Evaluation of Recycled Timber Members

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Abstract

An experimental study was conducted to evaluate the residual shear capacity of large Douglas-fir timbers used in a military facility in Ardeen Hills, MN. A S-point and 4-point bending test was used to determine the effects of checks and splits on the shear strength capacity. Experimental results are compared to past shear and flexural studies.

Introduction

Currently in the United States there is a movement to re-use or recycle construction products or materials. One of the many obstacles to direct re-use of wood materials as a construction product is the determination of its remaining strength. Wood experiences duration of load effects, moisture cycling, and fabrication changes during its service life. One of the potential negative effects is the development of splits or checks because of in service drying of wood.

The research reported in paper was conducted to will evaluate the effects of splits and checks on the shear capacity of timber beams recovered from a surplus military structure in Ardeen Hills, MN. Adjusted experimental results will be compared to past shear studies and flexural studies.

Background

Ince and McKeever (1994) analyzed actual and potential recycling capacities of wood waste in the United States. Their analysis showed that currently 0.37 millon tonnes of wood waste is recycled annually, less than 1 percent of the 39 million tonnes potential One barrier to the direct re-use or recycling of members after minor

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fabrication is the determination of remaining or residual strength. Manufacturers re-use heavy timber for post and frame buildings because it is typically dry and stable but assignment of a grade or design stress is a significant obstacle (Plume 1996).

Several researchers have investigated the properties of wood material that has been in-service for a considerable period of time. Lanius et. al. (1981) used in-situ stress wave techniques to non-destructively determine the elastic modulus of floor joists. They suggested that after the elastic modulus is determined, this property can be used to determine the modulus of rupture from existing elastic modulus-strength relationships. It is important to note that they stated this method should be used in conjunction with a visual inspection for splits or checks. Fridley et. al. (1996) evaluated the wood strength of roof trusses after 85 years of service life. They cut small clear specimens from several truss members to determine the flexural and compression parallel to grain properties. A comparison of these values to historical research values showed no difference in clear wood material strength. It should be noted that both studies did not evaluate the strength properties of standard size members with natural splits and checks.

Decommissioning of United States government military facilities gave the USDA Forest Products Laboratory (FPL) the chance to evaluate the strength capacity of full-size members for future re-use or recycling opportunities. In phase one, Falk et. al. (1998) evaluated the grade yield and flexural properties of 38 by 89 mm members. On site grading indicated that 30 percent of the graded members were downgraded by damage occurring during the deconstruction process. A total of 100 members, that included three wood species and two grades were mechanically tested. Stiffness results were consistent with today’s lumber values, but, modulus of rupture levels are lower than currently acceptable values. However, this conclusion was limited because of the small sample size of between 6 and 36 samples for each combination of species and grade.

In the second phase, Falk et. al. (1999) tested the column buckling capacity of sixty split and non-split 203 by 203 mm intermediate length columns. No noticeable reduction of intermediate column buckling capacity was determined by comparisons to current design practice and historical column test databases.

Preliminary finding of the third phase of this project are presented here. This phase looks at the effect of splits and checks on shear strength capacity

Testing Program

Large solid sawn beams for determining the asymptotic shear strength of Douglas-fir were donated by the US Army from the demolition of the Twin Cities Army Ammunition Plant (TCAAP) in Arden Hills, MN. The number and average size of Douglas-fir specimens selected are listed in Table I.

Two general categories of beams were selected for evaluation. First, for each beam size, twenty members were selected that had little visual evidence of checking along the length. Secondly, for each beam size, twenty members were selected that had significant checking and splitting along the length. Beams were stored at the TCAAP in an unprotected condition, which exposed them to wetting and drying cycles. After transportation to the Forest Products Laboratory (FPL) the beams were covered but still remained in an uncontrolled temperature environment and tested in an uncontrolled environment. Each member size was re-sorted based on a visual inspection of the degree of checking or splitting. The twenty least checked or split members were tested to determine a baseline shear strength value.

Table 1. Size and Number of Douglas-fir Specimens

Beam Size (mm by mm)	Width (mm)	Depth (mm)	Length (m)	Number of Specimens
152 by 356	135.9	334.7	5.4	35
254 by 457	249.9	448.6	5.3	34

Two test setups were used to evaluate the shear strength baseline and cracked recycled beam members. These setup can be described as a five-point and four-point bending configuration. A five-point bending test is used to produce a high percentage of beam shear failures. This method has been used successfully to create shear failures (Rammer and Lebow 1997). A beam specimen is tested over three supports and concentrated load is applied at the middle of each span. This arrangement produces an area of high shear force between the load point and the middle support making shear failures more likely. For recycled beams, this type of configuration investigates the shear strength near the middle of the beam, typically where a member is only effected by checks, not severe end splits. Twenty least visual checked or split members, for each size, were tested in this manner after one and one-half years of storage at FPL.

A four-point test is used for testing because a constant shear force is active where the greatest occurrence of splits and checks are, at the end of the beam. Typically splits and deep checks occur at the ends of the beams.

