Forest&Wood Products Australia
Knowledge for a sustainable Australia

PRODUCTS & PROCESSING

PROJECT NUMBER: PRB046-0809 July 2009

Characterisation of plywood properties manufactured from plantation grown eucalypts

This report can also be viewed on the FWPA website
www.fwpa.com.au
FWPA Level 4, 10-16 Queen Street,
Melbourne VIC 3000, Australia
T +61 (0)3 9614 7544 F +61 (0)3 9614 6822
E info@fwpa.com.au W www.fwpa.com.au

Characterisation of plywood properties manufactured from plantation grown eucalypts

Prepared for

Forest & Wood Products Australia

by

D. Thomas, B. Joe, S. Austin and M. Henson

Publication: Characterisation of plywood properties manufactured from plantation grown eucalypts

Project No: PRB046-0809

ISBN: 978-1-920883-74-4

Researcher:

D. Thomas
Tree and Plantation Improvement Program
Forests NSW, PO Box J19
Coffs Harbour Jetty, NSW 2450

B. Joe
Tree and Plantation Improvement Program
Forests NSW, PO Box 100
Beecroft, NSW 2119

S. Austin
Big River Timber
Brickworks Road, South Grafton
NSW 2460

M. Henson
Sunshine Technology
PO Box 212880
Dubai, UAE

Final report received by FWPA in July, 2009

Forest & Wood Products Australia Limited
Level 4, 10-16 Queen St, Melbourne, Victoria, 3000
T +61 3 9614 7544 F +61 3 9614 6822
E info@fwpa.com.au
W www.fwpa.com.au

Executive summary

Objectives

The key objective was to determine suitability of selected plantation eucalypts for production of plywood.

Quantity and quality of manufactured veneer and plywood produced from 5 species (*Eucalyptus agglomerata, E.dunnii, E.grandis, E.pilularis, E.saligna*) aged 34 years and also *E. dunnii* aged 12 and 17 years were assessed. As such 3 ages of *E.dunnii* were examined.

Veneers were graded to Australian and New Zealand Standard *AS/NZS 2269.0:2008. Plywood – Structural, Part 0: Specifications.* (Standard Australia, 2008).

Plywood panel quality was determined by evaluating mechanical properties, stress grade, bond strength, moisture content and formaldehyde emissions.

Key Results

- Recovery of veneers depended on species and log diameter. The species component was related to a combination of effects including 'spin out', splitting, and factors such as decay/kino.
- Recovery of veneers was reduced by end-split on economics of plantation forestry.
- Formaldehyde emissions was influenced by species in the 34 year old trial, and also between ages in the *E. dunnii* age trial. Mean emission level was very low and ranged from 0.082 mg/L for *E. saligna* to 0.267 mg/L for *E. pilularis*. Formaldehyde emission appears to be significantly affected by wood age with higher emission levels recorded for younger plantations.
- Bond strength was excellent in the 34 year-old *E. dunnii* and *E. grandis* (100% of the samples having acceptable Type B bond), followed by *E. agglomerata* (88%), *E. saligna* (83%) and *E. pilularis* (78%).
- The results were of some concern for younger *E. dunnii* with only a low 27% (12 year-old) and 80% (17 year-old) having acceptable bond strength. A re-test of the *E. dunnii* population confirmed the poor results, although there was a marked improvement in the pass rate (from 27% to 60%) for the 12 year-old material, but a small decline for the 17 year-old material (from 80% to 70%). The bond quality for re-tested 34 year-old *E. dunnii* plywood was unchanged with 100% pass.

- The results for *E. dunnii* suggests there is an age effect on bond quality and further work is needed to fully understand the factors involved and for suitable glues to be developed.

- Plywood grade recovery was similar for *E. pilularis*, *E. agglomerata* and *E. dunnii* with at least 76% of the recovered plywood panels making F27 or better. Recovery of the same grades for *E. grandis* and *E. saligna* was disappointingly low at around 30% - a result most likely attributed to the high presence of injury related gum pockets and borer attack in this study.

- The results from the age effect study for *E. dunnii* produced some surprising and favourable outcomes. The 17 year-old *E. dunnii* gave 80% recovery of F27 or better, whilst the 12 year-old material gave 68% for the same grades. These results were encouraging, particularly when *E. dunnii* is not widely regarded by the timber industry. The potential to produce high grade plywood from a species at such an early age is undoubtedly economically beneficial to forest growers.

- Plywood manufactured from 34 year-old *E.agglomerata* and *E.pilularis* had the highest MOR and MOE (of approximately 110 MPa and 23000 MPa respectively), which were not significantly higher than results for 34 year old *E. dunnii*. MOR and MOE of panels produced from 34 year-old *E. grandis* and *E. saligna* were significantly lower.

- MOR and MOE of the younger *E. dunnii* (12 and 17 year-old) were only slightly lower than of the 34 year-old material. There was no significant difference in MOR and MOE amongst the 12, 17 and 34 year-old *E. dunnii*.

- MOE of test plywood pieces was better able to be predicted from Director HM200 acoustic resonance on logs than Fakopp acoustic velocity on standing trees.

- There was significant difference in hardness between species in the 34 year old species trial. All species except for *E. grandis* compared favourably or reasonably well with hardness values published for solid wood.

- Age had a significant effect on hardness with the older (34 year old) *E. dunnii* plywood having a higher hardness value than the younger 12 and 17 year old material. There was significant difference in hardness between the 12 and 17 year old plywood.

Table of Contents

1 Introduction

Plantation hardwood will meet a greater part of NSW timber supply in future years yet knowledge of its quality to meet high value end product uses is limited. Therefore concern over quality of plantation grown timber is considerable. Forests NSW (FNSW), as the largest wood supplier in NSW, have been working with a number of timber processors to evaluate the end product potential of plantation eucalypts, be that solid wood, manufactured wood or pulp. From a 34 year old eucalypt plantation trial FNSW are evaluating timber qualities of the best performing, in terms of stand volume, eucalypt species including *E. pilularis, E. dunnii, E. grandis, E. saligna* and *E. agglomerata*. For each species 9 trees encompassing a range of diameters were selected for processing.

Eucalyptus dunnii from two younger aged plantations aged 12 and 17 years were examined as this species has been planted extensively in recent years to meet expected shortfalls in timber supply yet there is almost no information on manufacturing potential of this timber from plantations in sub-tropical Australia. The information from these younger plantations is combined with the data of *E.dunnii* from the 34 year old plantation to expand the knowledge base about the influence of plantation age on wood quality. Ten trees from each of the younger plantations were selected for processing.

The results from the veneer mill, and plywood quality is reported in this report.

2 Materials and Methods

2.1 Description of Plantation

2.1.1 Wild Cattle Creek (34 year old plantation hardwood species trial)

This species trial (G1214D) located in compartment 557 of Wild Cattle Creek State Forest was established on four sites with Wild Cattle Creek state forest. Two adjoining sites designated as hardwood ridge and rainforest ridge were utilized for this study. The original overstorey vegetation of the hardwood ridge consisted of *Eucalyptus grandis*, *E. saligna*, *E. microcorys* and *Syncarpia glomulifera*, while the original overstorey of the rainforest ridge was dominated by *Cerapetalum apetalum*, *Araucaria cunninghamii*, *Orites excelsia* and *Schizomeria ovata*. The geology of the area is Coffs Harbour association *Coramba beds* (Cccs) of lithofeldspathic wacke, siliceous siltstone, mudstone, metabasalt, chert and hasper. The soil consists of well structured loam to clay topsoil and well structured to moderately structured clay loam to clay subsoils. The elevation of the trial is approximately 640m.

The species trial consisting of 13 species with two seedlots of three of these species was planted in March 1973 and the plantation clearfelled in July 2007. Original stocking was a 3*3 m spacing (1111 stems per hectare). No thinning had been carried out on this site. Tree growth (diameter and height) were measured periodically (typically each 5 years) with the last measurement at age 32 year. On this last measurement date stem form, branching characteristics, height to first branch were also measured. Five species showing better growth performance were selected for more detailed studies. These species were *Eucalyptus pilularis* (Blackbutt), *E. dunnii* (Dunn's white gum), *E. grandis* (Flooded gum), *E. saligna* (Sydney blue gum) and *E. agglomerata* (Blue leaved stringybark).

2.1.2 Newry (17 year old *Eucalyptus dunnii* plantation)

The hardwood plantation in Newry State Forest was established by APM forests on previously clear/semi grazing land. The original forest type would have consisted of *Eucalyptus pilularis* forest types on ridges and upper slopes, mixed hardwoods forest types on lower slopes and moist forest types along major creek lines. The geology of the region within Newry State Forest of interest consists of Nambucca beds/Unnamed phyllite consisting of phyllite and schist. The soil unit type is mapped as south creek, an alluvial soil consisting of brown podzolic soils, however, it is infact more closely aligned to Bellinger, an alluvial soil consisting of brown earths, and brown podsolics grading to highly variable alluvial soils on recent floodplains.

The original plantation was established in 1972 with *Eucalyptus grandis*. This species subsequently failed due to high mortality and poor form of remaining stems as a consequence of being 'off site'. Part of the plantation was clearfelled and replanted with *E. pilularis* and *E. dunnii* in 1990. Growth of both species was vigorous and the stand in compartment 297 received its first thinning in 2005 with the intended retention of 14m^3 ha^{-1}. An area of 1.5 hectares of compartment 297 was marked for conversion into a seed stand with an intended stocking of 150 sph. Material from this thinning operation was sourced for this study.

2.1.3 Boambee (12 year old *Eucalyptus dunnii* plantation)

The *E. dunnii* progeny trial located in compartment 601 of Boambee State Forest was established in February 1995. The original forest type would have consisted of *E. pilularis* forest types on ridges and upper slopes, mixed hardwoods forest types with wet sclerophyll and rainforest types on the lower slopes and creek margins. The geology is classified as Coffs Harbour association *Blooklana beds* comprising thinly bedded siliceous mudstone and silt with rare lithofeldspathic wacke, locally chert, jasper and metabasalt. The soil in the trial area is classified as Dairyville, an alluvial soil on level to undulating terraces and floodplains consisting of deep well drained alluvial soil. It consists of black loam at the surface to reddish brown clay loam at depth. Parts of the progeny trial which were not sampled in this study consist of Mount Coramba, a soil of steep slopes and narrow ridges consisting of lithosols, minimum krasnozems, red, brown or yellow podsoics or yellow earths.

A *E. grandis* plantation was established in the 1970's after regeneration of native forest was deemed to have failed. This *E. grandis* plantation was harvested in the 1990's and replanted to the current *E. dunnii* trial. The *E. dunnii* progeny trial comprising 219 families/seedlots plus one *E. grandis* seedlot (G023101) at a spacing of 3 m rows and 2.4 m within rows (1389 stems per hectare). Tree plots of four trees per seedlots were established in a randomised block design with 6 replicates.

Boambee is a high quality site with predicted MAI at 20 years of 20 m^3 ha^{-1} (Henson and Vanclay, 2004). The Boambee progeny trial had a basal area at 1.3m tree height of 10 m^2 ha^{-1} at age 3 (1998). The trial was thinned to 694 stems per hectare (sph) at age 4.5 year following an operation to leave only the two individuals per seedlot per replicate with best stem form and highest volume. The basal area at age 6 was 19.2 m^2 ha^{-1} and had increased to 25.2 m^2 ha^{-1} at age 8. Pilodyn measurements to determine density of the outer wood, and acoustic properties measured using the FAKOPP were measured in each tree at Boambee in 2003 (aged 8 years).

A seed orchard will be established at Boambee created by retention of the single best (stem form and volume) individual tree per seedlot in each replicate. This seed orchard will have a stocking of approximately 347 sph.

