Specialty Wood Products Research Partnership

Bonding of E. bosistoana and E. quadrangulata veneer

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FOREST GROWERS RESEARCH

Laboratory Report

Topic: Bonding of *E. bosistoana* and *E. quadrangulata* veneer

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Report to: Brendan Smith

Aim of this work:

To determine if two standard Hexion commercial phenolic resins will bond the *E. bosistoana* or *E. quadrangulata* veneer. Previous Hexion work has shown poor bonds with a number of different phenolic resins on *E. bosistoana* veneer.

Information on *E. bosistoana* veneer:

- Veneer samples provided had a density of 739 to 969 kg/m^3.
- The veneer was from 15-year old logs.
- Veneer moisture content was conditioned to 4 to 5% in Hexion's conditioning room.
- Veneer was nominally 3 mm in thickness.
- The age of the veneer samples was greater than would usually be seen in a commercial operation. It was peeled in November 2018 and sat round at ambient temperatures for about 8 to 9 months. Hexion conditioned the veneer to a 4 to 6% moisture range prior to gluing. It is not known if this had a negative effect on the adhesion tests.

Information on *E. quadrangulata* veneer:

- Veneer samples provided had a density of about 557 to 789 kg/m^3.
- The veneer was from 15-year old logs.
- Veneer moisture content was conditioned to 4 to 5% in Hexion's conditioning room.
- Veneer was nominally 3 mm in thickness.
- The age of the veneer samples was greater than would usually be seen in a commercial operation. It was peeled in November 2018 and sat round at ambient

temperatures for about 8 to 9 months. Hexion conditioned the veneer to a 4 to 6% moisture range prior to gluing. It is not known if this had a negative effect on the adhesion tests.

Phenolic resole resins:

Phenolic resole resins can be made to a wide range of molecular weights and properties for the plywood and LVL industry. The phenolic resoles are made from phenol formaldehyde using caustic soda as a catalyst. The resoles typically used in plywood and LVL are pH 11.5 to 13.5.

When they phenolic resoles are applied to Radiata pine veneers the typical pH of the finished LVL which is soaked in water is pH 6 to 7.5 depending on the phenolic resin formulation.

The pH would be expected to be higher where the phenolic resin contacts the veneer surface. This pH in the case of blackbutt is capable of solubilizing an alkaline extractive. This extractive was analysed by CSIRO in Australia and shown to cause adhesion issues. There are a number of papers published on it. Blackbutt is *Eucalyptus pilularis*, a species of medium-sized to tall tree that is endemic to eastern Australia. The extractive is a methyl phenol species in its sodium salt form and is described in a number of CSIRO articles.

The other issue with very acid wood species is they can neutralise the catalyst (Caustic soda) which is essential for phenolic resin cure. Phenolic resins cure speed is at a minimum at about pH 3 to 6.

Conclusion:

1. The bonds produced with the tolerant A Bond plywood resin on *E. bosistoana* and *E. quadrangulata* veneer were variable and would not consistently meet an AS/NZS 2269.0 Plywood A bond standard. The AS/NZS 2269.0 A bond standard requires a minimum average bond of not less than 5 with no bonds less than 2.

2. The bonds produced with the phenolic A Bond LVL resin on *E. bosistoana* and *E. quadrangulata* veneer were variable and only just meet the AS/NZS 4357.0 structural LVL A bond standard which requires a minimum average bond of not less than 5 with no bonds less than 2.

3. The bonds observed were either very good on a glue line or very poor. The poor bonds showed 100% glue transfer, but no bond.

Discussion of results

1. The observation that the poor bonds showed 100% glue transfer, but no bond is consistent with what has been observed in Australia with resin extractives interfering with the alkaline phenolic adhesive bonds in other Eucalyptus species. Previous work (appended to this document) with old growth *E. bosistoana* veneer also showed similar issues.

2. All the panels were prepared from the same veneer species. A common industry practise is to bond Radiata pine veneers to a Eucalyptus species. This usually results in an improved bond quality. This was not part of the scope of this work.

