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PHYSICAL AND MECHANICAL PROPERTIES EVALUATIONS OF A NEW ENGINEERED WOOD PRODUCT

By

Jonathan Michael Linton

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Submitted to the Faculty of
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in Partial Fulfillment of the Requirements
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in Forest Products
in the Forest Products Department

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PHYSICAL AND MECHANICAL PROPERTIES EVALUATIONS OF A NEW ENGINEERED WOOD PRODUCT

By

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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. This research deals with a new structural composite from small diameter raw logs using a technology called steam-pressed scrim lumber (SPSL). Mechanical and physical properties were performed and evaluated for each species. This research was conducted to evaluate these properties and to determine the suitability for commercialization.

Key words: steam-pressed scrim lumber, mechanical properties, southern pine, lodgepole pine, ponderosa pine

DEDICATION

To my wife Ashley; your constant love and support gave me the confidence and encouragement to pursue this dream.

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I would like to express gratitude to everyone within the Forest Products Department at Mississippi State University who helped make this dream a reality. Special thanks to my two major professors, Dr. Dan Seale and Dr. Mike Barnes. Their patience and guidance throughout this research was instrumental in its successful completion. I would also like to express thanks to Dr. Rubin Shmulsky for his leadership and guidance throughout my time within the department. I would also like to express thanks to Mr. John Black, TimTek Plant Superintendent, for his support during the manufacturing process.

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CHAPTER I

INTRODUCTION

The Forest Products industry has seen many changes through the decades. Many solid-sawn wood products have been replaced by engineered wood products which can utilize small diameter, plantation grown timber. In the south, landowners have little incentive to conduct first thinnings of their plantation timber. In western states, lack of markets are impacting silvicultural practices on millions of acres causing a surplus of small diameter timber. Steam-pressed scrim lumber (SPSL) is a new engineered wood product that utilizes this small diameter timber and converts it to a finished product.

The Forest Products Industry

The state of the United States and world economies has impacted the forest products industry through the decades. One of the key drivers of the industry is housing starts. Housing starts refer to the number of privately owned housing units on which construction has been started within a given period of time. Figure 1.1 shows yearly housing starts for the United States from 1990 - 2008. This data shows an upward trend in housing starts until 2005/2006 when the housing market started to decline. Soon after the decline in the housing market, the United States entered a recession.

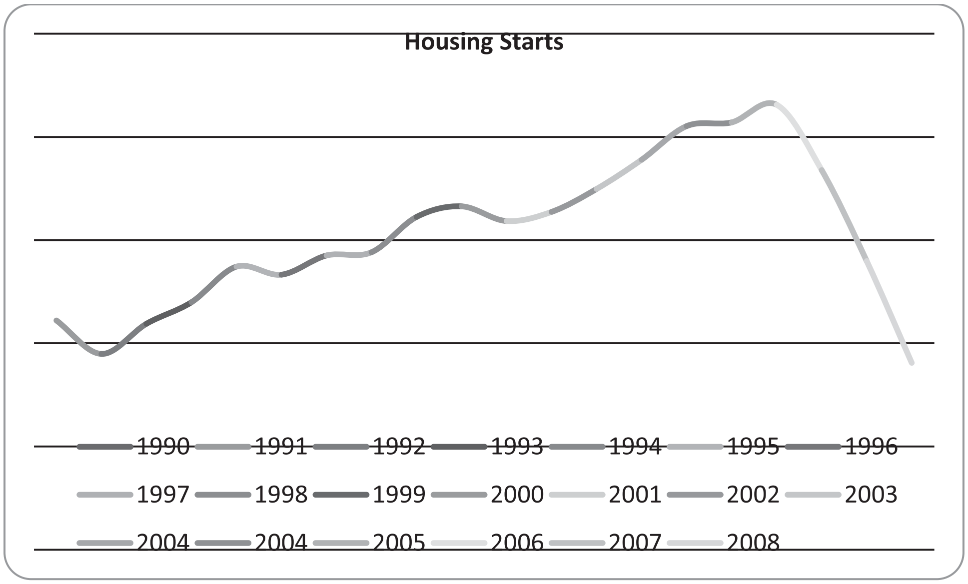

Figure 1.1

Yearly housing starts (United States Census Bureau 2009a)

Not only has the forest products industry seen a steady increase in housing starts, but the size of homes has increased as well. In 1978, only 30% of new homes were greater than 2000 square feet. In 2007, this number was 62%. Additional square footage data can be found in Figure 1.2. With this upward trend in square footage, the forest products industry has had to make a dramatic switch in the material supplied for construction due to the fact that old growth timber no longer exists for commercial purposes in the United States (Guss 1995). Modern day engineered wood products no longer require old, mature growth timber, but must be able to utilize small diameter, plantation grown timber that the industry had previously been unable to use.

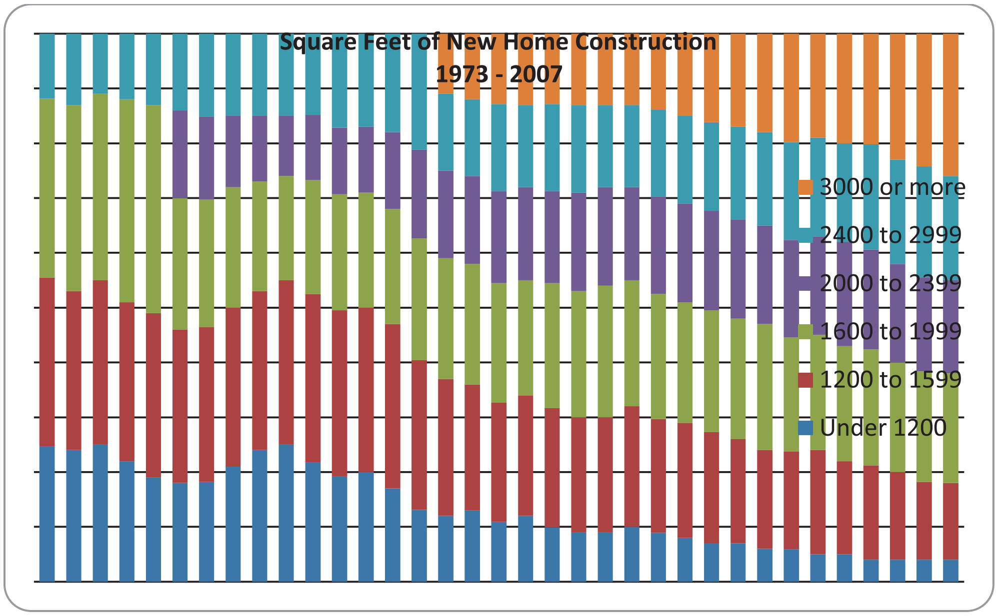

Figure 1.2

Square feet of new home construction 1973 – 2007 (US Census Bureau 2009 b)

Small Diameter Timber

Throughout the 20th century, forest product industries were able to rely on an abundant supply of large diameter, old growth timber to produce large volumes of solid-sawn wood products (Lam 2001). As the industry neared the latter years of the century, this large diameter timber had become almost non-existent in both the southern and western United States (Covington and Moore 1994) (McKeever 1997). To combat this emerging issue in the south, many companies began planting pine plantations on clearcut sites, as well as, former agricultural fields. One of the problems companies encountered was plantations did not produce the large diameter timber that was previously used, but instead contained small diameter, fast grown wood. This wood contained more juvenile wood which reduced the overall physical and mechanical properties of the timber (Bendtsen 1978) (Zhang 1995) (Bao et al. 2001).

Small diameter timber has also become an issue in western states. This problem was caused by years of fire suppression and minimal self-thinning (Erikson et al. 2000). Willits *et al*. (1996) performed a study on western forests that showed that unthinned stands of timber had minimal large diameter (>20 in.) timber even after 150 years. This timber is prone to forest fires (Pollet and Omi 2002) and bark beetle epidemics (McHugh et al. 2003).

Engineered Wood

During the last decade of the 20th century, consumers made a dramatic switch to engineered wood products. Much of this was due to the changing nature of the softwood fiber supply in all regions of the United States (Schuler et al. 2001).

Plywood is generally considered the original engineered wood product (Guss 1995). Its uses can be traced back for centuries, first used by the ancient Egyptians and later utilized by the Greeks and Romans. Plywood was not commercially manufactured until the early 1900's in the Pacific Northwest. This early commercially manufactured plywood was produced using large, old-growth timber, but as the softwood timber supply changed, so did the type of log the manufacturers had to use (Sellers 1985). The physical make-up of plywood requires it to be produced from mature wood. Although manufactures were using smaller logs, they still contained enough mature wood that product quality wasn't severely impacted.

