PILOT MANUFACTURE & TESTING OF LAMINATED VENEER LUMBER FROM SUNPINE VENEER

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* Note to readers:	metric equivalency ratios are not consistent throughout the data within this report.

ABSTRACT

Pilot manufacture of 1 3/4" x 4' x 8' (44.5 mm x 1220 mm x 2400 mm) laminated veneer lumber (LVL) billets from Sunpine veneers was successfully done at the Alberta Research Council's Panel Development Laboratory under contract with Sunpine Forest Products Ltd., Sundre, Alberta.

The test results show that it is technically possible to manufacture LVL from Sunpine veneer.

The test results also show that the method of end-jointing of the veneers during LVL manufacture had no significant effect on the resulting mechanical properties of Sunpine LVL.

The properties of lodgepole pine/Sunpine LVL fall somewhat below that of coastal Douglas fir and spruce LVL. The possibility of upgrading Sunpine veneer for higher strength LVL exists by stress grading veneers and/or veneer densification.

ACKNOWLEDGEMENTS

The financial contribution by the Canada-Alberta Partnership Agreement in Forestry is greatly appreciated.

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Appendices are not included in this report.
They are available upon request from the Alberta Research Council, Forestry.

INTRODUCTION

Objective

Alberta industry, the Alberta Forest Products Association and various provincial and federal government departments have identified value-added opportunities for Alberta forest products existing in a number of areas.

In particular, value-added potential exists for straight grain wood with high density/strength in demanding applications such as straight or bent furniture components, wood-I's, laminated veneer lumber (LVL), oriented strand lumber and traditional glulam beams.

The objective for this project, contracted by Sunpine Forest Products Ltd. to the Alberta Research Council (ARC), is to demonstrate that veneer generated from a spindleless lathe is capable of producing LVL products.

Background

LVL is normally made from sheets of veneer that are rotary peeled from logs of the same quality used to produce sheathing plywood for construction. Subsequent to peeling, the veneers are dried to approximately 7% moisture content before being bonded together using adhesive, heat and pressure. The lay-up of the LVL veneers differs from plywood in that the veneers are oriented with the grain direction of all veneers parallel. LVL is available in lengths of up to 24 m (~ 80'), widths of 2.4 m (~ 8') and thicknesses up to 50 mm (~ 2"). The manufactured LVL blanks are cut up according to the needs of the clients for applications such as floor joists, flanges of wood-I's and planks for scaffolding.

The three principle steps in LVL manufacture include:

Sawing - Rotary Peeling - Clipping - Drying

Debarked logs are rotary-cut into 3 mm thick veneer. Using this method, the raw material can be utilized very effectively. The veneer is uniformly dried for processing and, at the same time, poor quality veneer is graded out. The veneer is classified according to dimension so that no further grading is required.

Gluing - Lay-up - Hot-Pressing

In a controlled process the panels are glued and then hot-pressed in a continuous press. The through-put time is relatively short. The production line can manufacture continuous panels from 1" - 3" in thickness to 72" in width. The process enables the use of weather resistant glues. After hot-pressing, the product has a final moisture level less than 10%

Crosscut Sawing - Rip-Sawing - Warehousing

> *The continuous panels can be sawn exactly to length and can then be cut as required into slabs, beams, strips, battens or other cut sections.*[1]

Currently, there is no western Canadian production of the value-added product, and structural beams and headers of LVL are shipped in from the northwestern United States. This testing will facilitate the opening of the Sunpine LVL plant which will create up to 150 man years of employment annually and bring in up to $50 million in sales to the Alberta economy.

The small average log diameter requires an evaluation of the performance of this veneer in LVL manufacture. The veneers in this study were peeled on a spindleless lathe.

PROJECT ACTIVITIES

Manufacture of LVL from Commercial Veneer

The 1/8" (3.2 mm) veneer used was lodgepole pine supplied by Sunpine that was peeled on a spindleless lathe. From this veneer, four types of LVL lay-ups of the veneers were manufactured after double sided resin application with a plywood roller coater using Borden phenolic resin and hot pressing. Due to the roughness and thickness variations of the veneer used, bare spots occurred when resin was applied with the roller coater. A video was taken to document this.

The Sunpine LVL was laid up at ARC with 15 layers hot pressed and cut to billets sized 1 3/4" x 4' x 8' (44.5 mm x 1220 mm x 2440 mm). Four different end jointing methods for the veneers were used:

- no-joint (full sheet veneer)
- butt joint (one joint for each 6" (152 mm) of finished LVL)
- overlap (1 - 1 1/2 overlap, one joint for each 6" (152 mm) of finished LVL)
- scarf joint with 7° slope

The lay-up patterns for the butt, overlayed and scarf joints, sample production specifications and sample press parameters used at the ARC Pilot Plant are included in Appendix A.

