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Effect of Species-type on Properties of Steam Pressed Scrim Lumber (SPSL)

Jonathan Linton,
Graduate Research Assistant, jlinton@cfr.msstate.edu,

H. Michael Barnes,
Thompson Professor of Wood Science & Technology
mbarnes@cfr.msstate.edu

R. Daniel Seale,
Professor of Forest Products, dseale@cfr.msstate.edu

Department of Forest Products
Mississippi State University

Abstract

Finding alternative uses for small diameter raw materials is a critical problem throughout the United States. Insufficient markets for small diameter, southern yellow pine (*Pinus* spp.) trees from first plantation thinnings are impacting silvicultural practices on millions of acres of land. In western states, the lack of markets for small diameter ponderosa pine (*Pinus ponderosa*) and lodgepole pine (*Pinus contorta*) creates multiple problems in terms of excess material in the forest. This excess material enhances fire potential and reduces land management practices. A pilot plant at the Mississippi State University Forest Products Lab was used to produce new structural composite beams from small diameter raw materials using a new technology called steam-pressed scrim lumber (SPSL). The process crushes small diameter logs into scrim and glues the scrim together using a chambered steam press to form the manufactured billets called steam-pressed scrim lumber. Small samples cut from the manufactured billets were tested to obtain physical and mechanical properties. Differences among species were noted and correlation with non-destructive test parameters is presented.

Keywords: steam-pressed scrim lumber, structural composite lumber, SPSL, lodgepole pine, ponderosa pine, static bending, internal bond strength, flexure properties, non-destructive parameters

INTRODUCTION

Finding alternative uses and/or markets for small diameter raw materials is a critical problem. In western states, lack of markets for small diameter lodgepole pine and ponderosa pine is impacting silvicultural practices on millions of acres of forests. Because many of these forests are so overstocked with small diameter trees, many have deteriorated to a point where their ability to meet current and future demand for forest products have been compromised (Wolfe 2000). This leads to many destructive problems such as; fire and insect attack, (Wang *et al*. 2003).

Wildfires in the western United States have always been a significant problem. Over the past decade, there has been a substantial increase in the number of these wildfires and the number of acres burned by them (Hill 1999). There are many factors that have attributed to this increase of wildfires. Severe drought conditions along with the long-term effects of a national wildfire suppression policy, has led to an unnatural buildup of brush and small trees in our forests (Levan-Green and Livingston 2001).

Insect attacks are also major problems in Western States. From 2001 to 2003, Arizona and New Mexico experienced a major bark beetle outbreak that attacked ponderosa pine stands that left the standing timber dead and prone to wildfire (Zausen 2005). Many experts believe that prolonged drought conditions and overstocked forests were the major contributors to the severe outbreak (Parker *et al.*2006). Thinning ponderosa and lodgepole pine stands would significantly help reduce the number of acres destroyed by wildfires and insect attack. Currently it is not economically feasible for landowners to thin trees, because they have little value in today's market.

A new engineered structural composite lumber product (SCL), steam pressed scrim lumber (SPSL), which utilizes small-diameter timber has been developed based on the Tim-Tek™ technology developed in Australia. If proven successful, it could be an option that would increase small-diameter timber prices that would make it economically feasible for landowners to thin overstocked stands, thus reducing wildfire and insect attack risks. The purpose of this study is to investigate the mechanical properties of small samples cut from structural beams made from small-diameter ponderosa and lodgepole pines.

METHODS AND MATERIALS

Beam/Sample Production

Initial work was done with fire-killed lodgepole and ponderosa small diameter stock. The resultant furnish produced by scrimming was of poor quality and was short in length. The resultant beams fabricated with this furnish were not suitable for testing. Consequently, lodgepole and ponderosa pine logs, ranging from 3-7 inches in diameter, were harvested in Oregon, end-coated, and shipped to Mississippi where they were they were stored under water spay until used. The storage period did not exceed one month. Logs were removed from water storage and debarked. The debarked logs were soaked in a hot bath at 130 °F for six hours prior to being sent through a scrimming mill where they were crushed and passed down the line to a series of scrimming heads of successively smaller size. These scrim mills produced scrim that was approximately 0.25 inches thick and 7-8 feet long. A demonstration of the technique can be seen at the following web address: http://www.cfr.msstate.edu/timtek/index.asp. A process description has been provided by Seale *et al*. (2006). After scrim production, the scrim was loaded into a kiln and dried to a nominal 20% moisture content. The dried scrim was then coated with a stage B resole phenol formaldehyde resin to yield 12% resin solids. The coated scrim was sent through a conveyor dryer to achieve a moisture content of 6% or less. The scrim was laid into a mat in a forming box to get the correct beam weight and form. The finished mat was loaded into a proprietary steam press and was pressed to form a rough beam measuring 1.75-in wide x 16.5-in deep x 18.5-ft long (Barnes *et al*. 2006). The rough beams were then trimmed to a final size of 1.75-in x 11.75-in x 18-ft. A total of nine lodgepole pine beams and eight ponderosa pine beams were produced from which test samples measuring 1.75- x 2.5- x 51-in were cut. A total of 160 lodgepole and 128 ponderosa samples were tested.