As high quality lumber became more difficult to obtain, several new types of engineered wood were introduced. Several of these types of products can be classified as structural composite lumber or SCL. Laminated veneer lumber (LVL), laminated strand lumber (LSL), parallel strand lumber (PSL), and oriented strand lumber (OSL) are all products that are in this classification. SCL products can be characterized by having their raw materials being smaller pieces of wood that are glued together and pressed into dimensions common to solid-sawn lumber (USDA 2007).

New products were also introduced on the panel side of the industry to combat the small timber issue. These products include oriented strand board (OSB), particleboard, and medium density fiberboard (MDF). These products either utilize small-diameter trees, OSB, or bi-products from other wood processing plants, MDF and particleboard (USDA 2007). While these products were able to use small-diameter trees and small amounts of juvenile wood, the industry was still faced with the growing problem of an over abundance of juvenile wood.

As the problem with juvenile timber continued to grow across the United States, the industry searched for a sustainable, value-added product that would fight this ever-growing issue. Around this same time a new technology called TimTek was being developed in Australia. The emphasis in developing TimTek was utilization of this low-value pulpwood-size raw material that was previously unused to manufacture a high-strength, engineered lumber product (SCL). SPSL, which utilizes small-diameter timber, has been developed based on the TimTek technology to produce products for use in residential and home construction.

Purpose

The purpose of this research is to evaluate mechanical and physical properties on SPSL which is a new engineered wood product. SPSL uses TimTek technology to manufacture a high density, high strength product using small diameter timber. Two studies were performed for this research. The first study utilized small diameter southern yellow pine (*Pinus spp*.) timber from first plantation thinnings. The second study focused on small diameter lodgepole (*Pinus contorta*) and ponderosa (*Pinus ponderosa*) timber. Physical and mechanical tests, as well as, non-destructive tests were also performed on these sample billets in both studies. Differences in species were noted in the latter study. The thesis is written as a series of complete articles conforming to the style of the Forest Products Journal followed by a section summarizing the two studies and the literature cited in the general introduction above.

Literature Cited

Bao, F.C., Z.H. Jiang, X.M. Jiang, X.X. Lu, X.Q. Luo, and S.Y. Zhang. 2001. Differences in wood properties between juvenile wood and mature wood in 10 species grown in China. Wood Science and Technology 35(2001):363-375.

Bendtsen, B.A. 1978. Properties of wood from improved and intensively managed trees. Forest Products J. 28(10):61-72.

Covington, W.W., and M.M. Moore. 1994. Southwestern Ponderosa forest structures. Journal of Forestry 92(1):39-47.

Erikson, R.G., T.M. Gorman, D.W. Green, and D. Graham. 2000. Mechanical grading of lumber sawn from small-diameter Lodgepole pine, Ponderosa pine, and grand fir trees from northern Idaho. Forest Products Journal 50(7/8):59-65.

Guss, L. 1995. Engineered wood products: The future is bright. Forest Products Journal 45(7-8):17-23.

Lam, F. 2001. Modern structural wood products. Progress in Structural Engineerein and Materials 3:238-245.

McHugh, C.W., T.E. Kolb, and J.L. Wilson. 2003. Bark beetle attacks on Ponderosa pine following fire in northern Arizona. Environmental Entomology 32(3):510-522.

McKeever, D.B. 1997. Engineered wood products: A response to the changing timber resource. Pacific Rim Market Report. No. 123, November, p 5,15.

Pollet, J. and P.N. Omi. 2002. Effect of thinning and prescribed burning of wildfire severity in Ponderosa forests. International Journal of Wildland Fire 11:1-10.

Schuler, A., C. Adair, and E. Elias. 2001. Engineered lumber products: Taking their place in the global market. Journal of Forestry 92(12):28-35.

Sellers, T. 1985. Plywood and Adhesive Technology. Marcel Dekker, New York, NY. 661 p.

United States Census Bureau. 2009a. New privately owned housing units authorized by building permits in permit-issuing places. www.census.gov/const/www/newresconstindex.html (accessed August 8, 2009).

United States Census Bureau. 2009b. Square feet of floor area in new one-family houses completed. www.census.gov/const/C25Ann/sftotalsqft_2007.pdf. (accessed October 15, 2009).

USDA. 2007. The Encyclopedia of Wood. United States Department of Agriculture. pp 10.13 – 11.9.

Willits, S., R.J. Barbour, S. Tesch, D. Ryland, J. McNeel, R. Fight, S. Kumar, G. Myers, B. Olson, and A. Mason. 1996. The Colville Study: Wood utilization for ecosystem management – Preliminary results of study of product potential from small-diameter stands. Res. Pap. FPL-RP-559. Madison, WI: USDA, Forest Service, Forest Products Laboratory. 11 p.

Zhang, S.Y. 1995. Effect of growth rate on wood specific gravity and selected mechanical properties in individual species from distinct wood categories. Wood Science and Technology 29 (6):451- 465.

CHAPTER II

PROPERTIES EVALUATION OF A NEW ENGINEERED WOOD PRODUCT, STEAM-PRESSED SCRIM LUMBER

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. A pilot plant at was used to produce new structural composite beams from small diameter raw materials using a new technology to produce a structural composite lumber (SCL) product called steam-pressed scrim lumber (SPSL). Full-sized beams and small samples cut from the manufactured billets were tested to obtain physical and mechanical properties. MOR, MOE, tension, and compression perpendicular-to-the-grain properties were obtained. Adjustment factors for each property were calculated to achieve design stress values.

Introduction

Finding alternative uses and/or markets for small diameter raw materials is a critical problem. In the South, lack of markets for southern yellow pine (*Pinus spp.)* pulpwood is impacting silvicutural practices on millions of acres of pine plantations.

Silvicultural treatments such as thinnings and stand improvements promote increased growth, size, and value of the remaining trees. These treatments would be more economical if there were viable markets for the removed material (Han 2006). Economical and value added uses for small-diameter timber can help offset forest management costs and provide economic opportunities for many small, forest based communities, but the variability and lack of predictability of the strength and stiffness of juvenile timber can cause problems in many engineering applications (Wang 2003).

Juvenile wood differs from mature wood in that it has a lower percentage of summerwood, lower specific gravity, shorter tracheids with larger fibril angles, and occasionally disproportionate amounts of compression wood, distorted grain patterns, and pitch deposits (Larson 2001). There is no definite line of demarcation between juvenile and mature wood within an individual tree, the transition from juvenile to mature wood gradually takes place over several years, but is thought to generally take place over a period of 10 years (Pearson and Gilmore 1971). The strength of juvenile wood is inferior to that of mature wood. The specific gravity of juvenile wood is significantly lower and the micro fibril angle in the critical S-2 layer of the fiber is steeper. This results in greater longitudinal shrinkage and lower strength and stiffness properties (Lulay and Galligan 1981). Bendtsen and Senft (1986) conducted a study of plantation-grown loblolly pine (*Pinus taeda L.*) to see how MOE values are affected by the presence of juvenile wood. They discovered there was a 5-fold increase in MOE values from juvenile wood to mature wood with one tree showing a 10-fold increase. MOR values are also affected by juvenile wood. In another study by Pearson and Gilmore (1971), MOR values were shown to increase by approximately 50% from juvenile wood to mature wood.

Kretschmann and Bendtsen (1992) conducted a study to see how ultimate tensile stress was affected by juvenile wood for fast-grown plantation loblolly pine lumber. They found that the average ultimate tensile stress in lumber containing juvenile wood was nearly half as much as lumber composed entirely of mature wood. Kretschmann (1997) also conducted a study to determine the effects juvenile wood has on compression perpendicular-to-grain strength properties of loblolly pine lumber. Loads applied to the radial face of the sample were more sensitive to changes in juvenile wood content than loads applied to the tangential face.

Juvenile wood can significantly decrease the performance of many wood products (Pugel 1989). With the expected increase of demand for forest products, most of the future timber supply will come from managed plantation-grown trees (Kretschmann 1997). A new engineered structural composite lumber product (SCL), steam pressed scrim lumber (SPSL), which utilizes small-diameter timber from first plantation thinnings has been developed based on the Tim-Tek™ technology developed in Australia. The purpose of this research was to characterize the mechanical properties for SPSL and determine design stress values for this new type of SCL.