3. The New Zealand Australia standard require wood fibre failure of greater than 50% to be achieved a pass. This is based on the premise that the glue will strengthen the area around the glue line. This makes the wood immediately next to the glue line weaker. If a good adhesive bond is formed, that is durable, a high level of wood fibre will be seen. The Japanese standard for plywood has a strength requirement. The wood fibre failure requirement is lowered at failing loads increases. The US plywood standard has removed the strength requirement and moved to a wood fibre requirement only for the same test.

4. Wood fibre gives a good indication of the durability of an adhesive bond. A low wood fibre failure does not mean a bond will fail in service. The likelihood is increased. Washed out bonds are reported by EWPAA to be less likely to fail than a dried-out bond.

5. The phenolic resins properties such as viscosity and molecular weight are adjusted for each wood species. Higher density wood species are often slower to wet which can retard resin cure which can cause wash out.

6. Some wood species like Blackbutt in Australia have an alkaline extractive which causes issues with alkaline phenolic. This species is bonded with melamine formaldehyde resins and Hybrid phenolics (Hexion has commercially used technology that works) CSIRO did a lot of work in this area. Emulsion phenolic can bond black butt (which have high levels of extractives) but they are expensive.

7. The adjustment of the resin formulation / polymer molecular weight/ alkalinity as well as the process parameter like glue spread and assembly are likely, to allow these species to be bonded. This would have to be proven in laboratory work.

8. Understanding the pH of these wood species and its interaction with the phenolic resin is an area that should be investigated

9. **Recommendations:**

    1. This work indicates that the phenolic resins used to bond radiata pine are likely to need to be modified to bond the *E. bosistoana* and *E. quadrangulata* veneer if an AS/NZS 2269.0 / AS/NZS 4357.0 A bond needs to be met.

    2. The LVL phenolic resin performed better than the tolerant plywood phenolic resin.

    3. There appears to be some area in both the *E. bosistoana* and *E. quadrangulata* veneer that are harder to bond. It is not clear what this is due to. In these areas the phenolic adhesive seems to wash out and the glue line is very black.

    4. It may be worth mapping the extractives in a sheet of veneer then seeing if this is the area where a poor bond is produced.

    5. Understanding the pH of these to wood species and its effect on the glue line pH would help in the formulation of a phenolic resin to bond them.

Laboratory panels:

The *E. bosistoana* and *E. quadrangulata* veneer was supplied in sheets that were nominally 400 mm square. 5 ply LVL panels were prepared. The panels were prepared under the following conditions:

- No separation of Sap wood and Heart wood was attempted.
- The sheets of veneer were selected from the material provided.
- Glue spread of 180 to 200 gsm on a single glue line basis.
- 5-minute open assembly time was used for all the panels except for 2 panels.
- One panel from each veneer species (except pine) was made with an hour open assembly time using the highly tolerant phenolic plywood resin.
- Pre-press time of 10 minutes at about 9kgf/cm^2.
- 10-minutes closed assembly.
- 12-minute hot press time at 150^o C hot press pressure was 12kgf/cm^2.
- Two well proven Hexion resins were used. The first two panels in each veneer series were prepared with.

- A fast curing catalysed LVL resin – RCA (Reactor complete adhesive).
    - Panels made were labelled as Q1, Q2, B1, B2 and P1, P2 using the RCA resin.
- A very tolerant phenolic plywood - Glue mix
    - Panels made were labelled as Q, Q3, Q4, and B, B3, B4 and P3 , P4 Using the highly tolerant plywood resin.

Note:

- Q stands for using E. quadrangulata veneer
- E stands for using E. bosistoana veneer
- P stands for using Radiata pine veneer

Adhesives systems used and glue mix:

Phenolic LVL resin:

100 parts phenolic resin at 42.5% solids.

2 parts of Liquid catalyst.

The viscosity was about 2000 cps at 25^{o} C.

Tolerant phenolic plywood glue mix:

100 parts phenolic resin at 45% solids.

17.6 parts Filler.

11.2 Parts Extender (Wheat flour).

9.5 parts water.

The viscosity was about 3000 cps at 25^{o} C.

Bond results on Panels;

The bonds on each of the LVL panels prepared were tested by chiselling, dry chisel test, after a 6-hour pressure steam or a 30 minutes vacuum cycle then 30-minute pressure cycle.