Non-Destructive Testing

Test samples were non-destructively graded using an Inspex™ x-ray inspection system. The samples were x-rayed to determine number and location of any low density areas. These areas of low density are formed during layup when scrim furnish bridges across pieces resulting in an uneven density mat. This causes parts of the scrim not to bond well with the other pieces that surround it and can cause a decrease in the mechanical properties of the sample. The x-ray procedure has been found to be effective for quality control of beams and was the topic of a poster presented at the Smallwood 2006 conference (Leng *et al*. 2006). Figure 1 shows an x-ray image taken from a set of samples. Number 1 shows a sample that does not contain any low density

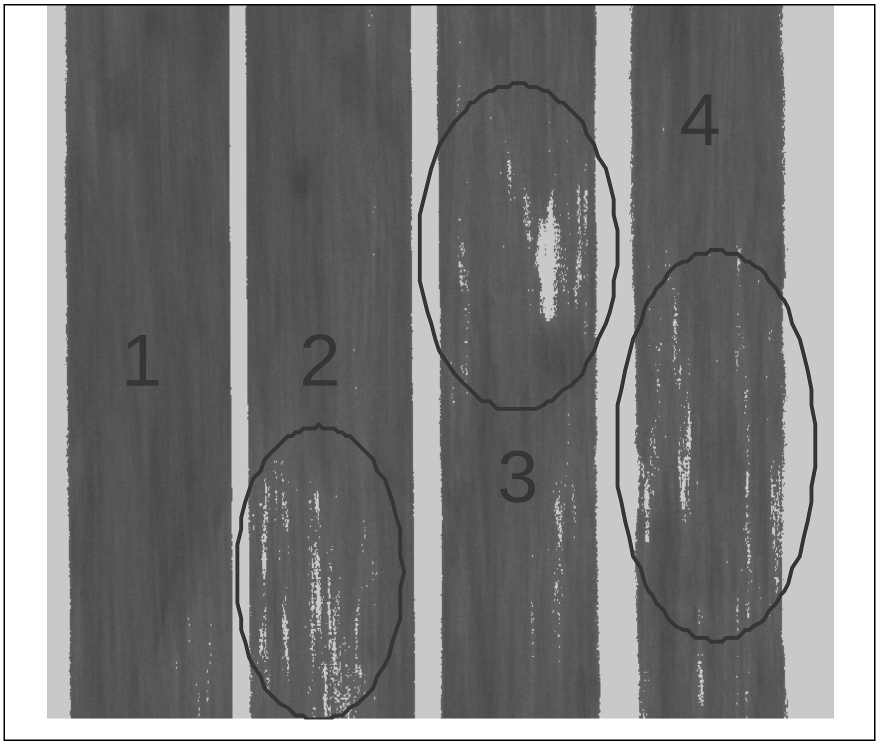

Figure 1. X-ray of SPSL beam showing areas of low density.

areas. The remainder shows samples that contain low density areas (indicated by circles) where the scrim mat was not formed properly and resulted in areas not bonded well.

Samples were also non-destructively tested using Falcon Engineering[1] A-grader (http://www.falconengineering.co.nz/products/grading.php), an instrument based on sonic resonance using compression wave technology. The A-grader measures both the density of the timber and speed of the sonic waves in the timber to produce a stiffness value for the timber.

Mechanical Testing and Analysis

After all non-destructive tests were completed; each sample was tested in static bending to determine the flexure properties. Testing was done using an Instron™ 5566 testing machine using center point loading bending tests according to ASTM D143. The span to depth ratio was 18, the span was 45 in, and samples were tested at a machine speed of 0.96 in/min. Bluehill™ software, version 2.3, was used to acquire the data. Modulus of rupture (MOR), modulus of elasticity (MOE), and work to maximum load (WML) were calculated for each sample. After the mechanical testing was completed, a moisture content and specific gravity block was cut out of each sample. Data were analyzed using analysis of variance and means were separated using Tukey's test (SAS 2008).