2.2 Climate

Climate data was gathered from Silo datadrill from 1957 to 2005 (Figure 1). There is a distinct seasonality in climate with wet warm summers and cool dry winters prevailing in all three sites (Wild Cattle Creek, Newry, Boambee). Wild Cattle Creek has the lowest minimum temperatures of the three sites but similar maximum temperatures to Boambee. Newry has the hottest maximum temperatures and is the driest with 1507 mm mean annual rainfall. Mean annual rainfall at Wild Cattle Creek is slightly higher at 1599 mm. Boambee has the highest mean annual rainfall with 1853 mm.

At Wild Cattle Creek high monthly rainfall of over 150 mm /month occurs from December to March, and low monthly rainfall from 50 to 100 mm/month occurs from June to September. Monthly maximum temperatures range from 15°C in June -July to 25°C in December –January; while monthly minimum temperatures less than 5 °C occur from June to August.

At Newry high monthly rainfall of over 150 mm /month occurs from January to April; and low monthly rainfall from 50 to 100 mm/month occurs from July to September. Monthly maximum temperatures range from 20°C in June -July to 28°C in December –January; while monthly minimum temperatures less than 10 °C occur from June to August.

At Boambee high monthly rainfall of over 150 mm /month occurs from November to May; and low monthly rainfall from 50 to 100 mm/month occurs from July to September. Monthly maximum temperatures range from 18°C in June -July to 26°C in December –January; while monthly minimum temperatures less than 10 °C occur from June to September.

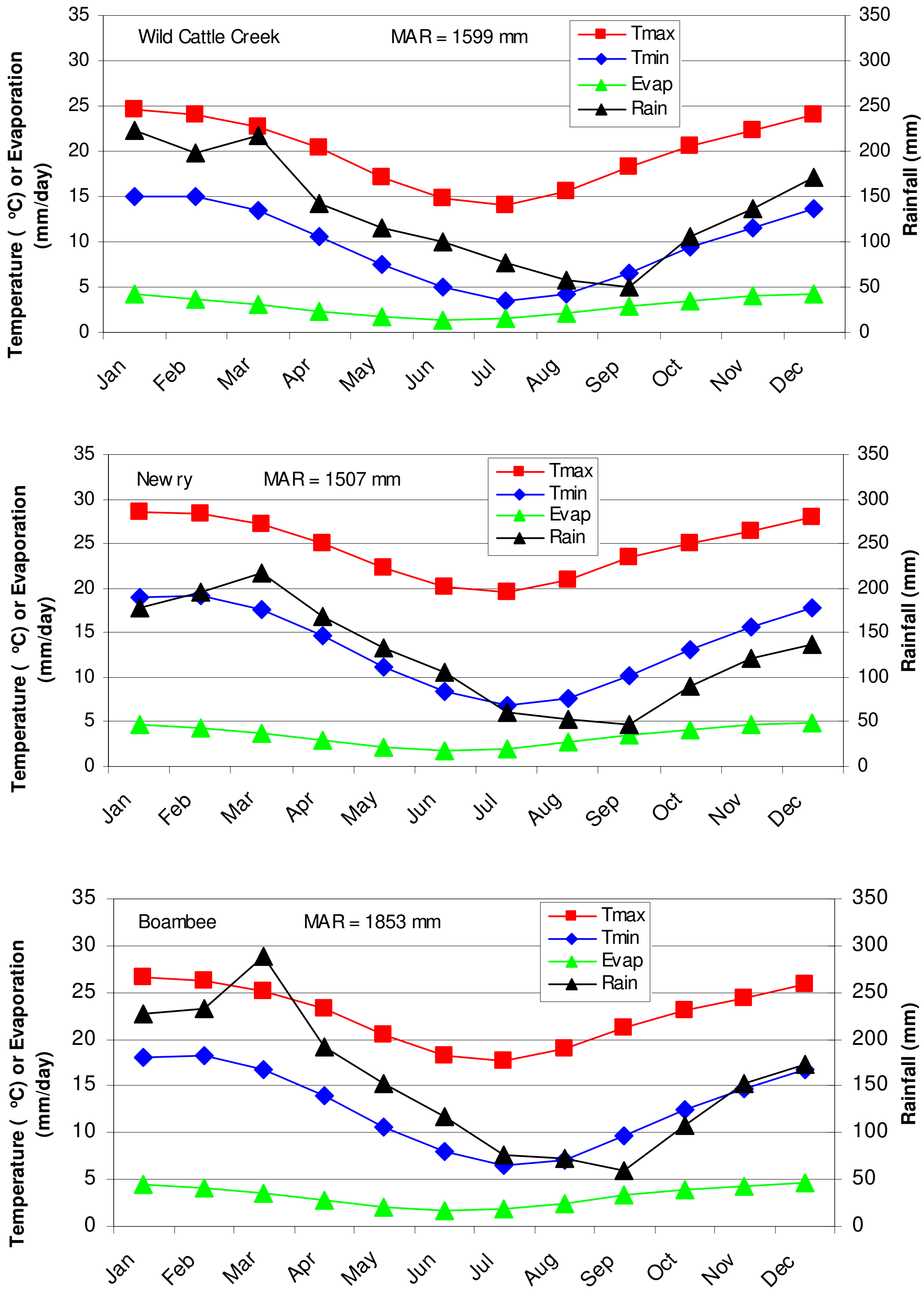


Figure 1. Monthly climate averages of rainfall, maximum temperature, minimum temperature and daily evaporation of the three plantations: Wild Cattle Creek, Newry and Boambee. Average taken from Silo Data drill from 1957 to 2005.

2.3 Tree selection, Harvesting and Log descriptions

At Wild Cattle Creek plantation a series of non-destructive wood quality measurements were taken on all surviving trees when aged greater than 32 years. These include diameter over bark at 1.3m (DBHOB), Pilodyn pin penetration measurements at 1.3m, and acoustic properties measured using the FAKOPP between 0.3m to 1.8m longitudinally.

At Newry plantation and Boambee plantation tree height and diameter over bark at 1.3m (DBHOB) was measured on each tree of four inventory plots (radial 0.1 ha) established in October 2006 in Newry and two inventory plots at Boambee plantation. Pilodyn measurements to determine density of the outer wood at 1.3m, and acoustic properties measured using the FAKOPP between 0.3m and 1.8m were measured on each tree in the inventory plots.

MOE was calculated from green density (GD) and fakopp acoustic velocity (V_{Fak}) as $MOE_{Fak} = GD*V_{Fak}^2$

"Research" trees were selected to cover a wide range of diameters, and were of good form with minimal sweep, and no branches or obvious scars in the lower 8m tree height. Pilodyn pin penetration and Fakopp were not used as selection traits in this study.

2.3.1 Sample locations from within each 'Research' Log

Wild Cattle Creek plantation was harvested in July 2007. Newry was harvested in October 2007 and Boambee in November 2007.

For each "Research" log the first 7.5 m were processed (Figure 2). This allowed detailed examination of mechanical wood properties from 0.5 to 2.0 m tree height and a veneer log of 5.5 m length (from 2.0 to 7.5 m tree height). Detailed knowledge of wood quality are required to determine relationships with processed timber quality and in-service use. These properties are essential for defining the economic value of processed timber, and hence economic value of plantations.

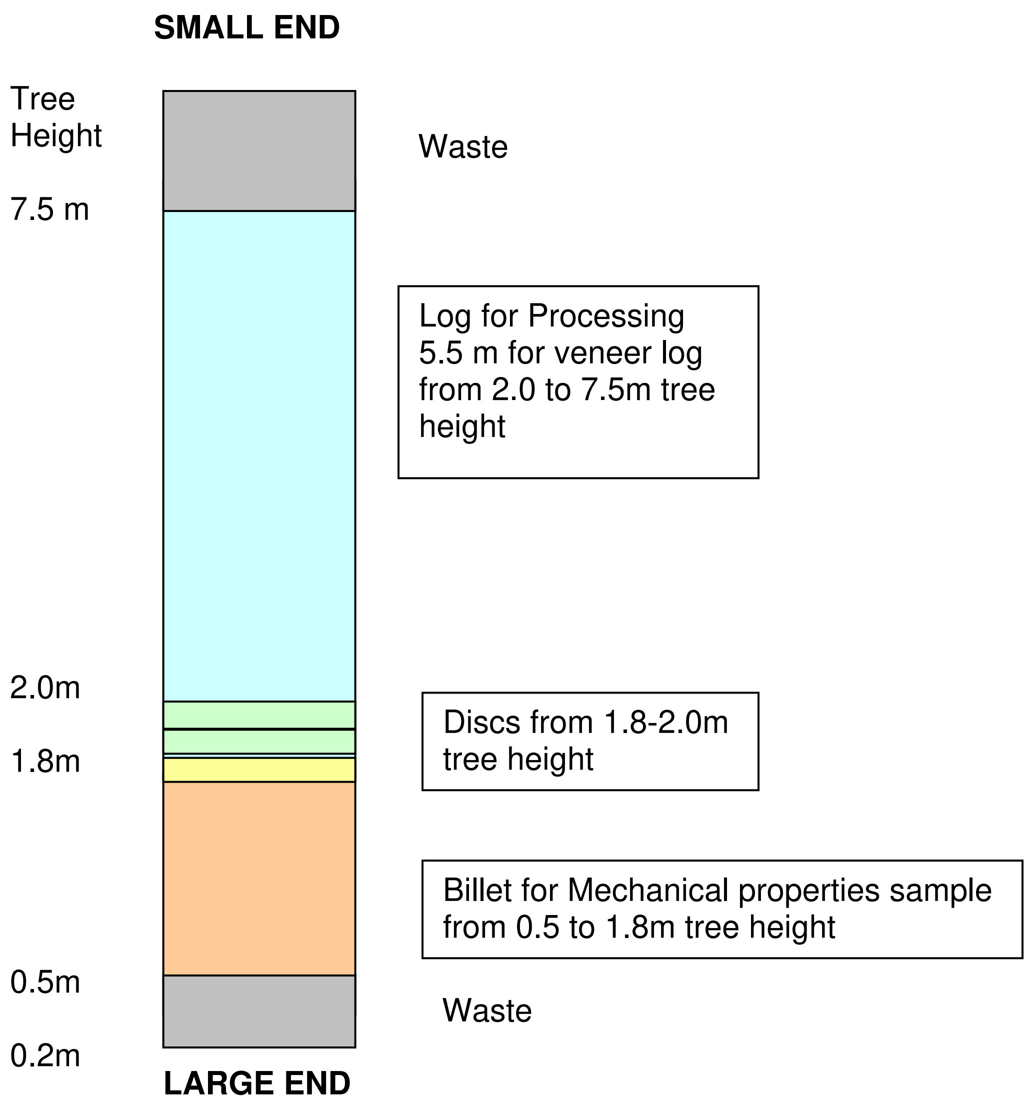


Figure 2 – Schematic of "Research" buttlog

Mechanical and physical wood properties of radial variation in shrinkage, hardness, MOE, and MOR were measured on a central flitch sampled from 0.5 – 1.8m (Figure 3). A central flitch from northern to southern aspect of the tree of 90-100mm thick was sampled. This flitch was sectioned into three pieces from 0.5 – 1.0m (for determining bending, MOR, MOE), 1.0 – 1.4m (for determining hardness), 1.4 – 1.8m (for determining dimensional stability and shrinkage). These measurements are not reported in this study.

