicular test, SBL had a 27% and 80% higher $F_e$ than LVL and YP lumber, respectively. In the 19.05mm (¾ in) tests, SBL $F_e$ values were 0.3% higher than LVL and 23% higher than YP lumber in the parallel tests, and 72% higher than LVL and 123% higher than YP lumber in the perpendicular tests. These $F_e$ values are shown in Table 2.

Reversed diameter effects were observed for all products in the FH tests loaded parallel-to-grain. $F_e$ values for SBL specimens loaded perpendicular-to-grain also increased with increasing bolt diameter. However, $F_e$ values for LVL decreased approximately 8% for 19.05mm (¾ in) versus 12.7mm (½ in) diameter bolts loaded perpendicular-to-grain, and $F_e$ values for YP lumber load perpendicular-to-grain remained constant.

$F_e$ values from the FH test were lower than $F_e$ values from the HH test for all test scenarios except SBL specimens with 19.05mm (¾ in) diameter bolts. The largest decrease in $F_e$ is a 48% drop with LVL 12.7mm (½ in) perpendicular-to-grain. The disparity in $F_e$ values for FH versus HH tests was greatest for the 12.7mm (½ in) diameter bolt specimens. This was possibly due to elastic bolt deflection within the FH specimen, causing a non-uniform stress distribution through the thickness of the specimen. Differences between the FH and HH were less pronounced for 19.05mm (¾ in) bolts.

**Table 2. Average Dowel-Bearing Strengths for the FH Configuration, MPa (psi).**

| Bolt Diameter | | 12.7mm (½ in) | 12.7mm (½ in) | 19.05 mm (¾ in) | 19.05 mm (¾in) |
|---|---|---|---|---|---|
| Grain Orientation | | Parallel | Perpendicular | Parallel | Perpendicular |
| Material | Avg SG | MPa (psi) | MPa (psi) | MPa (psi) | MPa (psi) |
| YP | 0.491 | 33.2 (4828) | 18.7 (2713) | 43.5 (6310) | 18.8 (2727) |
| LVL | 0.517 | 33.1 (4799) | 23.1 (3359) | 45.4 (6579) | 21.4 (3097) |
| SBL | 0.627 | 35.8 (5191) | 29.5 (4283) | 46.9 (6805) | 36.7 (5324) |

## *Conclusions*

While this study validates some attributes of a previous $F_e$ and bolt diameter study, it also suggests that other relationships exist that warrant further testing. Specifically, a "reverse" diameter effect for two bolt sizes loaded perpendicular-to-grain, and the existence of a correlation between $F_e$ and bolt diameter for specimens loaded parallel-to-grain, were observed. This research also indicates that YP-based engineered composite lumber exhibits higher $F_e$ values when compared to YP dimension lumber using the FH test configuration. Engineered wood products also exhibit higher $F_e$ values than lumber when loaded perpendicular-to-grain using either test configuration. Though it was initially assumed that the two test configurations would give similar results, the FH test resulted in equivalent or increased Fe values for 19.05mm (¾ in) diameter bolts only. The initial results indicate that further investigation of the FH versus HH configurations in ASTM Standard D5764 (1998) may be warranted for a wider range of fastener diameters and structural wood-based products.

## *Acknowledgement*

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