Materials and Methods

Furnish

Juvenile southern yellow pine trees from young plantations were harvested from east central Mississippi and west central Alabama. Logs measuring 79-178 mm in diameter were harvested, cut into 244 cm and debarked representing the first step in a production process for beams.

Beam Production

Debarked logs were soaked in a hot water bath at 54-60°C for six hours. The hot logs were then sent through five crushing and cracking mills where longitudinal cracks were formed over the length of the work piece. After the crushing and cracking mills the blocks passed down the scrim line where a series of scrimming heads of successively smaller size refine the cracked blocks into scrim. These scrim mills produced scrim that was approximately 6-7 mm thick and 2.1-2.4-m long (for a demonstration of the technique see http://www.cfr.msstate.edu/timtek/index.asp) (Anon 2006). Beam production and the scrimming process have been described by Barnes *et al*. (2006) and Seale *et al.* (2006). The scrim was kiln-dried to a nominal moisture content of 20% at 80 °C with no wet bulb control followed by spraying with a stage B resole phenol formaldehyde resin to yield 12% solids. The scrim was re-dried in a commercial conveyor drier at 115 °C to 6% moisture content or less. Following hand forming by students employing random lay-up techniques, the beams were consolidated in a proprietary steam press. The press is a unique steam chamber technology but it is serial number 1 and has some inherent design problems that impact billet properties. The design problems are associated with the side dams and two distinct problems are created. The first problem is the side dams are made from a material that is not stiff enough to produce a billet with strait edges. As a result the width of each billet varies along the length resulting in density variation. The second problem, also associated with the side dams, is associated with the closure rate of the dams. The side dams close via a cam mechanism that controls the side dam position as the top platten closes. As constructed, the side dams allow billet raw material to escape between the side dam and top platten creating billet edges that may be lower in density than the overall density target of the billet. These density variation impacts interact to effectively lower the bending properties of the product. The rough beams were trimmed to a final size of 44.5- x 298-mm x 5.5-m.

Non-destructive Evaluation

The finished beams were non-destructively evaluated using an Inspex™ x-ray inspection system to determine if there were any low density areas (LDA's) in them. These LDA's are formed during the random lay-up process when scrim is placed in the mat in a non-uniform manner. A non-uniform mat results in localized areas with wide density variation that creates variation in mechanical properties of finished products. Commercial production of the SPSL would utilize a non-random mechanical lay-up to minimize density variation in the product. A simulated mechanical lay-up was tested and found to virtually eliminate LDA's, but the time required to produce billets using the simulated lay-up would not have permitted completion of the project on time or budget. Thus, using x-ray scanning technology enabled the location of LDA’s, subsequent determination of cut up parameters to allow random lay-up billets simulate non-random mechanical lay-up billets in terms of density uniformity. We discovered that determination of where and how each piece will break by looking at the x-ray is possible. Figure 2.1 shows the x-ray images taken from a set of samples. Number 1 shows a sample that does not contain any LDA’s. This is an example of a sample that would be sent to be tested. Numbers 2, 3, and 4 show typical samples rejected because of LDA’s in each piece. The light areas in each piece indicate LDA locations. After the initial x-ray scans are done, the beams were cut into selected sample sizes. It is anticipated that x-ray technology would be employed by SPSL manufacturers as a check to ensure that mechanical lay-up systems are performing as designed.

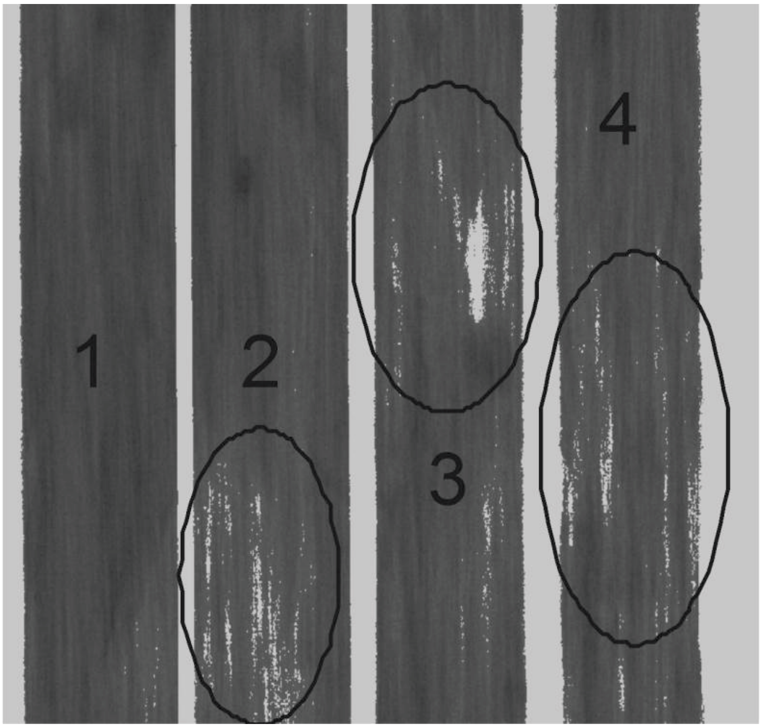

Figure 2.1

Typical x-ray picture of low density areas (LDA's)

Sampling and Testing

Two groups of samples were sent to APA-The Engineered Wood Association for certification. The first set contained full-sized beams measuring 44- x 286-mm x 5.3-m samples. The second set contained small sized samples of different depths cut from the larger parent beams. All samples were nominally 44 mm in width. Samples were tested using ASTM standard D 4761 (2007) using third point loading in bending to determine modulus of rupture (MOR) and modulus of elasticity (MOE). All bending samples were tested on an 18 depth/span ratio. Both depth and volume effects were determined. Sample sizes and information are given in Table 1. Tension tests were also conducted in the fiber direction using ASTM D 4761 (2007) (see Table 1). Compression testing was conducted in both along and across the fiber direction using ASTM D 4761 (2007). The compression tests had sample sizes of 1.5-in x 6-in, 2-in x 6-in, and 2-in x 8-in. The spans for these tests were the same as the lengths for each sample.

Table 2.1

Sample dimensions for D 4761 testing.

Test	Depth (mm)	Length (m)	Span (m)
Static bending	63.5	1.30	1.14
	89.9	1.75	1.60
	184.2	3.47	3.31
	285.8	5.30	5.14
			Gauge length (m)
Tensile testing	63.5	2.13	0.61
	63.5	2.74	1.22
	63.5	3.96	2.44
	63.5	4.88	3.35

Data Handling

Design values were calculated for the various mechanical properties using ASTM D5456 (2004).

Results and Discussion

The results presented here are associated with billets produced at Mississippi State University using random lay-up techniques.

Static Bending

Using the MOE and MOR values from the static bending tests in Table 2.2, we were able to calculate the design stress values for SPSL. ASTM standard D 5456 contains a table with adjustment factors for different mechanical properties of wood. Table 2.3 contains each property and its associated adjustment factor.

Table 2.2

Average values for mechanical properties by beam depth

	MOE/10^6 (psi)	**MOR (psi)**
63.5 mm depth		
Number of Samples	78	78
Mean	2.43	8,663
Maximum	2.79	11,566
Minimum	1.99	6,380
COV %	7.6	11.7
89.9 mm depth		
Number of Samples	36	36
Mean	2.45	7,704
Maximum	2.88	9,872
Minimum	1.94	5,965
COV %	9.2	13.4
184.2 mm depth		
Number of Samples	20	20
Mean	2.57	7,490
Maximum	2.81	8,728
Minimum	2.28	5,921
V COV %	6.1	12.3
285.8 mm depth		
Number of Samples	20	20
Mean	2.22	5,871
Maximum	2.46	6,972
Minimum	1.92	5,111
COV %	6.6	8.8

Table 2.3

Adjustment factors (ASTM 2004)

Property	Adjustment Factor
Apparent modulus of elasticity	1.00
Bending strength	2.10
Tensile strength parallel to grain	2.10
Compressive strength parallel to grain	1.90
Longitudinal shear strength	
Shear block test	3.15
Structural-size shear test	2.10
Compressive strength perpendicular to grain	1.67

Using these adjustment factors we are able to calculate our design stress values by dividing each value by the associated adjustment factor. Table 2.4 contains the design stress values for static bending tests conducted on SPSL.

Table 2.4

Design stress values for SPSL.

