Eucalyptus globoidea peeling/LVL trial Part 2 – LVL

This LVL project report is part of the SFF 407602 project “Minimising growth-strain in eucalypts to transform processing”. It describes a peeling/LVL trial to test the suitability of NZDFI eucalypts for LVL production. Timber of these eucalypts has a high stiffness and density while also having naturally durable heartwood. However, these eucalypts are more challenging to process as often logs split making peeling into veneers difficult. Splitting is thought to be associated with internal growth-strain in the trees. The SFF project aims to reduce growth-strain in the trees through a genetic screening programme.

Material

Ten *E. globoidea* trees age 30-32 years were harvested on a Manawatu farm forestry property on the 31st May 2016 (Figure 1). These trees were of unknown genetic origin. Immediately after harvesting the stems were manually debarked. The ten trees yielded 26 suitable logs for peeling of 2.7 m in length. The logs were transported to Nelson Pine Industries Ltd, Richmond for processing. The logs were heated for 24 h in a water bath before peeling on the 8th of June. After clipping, 296 veneer sheets were obtained. Details on peeling and growth-strain were reported in the Part 1 of the report.

Figure 1: Debarked *E. globoidea* logs used for LVL trial

Methods

Processing data

From the dryer line Metriguard acoustic velocity and Novascan images including sheet width was available for each veneer sheet. The veneer sheets were traceable back to each log and position in the log.

Veneer lab data

A strip around 200-300 mm width was taken from a sheet near the start and the end of each veneer mat. These were cut into smaller sizes, measured for size and weighed to obtain green density. The pieces were oven dried to obtain moisture content, basic density and shrinkage values.

Bond test

Ten lab scale 10-ply LVL panels were manufactured. 6 panels were made of 100% eucalyptus veneer, choosing veneer sheets over the range representing the available MoE (Modulus of Elasticity) values (12 – 17.5 GPa) and densities (641 – 860 kg/m^3). Each LVL panel contained veneer from 1 (or 2) log(s) only. Another four panels were made of 5 radiata and 5 eucalyptus veneer plies. 2 radiata grades and a range of eucalypts grades were used in the panels. Detail of the layup of the LVL panels can be found in Table 3 and Table 4.

The quality of the glue line was tested by assessing the relative breakage in the glue and the wood veneers. A steam and a vacuum pressure method were used.

Shear test

The LVL panels produced for the bond test were also tested in shear. Fiveshear tests were conducted parallel to the glue line for each panel. The bond quality as well as the shear strength was recorded. The values were averaged for each panel.

Bending test

Another 18 10-ply LVL panels were made from a variety of tracked veneer sheets for bending tests, spanning the range of acoustic MoE and density of the veneers. From each of the 18 panels 2 samples were cut for testing. By applying the edge-wise 4-point bending tests the actual static MoE and MoR (Modulus of Rupture) of the LVL panels was obtained. The air-dry and oven-dry densities and the moisture content of the samples were also measured. The moisture content of the samples varied between 5 and 10%.

Results

Drying

The moisture content of the veneers after drying indicated homogeneous drying of the *E. globoidea* veneers. No excessively high or low moisture contents were found.

Shrinkage

The average shrinkage of the *E. globoidea* veneers was 9.9 % tangentially and 6.9% radially. This resulted in a volume loss of 16.1%. Tangential shrinkage varied between 6.1 and 14.6% for the veneer sheets.

For comparison typical radiata pine shrinkage values for sapwood are 6.4% (tangential) and 2.9% (radial) resulting in a volume loss of 9.1%. It should be noted that within species heartwood typically displays lower shrinkage than sapwood.

Physical properties – Density, acoustic velocity, MoE

The average dynamic MoE calculated for the *E. globoidea* veneer sheets from Metriguard acoustic velocity and interpolated lab density was 14.67 GPa ranging from 9.59 to 20.26 GPa (Figure 2). The dynamic MoE is overestimating the for LVL relevant static MoE, for which an average value of 12.73 GPa was estimated. Further the marketable static characteristic MoE must include variability in production and time what will further reduce the value reported in this study. The currently produced LVL from radiata guarantees MoE of 8 or 11 GPa. The *E. globoidea* MoE values are higher compared to radiata pine but do not match reported value of 17 GPa for sawn timber of *E. globoidea* sourced from Australian old-growth forests.