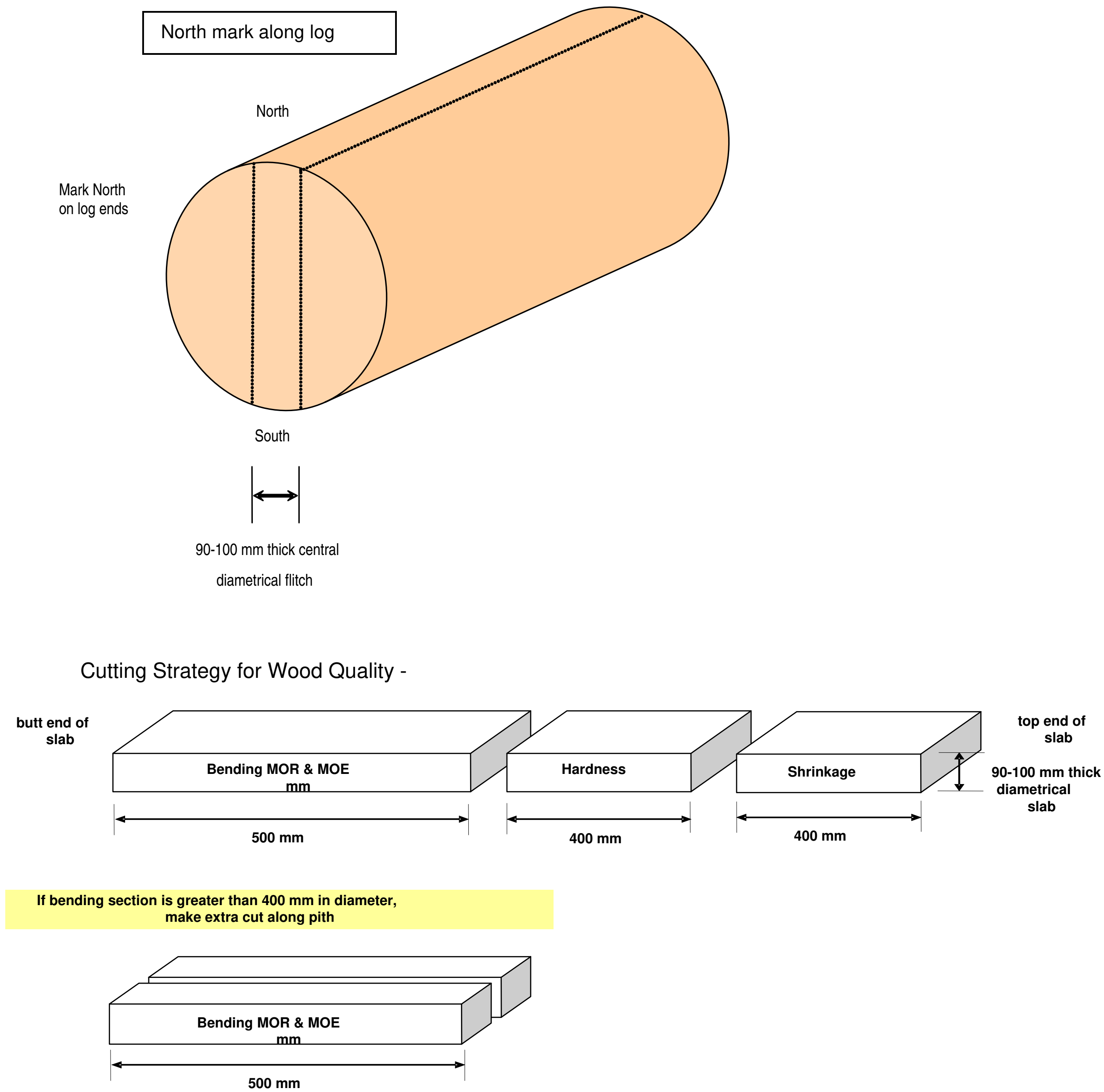


Figure 3 Cutting of central flitch for Wood quality measurements.

Mechanical and physical wood properties of radial variation in density, and grain properties were cut from the log between 1.8m to 2.0m. The first disc was placed in a plastic bag and later used for determining wood density. The remaining discs were air dried. One disc was use to measure interlocking grain. The remaining disc was used as a spare.

2.3.2 Wood density

The 1.8m height disc samples for determination of green and basic densities were processed at the Forests NSW laboratory at West Pennant Hills. A wedge was cut from the northern and southern aspects of each disc and sectioned into three sub-samples (representing inner, intermediate and outer wood) for assessment of variation in basic density across the radial extent (Figure 4). Basic density (oven-dry weight divided by green volume) of the samples was measured gravimetrically in accordance with Australian and New Zealand Standard AS/NZS1080.3:2000 Timber – Method of test – Method 3: Density (Standards Australia, 2000). The displacement method as described in ASTM (2001) was used to determine the green volume. Green density was determined as green weight divided by green volume.

Average green and basic densities for the whole disc was estimated by dividing the combined oven-dry weights by the combined green volumes of the three sub-samples from each disc.

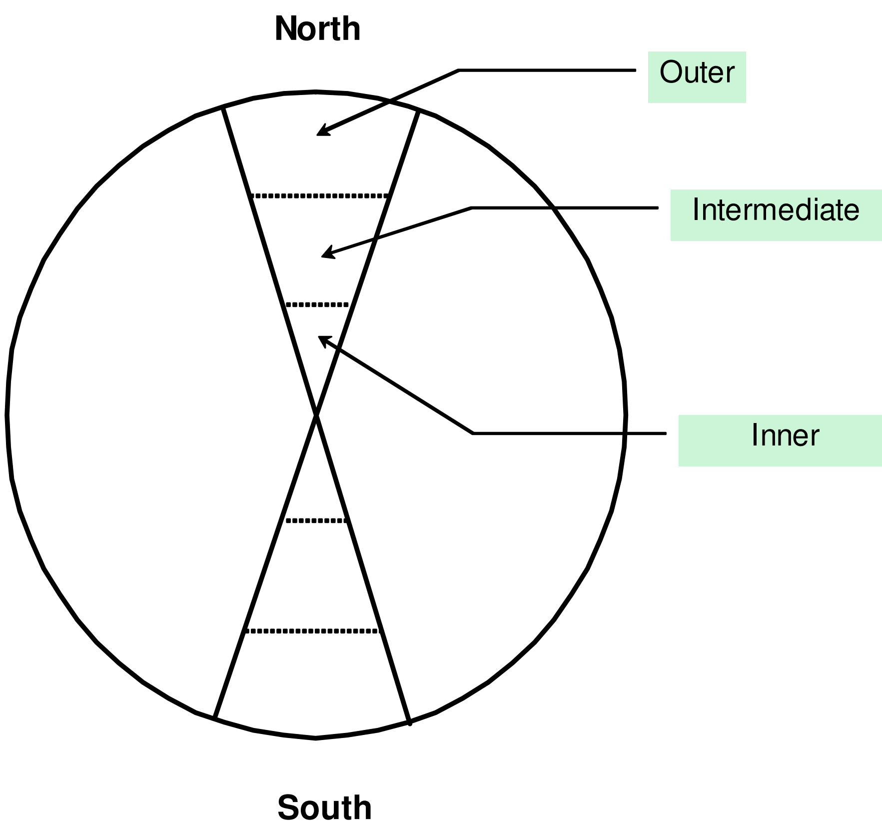


Figure 4 Sectioning of disc sample for basic density measurements.

2.3.3 Heartwood

The width of the sapwood band and the thickness of the heartwood core were measured with a measuring tape to 1 mm accuracy after spraying log ends with 0.1% methyl orange dissolved in methylated spirits. Measurements were recorded at each end of the sample in the longest and shortest diameters in each cross-section. The proportion (%) of heartwood for each log was calculated by first averaging the east-west and north-south directions, then averaging the small-end and butt-end areas (mm^2).

2.3.4 Acoustic resonance

The length of the log was measured, and the acoustic resonance of each log determined using a DIRECTOR HM200 tool.
MOE was calculated from green density (GD) and Director HM200 acoustic velocity (V_{Dir}) as $MOE_{Dir} = GD*V_{Dir}^2$

2.3.5 Kino

Length (to 1cm accuracy) and radial degree of all Kino gum veins were measured. The total length of Kino veins was calculated per log end then averaged per log. The sum of all radial angles was calculated for each log end and averaged per log (Figure 5).

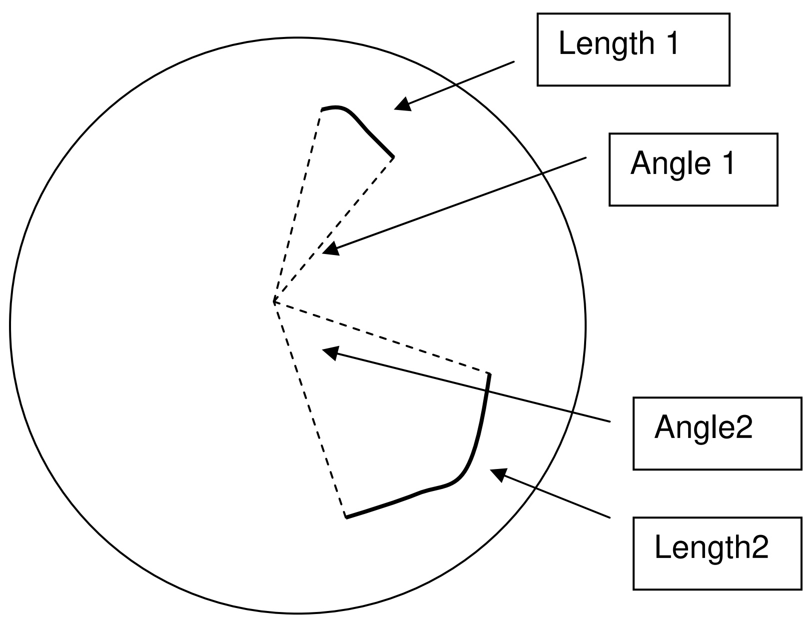


Figure 5. Determining Kino length and angle.

2.3.6 End-splitting

The extent of end-splitting at large and small ends of logs were scored both prior to and after steaming. Steaming occurred within 5 days of harvest. The method of scoring end-splitting was adapted from Kapp *et al* (2000) (Figure 6). Length of splits, and the width of peripheral openings were measured. An end-split score was assigned to each split which depended on type, length and width as follows: 1 point for a radial split that was 0.5 the radius long;1.5 points for a radial split that was 0.75 the radius long; 2 points for a radial split that was full radius long; 1 point per 0.5 radius length for a non radial (tangential split), and 1 point per mm of peripheral opening. The score for each log end was summed and the average log end split score for each log calculated. In addition the distance along log of peripheral splits was measured and averaged for each log.

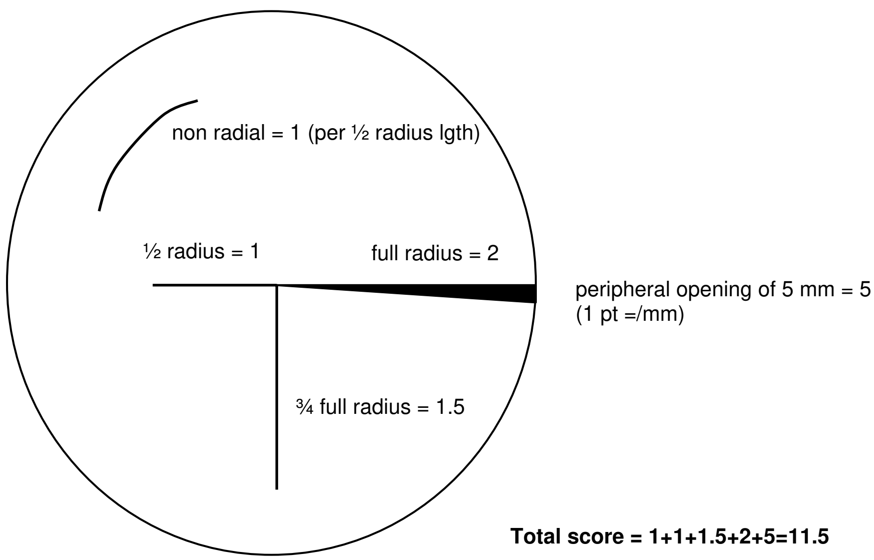


Figure 6. Determining end-split score

2.4 Processing and manufacture of plywood

Logs from different aged *E. dunnii* plantations; and from different species aged 34 years were processed at Big River Timbers, Grafton, NSW within 1 week of harvest.

