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GLUED LAMINATED TIMBER AND LAMINATED VENEER LUMBER STRUCTURAL PRODUCTS MANUFACTURED FROM AUSTRALIAN SOUTHERN BLUE GUM GROWN FOR WOODCHIPS

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ABSTRACT: Demand for wood products is growing internationally, and new initiatives are necessary to sustainably meet this demand. This paper presents such an initiative investigating the possibility of manufacturing glued laminated timber (GLT) and laminated veneer lumber (LVL) structural products from Australian southern blue gum (*Eucalyptus globulus*) plantation logs traditionally grown for woodchip purposes. 120 logs were harvested from two different plantations (15-year-old and 19-year-old) and processed at the Salisbury Research Facility into rotary peeled veneers (80 logs) and sawn boards (40 logs). The modulus of elasticity and visual grade distributions of the recovered veneers were assessed, as well as the compressive, tensile, shear, and bending strengths, density and modulus of elasticity of 240 sawn boards. The collected data were then used to assess the product grades which could be manufactured from the resources using different construction scenarios. GLT and LVL were finally manufactured and experimentally tested to confirm the potential of the resources in the production of suitable engineered wood products. This conference paper focusses on presenting the key data on the raw material, specifically the modulus of elasticity distribution of the veneers, and the tensile and compressive strengths of the sawn boards. The results from selected manufactured GLT and LVL are also presented and discussed.

KEYWORDS: Southern blue gum (*Eucalyptus globulus*), Pulpwood, Woodchips, GLT, LVL

1 – INTRODUCTION

To identify high value markets and facilitate the establishment of Australian manufactured Engineered Wood Products (EWP) from Australian plantation logs grown for woodchip purposes, the "Splinters to Structures" project was awarded by the Agricultural Trade and Market Access Cooperation (ATMAC) to Forest and Wood Products Australia (FWPA) in partnership with the Green Triangle Forest Industries Hub (GTFIH). From a market study and Australian manufacturing capabilities, the executive committee decided to investigate the possibility of manufacturing glued laminated timber (GLT) and laminated veneer lumber (LVL) structural products out of the resources of interest. The resources relevant to this paper consisted of southern blue gum (*Eucalyptus globulus*) trees. Southern blue gum represents 121,000 Ha of available hardwood plantations in the Australian Green Triangle region [1].

The Forest Product Innovations team of the Queensland Department of Primary Industries (DPI) was commissioned to deliver the R&D activities on the

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structural products to be manufactured out of the resources.

Demand for wood products is growing in Australia and internationally. For instance, in 2020, Australian domestic sawn timber sales were slightly below 2.9 million m^3 while demand was slightly above 3.4 million m^3, driven almost exclusively by structural products. Regarding EWP, Australia produced 60,000 m^3 of Laminated Veneer Lumber (LVL) in 2020 but imported another 140,000 m^3 to meet the demand. Similarly, the annual production of GLT of 25,000 m^3 represented half the demand [2].

For this project, 120 southern blue gum trees were harvested in the Australian Green Triangle and processed at the Salisbury Research Facility of the Queensland Department of Primary Industries near Brisbane. The logs were either rotary peeled for LVL manufacturing or sawn into boards for GLT manufacturing. The properties of the veneers and sawn boards were measured. The collected data were then used as input in numerical simulations to understand the potential LVL and GLT types, with associated volumes, that could be manufactured from the resources. Finally, LVL and GLT were manufactured and tested.

The paper presents and discusses the main outcomes of the study extracted from the final report [3] which will be available from the FWPA website.

2 – METHODOLOGY

2.1 HARVESTING

Sixty 15-year-old (Site 1, named "Caves") and sixty 19-year-old (Site 2, named "Barker") southern blue gum trees of targeted Diameter at Breast Height Over Bark (DBHOB) ranging (1) between 17 cm and 23.6 cm (30 trees per site) and (2) between 23.6 cm and 31.8 cm (30 trees per site) were harvested near Hamilton, Victoria. The ends of the logs were sealed to limit moisture loss and shipped to the Salisbury Research Facility for processing. Figure 1 shows harvested trees ready to be shipped.

Figure 1. Harvested trees ready to be shipped for processing.

2.2 PROCESSING

2.2.1 Veneers

2/3 of the logs (80 logs) harvested in Section 2.1 were merchandised into three billets. Each billet was then rotary peeled using a spindleless lathe into 3.2 mm thick green veneers. Figure 2 shows a photo of the veneer ribbon obtained after peeling a billet. The veneer ribbons obtained were marked and clipped into veneer sheets. The veneers were then dried in a conventional jet box veneer drying system.