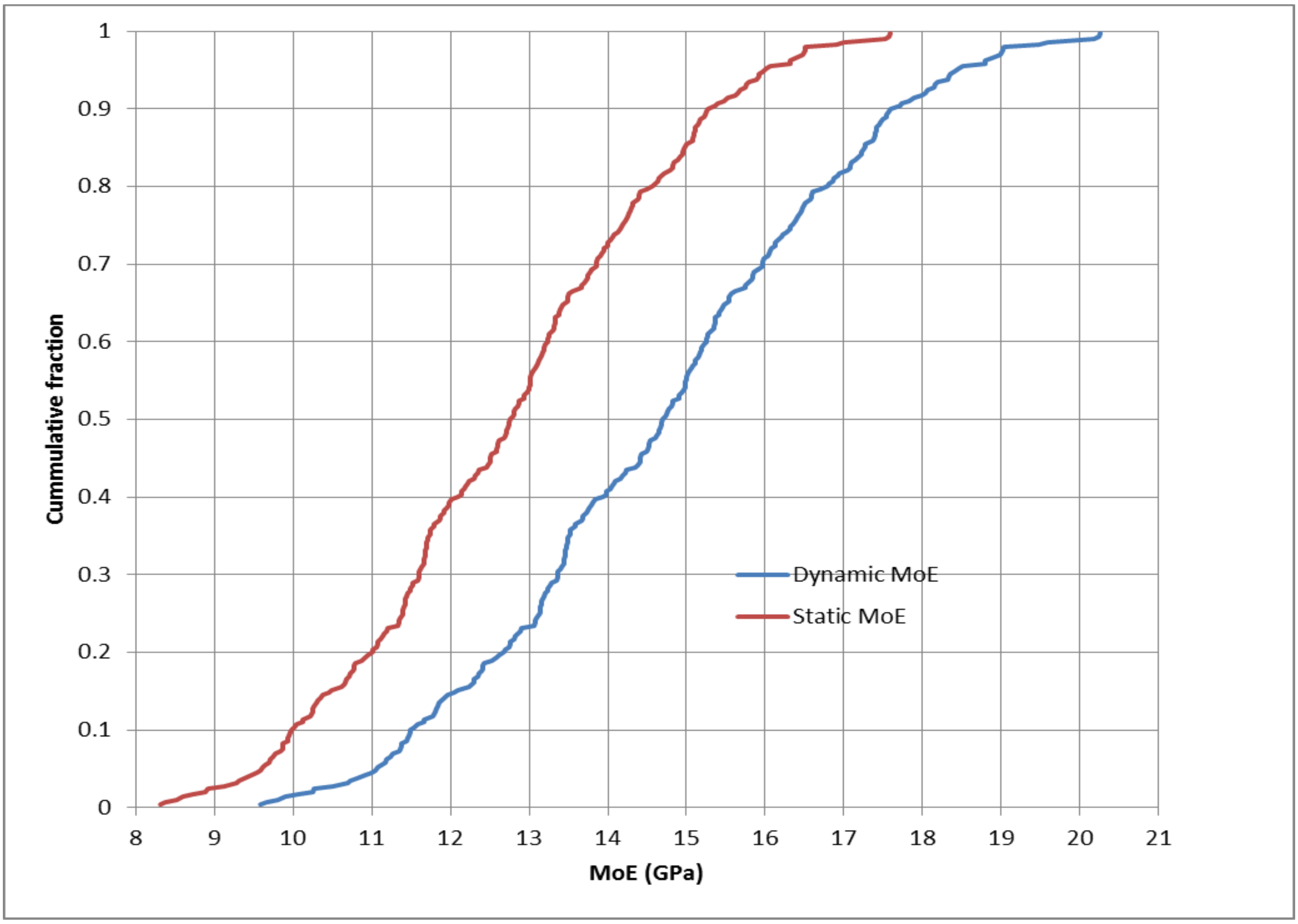

Figure 2: Cumulative dynamic and static MoE of veneer sheets peeled from 30 year-old *E. globoidea*.

It has been noted that the tested *E. globoidea* material was unimproved genetic material, thereby the results demonstrate the wide natural variability in wood properties. When MoE is analysed for individual trees significant differences were found for the individual trees (Figure 3). When normalised for radius, the stiffest log had a 26% higher MoE than the average while the least stiff tree produced veneer with a 14% lower dynamic MoE (Table 1). Or in other words trees were varying between 10 and 18 GPa 50 mm from the pith. This result supports that NZDFI's selection programme could significantly increase the stiffness of *E. globoidea* to enhance its suitability for use in LVL.

MoE increased from pith to bark by 0.01 GPa per mm in the assessed diameter range (50 - 200 mm) (Table 1). Stem height had no statistically significant effect in this sample, in contrast what is commonly found in other species. The larger diameter peeler cores avoided evaluating the poorest corewood and may have contributed to this observation.