[1] Durand-Raute brochure on LVL Manufacture

Testing of Four Different Types of Sunpine LVL and Commercial D. Fir LVL

Table 1 outlines the testing carried out to characterize the Sunpine LVL produced in this project with commercial D. fir LVL.

Table 2 gives an overview of all the most important tests conducted just after production with a moisture content of 8%.

Density and Moisture Content

The "density at test" was measured for all the tests conducted. In addition, the moisture contents were determined at the time of all the destructive tests.

The results in Table 3 show that the density of the D. fir LVL control samples was approximately 12% higher than the Sunpine LVL produced by ARC. It should be noted that the commercial LVL producer states that density is 620 kg/m^3 and not 560 kg/m^3 as ARC measured.

Bending Stiffness and Strength of Sunpine Veneer

Stiffness testing and strength tests of LVL were conducted with the gluelines in both the "on edge" and the "on flat" modes. The tests show no clear significant difference between modes of testing and the way the veneers are end jointed. The results of flexure tests on LVL manufactured with full sheet veneers (i.e. no joints) are given in Table 3.

"MOR and "MOE" on Edge of Structural Sized LVL Beams

The bending tests according to ASTM D4761 were conducted on 1 3/4" x 4 1/2" (44.5 mm x 114 mm) cross section beams with a span depth ratio of approximately 1:18. There appears to be no clear difference between the strength and stiffness of the various end jointing methods used for the veneers.

"MOR" and "MOE" on Flat of Structural Sized LVL

Flexure testing was conducted on LVL beams of the size 1 3/4" x 4 1/2" x 96" (44.5 mm x 114 mm x 2440 mm) and 1 3/4" x 4 1/2" x 48" (44.5 mm x 114 mm x 1220 mm). The beams were simply supported on the flat face and were centre loaded to destruction according to ASTM D4761. The effect of increased beam width from 4 1/2" to 9" (114 mm x 229 mm) suggests no size effect as for solid lumber.

Table 1. Testing Plan Followed by ARC for LVL with Sunpine Veneers and Commercial LVL Controls

Test	Pine SP-F no-joint	Pine SP-B butt-joint	Pine SP-O overlap	Pine SP-S scarf	D. Fir TJM-C control	Test Standard or Code	Test Sample Dimen. in. (mm)
MSR (on flat)	40	40	40	40	35	BS 5268/4978	1.75x4.5x96 (44x114x2438)
MOE/MOR (on edge)	10	10	10	10	10	ASTM D4761	1.75x4.5x96 (44x114x2438)
MOE/MOR (on flat)	10	10	10	10	10	ASTM D4761	1.75x4.5x48 (44x114x1219)
MOE/MOR (wide on flat)	10	10	10	10	10	ASTM D4761	1.75x9.0x48 (44x229x1219)
TENS. E/UTS (paral.)	10	10	10	10	10	ASTM D4761	1.75x4.5x96 (44x114x2438)
Comp. (max-paral.)	20	20	20	20	20	ASTM D143	1.75x2x8.0 (44x51x203)
Shear (par. gr. + par. gl.)	20	20	20	20	20	ASTM D143	1.75x2x2.5 (44x51x64)
Shear (per. gr. + par. gl.)	20	20	20	20	20	ASTM D143	1.75x2x2.5 (44x51x64)

SP-F = No veneer end jointing (1/8" (3.18 mm) Sunpine Veneer)
SP-B = Veneer butt jointed (1/8" (3.18 mm) Sunpine Veneer Staggered 12" (304.8 mm))
SP-O = Veneer lap jointed (1/8" (3.18 mm) Sunpine Veneer-11/2" (38.1 mm) (Overlap Staggered 12" (304.8 mm))
SP-S = SCAF joint (1/8" (3.18 mm) Sunpine Veneer 7° Scarf Joints)
TJM-C = Commercial 1.8E LVL (1/10" (2.54 mm) D. Fir Veneer)

Table 2. Summary of Physical Mechanical Testing of ARC Produced Sunpine LVL and Commercial LVL Controls