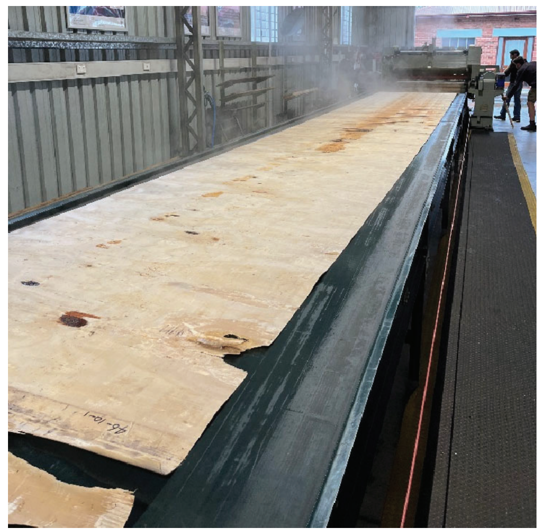

Figure 2. Veneer ribbon obtained after peeling.

2.2.2 Boards

The remaining 1/3 of the logs (40 logs) were merchandised into two billets and sawn into boards, aiming at boards with a dressed and dry thickness of 19 mm. The boards were air dried to a moisture content of about 18% to 20%, then transferred to solar kiln for drying to a moisture content of about 14%, and finally dried in a kiln to a moisture content of 12%. Note that while 19 mm thick boards are not commonly used in the manufacturing of GLT, this thickness was chosen to limit the air-drying time and obtain boards for both testing and GLT manufacturing within the timeframe of the project.

2.3 MEASUREMENTS

2.3.1 Veneers

For each veneer sheet. the following key parameters were measured:

- Location relative to the radius of the tree.
- Green and dry thicknesses.
- Density.
- Acoustic Modulus of Elasticity (MOE).
- Visual grade according the Australian and New-Zealand standard AS/NZS 2269.0 [4].

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2.3.2 Boards

240 southern blue gum dried boards of a nominal length of 3.1 m were randomly selected from the dried sawn boards. The boards were dressed using a four-sider Wadkin planer (Figure 3). The following was measured from each board:

- The geometric imperfections (bow, spring, twist and cup) before and after planing to understand by how much these imperfections were reduced after planing.
- The presence and distribution of characteristics which would impact the manufacturing of GLT.
- The density.
- The acoustic MOE.

Finally, the boards were divided into three stacks of equivalent MOE distributions for mechanical testing according to the Australian and New-Zealand standard AS/NZS 4063.1 [5], with the first stack used for tension testing, the second for compression testing and the third for flat bending and shear testing.

Figure 3. Boards being dressed in a four-sider Wadkin planer.

2.4 NUMERICAL SIMULATIONS

Numerical simulations with different manufacturing scenarios were performed to understand the LVL and GLT types, with associated volumes, that could be manufactured using the southern blue gum veneers and boards, respectively.

2.4.1 LVL

For the LVL, LVL12, LVL15, LVL18 and LVL21, i.e., LVL with characteristic (or design) MOE of 12,000 MPa, 15,000 MPa, 18,000 MPa and 21,000 MPa, respectively, were the main targeted products. LVL12 represents a commodity product (large volume), while LVL15 to LVL21 would have applications where higher performing products are needed, such as in sub-floor framing structures, stairwells and lintels. For GLT, GL13 and GL18 beams (with the grades defined in AS 1720.1 [6]) were the main targeted products. GL13 represents a commodity product, while GL18 would have applications where high performing products are required, such as above garages (long spans).

The simulations used the MOE distribution of the veneers obtained from the measurements mentioned in Section 2.3.1 to simulate the characteristic MOE of 15-ply LVL products manufactured from randomly selected veneers. The peeled veneers are assumed to be separated into bins based on their MOE value, and one LVL product is manufactured per bin. In total four different scenarios were run from manufacturing an unique LVL product (i.e., with no sorting of the veneers into bins) to the manufacturing of both LVL12 and higher performing products.

2.4.2 GLT

For the GLT, similar simulations were run using the density distribution of the boards obtained from the measurements mentioned in Section 2.3.2 and the relationship between density and MOE to predict the characteristic MOE of 300 mm deep GLT manufactured with a combination of boards of different densities. The bending and shear strengths of the GLT beams were also estimated from the mechanical properties of the tested boards in Section 2.3.2. Two scenarios were run, either manufacturing one unique product or manufacturing two products. In all cases, a GLT beam was numerically manufactured using the denser boards as outer lamellas to maximise the bending MOE and strength.

(a) *(b)*

Figure 4. Selected stages of the LVL manufacturing (a) applying adhesive with a double roller glue spreader and (b) LVL being hot-pressed.