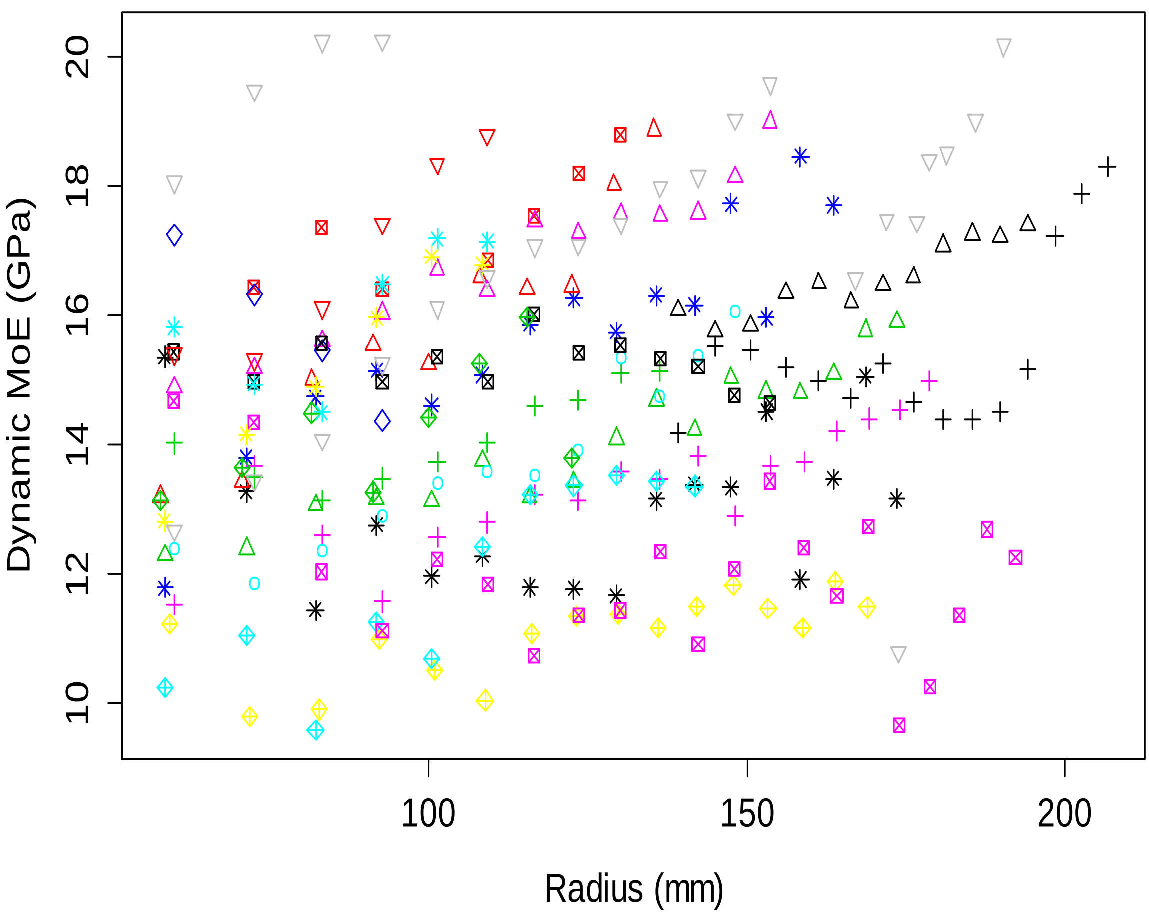

Figure 3: Dynamic MoE of veneer from *E. globoidea* logs in relation to stem radius. Colours indicate trees, while characters indicate logs.

Table 1: Statistical model of veneer MoE considering tree and radius.

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Call:
lm(formula = Data$MoE_dynamic ~ Data$Radius + as.factor(Data$Tree))

Residuals:
    Min      1Q  Median      3Q     Max 
-6.9495 -1.2220 -0.0415  1.2144  4.7916 

Coefficients:
                       Estimate Std. Error t value Pr(>|t|)    
(Intercept)           12.614468   0.624550  20.198  < 2e-16 ***
Data$Radius            0.010749   0.003116   3.449 0.000658 ***
as.factor(Data$Tree)2  1.708696   0.582449   2.934 0.003658 ** 
as.factor(Data$Tree)3  0.174113   0.597988   0.291 0.771164    
as.factor(Data$Tree)5  2.408964   1.050243   2.294 0.022627 *  
as.factor(Data$Tree)6  3.268997   0.616428   5.303 2.48e-07 ***
as.factor(Data$Tree)7 -0.003204   0.595879  -0.005 0.995714    
as.factor(Data$Tree)8  0.805404   0.589700   1.366 0.173219    
as.factor(Data$Tree)9 -1.710841   0.605679  -2.825 0.005110 ** 
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Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 1.811 on 253 degrees of freedom
  (29 observations deleted due to missingness)
Multiple R-squared:  0.4044,	Adjusted R-squared:  0.3856 
F-statistic: 21.48 on 8 and 253 DF,  p-value: < 2.2e-16
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Comment on species choice

E. globoidea was chosen for the peeling trial as trees of the required diameters were available. While NZDFI is working on *E. globoidea* it is not included in the screening programme of this SFF project “Minimising growth-strain in eucalypts to transform processing”. The species screened in this project for low growth-strain, early growth, stiffness and volumetric shrinkage are *E. bosistoana* and its close relative *E. argophloia*. However, no *E. bosistoana* or *E. argophloia* trees of the required size for peeling could be located in New Zealand. Table 2 lists the MoE and basic density of relevant species when sourced from Australian old-growth forests. *E. bosistoana* appears to have an advantage considering stiffness for LVL.