The percentage wood fibre failure was rated using the AS/NZS 2098.2, table 1, scale of 0 to 10. 0 to 5% wood fibre failure is a 0. 50% wood fibre failure is a 5 and >95% wood fibre failure is a 10.

The results are as follows:

The bonds produced with the tolerant plywood resin did not meet the requirements for AS/NZS4357.0 or AS/NZS 2269.0 A bond standard on the *E. quadrangulata* veneer (Panels Q, Q3 and Q4).

The bonds produced with the phenolic LVL resin meet the requirements for AS/NZS4357.0 or AS/NZS 2269.0 A bond standard on the *E. quadrangulata* veneer. There were some glue lines that showed wash out (Panels Q1 and Q2).

E. Quadrangulata (Q)																						
Dry Bonds						Average		6 hour pressure steam						Average		Vacuum pressure soak						Average
Q1	9	8	9	8		**8.50**		Q1	9	9	2	3		**5.75**		Q1	9	7	3	4		**5.75**
Q2	7	9	8	5		**7.25**		Q2	8	7	5	8		**7.00**		Q2	9	7	7	2		**6.25**
Q3	6	7	8	8		**7.25**		Q3	2	4	2	9		**4.25**		Q3	8	6	3	6		**5.75**
Q4	8	9	8	8		**8.25**		Q4	9	3	2	2		**4.00**		Q4	7	8	3	2		**5.00**
Q	9	8	7	8		**8.00**		Q4	9	3	2	2		**4.00**		Q4	7	6	4	1		**4.50**

NB. Bonds highlighted in yellow show wash out.

The bonds produced with the tolerant plywood resin did not meet the requirements for AS/NZS4357.0 or AS/NZS 2269.0 A bond standard on the *E. bosistoana* veneer (Panels B1 and B2).

The bonds produced with the phenolic LVL resin did not meet the requirements for AS/NZS4357.0 or AS/NZS 2269.0 A bond standard. There were some glue lines that showed wash out (Panels B, B3 and B4).

E.Bosistoana (B)																						
Dry Bonds								6 hour pressure steam								Vacuum pressure soak						
B1	7	7	3	5		**5.50**		B1	7	4	5	7		**5.75**		B1	6	3	0	0		**2.25**
B2	5	8	7	7		**6.75**		B2	5	8	9	7		**7.25**		B2	3	8	8	9		**7.00**
B3	8	7	4	9		**7.00**		B3	3	6	1	9		**4.75**		B3	9	8	8	7		**8.00**
B4	8	9	2	9		**7.00**		B4	9	7	1	1		**4.50**		B4	5	8	2	2		**4.25**
B	8	8	7	7		**7.50**		B	2	7	5	7		**5.25**		B4	3	3	6	3		**3.75**

NB. Bonds highlighted in yellow show wash out.

The bonds produced with the tolerant plywood resin and phenolic LVL resin easily meet the requirements for AS/NZS4357.0 or AS/NZS 2269.0 A bond on radiata pine veneer. These resins are designed to run on radiata pine.

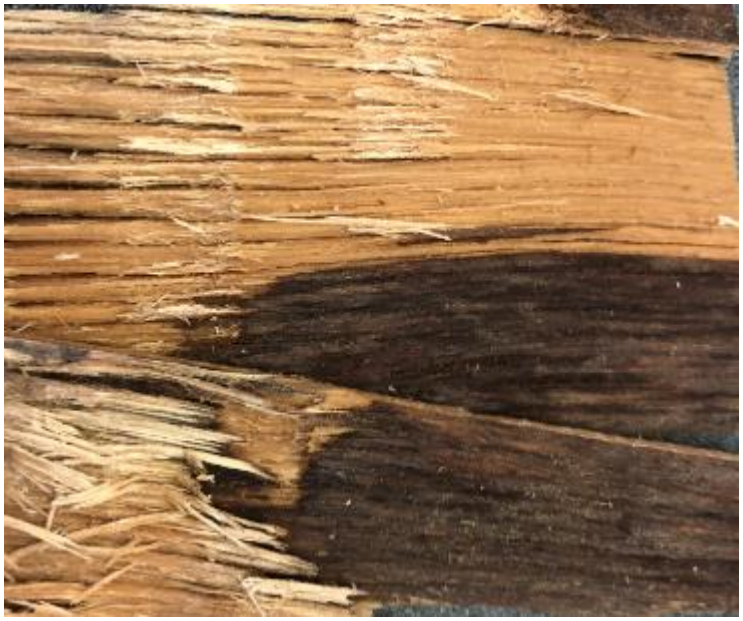
Radiata Pine																							
Dry Bonds								6 hour pressure steam								Vacuum pressure soak							
P1	9	8	8	8	8	**8.20**		P1	9	7	9	7	9	**8.20**		P1	9	7	8	6	9	**7.80**
P2	9	8	8	8	8	**8.20**		P2	9	8	9	8	8	**8.40**		P2	8	7	7	7	8	**7.40**
P3	9	8	7	8		**8.00**		P3	8	8	8	8		**8.00**		P3	8	5	7	7		**6.75**
P4	9	8	8	9		**8.50**		P4	9	9	8	8		**8.50**		P4	8	7	7	7		**7.25**
Yellow high lighted cells show bonds with good transfer but washed out (Excessive glue flow)																							