Test	Units	LVL Material Properties							
		Pine SP-F no joint	Pine SP-B butt joint	Pine SP-O overlap	Pine SP-S scarf	D. Fir TJM-C control	MC in % at Test	Test Standard or Code	Test Sample Size in. (mm)
Density at Test	kg/m^3	488	512	506	497	560	8.3		
MSR (low E on flat)	GPa	8.7	8.6	8.8	8.8	11.6	apprx. 8.5	BS 5268/4971	1.75x4.5x96 (44x114x2438)
MOE (4.5" on flat)	GPa	9.6	10.1	10.2	9.3	15.1	8.4	ASTM D4761	
MOR (4.5" on flat)	MPa	53.5	54.4	54.2	52.7	75	8.4	ASTM D4761	
MOE (9.0" on flat)	GPa	10	10.7	10.7	10.5	15.4	8.4	ASTM D4761	1.75x9.0x48 (44x229x1219)
MOR (9.0" on flat)	MPa	58.1	53.3	54.4	55.4	77.5	8.4	ASTM D4761	
MOE (4.5" on edge)	GPa	10.3	11.1	10.6	10.4	14.1	8.5	ASTM D4761	1.75x4.5x48 (44x114x1219)
MOR (4.5" on edge)	MPa	46	46.8	44.7	44.8	54.5	8.5	ASTM D4761	
E-Tension (paral.)	GPa	10.7	10.5	11.3	11.3	16.6	8.6	ASTM D4761	1.75x4.5x96 (44x114x2438)
UTS (paral.)	MPa	30.7	30.2	30.2	34	38.1	8.6	ASTM D4761	
Comp. (max. paral.)	MPa	44.3	44.7	43.2	43.2	51.6	8.3	ASTM D143	1.75x2x8.0 (44x50x203)
Shear (par.gr. + par.gl.)	MPa	3.8	5	4.5	4.8	3.3	8.6	ASTM D143	1.75x2x2.5 44x50x64)
Shear (per.gr. + par.gl.)	MPa	6.7	6.7	6.7	6.5	7.6	8.6	ASTM D143	

SP-F = No veneer end jointing (1/8" (3.18 mm) Sunpine Veneer)
SP-B = Veneer butt jointed (1/8" (3.18 mm) Sunpine Veneer Staggered 12" (304.8 mm))
SP-O = Veneer lap jointed (1/8" (3.18 mm) Sunpine Veneer-11/2" (38.1 mm) (Overlap Staggered 12" (304.8 mm))
SP-S = SCAF joint (1/8" (3.18 mm) Sunpine Veneer 7° Scarf Joints)
TJM-C = Commercial 1.8E LVL (1/10" (2.54 mm) D. Fir Veneer)

Table 3. Flexure Test on Sunpine LVL Beams

LVL Material Tested	Test Specimen Dimension in. (mm)	Property	Property	MC
Sunpine LVL No Joint of Veneer Ends	1 3/4 x 4 1/2 x 96 (45 x 115 x 2438)	MOE on Edge	10.3 GPa (cv = 3.6%) n = 10	8.5%
		MOR on Edge	46.0 MPa (cv = 8.2%) n = 10	8.5%
	1 3/4 x 4 1/2 x 48 (45 x 115 x 1219)	MOE on Flat	9.6 GPa (cv = 11.9%) n = 10	8.4%
		MOR on Flat	53.5 MPa (cv = 10.3%) n = 10	8.4%

Tension Stiffness and Strength of Spruce LVL

Tension testing was conducted on LVL size 1 3/4" x 4 1/2" x 96" (44.5 mm x 114 mm x 2440 mm) according to ASTM D4761 using a Metriguard Tension Tester. The test results show no significant influence of end jointing method.

Compression Strength Parallel to Grain

Compression testing was conducted on 1 3/4" x 1 3/4" x 4" (44 mm x 44 mm x 100 mm) samples according to ASTM D143.

Shear Parallel to Grain

Block shear testing was conducted according to ASTM D143 parallel-to-the-grain, using the same technique used for glulam beams.

Machine Stress Rating of Structural Sized LVL

Using the Tecmach MSR machine for rating of dimension lumber, the Low Point Modulus of Elasticity values were measured for LVL sized 1 3/4" x 4 1/2" x 96" (44.5 mm x 114 mm x 2440 mm).

Comparison of Sunpine LVL with Alberta Spruce and Commercial D. Fir LVL

Using the LVL data obtained in a study done on spruce for Alberta Forestry, Lands & Wildlife, a comparison of the species effect was made. All testing was done with LVL material at approx. 7-8%. The compiled data is shown in Table 4. The relative difference is due to a combination of wood density and wood quality.

