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Assessing the Capacity of Three Types of Round-Wood Connections

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ABSTRACT: In the Western US, millions of acres of forestland have lost ecological integrity. These overstocked stands are at significant risk for disease and insect attack, and high risk for catastrophic wildfire. Finding alternative and higher value uses for material thinned from the forests can help pay for mechanical thinning. Three different types of connections for round wood members made of Douglas fir and Lodgepole pine were tested. Results showed that all three types of connections exceeded the anticipated design load. There were, however, significant differences between the ductility and deflection capacity.

KEYWORDS: Round-Wood Connections, Structural Screws, Bolted Connection, Gussets, Fasteners, Thinnings

1 INTRODUCTION

In the Western US, millions of acres of forestland have lost ecological integrity. These overstocked stands are at significant risk for disease and insect attack, and high risk for catastrophic wildfire. Prompted by the devastating forest fire season of 2000, President William J. Clinton initiated the development of what would become the National Fire Plan. The plan established four main goals: to improve prevention and suppression; reduce hazardous fuels; restore fire adapted ecosystems; and promote community assistance [1]. One of the most commonly used fire prevention techniques is fuel management, an idea that has been around for many years. In the 1960's, the U.S. Department of Agriculture (USDA) - Forest Service began managing fuels by using controlled burn techniques [2] where fires are initiated in areas where they can be contained in order to consume the small-diameter forest thinnings (SDTs) that might serve as fuel for future fires. Although this controlled burn technique has generally been effective, it has been stated to offer no economic benefits while carrying many risks. Finding alternative and higher value uses for material thinned from the forests can help defray the cost of fuel management. An alternative use for logs from small-diameter trees is in applications such as round-wood engineered structures and floor joists for log homes. Finding alternative and higher value uses for material thinned from the forests can help pay for mechanical thinning.

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2 BACKGROUND

Today, there are many uses for the small diameter trees that make up the majority of the forest thinnings. Uses for these thinnings include lumber, posts for highway guardrail systems, structural roundwood, wood composites, wood fiber products, compost, mulch, energy, and fuels [3]. Increasing the utilization of SDT materials is usually dependent on removing technical barriers. Technical barriers have been removed from using this SDT within guardrail systems [4]. Several technical barriers exist for a wider utilization of SDT in structural roundwood. Already a technical basis has been established for a proposed mechanical grading system for logs that are 3 to 7 inches in diameter [5]. In addition, we determined that visual grading procedures for small diameter logs result in conservative design properties, but a mechanical grading system is needed to significantly improve the assigned design properties. For example, for a mechanical grade assigned an MOE = 1.4 x 10^6 lb/in^2, mechanical grading of a set of small diameter lodgepole pine logs was shown to provide a 27% increase in MOE and a 72% increase in Fb compared with a No. 1 visual grade. Further field and laboratory studies, that lead to innovative uses of western softwoods in solid or composite form that can be used in housing, still need to be done. One such area of study is fastening systems for small diameter thinnings (SDT).

The structural advantages of using small-diameter timber in the round form are discussed by Wolfe [6, 7]. Cutting a 6-inch diameter ponderosa pine log into dimension lumber, converts roughly 60% of the log to low or no value slabs, chips and sawdust. The economic value of this waste material varies with the capabilities of the local infrastructure. In terms of the engineering value, however, the material taken off as slab contains the best wood.

Some advantages of using logs in the round form instead of sawing them into lumber include:

- Less susceptible to warp during drying
- Lower processing costs
- Load-carrying capacity two to four times that of largest rectangular member that can be sawn from a log
- Potential for higher economic value.

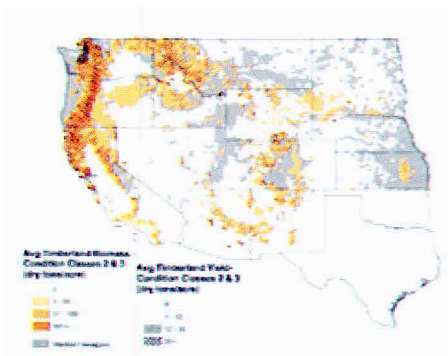

Figure 1: Potential high-priority fuel reduction thinning opportunities on timberland in the western United States [8, 9]

2.1 OBJECTIVES

Our research is intended to improve the utilization of small diameter roundwood for use as structural members by evaluating the physical and mechanical properties of small diameter logs, determining the effect of doweling on strength, developing grading systems to establish allowable design values, and improving structural connections. The objective of this particular study is to evaluate three different connections for round wood members made of Douglas fir and Lodgepole pine that would be obtained from the one of the high-priority fuel reduction thinning regions shown in Figure 1. The first and second connections were new designs intended to reduce cost and/or achieve higher design loads than connections currently in use (Figure 2A, 2B). The third connection was a bolt-and-plate style typically used in structural log assemblies (Figure 2C).