Table 2: Wood properties reported for relevant species. Note this is data considering the Australian resource (Bootle 2005)

NZDFI species	**MoE (dry) GPa**	**Basic density (kg/m^3)**
E. bosistoana	21	880
E. globoidea	17	680
E. quadrangulata	18	800
E. sideroxylon (tricarpa)	17	920
Other relevant species in NZ		
E. nitens	13	530
E. fasitgata	14	570
E. regnans	16	520
P. radiata	9.1	NA

Little is known about the wood properties of NZ grown durable eucalypts or their properties as young trees. Jones et al. 2000 report a MoE (joist) of 12 GPa (ranging between 9-18 GPa) for sawn timber recovered from 25 year-old NZ-grown *E. globoidea* for the butt log and 15 GPa (ranging between 11-20 GPa) for the 2nd log. A small sample (9 each) of *E. globoidea* and *E. bosistoana* trees were sampled to measure acoustic velocity in discs. The samples originated from thinning operations in NZDFI breeding trials at age ~4. Figure 4 shows the acoustic velocity (air dry) of *E. globoidea* and *E. bosistoana* close to the pith (<35 mm radius). The small sample indicated that the acoustic velocity of *E. bosistoana* was with ~4100 m/s 14% faster than that of *E. globoidea* with ~3600 m/s in the juvenile corewood. This would imply a ~30% higher MoE for *E. bosistoana* at the same density.

Considerable variation between trees was observed, indicating a potential for genetic improvement. The relatively high acoustic velocity of *E. bosistoana* in the corewood could allow peeling veneers to a smaller peeler core, increasing yields and allowing the use of a small diameter younger resource.

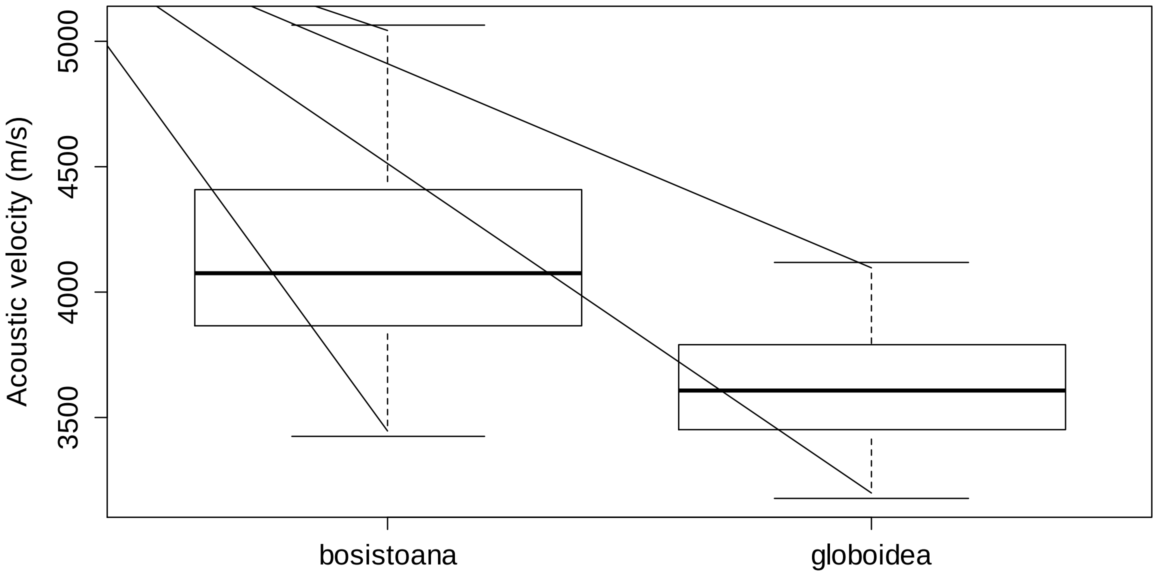

Figure 4: Acoustic velocity of *E. globoidea* and *E. bosistoana* close to the pith (<35 mm radius). Discs of 9 trees of each species were obtained from thinnings (~age 4) of NZDFI trials.

LVL

According to AS/NZ 4357 (Structural laminated veneer lumber) bonding between the plies in LVL shall be a Type A bond. This requires a phenolic adhesive complying with AS 2754.1 as well as when tested according to AS/NZS 2098.2 a bond quality of any single glueline not less than 2 and an average of not less than 5.

Bond test

The bond test revealed poor bonding of the plies. None of the produced panels passed the specifications for structural LVL (Table 3 and Table 4). Density seemed to exaggerate the bonding difficulty for the 100% *E. globoidea* LVL. Alternating *E. globoidea* and *P. radiata* veneers improved bond quality but the results were still below the specifications for structural LVL.

The glueline between radiata plies was excellent (Table 4, layer 4-5).