2.4.1 Production of veneers

Logs were steamed for 18 hours prior to trimming to individual billets and peeled in a rotary lathe to produce veneers of 3 mm thickness. Full lengths of veneer (120cm length) were collected, counted, dried and assessed for quality.

The veneers were dried in a "piece dryer" to a target 12% MC, stacked then graded to Australian and New Zealand Standard *AS/NZ 2269.0:2008 Plywood – Structural, Part 0: Specifications* (Standards Australia, 2008). Veneers were also graded to Big River Timbers' internal standards of veneers suitable for face veneers (referred to as either 'Face' or 'No holes'), and veneers suitable for cross veneers (referred to as either 'Cross' or 'Holes').

2.4.2 Plywood manufacture

Plywood (1.2 x 1.2 m) of 15 mm thickness was produced from individual wood billets. Some billets did not produce sufficient veneers to produce any plywood. On occasions veneers from several adjoining billets from an individual logs were grouped together for making plywood.

All plywood were of 5-ply standard lay-up construction (15-30-5) and the face veneers were minimum Quality 'C' or 'D'. The minimum quality/grade of the cross band veneers and the long band veneer in the middle of the plywood were 'D', but could be as high as 'A' if the billet produced sufficient 'A' quality veneers. A melamine urea formaldyhyde glue was used to achieve the target glue B bond. The plywood was manufactured as a structural product to comply with Australian and New Zealand Standard *AS/NZ 2269.0:2008 Plywood – Structural, Part 0: Specifications* (Standards Australia, 2008) except for bond quality. Type B bond was used instead of Type A as prescribed by Australian and New Zealand Standard *AS/NZS 2269.0:2008 Plywood – Structural, Part 0: Specifications* (Standard Australia, 2008).

2.5 Wood Quality testing

The quality of plywood was tested to Australian/New Zealand standards. All test pieces were sampled from a minimum of 100 mm from the plywood edges, and wrapped in plastic bags and stored at room temperature until testing.

Glue bond quality (Type B) and formaldehyde content was tested by Engineered Wood Products Association of Australasia (EWPAA) on test pieces of 300 x 300 mm, and 400 x 400 mm respectively to Australian and New Zealand Standards *AS/NZ 2098.2:2006 Methods of test for veneer and plywood - Bond quality of plywood (chisel test)* (Standards Australia, 2006) and *AS/NZS 2098.11 Methods of test for veneer and plywood - Determination of formaldehyde emissions for plywood* (Standards Australia, 2005). Bond quality and formaldehyde content were measured on one plywood panel per log. This plywood was randomly selected from all plywood panels produced from the bottom billet of each log. In addition bond quality was tested on one plywood panel sourced from the top billet of each *E. dunnii* log.

Structural properties (MOE, MOR) were determined on all plywood panels at Forests NSW's wood laboratory in accordance with Australian and New Zealand Standard *AS/NZ 2269.1:2008 Plywood – Structural, Part 1: Determination of structural properties – Test methods* (Standards Australia, 2008). Bending test pieces parallel to face grain, 780 x 300 mm, were cut from each panel and tested in a four-point bending test configuration using an Avery (Grade A) universal testing machine. Loading was applied at the third points of the span (720 mm) until failure occurred, whilst deflection of the test piece was measured at the mid-span. Load-deflection readings were recorded automatically and also plotted, which enabled the gradient of the straight-line portion of the curve (P'/Δ) to be determined for calculation of MOE. The maximum load was used to determine MOR.

Moisture content was determined on all bending test pieces immediately after the MOR test using the oven-dry method in accordance with Australian and New Zealand Standard *AS/NZS 1080.1:1997. Timber - Methods of Test - Moisture content.* (Standard Australia, 1997)

Hardness (Janka) was tested on a sample piece of 150 x 150 mm in accordance with Mack (1979). This test consists of measuring the force required to indent the surface of the test piece with a hemispherical end of a steel rod of 11.28 mm diameter to a depth of 5.64 mm.

2.6 Plywood grading

Grading in a plymill is normally done by passing each panel through a stress grader, which automatically measures MOE and assigns a grade. The grading threshold (minimum MOE) applicable to each grade is given in Table 1. For this study, plywood grade was similarly assigned to each panel, however, MOE was based on the test value as determined on the test piece and not the whole panel. Provided the test piece was representative of the panel, the MOE derived by either method could be considered the same for all intent and purposes.

Table 1 Thresholds used for plywood grades (Source: Adkins & Lyngcoln, 1985)

Stress grade	Cut off point for grade (MPa)
F34	21500
F27	18500
F22	16000
F17	14000
F14	12000
F11	10500
F8	9100
F7	7900

2.7 Evaluation of design properties

An evaluation of the design properties for a graded population of plywood (eg., F27) requires a minimum number of tested samples. According to Australian and New Zealand Standard *AS/NZS* AS/NZ 2269.1:2008*. Plywood – Structural, Part 1: Determination of structural properties – Test methods*. (Standard Australia, 2008) the minimum number of samples shall not be less than 30 test pieces for strength (MOR) and not less than 20 for stiffness, for a given grade and product type (thickness & panel construction).

This evaluation is normally undertaken as part of a mill's on-going quality assurance program to ensure the characteristic properties of a graded population (eg., F27 plywood) continue to meet or exceed the design properties as claimed for that grade.

2.8 Statistical analysis

The two experiments i.e. five species of 34 year old plantation material; and the influence of *E.dunnii* age were analysed as separate experiments. Covariate analysis was used to determine the effect of factors such as log size and the many measurements of log quality on recovery and quality of veneer and plywood. Data were analysed using Genstat 11.

3 Results and Discussion

3.1 Log size and quality

The characteristics of the trees used to source logs for peeling, and the logs themselves are shown on Tables 2 and 3. Overall *E.dunnii* and *E.pilularis* logs were largest and *E.saligna* logs smallest. Density was lowest in *E.grandis* and highest in *E.agglomerata*. Density of *E.dunnii* was comparable to *E.pilularis*. Heartwood percentage was lowest at 64% in *E.saligna*. Kino was present in all species, but not all individuals. A species ranking for Kino was difficult to determine owing to the large within-species variation, but *E.grandis* and *E.pilularis* could be considered amongst the worst for this trait. Splitting was worst for *E.grandis* then *E.dunnii* and increased during the steaming process. The end-split score attributable to extent of openings was less than that attributed to length of splits. This was particularly the case when splitting post steaming was measured.

Table 2. Characteristics of trees and of the logs sourced from Wild Cattle Creek. Means ±SEM (n=9) with range shown in parenthesis.

Characteristic	*E.agglomerata*	*E.dunnii*	*E.grandis*	*E.pilularis*	*E.saligna*
		Characteristics of the tree			
DBHOB (cm) at 34 years	44.2 ±1.9 (37.9-54.1)	47.9 ±1.9 (39.2-58.7)	40.9 ±1.0 (36.5-45.0)	46.8 ±1.5 (40.7-53.1)	38.4 ±1.6 (32.1-45.5)
Height (m) at 32 years	36.3 ±0.7	42.2 ±0.7	42.2 ±1.2	41.6 ±0.9	35.2 ±0.5
Acoustic velocity (km s^{-1}) from Fakopp	3.57 ±0.01 (3.12-3.82)	3.50 ±0.01 (3.13-3.83)	3.50 ±0.01 (3.16-3.88)	3.85 ±0.01 (3.49-4.16)	3.55 ±0.01 (3.33-3.82)
Basic density (kg m^{-3})	676 ±13	623 ±16	548 ±9	642 ±11	628 ±13
Green density (kg m^{-3})	1195 ±9	1175 ±9	1040 ±10	1130 ±10	1133 ±10
		Characteristics of the log			
Diameter of Large end (cm)	35.8 ±1.7	40.7 ±1.6	36.5 ±1.1	39 ±1.5	33.3 ±1.5

	(27.3 - 43.7)	(33.6 - 49.5)	(32 - 41.6)	(32.9 - 44)	(26.5 - 42.2)
Diameter of Small end (cm)	29.7 ±1.2 (23.6 - 35.7)	35.8 ±1.4 (30.1 - 43.8)	33.1 ±1.0 (29 - 38.7)	33.6 ±1.5 (28 - 39.8)	28.8 ±1.3 (22.8 - 35.8)
Heartwood (%)	77 ±0.9	68 ±1.0	72 ±1.2	77 ±0.8	64 ±1.9
Length of Kino veins (cm)	4.7 ±3.4	7.7 ±1.5	9.7 ±2.7	8.1 ±3.7	4.2 ±2.3
Angle of Kino veins (°)	27 ±20	48 ±9	89 ±21	73 ±38	51 ±28
Pre-steam End-split score	4.7 ±1.3	8.3 ±1.0	12.9 ±4.2	5.9 ±0.8	4.7 ±0.7
Pre-steam End-split score due to splits	3.4 ±0.7	5.6 ±0.4	6 ±0.5	5.4 ±0.5	4.2 ±0.5
Pre-steam End-split score due to openings	1.3 ±0.6	2.7 ±0.7	6.9 ±3.9	0.6 ±0.3	0.5 ±0.3
Post-steam End-split score	7.8 ±3.4	20.3 ±3.8	38.9 ±16.3	8.8 ±2.7	5.8 ±1.0
Post-steam End-split score due to splits	3.4 ±0.7	6.2 ±0.4	6.0 ±0.5	6.2 ±0.5	4.2 ±0.5
Post-steam End-split score due to openings	4.4 ±2.7	14.7 ±3.5	32.9 ±16.0	10.8 ±2.4	1.6 ±0.6
Acoustic resonance (km s^{-1}) from HM200	3.95 ±0.05 (3.71 - 4.21)	4.19 ±0.09 (3.82 - 4.52)	4.06 ±0.06 (3.79 - 4.29)	4.2 ±0.04 (4.05 - 4.35)	3.87 ±0.05 (3.62 - 4.06)

Eucalyptus dunnii trees and logs sourced from the older plantation were larger than the younger plantation with only minor differences between logs sourced from the 12 and 17 year old plantation. Basic density increased with plantation age, whereas green density showed less variation. Heartwood percentage differed little with plantation age ranging from averages of 63 to 68%. Kino was present in all plantations, but not all individuals, and was generally more extensive in the older plantation. Splitting was worst for logs sourced from younger plantations and increased during the steaming process. The end-split score attributable to extent of openings was less than that attributed to length of splits. This was particularly the case when splitting post steaming was measured.

Table 3. Characteristics of *E.dunnii* trees and of the logs sourced from different aged plantations used for producing veneer. Means and SEM (n=9 or 10) with range shown in parenthesis.