Table 4. Comparison of LVL Made with Different Wood Species

Test	LVL Material Properties		
	Pine	Spruce	D. Fir
Density (x 10 kg/m^3)	48.8	46	56
MOE GPa (9.0" (228.6 mm) flat)	10	11.6	15.4
MOR MPa (9.0" (228.6 mm) flat)	58.1	66	77.5
MOE GPa (4.5" (114.3 mm) edge)	103	n/a	14.1
MOR MPa (4.5" (114.3 mm) edge)	46	n/a	54.5
Tension GPa (paral.)	10.7	12.9	16.6
UTS MPa (paral.)	30.7	39.2	38.1
Comp. MPa (max. paral.)	44.3	50.5	51.6
Shear MPa (pa.g + pa.g)	3.8	2.7	3.3
Shear (pe.g + pe.g)	6.7	3.7	7.6

Influence of Moisture Content on the Properties of LVL

Moisture content of LVL is important for the properties of LVL just as it is for solid lumber. To enable adjustment of the LVL properties determined at the 8% moisture content at test as when produced, ten samples were conditioned at 23°C 65% RH prior to MSR and bending testing on edge. This data is expected to yield slightly lower strength and stiffness. Moisture content and bending properties are shown in Table 5.

Table 5. Moisture Content and Bending Properties of Sunpine LVL

Test	Units	Pine SP-F no joint	Pine SP-B butt joint	Pine SP-O overl ap	Pine SP-S scarf	D. Fir TJM-C control	MC (%)
MSR (low E on flat)	GPa	8.7	8.6	8.8	8.8	11.6	apprx. 8.5
MSR (low E on flat)	GPa	7.9	8.3	8.9	8.1	11.5	10.5
MOE (4" (114.3 mm) on edge)	GPa	10.3	11.1	10.6	10.4	14.1	8.5
MOE (4.5" (114.3 mm) on edge)	GPa	9.8	10.4	10	10	13.2	10.5
MOR (4.5" (114.3 mm) on edge)	MPa	46	46.8	44.7	44.8	54.5	8.5
MOR (4.5" (114.3 mm) on edge)	MPa	46.6	46.9	45.6	45.3	56.3	10.5

SUMMARY AND CONCLUSION

A summary of the Sunpine LVL data is presented in Table 6.

The study conducted showed clearly the technical feasibility of producing LVL from spindleless lathe 1/8" (3.18 mm) thick Sunpine veneer. However, due to the roughness of the veneers peeled with the spindleless lathe, roller application of resin left undesirable bare spots.

The effect of butt end jointing, overlap, and scarf all showed practical equivalence with full sheet veneer LVL which is important to consider when designing full scale production of spruce LVL.

Sunpine LVL appears to have properties as good as Douglas fir LVL on a weight basis. This last disadvantage of Sunpine LVL could be overcome by sorting and/or densification of the LVL veneers during manufacture by a new technique presently being discussed by Sunpine and ARC engineers.

RECOMMENDATIONS

A. To re-evaluate Durand-Raute's proposal with regards to end-jointing of veneers.

B. To consider resin application to the veneer by other means than roller coaters.

C. To evaluate veneer quality sorting procedures.

D. To proceed with spruce veneer LVL studies with densified veneer that would give volume equivalence with present commercial Douglas fir LVL.

Table 6. Summary of Sunpine LVL Data

Test	Units	Pine SP-F no joint	Pine SP-B butt joint	Pine SP-O overlap	Pine SP-S scarf	D. Fir TJM-C control	MC in % at Test
Density at Test	kg/m^3	488	512	506	497	560	8.3
MSR (low E on flat)	GPa	8.7	8.6	8.8	8.8	11.6	apprx. 8.5
MSR (low E on flat)	GPa	7.9	8.3	8.9	8.1	11.5	10.5
MOE (4.5" (114.3 mm) on flat)	GPa	9.6	10.1	10.2	9.3	15.1	8.4
MOR (4.5" (114.3 mm) on flat)	MPa	53.5	54.4	54.2	52.7	75	8.4
MOE (9.0" (228.6 mm) on flat)	GPa	10	10.7	10.7	10.5	15.4	8.4
MOR (9.0" (228.6 mm) on flat)	MPa	58.1	53.3	54.4	55.4	77.5	8.4
MOE (4.5" (114.3 mm) on flat)	GPa	10.3	11.1	10.6	10.4	14.1	8.5
MOE (4.5" (114.3 mm) on edge)	GPa	9.8	10.4	10	10	13.2	10.5
MOR (4.5" (114.3 mm) on edge)	MPa	46	46.8	44.7	44.8	54.5	8.5
MOR (4.5" (114.3 mm) on edge)	Mpa	46.6	46.9	45.6	45.3	56.3	10.5
E-Tension (paral.)	GPa	10.7	10.5	11.3	11.3	16.6	8.6
UTS (paral.)	MPa	30.7	30.2	30.2	34	38.1	8.6
Comp. (max. paral.)	MPa	44.3	44.7	43.2	43.2	51.6	8.3
Shear (par.gr.+par. gl.)	MPa	3.8	5	4.5	4.8	3.3	8.6
Shear (per.gr.+par.gl.)	MPa	6.7	6.7	6.7	6.5	7.6	8.6