In both cases, the test span was a constant 5.0 m and results in l/d ratios of 14.1 and 11 respectively for the 152 by 356 mm and 254 by 457 mm beams, The load was applied symmetrically a distance equal to one-quarter the span length. The worst visual checked and split members of each member sizes were tested in this manner after two and one-half years of storage at FPL. During testing the midspan deflection relative to the neutral axis over the end support was measured.

Test Results

Average specific gravity, moisture content, failure stress and the number of shear failures are listed in Table 2 for the 5-point bending configuration. The average failure stress for shear and flexure are calculated by classical mechanics using the load at the governing failure.

Table 2. Five-point bending results

Member size (mm)	No. of specimens	Specific gravity	Moisture content	Stress at failure Shear (MPa)	Flexural (MPa)	No. of shear failures
152 by 356	20	0.42	15.3	3.669	17.70	18
254 by 457	20	0.46	13.6	3.175	14.77	18

In addition to the above information, the 4-point test results in Table 3 included a flexure elastic modulus. The values were calculated using deformation of 20 to 40 percent the maximum failure load. These values include shear deformation in the measurement.

Table 3. Four-point bending results

Member size (mm)	No. of specimens	Specific gravity	Moisture content	Elastic Modulus (GPa)	Stress at failure Shear (MPa)	Flexural (MPa)	No. of shear failures
152 by 356	15	0.42	15.2	11.22	1.750	26.32	3
254 by 457	14	0.45	15.6	10.01[a]	1.586	17.73	14

[a] Average based on six data points.

Discussion

Shear strength for the 5-point bending tests are compared to recent shear strength studies; whereas, the 4-point bending tests result are compared to historical and current material properties values.

Usually strength values increase with specific gravity, but 5-point shear strength was greater for the lower specific gravity 152 by 356 mm member. However, the shear strength is also a function of the member size (Rammer and Lebow 1997). It appears the size effect has a greater consequence than the specific gravity effect for shear strength. Its not known why the high specific gravity specimens had a lower elastic modulus.

To evaluate the baseline shear strength of these recycled members, average results are compared to previous five-point shear studies of solid sawn saturated Douglas-fir beams (Rammer and Lebow 1997). Experimental values are adjusted to a saturated moisture condition using ASTM D245 (*Standard* 1998) adjustments. Adjustments resulted in a 3.31 MPa and 2.81 MPa for the 152 by 356 mm and 254 by 457 mm beams, respectively. Figure 1 plots saturated shear stress versus shear area. experimental values are considerably lower when compared to an expression relating shear area to unchecked green Douglas-fir shear strength. Rammer and others (1997) material was always maintained in a wet state and did not have the ability to generate significant drying checks; whereas, the 152 by 356 mm and 254 by 457 mm beams contained surface checks which in some cases were deep. These deep checks could possibly lead to a fracture of the dry military beams instead of elastic shear type failures observed in the saturated Douglas-fir beams. Another possible difference between the empirical expression and the data is appropriateness of using the total specific moisture adjustment of ASTM D245 for a specific wood species.

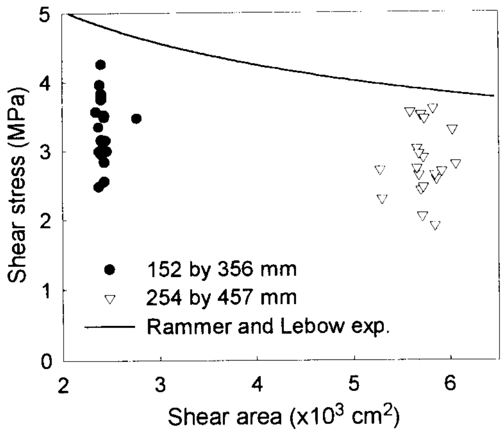

Figure 1. Comparison of experimental results with Rammer and Lebow (1997) expression relating shear strength to beam size.

For the 4 point bending test results, the 152 by 356 mm members generally failed in bending, These results are compared to historical flexural properties instead of shear values. A comparison of the average stiffness value for both tested sizes to an average of 10.7 GPa for historical structural sizes (Cline and Heim 1912) indicates both values are similar. However, the 152 by 356 mm modulus of rupture is 60% of the values found by Cline and Hiem (1912). This finding is similar to those of Falk et. al (1998) for the 38 by 89 mm members. Shear strength results for the 254 by 457 mm member is about half the baseline values from the 5-point test configuration which is lower than difference typically observed between the 5-point and 4-point bending test configurations (Cofer et. al. 1997). The average value for the 15 worst split specimens divided by a 4.1 adjustment factor (0.39 MPa) is lower than the allowable shear design values for Douglas-fir (0.62 MPa) which assume the member is completely split (*National* 1997) When re-using these full-size timbers, the number and location of splits and checks should be carefully evaluated for its effect on shear strength.

Conclusions

Tests on recycled timbers indicate that shear strength is effected by the presence of splits and checks when compared to research on unchecked material. Flexural stiffness values are similar to historical and current values for Douglas-fir, but, modulus of rupture values are significantly lower. Again, these findings are limited because of small sample sizes, only represent one building, and tested split members likely represent worst-case situations.

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May 10-12, 1999
Cincinnati, Ohio

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Lawrence C. Bank

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