Characteristic	Boambee 12 years	Newry 17 years	WCC 34 years
	Characteristics of the tree		
DBHOB (cm) [mean (range)]	43.1 ±0.9 (39.2-48.0)	41.6 ±1.0 (33.3-46.8)	47.9 ±1.9 (39.2-58.7)
Height (m)	36.9 ±0.6	38.5 ±0.5	42.2 ± 0.7
Fakopp velocity (km s^{-1})	3.51 ±0.05 (3.16-3.79)	3.57 ±0.06 (3.26-3.76)	3.50 ±0.01 (3.13-3.83)
Basic density (kg m^{-3})	538 ±9	557 ±10	623 ± 16
Green density (kg m^{-3})	1123 ±6	1120 ±7	1175 ±9
	Characteristics of the log		
Diameter of Large end (cm)	37.4 ±0.8 (32.4-41.6)	37.0 ±0.9 (33.9-41)	40.7 ±1.6 (33.6 - 49.5)
Diameter of Small end (cm)	31.5 ±0.7 (27.9-35.4)	31.8 ±0.9 (28-35.7)	35.8 ±1.4 (30.1 - 43.8)
Heartwood (%)	63 ±2	64 ±1	68 ±1.0
Length of Kino veins (cm)	1.2 ±0.6	1.0 ±1.0	7.7 ±1.5
Angle of Kino veins (°)	4 ±2	7 ±7	48 ±9
Pre-steam End-split score	13.8 ±3.9	15.5 ±3.1	8.3 ±1.0

Pre-steam End-split score due to splits	3.9 ±0.8	3.7 ±0.8	5.6 ±0.4
Pre-steam End-split score due to openings	9.9 ±3.3	11.8 ±2.5	2.7 ±0.7
Post-steam End-split score	26.6 ±7.6	17.0 ±3.2	20 ±3.8
Post-steam End-split score due to splits	6.8 ±0.6	6.2 ±0.7	5.6 ±0.4
Post-steam End-split score due to openings	19.2 ±7.2	10.8 ±2.6	14.7 ±3.5
Acoustic resonance (km s^{-1}) from HM200	3.83 ±0.06 (3.48-4.03)	3.99 ±0.04 (3.77-4.15)	4.19 ±0.09 (3.82 - 4.52)

3.2 Veneer recovery for 34-year-old species trial

Total volume of veneer recovered depended on species and log diameter (either DBHOB or SED of the log) ($P<0.05$) but the position in the log from which billets were sourced did not affect recovery. The species component was related to a combination of effects including 'spin out' related to splitting, and factors such as decay/kino.

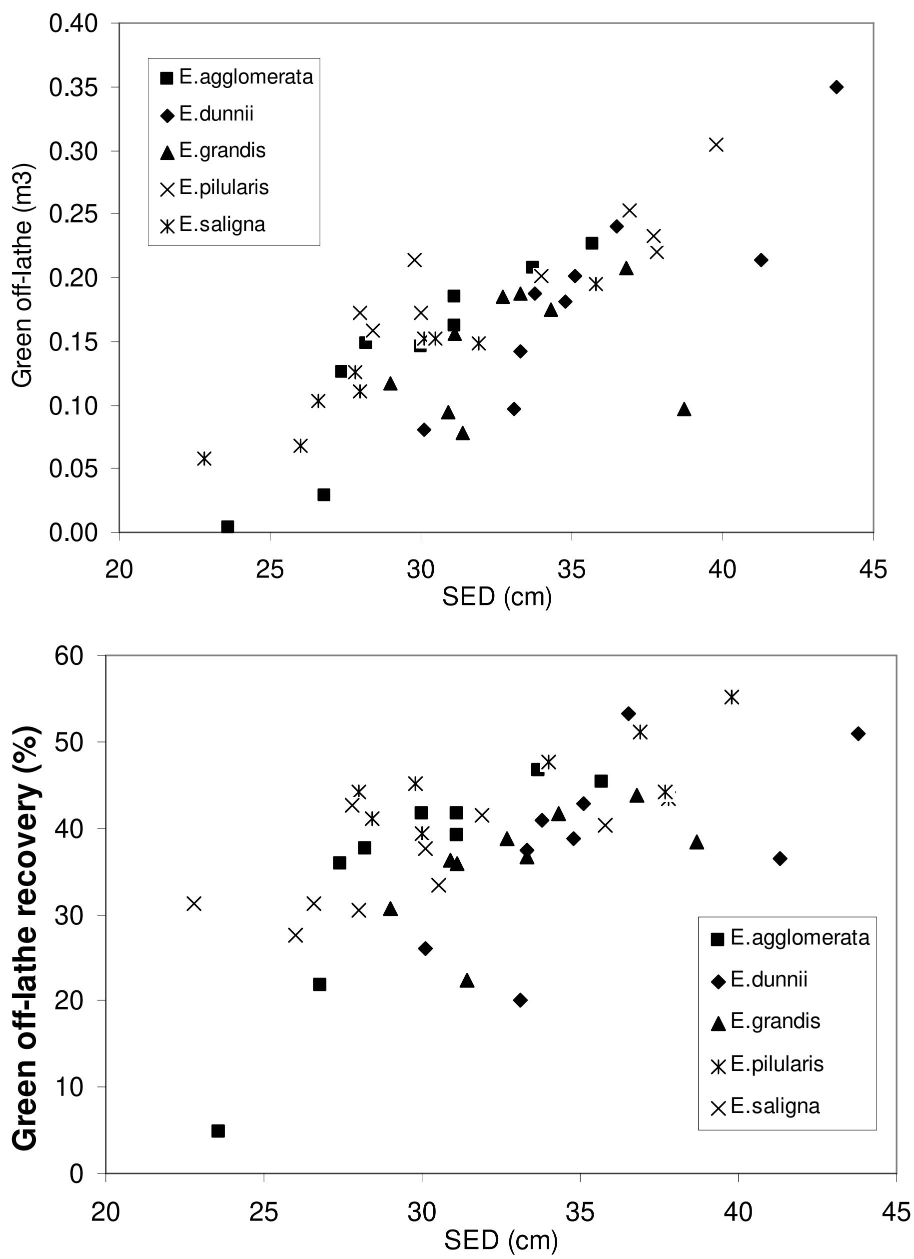


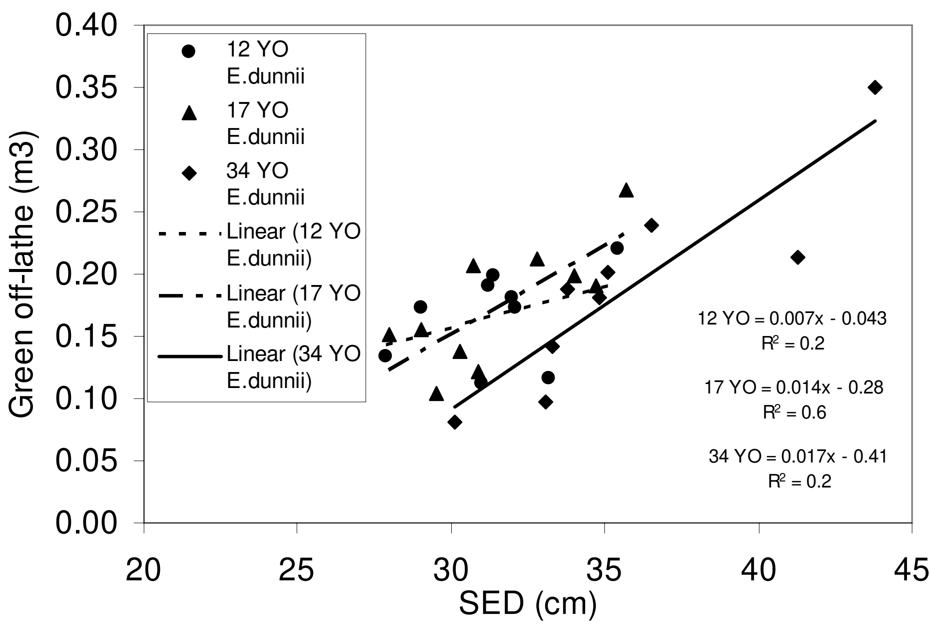
Figure 7. Green off-lathe recovery (m^3 and % volume) of five 34 YO species.

Recovery of veneers was reduced by greater extent of end-split (measured either before or after steaming) (P<0.05) highlighting the importance of splitting on economics of plantation forestry.

Percent of volume recovered after dying and grading veneers to either Australian and New Zealand Standard *AS/NZS 2269.0:2008. Plywood – Structural, Part 0: Specifications.* (Standard Australia, 2008) (i.e. Grade A – D as grade E considered discard) or Big River Timbers internal standards was not affected by species or billet position within a log (P>0.05). However log size (DBHOB or SED) showed a positive trend with increased %Recovery, whereas extent of end-splitting did not affect %Recovery.

3.3 Veneer recovery from Eucalyptus dunnii age trial

Volume of veneer produced at the lathe (prior to grading) was dependent on diameter of logs and age of plantation (P<0.05). The relationship was more apparent when relating volume recovered with the smallest diameter of the logs' small end rather than the average diameter of the logs' small end.



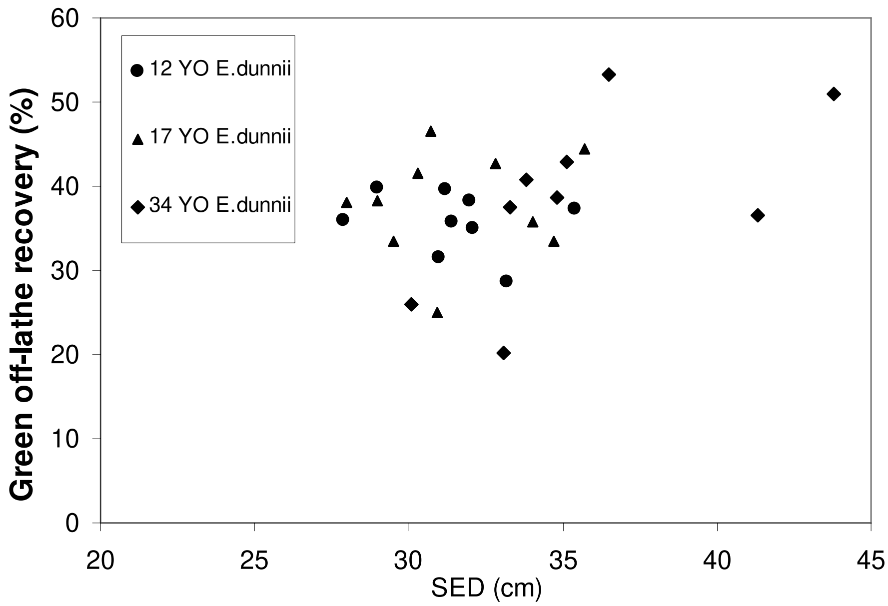


Figure 8. Green off-lathe recovery (m^3 and % volume) of *E.dunnii* aged 12, 17 and 34 year.

Both the percentage of log volume recovered as useable veneer which ranged from 30 to 55% with recoveries typically ranging from 35 - 45%, and percent of volume recovered after dying and grading veneers to either Australian and New Zealand Standard *AS/NZS 2269.0:2008. Plywood – Structural, Part 0: Specifications.* (Standard Australia, 2008) or to Big river Timber internal standards were related to log diameter or plantation age ($P<0.05$).

There was no relationship between log diameter and percentages of particular grades of veneers (*i.e.* A grade, A+B grade, or FACE) that were recovered. Surprisingly the total recovery of veneer or of particular veneer grades was not affected by extent of end-splitting, but this may have been related to similar extend of end-splitting in all three plantations.

3.4 Formaldehyde Emmision

All samples tested for formaldehyde emissions met the lowest E_0 class limit specified in Australian and New Zealand Standard *AS/NZS 2269.0:2008. Plywood – Structural, Part 0: Specifications.* (Standard Australia, 2008), except for one sample, which met next lowest class of E_1 (see Appendix for test data).

The formaldehyde limits appropriate to each emission class specified in Australian and New Zealand Standard *AS/NZS 2269.0:2008. Plywood – Structural, Part 0: Specifications.* (Standard Australia, 2008), are as follows:

E_0 = 0.5 mg/L max.

E_1 = 1.0 mg/L max.
E_2 = 2.0 mg/L max.
E_3 = above 2.0 mg/L

In this study, there were significant differences in formaldehyde emissions in the panels between species in the 34 year old trial, and also between ages in the *E. dunnii* age trial. Mean emission level ranged from 0.082 mg/L for *E. saligna* to 0.267 mg/L for *E. pilularis* (see Figure 9).

Formaldehyde emission appears to be significantly affected by wood age. Higher emission levels were recorded for 12 year old *E. dunnii* (0.357 mg/L) than the older 17 year old (0.297 mg/L) or 34 year old *E. dunnii* (0.233 mg/L).