Sample Size	MOE/10^6 (psi)	MOR (psi)
2.5 x 51	2.43	4125.10
3.5 x 69	2.45	3668.50
7.25 x 136.5	2.57	3566.88
11.25 x 208.5	2.23	2795.91

After reviewing MOR values, it was noticed that as depth increased, MOR values decreased. This can most likely be attributed to a depth effect. The theory of depth effect states that as depth of a test specimen becomes larger, there will be a decrease in mechanical property values. This theory is based on the notion that as depth increases, there is an increased chance that there will be some form of defect within the test specimen and this will cause a decrease in mechanical property values.

It was also noted that there was a sharp drop off of the MOR value for the 285.5 mm test sample. After further review of the data, it was discovered that the 285.5 mm test samples were manufactured several months before the other three sample lengths. During the period between these manufacturing dates, operating procedures, specifically press operations, were refined. This allowed us to produce a higher quality, stronger product for testing. To test the theory of depth effect on MOR values, a set of six beams were produced and tested at MSU. Results showed that there was a substantial increase in MOR values for the 285.5 mm tests using the refined operating procedures. Figure 2.2 shows the linear relationship of MOR values and depth effect.

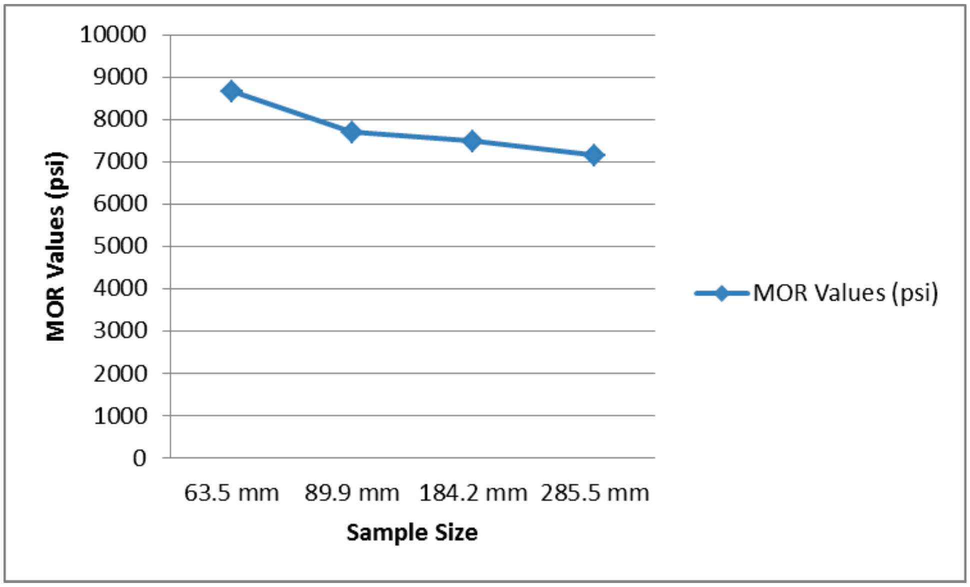

Figure 2.2

Linear relationship of MOR values and depth effect

Tension

Tension tests were conducted on four different gauge lengths; two feet, four feet, eight feet, and eleven feet, to achieve tensile stress values. Table 2.5 shows the mean, maximum, and minimum values along with the coefficient of variation (COV). Much like the static bending tests, an adjustment factor was applied to each of these properties. Table 2.3 shows the adjustment factor for tension to be 2.1. Table 2.6 shows the design stress values for tension properties after the adjustment factor is applied.

Table 2.5

Tension properties for SPSL.

Number of tests	**2 ft. gauge length**	**4 ft. gauge length**	**8 ft. gauge length**	**11 ft. gauge length**
	30	78	36	31
Mean	6,353	5,846	5,544	5,593
Maximum	7,663	7,809	6,784	6,598
Minimum	4,996	3,993	4,280	4,556
COV %	10.70	13.80	12.20	8.50

Table 2.6

Design stress values for tension properties of SPSL.

	2 ft. gauge length	**4 ft. gauge length**	**8 ft. gauge length**	**11 ft. gauge length**
Mean	6,353	5,846	5,544	5,593
Adjustment factor	2.10	2.10	2.10	2.10
Design Stress Value	3,025	2,784	2,640	2,663

Compression

Compression tests were conducted to achieve fcp values for SPSL. Tests were conducted in the perpendicular to the grain direction, both edgewise and flatwise. Values were recorded for each test at both 0.02-in. and 0.04-in. Results for each test can be seen in Table 2.7. There was also an adjustment factor applied to each test so that a weighted design stress value could be achieved. These design stress values are what test evaluations are based on. For compression properties, the adjustment factor is 1.67.

Table 2.7

Design stress values for compression properties of SPSL.

	Edgewise 0.02"	**Edgewise 0.04"**	**Flatwise 0.02"**	**Flatwise 0.04"**
Number of tests	30	30	30	30
Mean	1,471	2,466	1,124	2,022
Maximum	1,940	3,053	1,666	2,971
Minimum	1,000	1,779	757	1,408
COV %	15.9	13.4	21.6	20.4
Design Stress	881	1,476	673	1,211

After the compression values were evaluated further, it was noted that if you take the difference between the 0.04” and 0.02” values for both edgewise and flatwise, the values are relatively close to the 0.02” values. This relationship tells us that even as the compression test continues, the mean values stay the same for each 0.02” that is tested. It can be concluded from this discovery within the results that the samples are consistent and uniform in nature throughout the product.

Conclusions

The purpose of this research was to obtain the mechanical and physical properties of a new engineered wood product, SPSL, and apply an adjustment factor to them to find the design stress values. In this study, a new process using juvenile wood from first plantation thinnings was used to make structural beams. The SPSL process that crushes small diameter logs into scrim, resin is applied, and the scrim is pressed together to form a structural beam. These beams were then cut into various sample sizes and sent to the APA in Tacoma, Washington, for testing. Static bending, tensile strength, and compression perpendicular to the grain test were conducted to achieve the mechanical properties. After testing, the data was then sent back to the Forest Products Lab for analysis.

After data analysis, it was determined that each sample passed APA guidelines and certification tests. MOR and MOE samples were determined to be comparable, and in many cases exceeding, values for products already commercially available. Tensile stress values and compression perpendicular to the grain values also met expectations and are comparable to commercially available products.

SPSL was shown to be a product that can compete in today's market. Trees from first plantation thinnings typically have little value in today's market, but with forest products available such as, SPSL, landowners will be able to get more out of their investments in a shorter period of time. With increased value of small-diameter timber, landowners will be more apt to practice proper silvicultural practices on plantations which will promote increased growth, size, and value for the remaining trees.

Acknowledgements

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Literature Cited

American Society for Testing and Materials. 2004. Standard D 5456-03 Standard specification for evaluation of structural composite lumber products. ASTM Book of Standards, Vol. 4.10 Wood, West Conshohocken, PA, pp. 581-610.

American Society for Testing and Materials International. 2007. Standard ASTM D 4761-05 Standard test methods for mechanical properties of lumber and wood-base structural material. ASTM, West Conshohocken, PA.

Anon. 2006. MSU and TimTek: A partnership for utilization of small diameter tress. www.cfr.msstate.edu/timtek/index.html (June 14, 2007).

Barnes, H.M., Slay, R. A., Seale, R. D., Lindsey, G. B., 2006. Treatability of steam-pressed scrim lumber-SPSL. Proceedings, American Wood Protection Association 102:68-72.

Bendtsen, B.A. and J. Senft. 1986. Mechanical and anatomical properties in individual growth rings of plantation-grown eastern cottonwood and loblolly pine. Wood and Fiber Science. 18(1):23-28.

Han, G., Q. Wu, J. Lu. 2006. Selected properties of wood strand and oriented strandboard from small-diameter southern pine trees. Wood and Fiber Science 38(4):621-632.

Kretschmann, D.E. 1997. Effect of juvenile wood on shear parallel and compression perpendicular-to-grain strength of loblolly pine. *In*: Proceedings of the CTIA/IUFRO International Wood Quality Workshop; Aug. 18-22, 1997; Quebec City, Canada; Sainte-Foy, Quebec, Forintek-Canada Corp; p. VI-23 to VI-30.

Kretschmann, D.E., B.A. Bendtsen. 1992. Ultimate tensile stress and modulus of elasticity of fast-grown plantation loblolly pine lumber. Wood and Fiber Science 24(2):189-203.