2.2 METHODS

Logs for this study were obtained from a fuels reduction thinning in Montana. The three connections to be assessed were tested in tension at the USDA Forest Products Laboratory during the summer of 2010. An estimate of the design load for each connection type is given in the third column of Table 1.

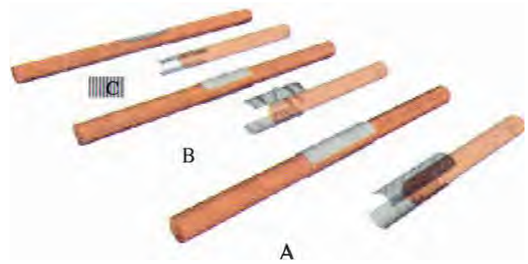

***Figure 2:** Three types of connections were studied A) Structural Screws, B) Gussets, and C) Bolt and plates*

2.3 TESTING

The test setup used to conduct the connection tests are shown in Figure 3. A 40 Kip actuator controlled by an MTS FlexTest controller was used to apply an axial tension load with a load head displacement of 2.5 min/min. The maximum load of the connection was reached between 3 and 18 minutes with an average for all tests of 10 minutes. The average time to failure for a connection was shortest for type B connections at an average of about 5 minutes and longest for Type A connections at an average of about 14 minutes. Loads were measured using a 110-kN (30,000 lb) load cell and two linear variable differential transformers (LVDT), one on each side, were used to measure average displacement across the connection of the two sections of logs making up the connection. Load and displacement data was digitally recorded and stored for each joint. After testing, photographs were take of each failure. Metal straps were placed directly outside the loading pins to help restrain the perpendicular to grain stress at the pins.

Figure 3: Connection test setup

3 RESULTS

3.1 LOAD DEFLECTION CURVES

Plots for the test results of Lodgepole Pine are shown in Figure 4. Plots of the load defection curves for Douglas Fir are shown in Figure 5. An examination of the curves show the ductile nature of the construction screw method Type A and the extremely brittle nature of the gusset method Type **B.**

The average loads for the three type of connections are given in Table 1. As would be expected, the Douglas fir samples produced the higher average loads for all connections types. For a given species the Type C bolt and plates method produced the highest loads. The Type A plate connection provided much more ductile failures while having similar load capacity to the Type **B** gusset fasteners.