Table 3: Bond test of LVL panels made from *E. globoidea* veneers

Test	Veneer	Grade	Density	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	Ave.
AC	1-6-8+2-3-5	12GPa	641	9	2	8	1	6	8	4	2	4	4.9
	1-11-17	16GPa	697	9	3	7	8	5	6	5	3	6	5.8
	1-11-16	16GPa	703	7	3	7	8	9	8	7	1	7	6.3
	1-2-9	16GPa	807	1	0	5	1	1	1	1	1	2	1.4
	1-13-8	14GPa	809	2	0	3	3	1	3	3	1	2	2.0
	1-9-1	17.5GPa	860	2	2	1	1	4	3	4	2	2	2.3
VP	1-6-8+2-3-5	12GPa	641	5	1	4	1	2	2	3	0	1	2.1
	1-11-17	16GPa	697	9	4	5	7	7	6	6	1	5	5.6
	1-11-16	16GPa	703	8	3	7	8	8	9	7	2	8	6.7
	1-2-9	16GPa	807	3	0	5	2	1	2	1	1	1	1.8
	1-13-8	14GPa	809	3	2	4	3	1	1	1	0	3	2.0
	1-9-1	17.5GPa	860	7	0	1	1	5	7	5	0	2	3.1

Table 4: Bond test of LVL panels made from a mixture of *E. globoidea* and *P. radiata* veneers

Test	Veneer	Layer, Species, (Grade) 1-2 E-R (14)	2-3 R-E (17.5)	3-4 E-R (17.5)	4-5 R-R	5-6 R-E (14)	6-7 E-R (14)	7-8 R-E (12)	8-9 E-R (12)	9-10 R-E (12)	Ave.
AC	Mix G4 Rad + Euc A	6	4	5	9	7	8	8	5	9	6.8
	Mix G4 Rad + Euc B	3	4	3	10	6	7	6	3	7	5.4
	Mix G2 Rad + Euc A	8	3	2	9	7	7	9	7	8	6.7
	Mix G2 Rad + Euc B	6	8	2	9	7	3	7	3	9	6.0
VP	Mix G4 Rad + Euc A	8	5	1	9	8	6	8	6	9	6.7
	Mix G4 Rad + Euc B	6	4	2	8	8	6	7	0	9	5.6
	Mix G2 Rad + Euc A	4	3	3	9	7	5	8	9	9	6.3
	Mix G2 Rad + Euc B	5	2	1	9	7	7	8	3	8	5.6

Shear test

The shear test showed that shear strength correlated to bond quality (Figure 5). A large variability in shear strength and bond quality was observed.

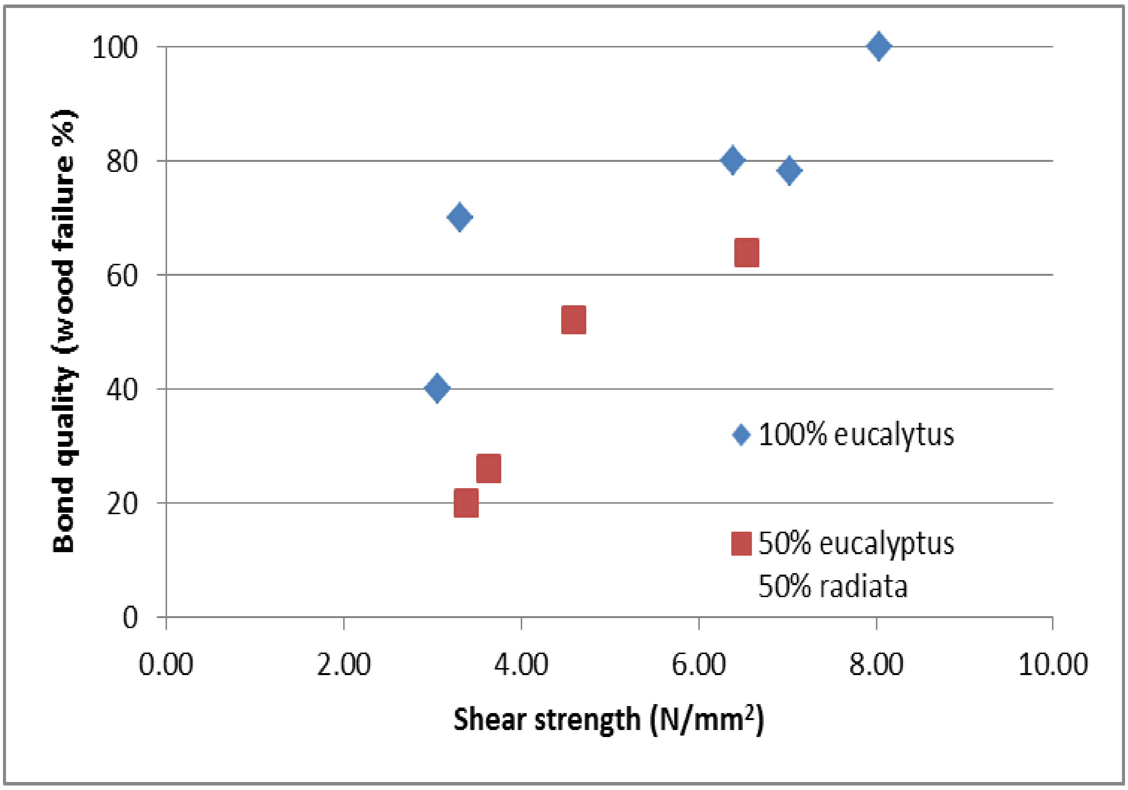

Figure 5: Shear strength vs bond quality of LVL containing *E. globoidea* veneers

Bending test

The bending tests revealed that the actual static MoE of the LVL was lower than the MoE predicted from the stiffness of the veneer sheets (Figure 6), ranging from 8.5 to 15.5 GPa for predicted grades of 12 to 17 GPa. The bending strength of the LVL panels was correlated (R^2 = 0.74) to the actual MoE (Figure 7).