Picture of Dry bonds:

This is a picture of a dry chiselled Phenolic bond produced on the *E. quadrangulata* veneer which was immediately placed in the hot press with less than 5 minutes total assembly time. It was badly washed out (excessive glue flow). The dry bonds had no wood fibre failure but 100% transfer.

The dry wood fibre failure is improved by increasing the open time. It did not always improve the 6-hour boil or vacuum pressure bond results.

This is a picture of the bond after the A bond boil test. In some cases, some wood fibre failure is good but right next to it is zero. The areas with poor bond looked washed out with plenty of glue transfer. This is a typical example of what is seen. The dark brown area has no wood fibre failure.



These are a series of pictures on *E. bosistoana* veneer bonds which show one glue line with 50% wood fibre failure on average, yet the other glue lines are greater than 80%. The one with 50% shows a large area of no bond.

Appendix 1

Subject: Samples for assessment of bonding in *E. bosistoana* and *E. quadrangulata* veneer

Date: 12/09/2019

Author: Clemens Altaner, Gert Hendriks and Monika Sharma

File No.: SWP-FN085

Objective

Sample preparation from rotary peeled veneers for commercial adhesive manufacturer to assess bonding of *E. bosistoana* and *E. quadrangulata*.

Table 1: Summary of veneers obtained from 15-year-old *E. bosistoana* grown in New Zealand

Error! Not a valid link.	Specie	Samples (400x400 mm^2) per sheet	Samples (400x400 mm^2) sent	Samples (400x400 mm^2) left	Density (kg/m^3)	Velocity (km/s)	MOE (GPa)
B1-1	*E. bosistoana*	11	5	6	848	4	13.5
B1-2	*E. bosistoana*	0	0	0	778	4.52	15.9
B1-3	*E. bosistoana*	3	2	1	780	4.74	17.6
B1-4	*E. bosistoana*	12	7	5	839	4.72	18.7
B1-5	*E. bosistoana*	6	3	3	827	4.72	18.5
B2-1	*E. bosistoana*	1	0	1	769	4.06	12.7
B2-2	*E. bosistoana*	2	1	1	745	4.29	13.7
B2-3	*E. bosistoana*	4	2	2	730	4.47	14.6
B2-4	*E. bosistoana*	12	7	5	775	4.56	16.1
B2-5	*E. bosistoana*	15	7	8	818	4.88	19.5
B2-6	*E. bosistoana*	12	7	5	776	4.8	17.9
B3-1	*E. bosistoana*	5	2	3	926	3.99	14.7
B3-2	*E. bosistoana*	5	3	2	904	4.43	17.8
B3-3	*E. bosistoana*	0	0	0	969	4.2	17.1
B3-4	*E. bosistoana*	13	7	6	835	4.53	17.2
B3-5	*E. bosistoana*	15	9	6	787	4.47	15.7
B3-6	*E. bosistoana*	11	6	5	792	4.81	18.3
B3-7	*E. bosistoana*	4	2	2	739	4.93	18
Total *E. bosistoana* samples		131	70	61			

Table 2: Summary of veneers obtained from 15-year-old *E. quadrangulata* grown in New Zealand