2.5 PRODUCT MANUFACTURING AND TESTING

2.5.1 LVL

From the results of the numerical simulations, it was decided to manufacture two different types of LVL (aimed at obtaining LVL12 and LVL21). Five LVL panels per LVL type were semi-commercially manufactured at the Salisbury Research Facility, with selected stages of the manufacturing process shown in Figure 4. The panels were cut into LVL products which were tested in bending, compression and shear according to the Australian and New-Zealand standard AS/NZS

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4357.2 [7]. Characteristic values were calculated according to the European standard EN 14358 [8].

2.5.2 GLT

One type of GLT (aimed at obtaining GL17 from the boards available after testing in Section 2.3.2) was manufactured in a commercial facility in Victoria. In total, four different beams were manufactured and tested in bending and shear according to the Australian and New-Zealand standard AS/NZS 4063.1 [5]. Figure 5 shows a GLT beam tested in four-point bending.

Figure 5. GLT beam tested in four-point bending.

3 – RESULTS

3.1 MEASUREMENTS

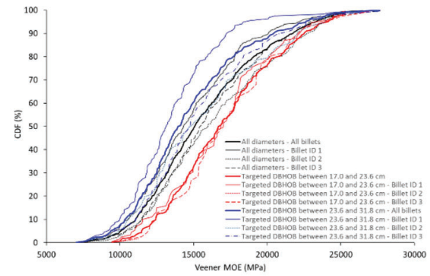
3.1.1 Veneers

Figures 6 (a) and (b) plot the Cumulative Distribution Functions (CDF) of the measured MOE of the peeled veneers for the first (Caves and 15-year-old) and second (Baker and 19-year-old) harvested sites, respectively. The distributions in the figure are broken down per targeted DBHOB and billet number, with Billets 1, 2 and 3 cut at the bottom, middle and top of the trees, respectively. The older trees in Site 2 provided veneers with higher MOE, with the average MOE of the recovered veneers for Sites 1 and 2 found to be 15,690 MPa and 20,119 MPa, respectively.

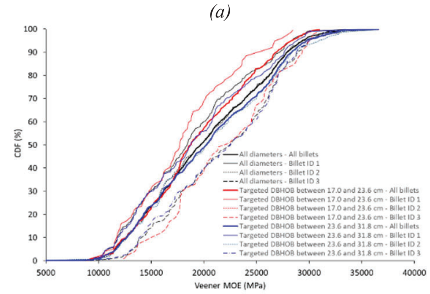
In terms of visual grading, D-grade dominated the feedstock and represented about 75% of the southern blue gum veneers. No A-grade veneers were recovered. This result indicates that visual appearance LVL products cannot be manufactured from the resources. Additionally, 17% to 23% of the southern blue gum veneers were F-grade and therefore failed to meet a visual grade. These veneers would have limited uses in the manufacturing process.

3.1.2 Boards

Table 1 summarises the average measured imperfections on the southern blue gum boards before and after planing. Planing was efficient in removing the spring and cup imperfections, with 72% of the boards having a spring less than or equal to 2 mm, and 82% of the boards having a cup less than or equal to 1 mm after planing. More than 40% of the boards had a bow less than or equal to 2 mm after planing. Note that bow is less an issue in the manufacturing of GLT than spring and cup as it can be eliminated when pressing the boards to form the GLT.



(a)



(b)

Figure 6. CDF of the veneer MOE for (a) Site 1 (Caves and 15-year-old) and (b) Site 2 (Barker and 19-year-old).

The acoustic MOE distributions of the recovered boards are provided in Figure 6. The figure shows that similarly to the veneers, the MOE of the boards from Site 2 (Baker and 19-year-old) are higher than for Site 1 (Caves and 15-year-old). Twenty percent of the southern blue gum boards have MOE greater than 21,000 MPa.

Table 1. Average board imperfections before and after planing.

	Bow (mm)	Spring (mm)	Twist (mm)	Cup (mm)
Before	9.4	10.5	10.7	3.6
After	4.6	2.3	2.3	0.2

Finally, Figure 7 shows the strength versus density relationships for two of the measured mechanical properties, namely tension and compression. High density southern blue gum boards reached tensile and compressive strength greater than 100 MPa and up to 70 MPa, respectively.

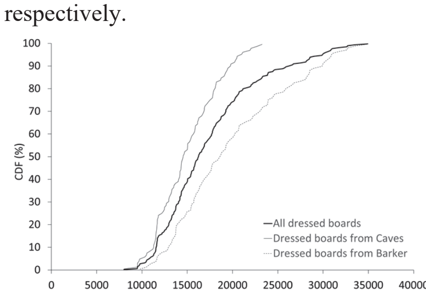


Figure 6. CDF of the board MOE for all sites.