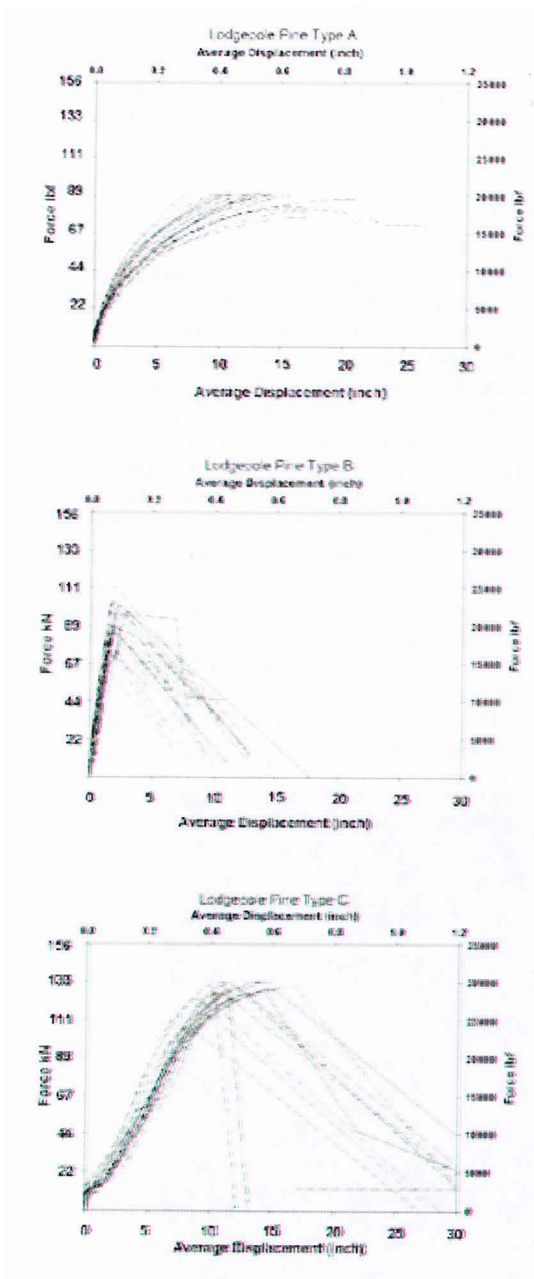

Figure 4: *Load deflection curves for Lodgepole Pine*

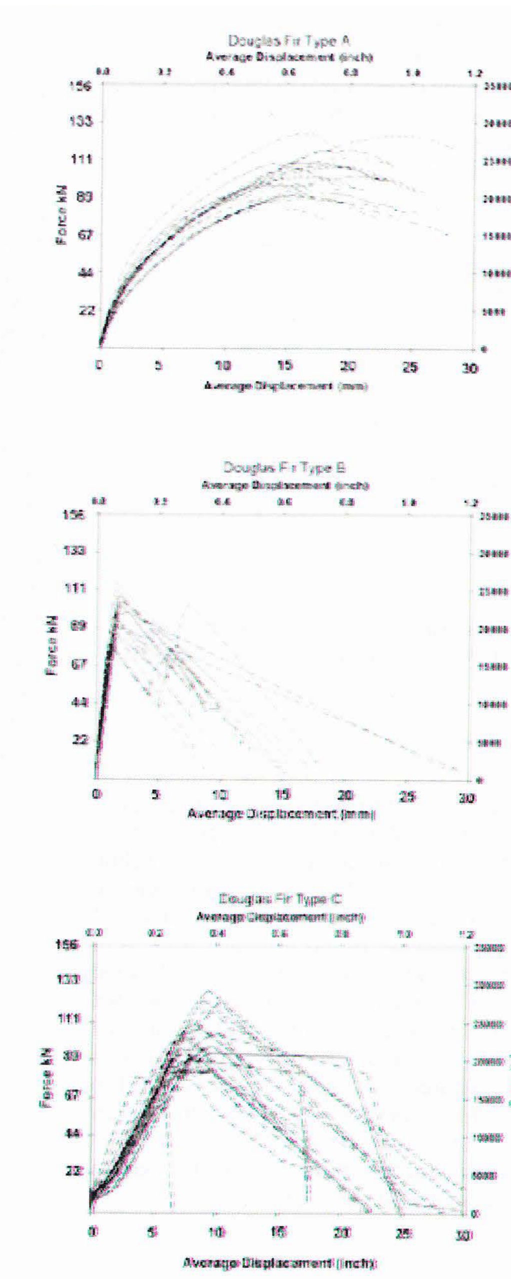

Figure 5: *Load deflection curves for Douglas Fir*

Table 1—Sumary of test results for connection systems

Species	Structural screws		Gussets (shear transfer)		Bolt-and-plates	
	Average (lbs)	Est. Design (lbs)*	Average (lbs)	Est. Design (lbs)	Average (lbs)	Est. Design (lbs)
Lodgepole pine	19,767+	8,215	20,138	6,775	22,613	11,600
Douglas fir	22,977	8,835	21,525	8,080	28,805	8,578

*Estimated non parametric 5th (lowest test value) divided by 2.1.
+This cell was limited to 21,000 lbs by test set up.

3.2 JOINT FAILURE MODES

The Type A bolt and plates method of connection proved to have some ductility but Douglas fir had a noticeably more brittle failure mechanism than the Lodgepole pine connections. The ductile nature of the Type A connection was directly a result of the gradual yielding of the multiple structural screws and thin plate used in this connection (Figure 6).

The Type B gusset connection failure was a direct result of a sudden shear failure which typically occurred at one end of the connections (Figure 7). The Type C bolt and steel plate connection tended to fail with a combination of the pin causing a wedge of material to fail in shear and the log to split (Figure 8).

***Figure** 6: The ductile yielding of Type A thin plates and bending of structural screws accounted for the ductile nature of the structural screw connection system*

***Figure 7:** Example of the Type B shear failures seen in the gusset style connection*

***Figure 8:** Typical Example of Douglas fir Type C bolt and plate connection failure*

4 CONCLUSIONS

Results showed that all three types of connections exceeded the anticipated design load. There were, however, significant differences between the ductility and deflection capacity. We would not recommend the gusset type fastener without further modifications. The thin plate Type A fastener did show promise as a rapid connection technique.

ACKNOWLEDGEMENT

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