The finding that there were more glue failures in the 12 year-old panels than the 17 year-old and 34 year-old panels (see Section 3.5) raises an interesting question: Assuming formaldehyde is a function of the glue and not wood, is there a relationship between the emission level and glue bond failure?

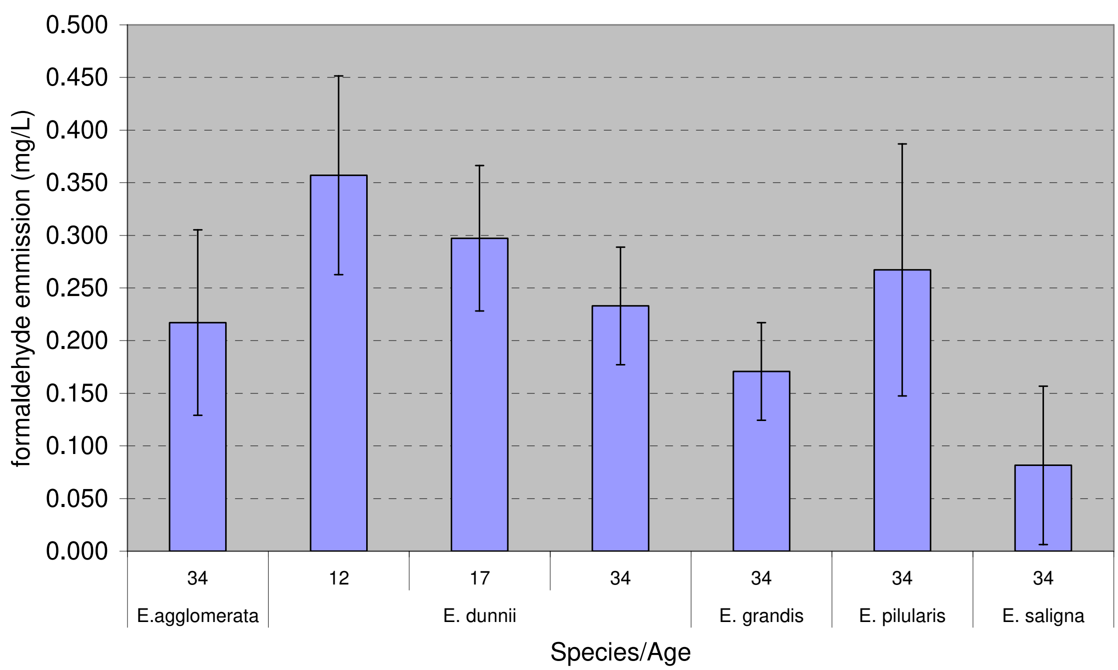


Figure 9 **Formaldehyde emmision from plywood. Error bars indicate +/- 1 std dev.**

3.5 Glue bond quality

Results of the glue bond tests by EWPAA are summarised in Table 4, which shows the number and proportion of plywood that passed or failed the Type B bond test. For a glue bond to be acceptable (ie., pass), the gluelines in a single test piece, prepared from each sample, shall have a bond quality score in any single glueline of not less than 2 and an average of not less than 5 when assessed in accordance with Australian and New Zealand Standard *AS/NZS 2098.2:2006. Methods of test for veneer and plywood - Bond quality of plywood (chisel test)* (Standard Australia, 2006).

The 34 year-old *E. dunnii* and *E. grandis* performed well with 100% of the samples having acceptable Type B bond, followed by *E. agglomerata* (88%), *E. saligna* (83%) and *E. pilularis* (78%). The results were of some concern for younger *E. dunnii* with only a low 27% (12 year-old) of the samples satisfying Type B bond quality. A re-test of the *E. dunnii* population confirmed the poor results, although there was a marked improvement in the pass rate (from 27% to 60%) for the 12 year-old material, but a small decline for the 17 year-old material (from 80% to 70%). The bond quality for re-tested 34 year-old *E. dunnii* plywood was unchanged with 100% pass. The results for *E. dunnii* suggests there is an age effect on bond quality and further work is needed to fully understand the factors involved and for suitable glues to be developed.

Figure 10 shows the overall bond score (mean of individual sample average) for all the samples tested. There was a noticeable trend of increasing bond quality (score) with age for *E. dunnii*.

Table 4 Summary of glue bond tests (Type B) by EWPAA, showing the number of individuals that passed or failed.

Species	Age (yr)	Results for Type B bond test		
		Fail (count)	Pass (count)	% Pass
E. agglomerata	34	1	7	88
E. dunnii	12	8	3	27
	17	2	8	80
	34	-	9	100
E. grandis	34	-	10	100
E. pilularis	34	2	7	78
E. saligna	34	2	10	83
(Additional tests)				
E. dunnii	12	4	6	60
	17	3	7	70
	34	-	10	100

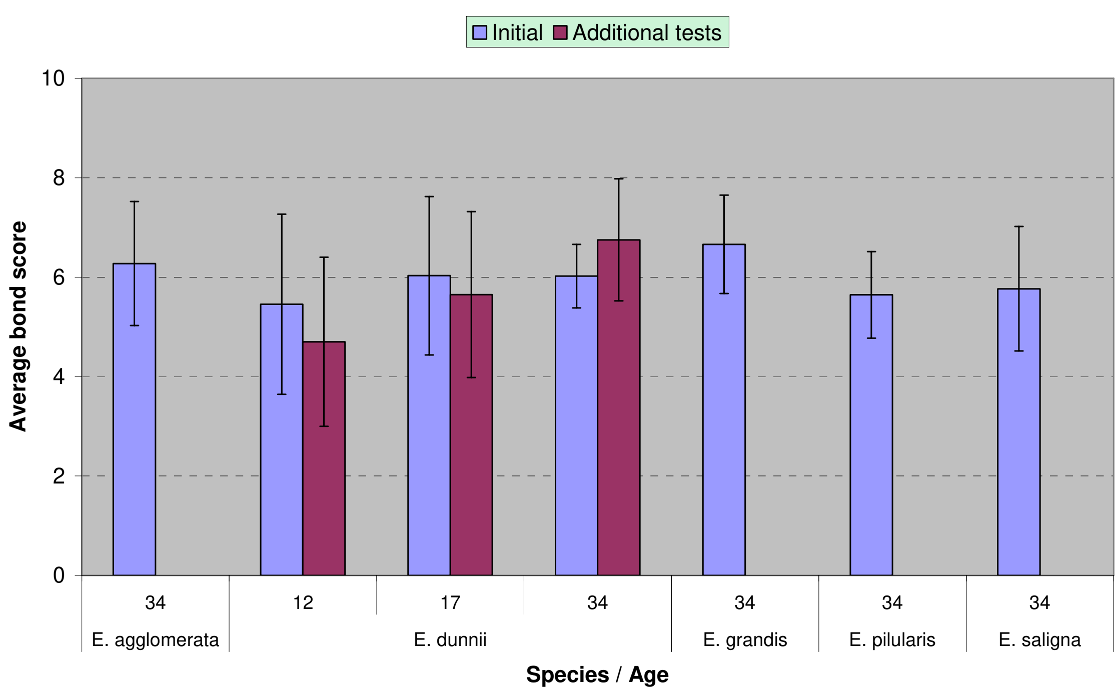


Figure 10 Overall bond score for all samples combined within each species and age. Error bars indicate +/- 1 std dev.

3.6 Moisture content

Moisture content was within the limits specified in Australian and New Zealand Standard *AS/NZS* 2269.1:2008*. Plywood – Structural, Part 1: Determination of structural properties – Test methods*. (Standard Australia, 2008) of being between 6% and 15%, except for one panel which was had a low value of 4.5%. Mean values for the 34 year-old species material ranged from 7.8% (*E. dunnii*) to 9.2% (*E. agglomerata*) (Figure 11). The mean moisture content of the 12 and 17 year-old *E. dunnii* panels was similar at around 9.5%; this being significantly higher than the older 34 year-old *E. dunnii* panels.

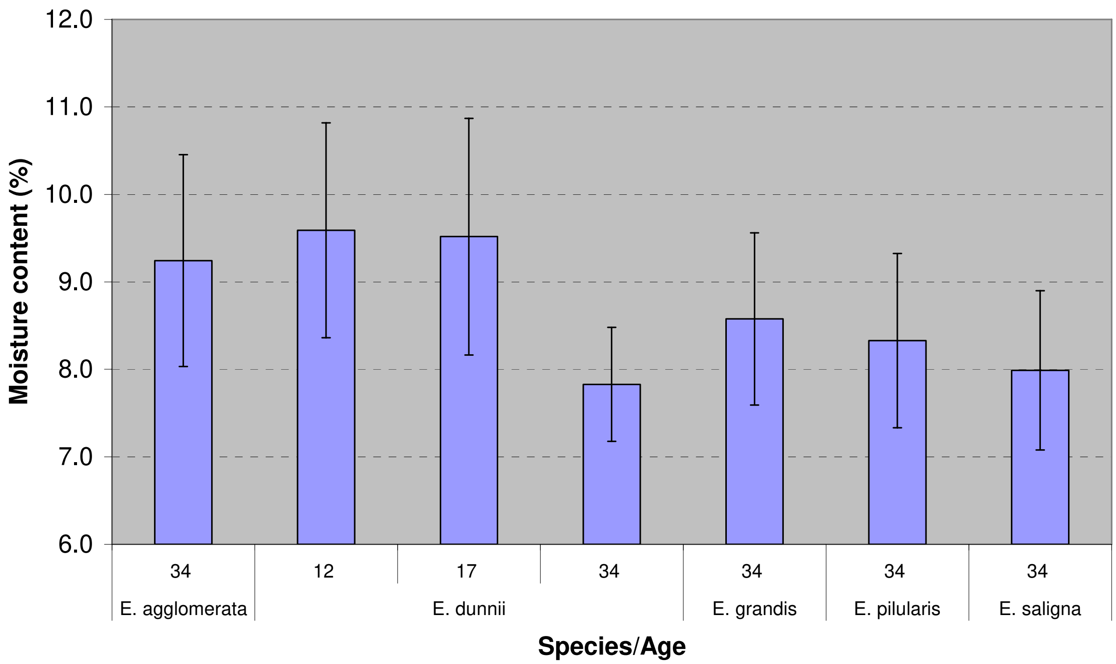


Figure 11 Moisture content of plywood. Error bars indicate +/- 1 std dev.

3.7 Grade recovery

Appendix A3 gives the individual stress grades of the panels based on MOE as measured on a test piece from each panel. The proportion of panels recovered in each grade is summarised in Table 5 according to species.

Stress grades ranged from F11 to F34 in increasing order of quality. The industry benchmark for high grade plywood is F27. For the 34 year-old material, grade recovery was similar for *E. pilularis*, *E. agglomerata* and *E. dunnii* with at least 76% of the recovered plywood panels making F27 or better. Recovery of the same grades for *E. grandis* and *E. saligna* was disappointingly low at around 30% - a result most likely attributed to the high presence of injury related gum pockets and borer attack in this study. The majority of the *E. grandis* or *E saligna* panels were rated F17 or F22. The results from the age effect study for *E. dunnii* produced some surprising and favourable outcomes. The 17 year-old *E. dunnii* gave 80% recovery of F27 or better, whilst the 12 year-old material gave 68% for the same grades. These results were encouraging, particularly when *E. dunnii* is not widely regarded by the timber industry. It is however a species of importance for planting in NSW. The potential to produce high grade plywood from a species at such an early age is undoubtedly economically beneficial to forest growers.