Larson, P.R., D.E. Kretschmann, A. Clark, J.G. Isebrands. 2001. Formation and Properties of juvenile wood in southern pines: A Synopsis. General Technical Report FPL-GTR-129, USDA Forest Products Lab, Madison, WI, 42 pp.

Lulay, R., and W. Galligan. 1981. The impact of juvenile and compression wood on lumber from small logs. Western Dry Kiln Clubs. Mill City, OR.

Pearson, R.G. and R.C. Gilmore. 1971. Characterization of the strength of juvenile wood of loblolly pine. Forest Products J. 21(1):11-14.

Pugel, A.D., E. W. Price, C.Y. Hse. 1989. Composites from southern pine juvenile wood. Part1. Panel fabrication and initial properties. Forest Products J. 40(1):29-33.

Seale, R. D., Sellers, Jr., T., Barnes, H. M., Shi, S. Q., Black, J., Leng, J., 2006. TimTek– a new engineered product made from small-diameter trees, Smallwood 2006, Forest Products Society, May 16-18, 2006, Richmond, VA, USA, http://www.forestprod.org/smallwood06seale.pdf (10 September 2008)

Wang, X., R.J. Ross, J. Punches, R.J. Barbour, J.W. Forsman, and J.R. Erickson. 2003. Evaluation of small-diameter timber for valued-added manufacturing-A stress wave approach. *In*: Proceedings, second international precision forestry symposium; June 15-17 2003; Seattle, WA, University of Washington Insitute of Forest Resources; Seattle, WA, p. 91-96.

CHAPTER III

USING LIVE AND FIRE-KILLED SMALL DIAMETER PONDEROSA AND LODGEPOLE PINE IN MANUFACTURING TIM TEK

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 lumber (SCL) beams from small diameter raw materials using a new technology called steam-pressed scrim lumber (SPSL). Based on the TimTek technology developed in Australia, the process crushes small diameter logs into scrim and glues and presses the scrim together to form SCL in a chambered steam press to form the manufactured billets called steam-pressed scrim lumber. Both green and fire-killed ponderosa and lodgepole logs were used in this study. Structural beams were manufactured and were both non-destructively tested and destructively tested for bending properties. The data was the

analyzed to find correlations in tests and species. Differences among species were noted and correlation with non-destructive test parameters is presented.

Introduction

A history of fire suppression, changes in the intensity and type of land management activities being performed on forest land, and prolonged periods of climatic change (e.g., drought) have contributed to conditions in national forests leading to an unnatural buildup of brush and small trees (Levan-Green and Livingston 2001). These conditions make stands prone to disturbances such as insect epidemics and uncharacteristically severe wildfires. These densely stocked stands of live and dead trees have compromised the ability of these forests to meet current and future demand for solid wood products (Wolfe 2000). Reducing stand density by thinning suppressed trees could restore them to a more natural state, improve resiliency to attack by insects, and reduce adverse effects from fire. 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 (*Pinus* contorta) and ponderosa pine (*Pinus* ponderosa*)* is impacting silvicultural practices on millions of acres of forests.

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 wildfires and the acreage burned by them (Hill 1999). There are many factors that have contributed 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 and 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 (Parker *et al.* 2006). Canada is experiencing an outbreak of mountain pine beetle attacking lodgepole pine that is predicted to move into the U.S. in the near future.

Both fire and insects affect the quality of wood and utilization opportunities when harvested. At a basic level, heat from the fire can cause significant changes in wood. The outer surface of the stem, or the wood immediately under the bark, is probably most affected with the effect decreasing towards the pith. The depth of thermal effect is a function of the properties that affect internal heat and the intensity of the fire. The temperature would logically be most elevated where the stem is small, the bark thin, and boundary temperatures most severe and long lasting. For wood scientists, this effect might be observed as changes in wood properties, while for foresters and entomologists, the effect might be observed as delayed tree mortality, post-fire insect activity, and rate of deterioration of standing injured and dead trees.

Fire-damaged and fire-killed trees provide host material to a number of deterioration agents including, but not limited to, numerous insect species and decay and stain fungi. Beetles are vectors of stain and decay fungi. Infestations typically will follow fire and are not confined to trees that have been killed by the fire. Many species will attack stressed trees and even adjacent green trees leading to an increase in mortality. What is lacking is information on the suitability of dead or dying trees as an input raw material for several new and emerging wood processing technologies. Wood unsuitable for solid wood appearance or structural- grade products could be suitable for engineered structural composite wood products (Yadama *et al*. 2009). Such value-added products, like steam pressed scrim lumber (SPSL) (Forrest 2003), are being developed. The emphasis in developing TimTek® scrimming technology[1] was utilization of green, low-value pulpwood-size raw material to manufacture a high-strength, engineered structural composite lumber product (SCL) for use in residential and home construction. There is a lack of information on the suitability of dead or dying trees or mature, suppressed trees as an input raw material to this manufacturing process. If proven successful, it could be an option that would provide a market for 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 that could offset fuel reduction treatment costs and compete with solid wood products in today's market. This project focuses on evaluating small diameter fire-killed and green trees (less than 177 mm diameter breast height) ponderosa and lodgepole pines for manufacture using the TimTek® process**.**

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[1] TimTek® is the name given SPSL when it was developed in Australia. A diagram and pictures of the complete process may be found at http://www.cfr.msstate.edu/timtek/index.asp.

Materials and Methods

Materials

An initial shipment of ponderosa and lodgepole pine logs was shipped from study sites located on the Confederated Tribes of Warm Springs Indian Reservation and the Deschutes National Forest, both in central Oregon, to the TimTek® pilot plant located at Mississippi State University. Both one year dead (fire-killed and left standing prior to being harvested) and live (green) logs of each species were sent. Each of these areas experienced major wildfires during the summer of 2003. The goal of the early research was to make two beams from each species and condition; *i.e*. two green and two fire-killed. The green logs from each species produced scrim that was not as good as southern yellow pine (SYP) scrim, but was good enough to make beams. A log may produce several hundred individual scrim pieces and the collection of the individual pieces is called a mat. Scrim mats are visually graded according to factors that impact manufacture of finished product. The average length and diameter are important because it impacts drying uniformity and bending properties in the final product. Defects in a log such as knots may create areas in the mat where the scrim pieces are shorter and smaller than the surrounding area and in some cases a knot in the log may result in a hole in the mat. Scrim quality is judged within and between mats in terms of uniformity. The process of scrimming is performed by two types of roll devices that apply pressure on the log. Logs are first processed in “crush” mills. The term crush mill was first used in Australia. Crush mills do not actually crush logs rather they apply just enough pressure to crack the log from end to end. Logs are processed through multi passes crush rolls and then processed on the scrim rolls. Scrim rollers are cylinders with flights that separate the cracked fiber into multi strand mats. The fire-killed logs did not scrim well. The logs broke and came apart when they were sent through the crush rolls, creating processing problems conveying short log segments and the resulting scrim was short and not uniform in diameter. Generally the process of converting logs to scrim works best with fresh raw material that has a high moisture content. Enough scrim was obtained to produce two beams from green logs of each species. After the beams were pressed, they were examined to see if there were any noticeable faults in them; *i.e*. blows. A blow is a physical defect in a manufactured billet that usually exhibits a longitudinal crack that follows the grain. Blows occur when internal gas pressure builds up during the pressing operation and exceeds the internal bond of the billet as the platens are removed. The root cause of the buildup in internal gas pressure is excess moisture that forms steam and builds pressure since it is sealed inside the billet being pressed. Blows in beams from the TimTek® process are not that uncommon when species are used which do not dry evenly producing wet pockets in the scrim. Southern yellow pine (*Pinus spp.*) dries well and produces few blows.

The ponderosa beams were blown, but had enough good wood in them to test some small samples. The lodgepole beams were blown so badly that there was not enough good wood to test even small samples. A second shipment of green lodgepole and ponderosa logs was sent to the pilot plant and was used to produce beams from which most of the data in this report is based. In this detailed study ten lodgepole pine and eight ponderosa pine beams were produced. The data in this paper came from samples produced from the second shipment of logs.

Lodgepole billets produced in the study exhibited many blows due to the uneven drying particularly around knots. The lodgepole scrim did not separate into individual strands like ponderosa and/or southern yellow pine. The material was run through the scrim rollers multiple times in an attempt to increase separation but the scrim did not separate well especially around knots. It is believed that when a sample contains blows the mechanical properties are greatly reduced. Figure 3.1 shows a lodgepole pine sample that contains a blow.