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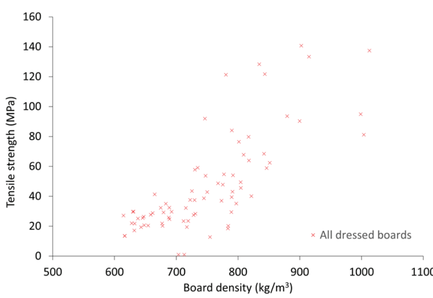
3.2 NUMERICAL SIMULATIONS

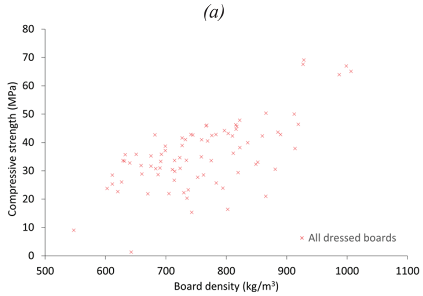
3.2.1 LVL

The following comments can be drawn from the LVL simulations:

- The southern blue gum resources offer enough high MOE veneers to mainly manufacture high performance LVL.
- Using 99% of the veneers recovered from the second harvested site (Barker) would allow the manufacturing of LVL18 as a unique product.
- Using 100% of the veneers recovered from both sites would allow the manufacturing of a unique LVL15, with the characteristic MOE of the resulting LVL being 8% higher than what would be required for LVL15.
- 64% and 35% of the veneers recovered from the first harvested site (Caves) can be used to manufacture LVL12 and LVL18, respectively.
- If a manufacturer targets using the highest MOE veneers to manufacture LVL21 (42% of veneers), then LVL12 (58% of veneers) would complement the high performing LVL.



(a)



(b)

Figure 7. Board density versus (a) tensile strength and (b) compressive strength.

3.2.1 GLT

The following comments can be drawn from the GLT simulations:

- In terms of MOE, a unique GLT product (using all available boards) would have a characteristic MOE about 1,000 MPa lower than the cut-off for GL18. When manufacturing two products from the southern blue gum resources, the first product (40% of the boards) would have a characteristic MOE more than 2,500 MPa greater than the cut-off for GL18, and the second product (60% of the boards) would meet a GL13 grade.
- The simulations also tend to indicate that the strength would be the limiting factor, with the characteristic bending strength typically resulting in a grade below the one obtained from the characteristic MOE. However, due to the nature of the model, the confidence in the strength values is less than for the MOE.

3.3 PRODUCT TESTING

3.3.1 LVL

Table 2 shows the characteristic values of the manufactured LVL. The targeted characteristic MOE of 12,000 MPa was achieved for the LVL12, but the characteristic MOE for the LVL21 was 480 MPa less than the targeted MOE of 21,000 MPa. Results detailed in [3] also indicated that at equivalent characteristic MOE, the manufactured and tested LVL typically have similar or higher characteristic strength values than commercial LVL or equivalent high grade sawn timber products. The study provided evidence that the southern blue gum resources can result in LVL products which can directly compete with commercial products.

Table 2. Characteristic mechanical properties of the manufactured and tested LVL.

	Targeted LVL type	
Mechanical properties	**LVL12**	**LVL21**
Edge bending MOE (MPa)	14,485	20,520
Flat bending MOE (MPa)	18,289	22,143
Edge bending strength (MPa)	86.3	102.7
Flat bending strength (MPa)	103.5	111.4
Compressive strength (MPa)	57.5	68.6
Edge shear strength (MPa)	6.9	7.1
Flat shear strength (MPa)	4.1	2.5

3.3.1 GLT

The tested GLT typically prematurely failed at a finger joint in the tension zone. This failure mode reflected finger jointing challenges, due to the cupping of the southern blue gum boards encountered during the manufacturing of the GLT beams (challenges which can be overcome as developed in [3]), the thin boards used in the manufacture (further creating finger jointing challenges) and the difficulty in bonding the southern blue gum finger joints in the trials performed in [3]. Additional work is needed to improve the finger jointing of southern blue gum boards.

In terms of bending MOE, the manufactured GLT beams achieved a GL18 grade, with a characteristic MOE of 18,727 MPa. However, due to the beams prematurely failing at a finger joint, the bending and shear characteristic strengths corresponded to a GL10 grade. Higher grades are to be expected if the bonding of the southern blue gum finger joints can be improved and pass the requirements set in the Australian standard AS 5068 (2006) for adhesive bond durability.

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4 – CONCLUSION

This paper presented the results from a study aiming at understanding which potential LVL and GLT structural products can be manufactured from Australian southern blue gum logs grown for woodchip purposes. 120 trees were harvested in the Australian Green Triangle and processed at the Salisbury Research Facility. Results showed that both commodity and high performing products can be manufactured from the resources of interest. Visual appearance LVL are unlikely to be manufactured as no A-grade veneers were recovered. Additional work is needed to understand how southern blue gum finger joints should be manufactured to pass the bond durability requirements.

5 – ACKNOWLEDGEMENTS

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