Within each predicted MoE grade a large variability in density was observed (Figure 8). The density range seemed to increase with MoE. Figure 9 and Figure 10 display the actual MoE and MoR of the *E. globoidea* LVL panels depending on density. While MoE and MoR increased with density up to 750 kg/m^3 a reduction in these value was observed for LVL with densities above 800 kg/m^3. The increased difficulty gluing high density veneers indicated in the bond test could be connected to these results.

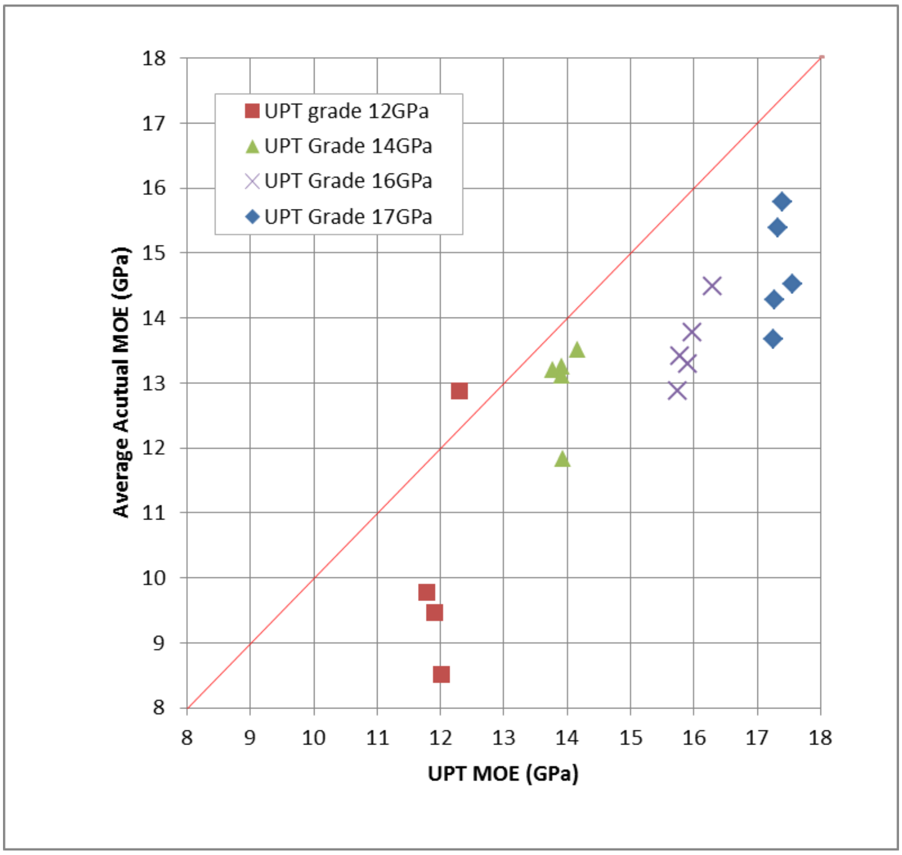

Figure 6: MoE predicted from veneer properties (UPT MoE) vs actual static MoE of LVL made from *E. globoidea*.