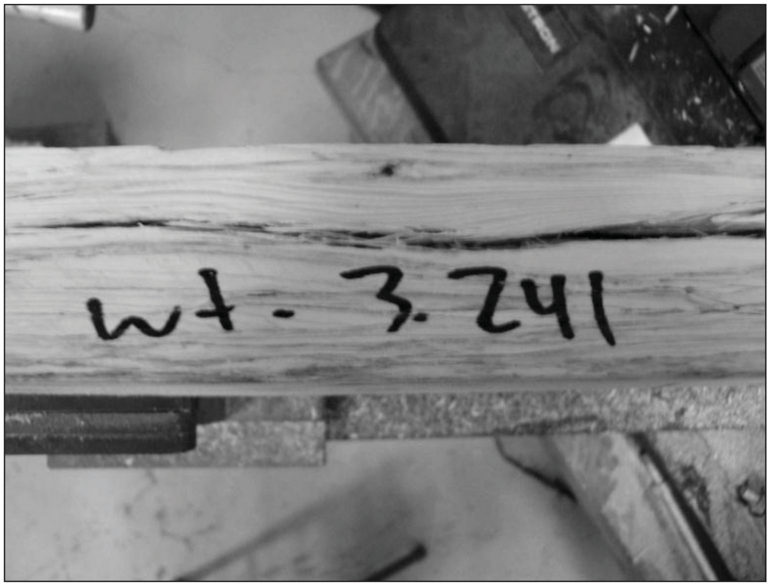

Figure 3.1

Typical blow in a lodgepole pine sample.

Beam Production

The process began with the harvesting of logs 76-178 mm in diameter in Oregon. These were 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 54-60°C for six hours (two hours for the initial study) prior to processing. This allowed any moisture lost from the air drying of the logs to be recovered before scrimming thus allowing for the highest yield of scrim out of each log.

After heating, logs were crushed and passed down the line through a series of scrimming heads of successively smaller size. These scrim mills produced scrim that was approximately 6.4 mm thick and 2.1-2.4 m long. A demonstration of the technique can be seen on the web at http://www.cfr.msstate.edu/timtek/index.asp. A process description can be found in the literature (Seale *et al*. 2006, Barnes *et al.* (2006).

After production, the scrim was loaded into a kiln and dried to a nominal 20% moisture content at 80 °C dry bulb temperature with no wet bulb control. The dried scrim was then coated with a stage B resole phenol formaldehyde resin to yield 12% resin solids. The resin is highly diluted with water and applied using a wand that literally floods the scrim with the resin mixture. Uptake of the resin is controlled with the initial drying process and with the dilution percentage of the applied resin. Since scrim is produced with the rolls rather than a knife, there are few smooth gluing surfaces. The resin must be the approximate viscosity of water to get application of resin solids into all the cracks and crevices of the material. The coated scrim was sent through a conveyor dryer at 115 °C 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 consolidated. The rough beams were trimmed to a final size of 44.5- x 298-mm x 5.5-m. Figure 3.2 shows a typical rough beam before trimming.

Figure 3.2

Typical rough beam shown immediately after pressing.

Sample Testing

Samples measuring 44- x 64- x 1295-mm (width x depth x length) were cut from parent beams and tested in edgewise bending. Prior to testing, samples were also evaluated non-destructively using the Falcon Engineering A-Grader[2], an instrument based on sonic resonance using compression wave technology. The A-grader measures both

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[2] http://www.falconengineering.co.nz/products/grading.php; the use of trade names is for the convenience of the reader only. Such use does not imply endorsement over other products equally suitable.

the density of the timber and speed of the sonic waves in the timber to produce a stiffness value for the timber. In the initial study, an attempt was made to correlate A-Grader readings from logs to the modulus of elasticity (MOE) values obtained with the beams, but there was not enough bending data to successfully compare A-Grader averages with the MOE due to the high number of samples that were blown and not tested. Further studies need to be conducted to see if the A-grader is a good method for predicting beam MOE properties from values obtained from the parent logs.

A total of ten lodgepole pine beams and eight ponderosa pine beams were produced in the detailed study. Although the majority of the ponderosa and lodgepole beams were blown, a total of 160 lodgepole and 128 ponderosa samples were prepared for testing. Prior to mechanical testing, each sample was non-destructively tested using the A-Grader.

Full-sized beams were also 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 3.3 shows an x-ray image taken from a set of samples. Circled areas show low density areas (LDAs) where the scrim mat was not formed properly and resulted in areas not bonded well. Number 1 shows a sample that does not contain an LDA. Numbers 2, 3, and 4 show typical samples rejected because of LDA's in each piece. The light areas in each piece indicate LDA locations.

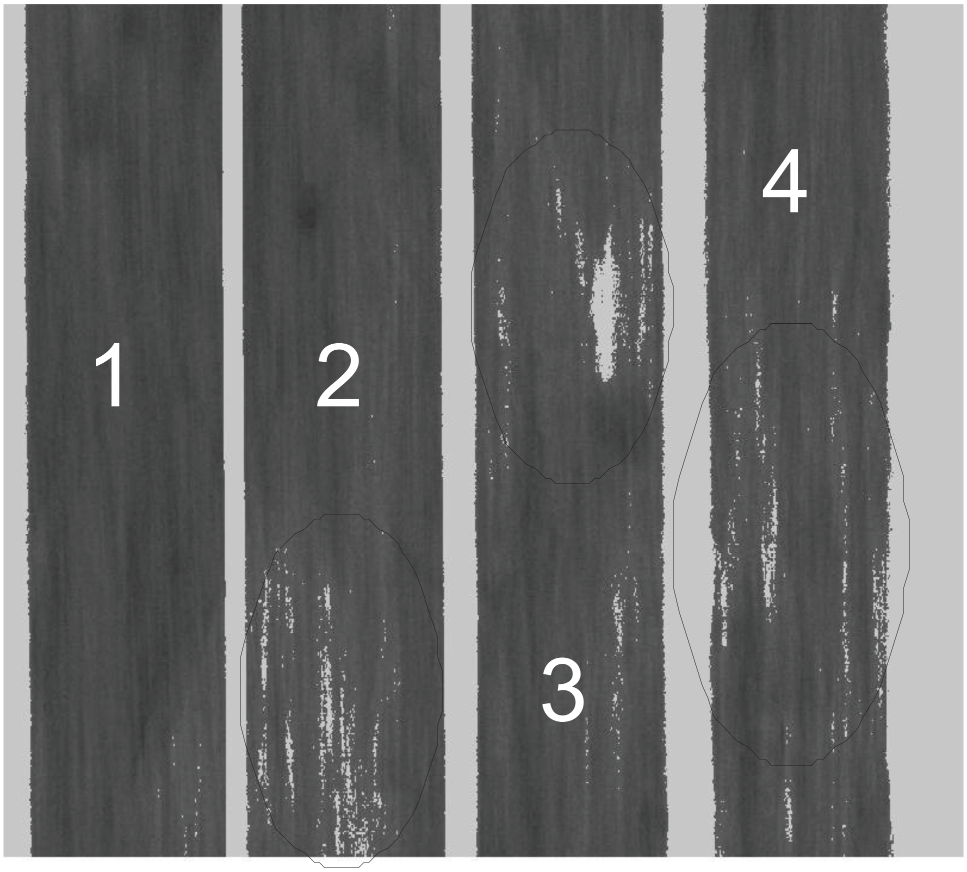


Figure 3.3

X-ray image of SPSL beam showing areas of low density

These LDA's are created when the mat that forms the billet is not formed with uniform density. Compounding low density areas are issues associated with the first steam chamber press. The issues have been studied extensively and would require major engineering changes and fabrication of another press. There are three main press issues that contribute to density variation. First, notice the edges of scrim that run the length of each edge of the raw billet in Figure 3.2. This scrim is called "squeeze out" because it is forced between the side dam and top platen while the hydraulic press is closing. Second, close inspection of the raw billet picture will indicate that there are 12 mm variations in width due to the internal configuration of the press. Finally, due to variations in delivered hydraulic pressure, there is thickness variation in the pressed billet. These three factors in combination greatly increase the difficulty to make a uniform density product and the differences in density significantly impact bending properties.

By using the x-ray scanner, we could determine where these LDA's were and use this information to determine where to cut the smaller bending samples. We can also determine where and how each large beam will break by looking at the x-ray.