Table 5 Stress grades recovered from each species

Species	Age (yr)	Stress Grade	Recovery (%)
E. agglomerata	34	F17	2.2
		F22	21.7
		F27	10.9
		F34	65.2
E. dunnii	12	F14	7.0
		F17	8.8
		F22	15.8
		F27	43.9
		F34	24.6
	17	F14	3.4
		F17	1.7
		F22	15.3
		F27	39.0
		F34	40.7
	34	F14	2.1
		F17	6.4
		F22	14.9
		F27	42.6
		F34	34.0
E. grandis	34	F11	4.0
		F14	8.0
		F17	28.0
		F22	30.0
		F27	18.0
		F34	12.0
E. pilularis	34	F14	1.5
		F17	4.5
		F22	16.7
		F27	22.7
		F34	54.5
E. saligna	34	F14	12.2
		F17	26.8
		F22	26.8
		F27	7.3
		F34	26.8

3.8 MOR & MOE results

Individual panel results for MOR and MOE are given in Appendix A3 and summarised in Table 6. Overall species and plantation age but not billet position influenced MOE or MOR.

Plywood manufactured from 34 year-old *E.agglomerata* and *E.pilularis* had high MOR and MOE (of approximately 110 MPa for MOR and 23000 MPa for MOE). These results were similar to, albeit slightly higher than results for 34 year old *E. dunnii*. (NB. There was no statistical difference between *E. agglomerata*, *E. pilularis* and *E dunnii*). MOR and MOE of panels produced from 34 year-old *E. grandis* and *E. saligna* were significantly lower (at approximately 18000 MPa for MOE and 90 MPa and for MOR). The result for *E. saligna* is somewhat unexpected, considering the clearwood properties for that species would normally be comparable with *E. agglomerata* or *E. pilularis* (cf. Bootle, 1983). *E. grandis* had the lowest MOR and MOE relative to the other four species.

MOR and MOE of the younger *E. dunnii* (12 and 17 year-old) were only slightly lower than of the 34 year-old material. There was no significant difference in MOR and MOE amongst the 12, 17 and 34 year-old *E. dunnii*.

The average MOR and MOE values according to species and stress grades are given in Table 7 and Table 8. As would be expected, MOR and MOE increased with grade, irrespective of species. In general there was little difference in MOR or MOE between species of the same grade; demonstrating that by segregating plywood on the basis MOE is also effective in segregating for MOR. Any differences in MOR or MOE between species of the same grade may have been attributed to differences in sample size tested within each grade, and/or differences in relationship between MOR and MOE between species. Technically, there should be no difference in MOR or MOE between species of the same grade. The reason being, according to the Australian grading system, there should only be one set of design properties for each grade with no distinction between species.

Table 6 **Species mean MOR and MOE for plywood panels. Std dev given in brackets.**

Species	Age (yrs)	No. tested	MOR (MPa)		MOE (MPa)	
E agglomerata	34	46	110.4	(21.2)	23109	(4564)
E. dunnii	12	57	98.1	(21.1)	19474	(3208)
	17	59	98.3	(20.9)	21062	(3339)
	34	47	103.6	(28.6)	21283	(4448)
E. grandis	34	50	88.0	(19.0)	17403	(3400)
E. pilularis	34	66	109.2	(24.0)	22293	(4358)
E. saligna	34	41	90.3	(23.5)	18313	(4628)

Table 7 **Mean MOR of plywood panels according to species and grade.**

Species	Age (yrs)	Mean MOR of panels according to stress grade (MPa)					
		F11	F14	F17	F22	F27	F34
E. agglomerata	34			70.2	91.1	104.0	119.3
E. dunnii	12		56.5	76.5	89.4	99.4	121.0
	17		51.7	73.7	83.1	91.2	115.7
	34		80.0	81.4	76.2	94.6	132.6
E. grandis	34	54.2	64.8	77.9	90.7	96.7	118.4
E. pilularis	34		61.6	76.1	85.8	103.4	122.9
E. saligna	34		63.4	76.9	81.9	102.2	121.3

Table 8 **Mean MOE of plywood panels according to species and grade.**

Species	Age (yrs)	Mean MOE of panels according to stress grade (MPa) F11	F14	F17	F22	F27	F34
E. agglomerata	34			15941	17252	20216	25783
E. dunnii	12		13287	14283	17597	20062	23252
	17		13399	15981	17417	19920	24373
	34		13594	14907	17320	20115	26153
E. grandis	34	11365	13253	15044	17456	19663	24166
E. pilularis	34		13747	14648	17518	19913	25619
E. saligna	34		12997	14845	17096	20633	24780

3.9 In-grade evaluation of design properties

An essential part of any timber grading is an assurance that the graded product does indeed meet or exceed the product specification, which includes design properties. For plywood, the design properties for each stress grade are contained in Australian Standard *AS* 1720.1-1997. *Timber structures - Design methods.* (Standard Australia, 1997).

In this study it was possible only to undertake a limited evaluation of the design properties, as the minimum number of test samples was not achieved for all species and grade. According to Australian and New Zealand Standard *AS/NZS* AS/NZ 2269.1:2008*. Plywood – Structural, Part 1: Determination of structural properties – Test methods*. (Standard Australia, 2008) the minimum sample needs to be at least 30 for strength (MOR) and 20 for stiffness for a given grade and product type.

Table 9 summarizes the evaluation for those species and grade that were able to be evaluated in accordance with Australian and New Zealand Standard *AS/NZS* 2269.2 2007. *Plywood – Structural, Part 2: Determination of structural properties – Evaluation methods*. (Standard Australia, 2007) and Australian and New Zealand Standard *AS/NZS* 4063:1992. *Timber – Stress-graded – In-grade strength and stiffness evaluation* (Standard Australia, 1992).

The results showed in all cases plywood stiffness far exceeded AS1720 requirements, ie, $E_k > E$. On the other hand, strength was marginal compared to AS1720 requirements, albeit only slightly less, ie.,$R_{k,norm} < f'_b$. Nevertheless, the results were encouraging given the relatively small number of panels tested, and indicated plantation eucalypts have the potential to produce high value veneer products.

Table 9 Comparison of evaluated in-grade MOR and MOE properties with AS1720.1.1997 design properties.

Species	Grade	No of tests	$R_{k,norm}$ (MPa)	E_k (MPa)	AS1720 f'_b (MPa)	AS1720 E (MPa)
E. pilularis	F34	36	99.1	25327	100	21500
E. agglomerata	F34	30	96.5	25400	100	21500
E. dunnii						
12 yrs	F27	25	**	19941	80	18500
17 yrs	F27	23	**	19806	80	18500
17 yrs	F34	24	**	24128	100	21500
34 yrs	F27	20	**	19981	80	18500

** no of tests <30

3.10 Relationship between calculated and measured MOE

MOE of test plywood pieces was better able to be predicted from Director HM200 acoustic resonance than Fakopp acoustic velocity (Figure 12). The relationship between MOE_{Dir} and MOE of test panels of different aged *E.dunnii* had a correlation coefficient between 0.4 and 0.5 depending on plantation, and the relationship was similar for plywood panels manufactured from logs sourced from the two younger aged plantations than from the 34 year-old plantation. The finding that Director HM200 can predict test panel MOE is interesting as it indicates the potential that logs could be segregated into those that will produce veneer that meets particular grades of plywood panels.

In contrast the relationships derived from the five species aged 34 years showed MOE of test panels did not have a significant relationship with MOE calculated from either Fakopp or Director HM200. Clearly the use of acoustic tools to predict MOE of finished products requires further attention.

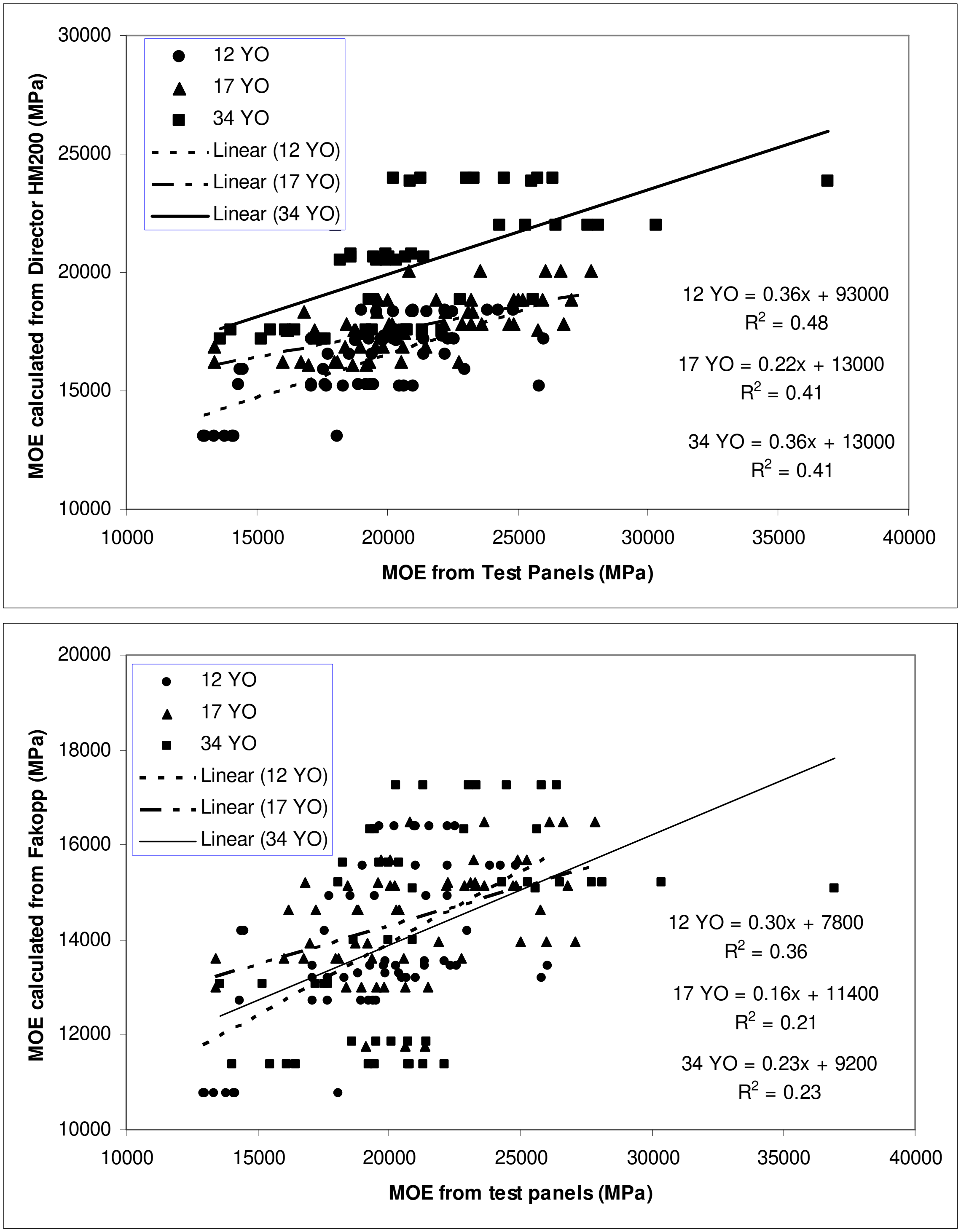


Figure 12 **MOE calculated from acoustic velocity of trees and logs, as a function of MOE measured on plywood panels manufactured from this material.**

3.11 Hardness (Janka)

The results of the hardness (Janka) tests conducted on the plywood samples are summarized in Table 10. These results provide an indication of the potential for plywood manufactured from plantation-grown eucalypts to be utilized as a flooring product such as T&G flooring.

There was significant difference in hardness between species in the 34 year old species trial. *E. agglomerata* had the highest hardness overall, followed equally by *E. pilularis* and *E. saligna*, then *E. dunnii* and *E. grandis* (Table 10). This trend closely mirrors that of basic density (Table 2), which is probably not surprising given that it is generally known that density correlates well with hardness. *E. agglomerata* performed exceptional well with a mean hardness of 9.7 kN compared to 7.5 kN for solid wood (Bootle, 1983). The hardness of 34 year old *E. dunnii* plywood also compared favorably with that for solid wood. Both *E. pilularis* and *E. saligna* hardness were comparable, albeit slightly lower, to that given by Bootle (1983) for solid wood. *E. grandis* was the only species with a hardness (5.4 kN) much lower than for solid wood (7.5 kN). However, it should be noted that the values given by Bootle (1983) have been obtained from tests on wood sourced from more mature native forests stands.