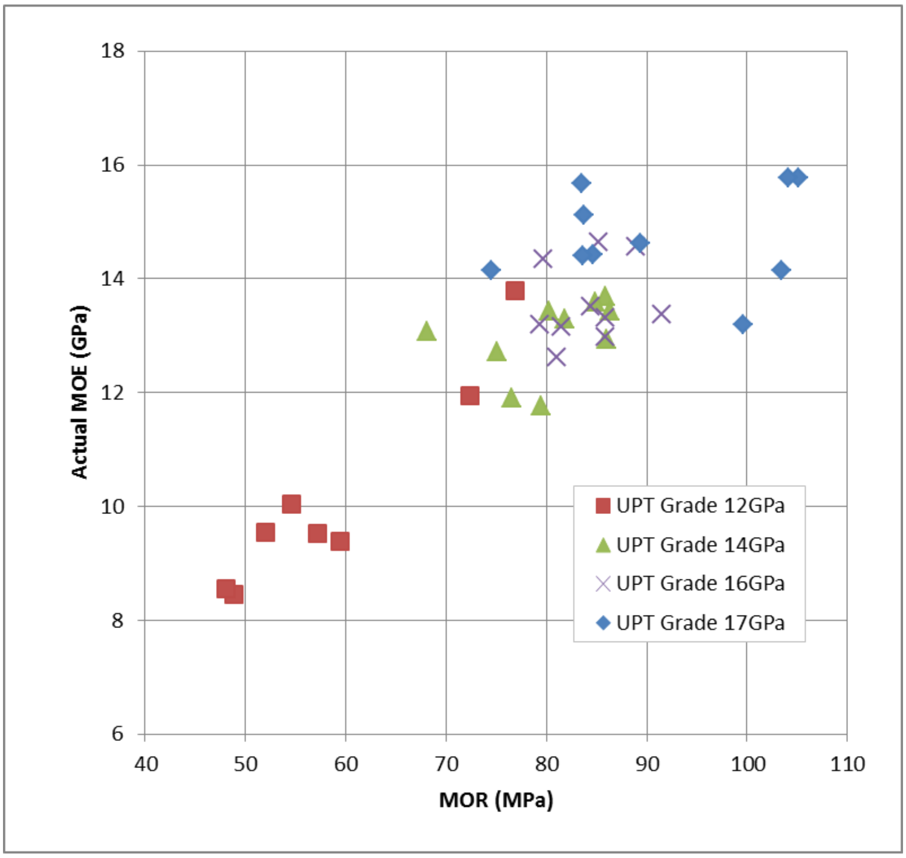

Figure 7: Actual MoE vs MoR of LVL made from *E. globoidea*.

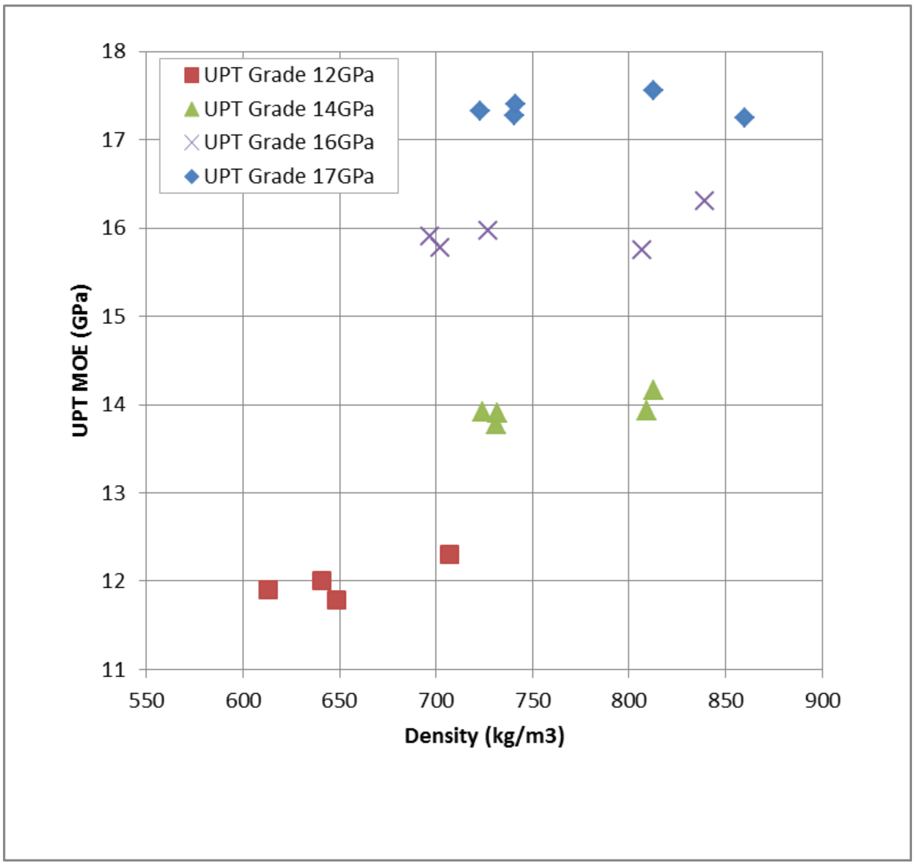

Figure 8: Density of *E. globoidea* LVL panels vs the predicted MoE class (UPT MoE).