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 according to ASTM Standard D 4761-05 (2007) using third point loading on an 1143-mm span. The span to depth ratio was 18 and samples were tested at a machine speed of 24 mm/min. Bluehill™ software version 2.3, was used to acquire the data. Modulus of rupture (MOR), modulus of elasticity (MOE), work to maximum load (WML), specific gravity (SG) and moisture content (MC) were calculated for each sample. MC and SG (oven-dry basis) were determined on a small block cut from each sample after bending.

Data Analysis

The data was analyzed using the GLM procedure in the SAS™ software system. By using this procedure, we were able to compare means of each species and property by using the least squares method. It was discovered that SG was the significant covariate in this analysis. Data was analyzed using analysis of variance and means were separated using Tukey's test (SAS 2008).

Results and Discussion

Non-destructive Evaluation

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 A-grader output for lodgepole pine samples (Figure 3.4). Reasonable correlation (R^2=76%) between results was found for ponderosa pine samples where there seems to be a direct correlation between the two numbers. This can probably be attributed to many factors, but the most likely reason is there were a higher number of lodgepole beams blown than ponderosa. The blows in the samples may have altered the A-Grader numbers slightly and caused an offset in the results. Further tests need to be conducted to see how blown samples affect the A-Grader numbers compared with non-blown samples. When extreme outliers were excluded from the analysis, output from the A-grader was reasonably correlated (R^2=79%) with modulus of elasticity for all samples. This indicates that such a device may have some value in a quality control program.

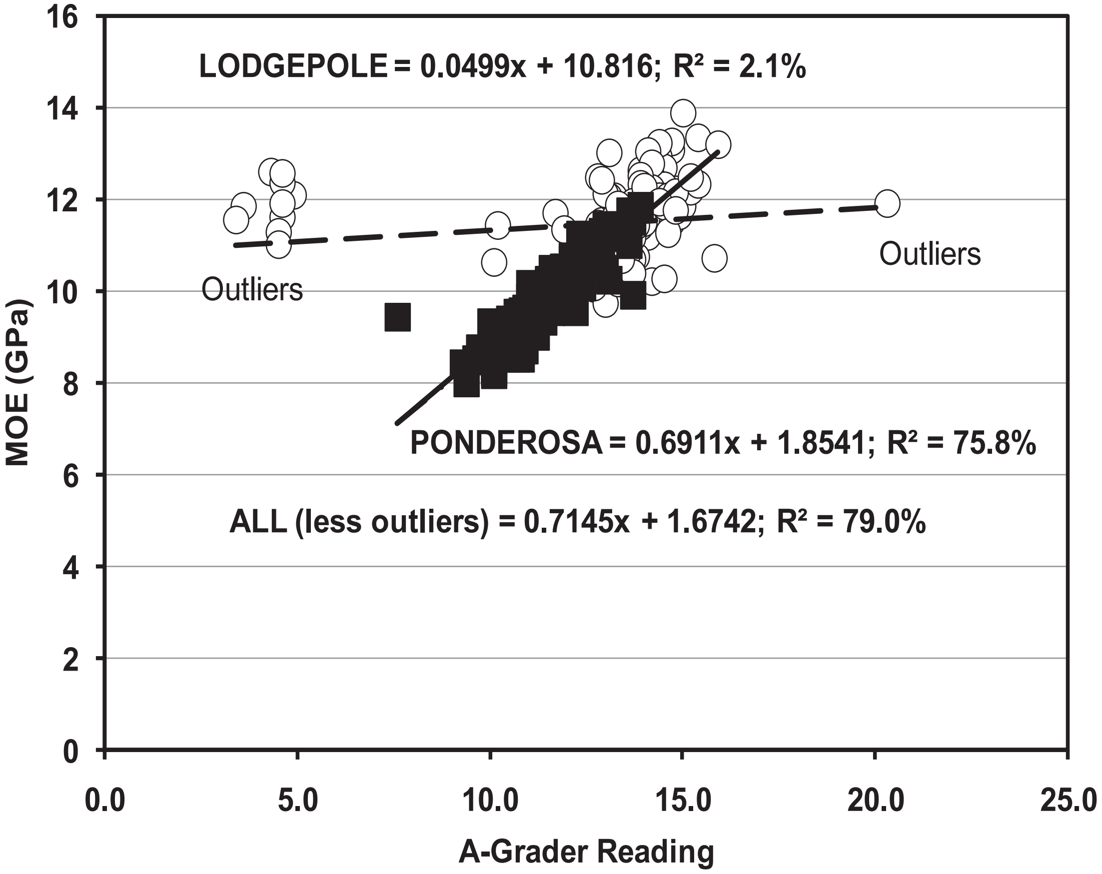


Figure 3.4

Correlation between MOE and Falcon A-Grader readings.

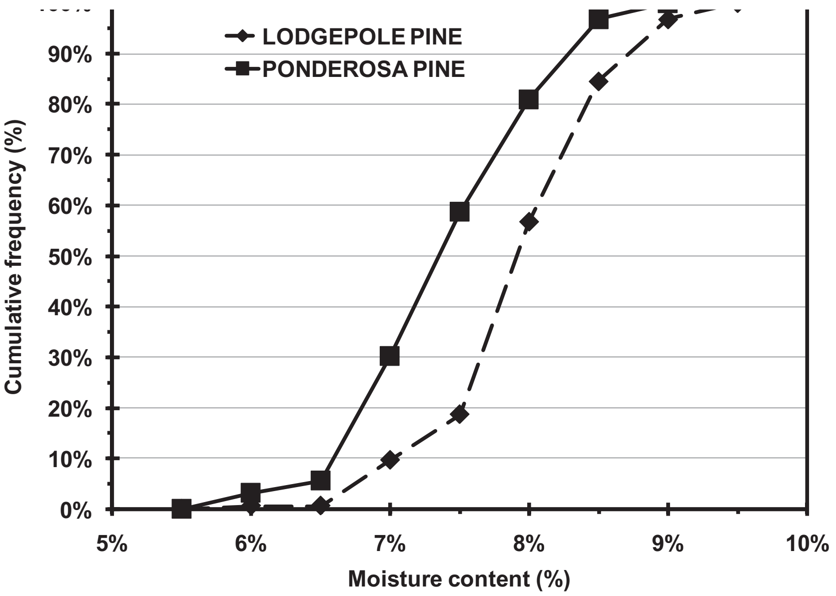
The use of x-ray to determine low density areas within the large beams was successful. It allowed us to take samples with reasonable density variation for testing. As a quality control tool, it should prove invaluable in making sure high quality beams are supplied to the marketplace

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 3.1 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 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.

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 Figure 3.5.



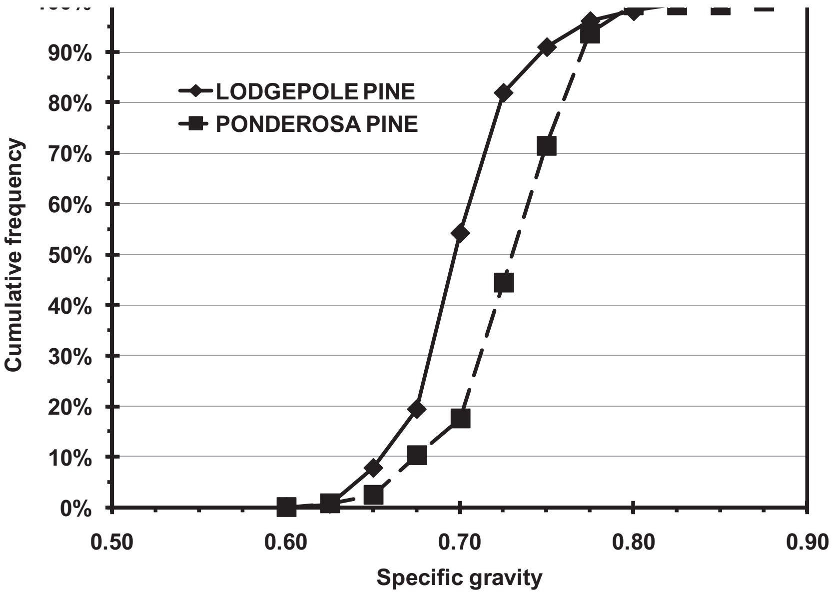


Figure 3.5

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 3.1. 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 3.2. 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 3.3) with the exception that no difference between was found for the MOR of samples with blows.