Results and Discussion

Non-destructive Evaluation

The use of x-ray to determine low density areas within the large beams was successful. It allowed us to take samples with reasonable density variation for testing. As a QC tool, it should prove invaluable in making sure high quality beams are supplied to the marketplace. An effort was made to correlate the stress wave timing results with the mechanical property values obtained from the testing program. Little correlation was found between property values and director output with one notable exception. When extreme outliers were excluded from the analysis, output from the Falcon director was reasonably correlated (R^2=79%) with modulus of elasticity (Fig. 2). This indicates that such a device may have some value in a quality control program.

Blows

Blows occur when scrim does not bond well, therefore separating when pressure is released from the press. This allows steam and other gases to escape. It is believed that when a sample contains blows, the mechanical properties are greatly reduced. Figure 3 shows a typical blow in a lodgepole pine sample. For samples tested, lodgepole pine samples had considerably more blows (155 out of 160) than did ponderosa pine (16 out

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[1] The use of trade names is for convenience of the reader only. Such use does not constitute endorsement by Mississippi State University over similar products equally suitable.

of 128). Given our success with beams made from southern pine, another hard pine, this result is somewhat surprising. The reasons for this are not entirely clear, especially given the almost identical anatomical characteristics of the two species. Additional research is required to determine the cause of this phenomenon. In all likelihood, it is process-related indicating that processing parameters will need to be altered to produce blow-free beams. We know that in scrimming lodgepole, the knots tend to stay in the scrim whereas with southern pine and ponderosa pine, the knots tend to fall out during the scrimming process. Lodgepole tends to produce scrim which stays intact rather than form discrete fiber bundles as with southern and ponderosa pines.

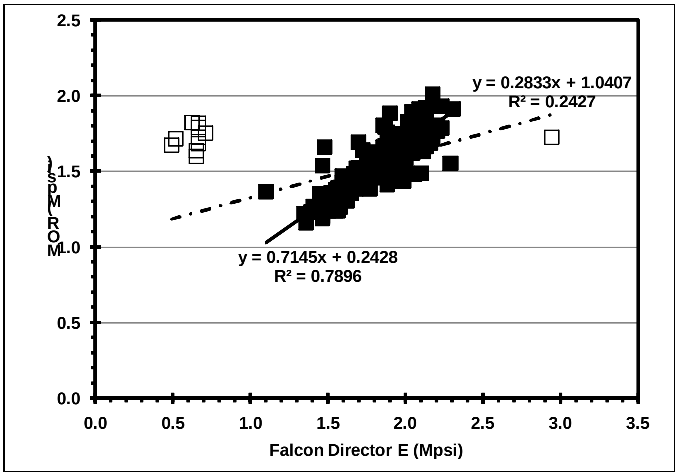

Figure 2. Correlation between MOE and Falcon Director output.

Figure 3. Typical blow in a lodgepole pine sample.

Moisture content and specific gravity

For lodgepole pine samples, the moisture content had a range of 5.8% to 9.0% with a mean of 7.9%. Ponderosa pine samples had an identical range a mean of 7.4%. Therefore, no correction to data for moisture content was required. Similar specific gravity distributions were found for both species so no correction was needed. Lodgepole pine samples ranged from 0.615 to 0.869 with a mean of 0.700. For ponderosa pine specific gravity had a range of 0.618 to 0.864 with a mean of 0.726. Moisture content and specific gravity distributions are shown in Fig. 4.