Sheet ID	Specie	Samples (400x400 mm^2) per sheet	Samples (400x400 mm^2) sent	Samples (400x400 mm^2) left	Density (kg/m^3)	Velocity (km/s)	MOE (GPa)
Q1/1-1	*E. quadrangulata*	3	1	2	657	4.41	12.8
Q1/1-2	*E. quadrangulata*	7	4	3	715	4.59	15.0
Q1/1-3	*E. quadrangulata*	10	6	4	692	4.41	13.5
Q1/2-1	*E .quadrangulata*	4	2	2	557	4.15	9.6
Q1/2-2	*E. quadrangulata*	17	10	7	689	4.31	12.8
Q1/2-3	*E. quadrangulata*	16	9	7	680	4.55	14.1
Q1/2-4	*E. quadrangulata*	5	3	2	693	4.46	13.8
Q1/2-5	*E. quadrangulata*	13	8	5	714	4.42	14.0
Q1/2-6	*E. quadrangulata*	10	6	4	703	4.21	12.4
Q1/3-1	*E. quadrangulata*	0	0	0	623	4.23	11.1
Q1/3-2	*E. quadrangulata*	7	4	3	632	4.27	11.5
Q1/3-3	*E. quadrangulata*	8	5	3	669	4.47	13.4
Q1/3-4	*E. quadrangulata*	5	3	2	753	4.57	15.7
Q1/3-5	*E. quadrangulata*	12	7	5	789	4.60	16.7
Q2-1	*E. quadrangulata*	4	2	2	682	5.12	17.9
Total *E. quadrangulata* samples		121	70	51			

Material

18 sheets of *E. bosistoana* (Table 1) and 15 sheets of *E. quadrangulata* (Table 2), for which details of peeling and veneer characterisation are given in report SWP FN-073 and SWP T-079, were used to make 400 x 400 mm^2 samples needed for adhesives tests. Number of samples obtained per sheet were variable due to cracks and knots in the sheets.

Methodology

Sheets were kept at room temperature and USB data logger was used to capture relative humidity for a week. The average temperature 17.6 °C and relative humidity was 71%. The acoustic velocity was measured using the time-of-flight Fakkop tool. Three measurements were taken per sheet and averaged. A small

sample of size ~100 x 50 mm^2 was cut to measure density. Density was measured using weight and dimensions of the cut piece. The average moisture content of small samples was 9%.

Sheets were cut to obtain 400 x 400 mm^2 samples with a jig saw (Figure 1). All samples were labelled with the sheet number they were cu from. In total 70 panels of each specie were made available for gluing and bonding assessment. The remaining samples remain in storage at UC SoF.

Figure 1: 400 x 400 mm^2 samples of *E .bosistoana* and *E. quadrangulata*

Appendix 2 This gives the veneers used in the various panels.

Panel Q1		**Panel B1**
Veneer label		Veneer label
Q 1/1-2 1 of 7		B1-4 6 of 12
Q 1/1-2 2 of 7		B1-4 5 of 12
Q 1/1-2 3 of 7		B1-4 4 of 12
Q 1/1-2 4 of 7		B1-4 1 of 12
Q 1/2-5 1 of 13		B2-4 1 of 12
Panel Q2		**Panel B2**
Veneer label		Veneer label
Q 1/2-6 2 of 10		B2-4 2 of 12
Q1/2-6 1 of 10		B2-4 3 of 12
Q1/3-4 3 of 4		B2-4 5 of 12
Q1/3-4 2 of 4		B2-4 6 of 12
Q1/3-4 1 of 4		B2-4 7 of 12
Panel Q3		**Panel B3**
Veneer label		Veneer label
Not recorded		Not recorded
Not recorded		Not recorded
Not recorded		Not recorded
Not recorded		Not recorded
Not recorded		Not recorded
Panel Q4		**Panel B4**
Veneer label		Veneer label
Not recorded		Not recorded
Not recorded		Not recorded
Not recorded		Not recorded
Not recorded		Not recorded
Not recorded		Not recorded
Panel QA long		**Panel BA long**
Veneer label		Veneer label
Q1/2-3 3 of 16		Not recorded
Q1/1 1of 6		Not recorded
Q1/2-1 2 of 4		Not recorded
Q1/2-1 1 of 4		Not recorded
Q 1/1-3 6 of 10		Not recorded