Table 3.1

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

Analysis	p-value	Ponderosa	Lodgepole
MOR (MPa)	<0.0001	51.7 A	48.1 B
MOE (GPa)	<0.0001	9.6 B	11.5 A
WML (kJ/m^3)	<0.0001	16.7 A	12.1 B

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

Table 3.2

Effect of blows on properties by species.[1]

Ponderosa Pine					
Analysis	**p-value**	**Blow**	**No blow**	**Blow**	**No blow**
MOR (MPa)	0.0192	48.1	52.2	B	A
MOE (GPa)	0.0132	9.1	9.7	B	A
WML (kJ/m^3)	0.1241	15.2	16.9	A	A
Lodgepole Pine					
MOR (MPa)	0.1874	48.2	44.2	A	A
MOE (GPa)	0.0828	11.4	12.1	A	A
WML (kJ/m^3)	0.0503	12.2	9.3	A	A

[1] Means are significantly different at p level indicated

Table 3.3

Comparison of species with and without blows.[1]

Between species with blows					
Analysis	**P-value**	**Ponderosa**	**Lodgepole**	**Ponderosa**	**Lodgepole**
MOR (MPa)	0.9619	48.1	48.2	A	A
MOE (GPa)	<0.0001	9.1	11.4	B	A
WML (kJ/m^3)	0.0003	15.2	12.2	A	B
Between species without blows					
Analysis	**P-value**	**Ponderosa**	**Lodgepole**	**Ponderosa**	**Lodgepole**
MOR (MPa)	0.0095	52.2	44.2	A	B
MOE (GPa)	<0.0001	9.7	12.1	B	A
WML (kJ/m^3)	0.0001	16.9	9.3	A	B

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

Conclusions

Wood utilization of small-diameter trees has been limited, particularly as mills close and increased hauling distances make production costs prohibitive. Composite products made from wood fibers and resins offer potential value-added opportunities both for private landowners and federal land managers who wish to use small-diameter trees resulting from thinning or from short-rotation forestry. Among the more complicated and controversial are decisions about the fate of fire-killed trees. Managers and wood products manufacturers alike are interested in the net recoverable revenue from fire-killed trees and how it varies, both within species and size classes and over time, because net revenue estimates per unit area affect the options available for post-fire restoration activities.

The purpose of this research was to evaluate the suitability of green and fire-killed small-diameter lodgepole and ponderosa pine logs for processing into beams using TimTek technology to produce a new engineered wood composite, steam-pressed scrim lumber (SPSL).

At this time, it appears that only green, small-diameter lodgepole and ponderosa logs are suitable for producing SPSL. Moisture content in fire-killed logs is too low for the logs to serve as furnish for SPSL.

Additional work still needs to be done before beams made from lodgepole and ponderosa pine can be produced commercially. Changes in operating parameters need to be done to ensure that each beam will not blow and the highest mechanical properties can be achieved. Lodgepole and ponderosa beams had a good MOR value, but MOE values were relatively low for each species, especially for the lodgepole pine samples. This is thought to be due to the fact that there were so many blows in the beams.

With a few changes to the production process, good mechanical property values can be achieved for both lodgepole and ponderosa pine beams made from green logs. While this option is not currently available, landowners in the western United States may have an incentive to properly thin lodgepole and ponderosa pine stands in the future. This would drastically reduce wildfires and insect attacks on stands of timber, and also give landowners a return on their investments much sooner.

Acknowledgements

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Literature Cited

American Society for Testing and Materials International. 2007. Standard ASTM D 4761-05 Standard test methods for mechanical properties of lumber and wood-base structural material. ASTM, West Conshohocken, PA.

Barnes, H.M., Slay, R. A., Seale, R. D., Lindsey, G. B., 2006. Treatability of steam-pressed scrim lumber-SPSL. Proceedings, American Wood Protection Association 102:68-72.

Forrest, R., 2003. Creating engineered wood from unwanted and unmarketable pulpwood. Specialty Wood Journal. 6(4):22-26.

Hill, Barry T., 1999. Western National Forests- A cohesive strategy is needed to address catastrophic wildfire threats. General Accounting Office GAO-RCED-99-65. Washington, D.C.

Leng, J., Seale, R. D., Barnes, H. M., Maupin, M., 2006. X-ray grading of steam-pressed scrim lumber (SPSL). Smallwood 2006, Forest Products Society, May 16-18, 2006, Richmond, VA, USA, http://www.forestprod.org/smallwood06barnesposter.pdf (10 September 2008).

Levan-Green, S. L., Livingston, J., 2001. Exploring the uses for small-diameter trees. Forest Products J. 51(9):10-21.

Parker, T.J., Clancy, K.M., Mathiasen, R.L., 2006. Interactions among fire, insects, and pathogens in coniferous forests of the interior western United States and Canada. Agricultural and Forest Entomology 8:167-189.

SAS Institute Inc., 2008. SAS Proprietary software, release 9.2. The SAS Institute, Cary, NC

Seale, R. D., Sellers, Jr., T., Barnes, H. M., Shi, S. Q., Black, J., Leng, J., 2006. TimTek– a new engineered product made from small-diameter trees, Smallwood 2006, Forest Products Society, May 16-18, 2006, Richmond, VA, USA, http://www.forestprod.org/smallwood06seale.pdf (10 September 2008)

Wolfe, R., 2000. Research challenges for structural use of small-diameter round timbers. Forest Products J. 50(2):21-29.

Yadama, V., Lowell, E.C., Peterson, N., Nicholls, D.L. 2009. Wood-plastic composites manufacture using beetle-killed spruce from Alaska's Kenai peninsula. Polymer Science and Engineering. 49(1):129-136.

Zausen, G.L., Kolb, T.E., Bailey, J. D., Wagner, M.R., 2005. Long-term impact of stand management on ponderosa pine physiology and bark beetle abundance in northern Arizona: A replicated landscape study. Forest Ecology and Management 218:291-305.

CHAPTER IV

CONCLUSIONS

This research was intended to determine if SPSL is a feasible alternative for small diameter timber. Extensive research has been conducted on small diameter timber from various softwood timber species, the physical and mechanical properties associated with them, and the abundance of it throughout the United States. This research has shown that in all species, small diameter, young growth timber contains an abundant amount of juvenile wood that negatively affects its properties. These negative properties have led both researchers and manufacturers to shy away from the development and use of this timber. SPSL was developed as alternative engineered wood product that takes these negative properties and use the TimTek manufacturing process to develop a product that can compete with other engineered wood products currently on the market. This research was conducted using three softwood species; southern yellow pine, ponderosa pine, and lodgepole pine.

The first test group was comprised of samples manufactured from juvenile, small diameter southern yellow pine timber. The purpose of these tests was to determine if SPSL could pass APA guidelines for engineered wood and could possibly compete with other commercially manufactured products already widely available. Data analysis showed that each sample passed APA guidelines and certification tests. MOR and MOE samples were determined to be comparable, and in many cases exceeding, values for products already commercially available. Tensile stress values and compression perpendicular to the grain values also met expectations and are comparable to commercially available products. Using southern yellow pine to manufacture SPSL is a viable alternative for small diameter timber use that can compete in today's competitive market.

The second test group contained samples manufactured from juvenile wood from both ponderosa and lodgepole pine that was both green and fire-killed. The purpose of these tests was to determine if SPSL is viable alternative for the over abundance of both green and fire-killed, small diameter lodgepole and ponderosa timber that is inundating the western United States. Results showed that only green timber from each species is suitable for producing SPSL. Fire-killed timber has such a low moisture content that it would not scrim well enough to produce a quality product. While MOR values were relatively high for the samples produced from green logs, MOE values were unexpectedly low. With a few changes in the manufacturing process, SPSL manufactured from green, small diameter, lodgepole and ponderosa pine timber may be a viable alternative for manufacturers in the future.

Small diameter pine timber is becoming a critical problem throughout the United States. Previously there were few alternatives for landowners in the south who wanted to thin plantations that are 5 – 10 years of age. This would lead to lower quality timber in the future which would in turn lead smaller returns on their investments. In western states, there are few alternatives for the over abundance of small growth timber that is quickly over taking forests. This can lead to widespread, deadly forest fires and insect attacks that can lead to the total loss of thousands of acres of potentially valuable timber. SPSL was introduced as a means to counter the issues with each of these species. Southern yellow pine has already proven to be a viable alternative for production of SPSL while with a few process changes and further research, lodgepole and ponderosa pine timber can become a viable alternative as well. Overall, the introduction of steam-pressed scrim lumber, SPSL, will allow landowners throughout the United States to have a viable alternative for combating the many issues they face with small diameter timber.