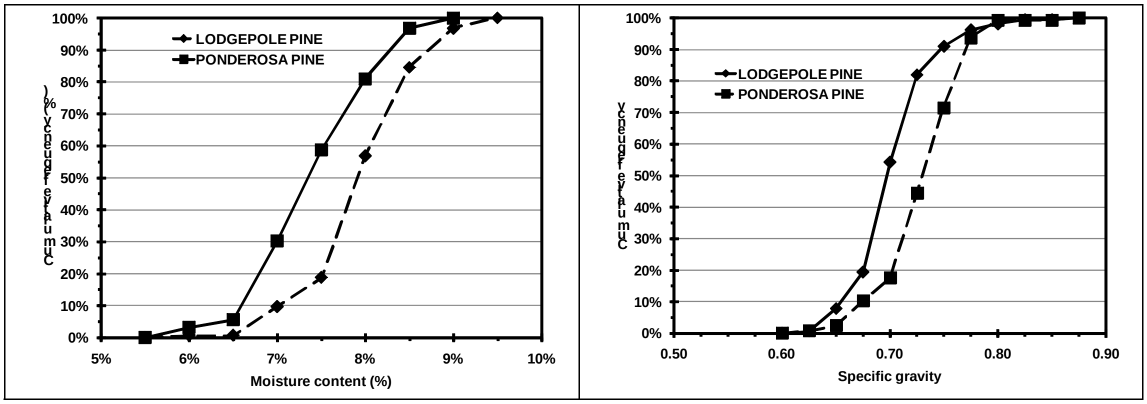

Figure 4. Distribution of moisture content and specific gravity for samples tested

Flexure Properties

A comparison of the various property values between species is shown in Table 1. As shown, the two species differed significantly in all three properties when all samples for each species were analyzed as a group. MOR and work values were higher for the ponderosa pine samples while lodgepole pine samples were stiffer. Within each species, the impact of the presence of blows can be seen in Table 2. Blows caused a reduction in MOR and MOE for ponderosa pine. No effect on WML was observed. For lodgepole pine, no effect was shown for any property. Some caution should be taken by the reader in interpreting these results since the numbers in each category differ widely by species.

When comparing across species (ponderosa *vs*. lodgepole) with and without blows, all properties were significantly different one from another (Table 3) with the exception that no difference between was found for the MOR of samples with blows.

Table 1. Comparison of mean mechanical property values between species[1]

Analysis	p-value	Ponderosa	Lodgepole
MOR (psi)	<0.0001	7,499 A	6,972 B
MOE (Mpsi)	<0.0001	1.392 B	1.663 A
WML (in-lbf/in^3)	<0.0001	2.42 A	1.75 B

[1] Means not followed by a common letter are significant different at p level indicated

The overriding trend shown in the data is that ponderosa SPSL tended to be stronger than lodgepole, while lodgepole SPSL was generally stiffer than that of ponderosa. Work values tended to be much lower than those found with solid wood of the same species. For comparison, the Wood Handbook (FPL 1999) gives a value of 7.1 in-lbf/in^3 for solid ponderosa pine compared with 2.5 in-lbf/in^3 for ponderosa SPSL found for material without blow. The corresponding values for lodgepole solid wood and SPSL are 6.8 and 1.4 in-lbf/in^3 respectively. Part of the reason for this is that SPSL exhibits very little plastic flow yielding stress-strain diagrams with almost no plastic region. Bending breaks tend to be more ceramic in nature as compared to solid wood.

Table 2. Effect of blows on properties by species[1].

Analysis	p-value	Blow	No blow	Blow	No blow
Ponderosa Pine					
MOR (psi)	0.0192	6,978	7,574	B	A
MOE (psi)	0.0132	1,322,374	1,402,358	B	A
WML (in-lbf/in^3)	0.1241	2.209	2.456	A	A
Lodgepole Pine					
MOR (psi)	0.1874	6,990	6,413	A	A
MOE (psi)	0.0828	1,659,984	1,758,354	A	A
WML (in-lbf/in^3)	0.0503	1.7634	1.354	A	A

[1] Means are significantly different at p level indicated

Table 3. Comparison of species with and without blows.[1]

Analysis	P-value	Ponderosa	Lodgepole	Ponderosa	Lodgepole
Between species with blows					
MOR (psi)	0.9619	6,978	6,990	A	A
MOE (psi)	<0.0001	1,322,374	1,659,984	B	A
WML (in-lbf/in^3)	0.0003	2.209	1.763	A	B
Between species without blows					
Analysis	**P-value**	**Ponderosa**	**Lodgepole**	**Ponderosa**	**Lodgepole**
MOR (psi)	0.0095	7,574	6,413	A	B
MOE (psi)	<0.0001	1,402,358	1,758,354	B	A
WML (in-lbf/in^3)	0.0001	2.456	1.354	A	B

[1] Means not followed by a common letter are significant different at p level indicated

CONCLUSIONS

The purpose of this research was to evaluate the difference in bending properties of small samples taken from structural beams of a new class of SCL called steam-pressed scrim lumber made using lodgepole and ponderosa pine. Properties of SPSL made from the two species compared favorably with ponderosa being stronger and lodgepole being stiffer. Processing parameters will need to be optimized in order to produce beams without blows, especially with lodgepole pine.

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