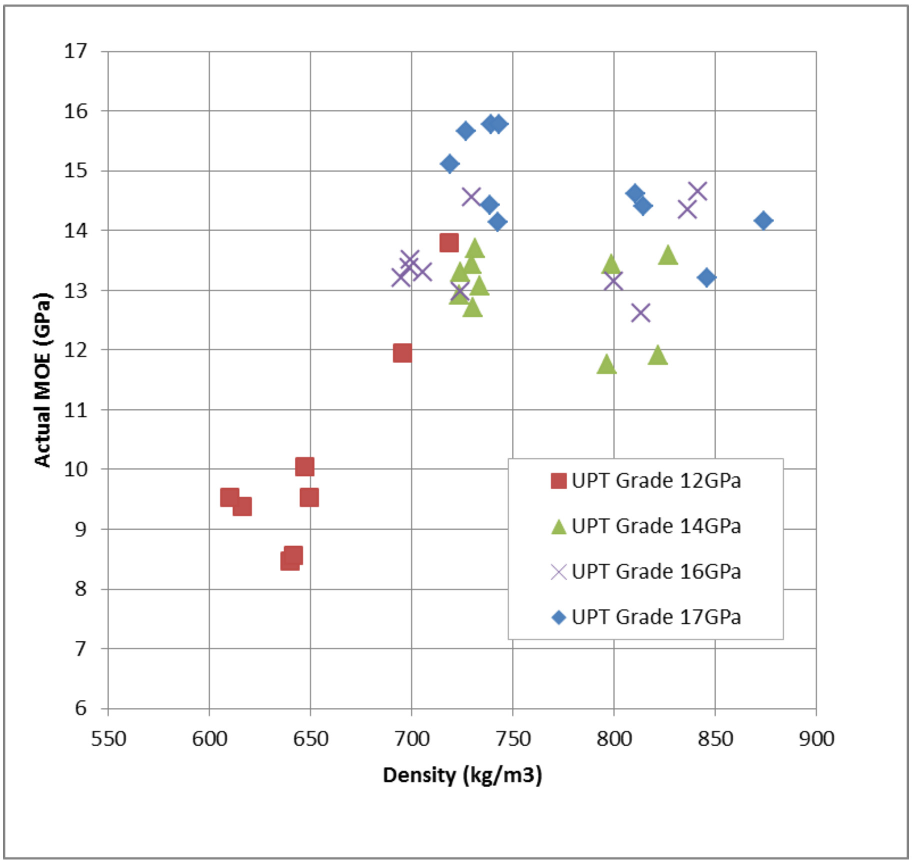

Figure 9: Actual MoE of *E. globoidea* LVL panels vs density.

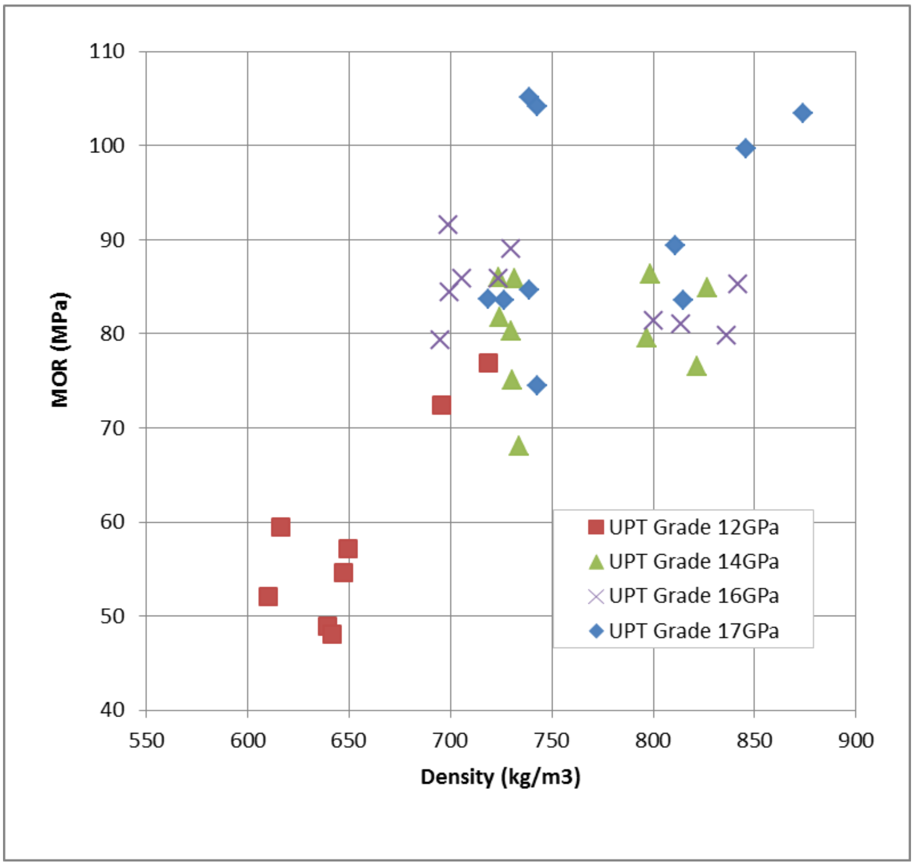

Figure 10: Actual MoR of *E. globoidea* LVL panels vs density.

Conclusion

- Although the average MoE of the *E. globoidea* veneers (12.7 GPa) was not matching reported values for the species, there were trees yielding high stiffness veneers. However, the results confirm the potential of durable eucalypts for LVL but also the need to include MoE as a trait in the NZDFI genetic wood quality improvement programme.
- Bonding and bending tests have highlighted the challenge of achieving quality glue lines for *E. globoidea* LVL. In particular increased density seemed to reduce bond quality. More work on gluing is required.
- With *E. bosistoana* having faster acoustic velocities than *E. globoidea* there is a possibility to achieve the same MoE at lower density. Therefore density and acoustic velocity appear to be important wood properties in the screening programme of this SFF project. (Note: Density and acoustic velocity are assessed).

References

Bootle, K. R. (2005). Wood in Australia. Types, properties, and uses, McGraw-Hill Australia.

Jones , T. G., R. M. Mcconnochie , T. Shelbourne and C. B. Low (2010). "Sawing and grade recovery of 25-year-old *Eucalyptus fastigata*, *E. globoidea, E. muelleriana* and *E. pilularis*." New Zealand Journal of Forestry Science **40**: 19-31.