Age had a significant effect on hardness in the *E. dunnii* age effect trial. The hardness of the 34 year old material was significantly greater than those for the 12 and 17 year old material. The older material had a hardness of 7.7 kN compared to the younger material of around 6.0 kN. There was no significant difference in hardness between the 12 and 17 year old wood.

Table 10 Mean hardness (Janka) values according to species and age, and number of test pieces. Std dev given in brackets.

Species	Age (yrs)	No. tested	Hardness (*Janka*) (kN)	Ref. values* (Bootle, 1983)
E. agglomerata	34	29	9.7 (1.3)	7.5
E. dunnii	12	57	5.7 (1.0)	-
	17	59	6.0 (1.1)	-
	34	44	7.7 (1.7)	7.2
E. grandis	34	42	5.4 (1.0)	7.5
E. pilularis	34	54	8.5 (1.6)	9.1
E. saligna	34	28	8.5 (1.4)	9.0

*Reference values given in Bootle have been derived from tests on mature native hardwood.

4 Conclusion

Recovery of veneers depended on species and log diameter. The species component was related to a combination of effects including ‘spin out’, splitting, and factors such as decay/kino which would affect the economics of plantation forestry. Plywood grade recovery was similar for *E. pilularis*, *E. agglomerata* and *E. dunnii* with at least 76% of the recovered plywood panels making F27 or better. Recovery of the same grades for *E. grandis* and *E. saligna* was disappointingly low at around 30% - a result most likely attributed to the high presence of injury related gum pockets and borer attack in this study. The 17 year-old *E. dunnii* gave 80% recovery of F27 or better, whilst the 12 year-old material gave 68% for the same grades. These results were encouraging, particularly when *E. dunnii* is not widely regarded by the timber industry. The potential to produce high grade plywood from a species at such an early age is undoubtedly economically beneficial to forest growers. Quality defects in the plywood included poor bond strength in some instances. Poor bond strength were of some concern for younger *E. dunnii* with only a low 27% (12 year-old) and 80% (17 year-old) having acceptable bond strength. A re-test of the *E. dunnii* population confirmed the poor results, although there was a marked improvement in the pass rate (from 27% to 60%) for the 12 year-old material. The results for *E. dunnii* suggests there is an age effect on bond quality and further work is needed to fully understand the factors involved and for suitable glues to be developed. However, bond strength was excellent in the 34 year-old *E. dunnii* and *E. grandis* (100% of the samples having acceptable Type B bond), followed by *E. agglomerata* (88%), *E. saligna* (83%) and *E. pilularis* (78%). Mechanical properties of plywood manufactured from 34 year-old *E.agglomerata* and *E.pilularis* were similar and had the highest MOR and MOE (of approximately 110 MPa and 23000 MPa respectively), which were not significantly higher than results for 34 year old *E. dunnii*. MOR and MOE of panels produced from 34 year-old *E. grandis* and *E. saligna* were significantly lower. Encouragingly MOR and MOE of the younger *E. dunnii* (12 and 17 year-old) were only slightly lower than of the 34 year-old material. There was no significant difference in MOR and MOE amongst the 12, 17 and 34 year-old *E. dunnii*. There were indications that MOE of test plywood pieces was able to be predicted from Director HM200 acoustic resonance on logs suggesting acoustic tools could be employed to segregate logs into different quality classes. Hardness of plywood differed between species with all species except for *E. grandis* compared favourably or reasonably well with hardness values published for solid wood. However, age had a significant effect on hardness with the older (34 year old) *E. dunnii* plywood having a higher hardness value than the younger material with the 12 year-old material being least hard.

5 Acknowledgements

This research would not have been possible without the support of Forests NSW for provision of the logs and considerable technical and scientific support; of Big River Timber for processing the logs, production of plywood and allowing the generous use of equipment and facilities to Forests NSW staff. FWPA contributed financial support for testing the quality of plywood panels.

6 References

Adkins, D. and Lyngcoln, K.J. (1985) Stress grading plywood to Australian Standards. Plywood Association of Australia Ltd, Queensland.

ASTM (2001) Standard test methods for specific gravity of wood and wood-based materials. D2395-93, Vol 04.10 (Wood). American Society for Testing Materials, West Conshohocken, PA.

Bootle, K.R. (1983) Wood in Australia – Types, properties and uses. McGraw-Hill, Australia, 443pp.

Kapp, S., Müller, P., Mabaso, L. and Kietzka, E. (2000) Assessment of 14 year old E. grandis for higher value lumber production. Proceedigns of IUFRO Working Party 2.08.01 Conference: "Forest Genetics for the Next Millennium", Durban, South Africa, October, 2000.

Mack, J.J. (1979) Australian Methods for Mechanically Testing Small Clear Specimens of Timber. CSIRO Division of Building Research Paper (2nd Series) No. 31.Melbourne.

Standards Australia (1992) *Timber – Stress-graded – In-grade strength and stiffness evaluation* AS/NZS 4063:1992. Standards Australia, Sydney.

Standards Australia (1997) *Timber structures - Design methods* AS 1720.1-1997. Standards Australia, Sydney.

Standards Australia (1997) *Timber - Methods of Test. Method 1: Moisture content* AS/NZS 1080.1:1997. Standards Australia, Sydney.

Standards Australia (2000). *Timber – Method of test – Method 3: Density. AS/NZS1080.3:2000* Standards Australia, Sydney.

Standards Australia (2005) *Methods of test for veneer and plywood. Method 11: Determination of formaldehyde emissions for plywood* AS/NZS 2098.11:2005. Standards Australia, Sydney.

Standards Australia (2006) *Methods of test for veneer and plywood. Method 2: Bond quality of plywood (chisel test) AS/NZ 2098.2:2006* Standards Australia, Sydney.

Standards Australia (2007). *Plywood – Structural, Part 2: Determination of structural properties – Evaluation methods*. AS/NZ 2269.2:2007. Standards Australia, Sydney.

Standards Australia (2008). *Plywood – Structural, Part 0: Specifications*. AS/NZ 2269:2008. Standards Australia, Sydney.

Standards Australia (2008). *Plywood – Structural, Part 1: Determination of structural properties – Test methods*. AS/NZ 2269.1:2008. Standards Australia, Sydney.

7 Appendices

Appendix A1: Formaldehyde emmission test results

EWPAA

ENGINEERED WOOD PRODUCTS ASSOCIATION OF AUSTRALASIA

PRODUCT CERTIFIED

JAS-ANZ

NATA

Accredited for compliance with ISO/IEC 17025

EWPAA Test Report Ref : 17/09/2008 9-78

Dane Thomas
Forests NSW
PO Box J19

Results of Plywood Formaldehyde Tests of Samples Recieved 17/09/2008 (Batch 9-78)

Sample Description					Species	Comments	Finish	Abosorbance	Emission	E-Class	Result
9-78-1-08	B Bond	Exterior	15 mm	5 ply	Other	5	Not Finish	0.132	0.207	E0	E0
9-78-2-08	B Bond	Exterior	15 mm	5 ply	Other	11	Not Finish	0.018	0.028	E0	E0
9-78-3-08	B Bond	Exterior	15 mm	5 ply	Other	13	Not Finish	0.02	0.031	E0	E0
9-78-4-08	B Bond	Exterior	15 mm	5 ply	Other	14	Not Finish	0.02	0.031	E0	E0
9-78-5-08	B Bond	Exterior	15 mm	5 ply	Other	15	Not Finish	0.027	0.042	E0	E0
9-78-6-08	B Bond	Exterior	15 mm	5 ply	Other	25	Not Finish	0.106	0.166	E0	E0
9-78-7-08	B Bond	Exterior	15 mm	5 ply	Other	32	Not Finish	0.085	0.133	E0	E0
9-78-8-08	B Bond	Exterior	15 mm	5 ply	Other	33	Not Finish	0.086	0.135	E0	E0
9-78-9-08	B Bond	Exterior	15 mm	5 ply	Other	35	Not Finish	0.076	0.119	E0	E0
9-78-10-08	B Bond	Exterior	15 mm	5 ply	Other	42	Not Finish	0.162	0.254	E0	E0
9-78-11-08	B Bond	Exterior	15 mm	5 ply	Other	57	Not Finish	0.138	0.217	E0	E0
9-78-12-08	B Bond	Exterior	15 mm	5 ply	Other	58	Not Finish	0.17	0.267	E0	E0
9-78-13-08	B Bond	Exterior	15 mm	5 ply	Other	79	Not Finish	0.352	0.553	E1	E1
9-78-14-08	B Bond	Exterior	15 mm	5 ply	Other	47	Not Finish	0.11	0.173	E0	E0
9-78-15-08	B Bond	Exterior	15 mm	5 ply	Other	67	Not Finish	0.106	0.166	E0	E0
9-78-16-08	B Bond	Exterior	15 mm	5 ply	Other	82	Not Finish	0.156	0.245	E0	E0
9-78-17-08	B Bond	Exterior	15 mm	5 ply	Other	92	Not Finish	0.046	0.072	E0	E0
9-78-18-08	B Bond	Exterior	15 mm	5 ply	Other	95	Not Finish	0.018	0.028	E0	E0
9-78-19-08	B Bond	Exterior	15 mm	5 ply	Other	106	Not Finish	0.106	0.166	E0	E0
9-78-20-08	B Bond	Exterior	15 mm	5 ply	Other	110	Not Finish	0.064	0.100	E0	E0

Thursday, 30 October 20 — Page 1 of 4

Sample Description					Species	Comments	Finish	Abosorbance	Emission	E-Class	Result
9-78-21-08	B Bond	Exterior	15 mm	5 ply	Other	116	Not Finish	0.079	0.124	E0	E0
9-78-22-08	B Bond	Exterior	15 mm	5 ply	Other	118	Not Finish	0.033	0.052	E0	E0
9-78-23-08	B Bond	Exterior	15 mm	5 ply	Other	120	Not Finish	0.237	0.372	E0	E0
9-78-24-08	B Bond	Exterior	15 mm	5 ply	Other	123	Not Finish	0.181	0.284	E0	E0
9-78-25-08	B Bond	Exterior	15 mm	5 ply	Other	124	Not Finish	0.029	0.046	E0	E0
9-78-26-08	B Bond	Exterior	15 mm	5 ply	Other	146	Not Finish	0.068	0.107	E0	E0
9-78-27-08	B Bond	Exterior	15 mm	5 ply	Other	148	Not Finish	0.137	0.215	E0	E0
9-78-28-08	B Bond	Exterior	15 mm	5 ply	Other	152	Not Finish	0.136	0.214	E0	E0
9-78-29-08	B Bond	Exterior	15 mm	5 ply	Other	169	Not Finish	0.161	0.253	E0	E0
9-78-30-08	B Bond	Exterior	15 mm	5 ply	Other	173	Not Finish	0.182	0.286	E0	E0
9-78-31-08	B Bond	Exterior	15 mm	5 ply	Other	176	Not Finish	0.142	0.223	E0	E0
9-78-32-08	B Bond	Exterior	15 mm	5 ply	Other	178	Not Finish	0.173	0.272	E0	E0
9-78-33-08	B Bond	Exterior	15 mm	5 ply	Other	181	Not Finish	0.157	0.246	E0	E0
9-78-34-08	B Bond	Exterior	15 mm	5 ply	Other	185	Not Finish	0.177	0.278	E0	E0
9-78-35-08	B Bond	Exterior	15 mm	5 ply	Other	190	Not Finish	0.167	0.262	E0	E0
9-78-36-08	B Bond	Exterior	15 mm	5 ply	Other	194	Not Finish	0.196	0.308	E0	E0
9-78-37-08	B Bond	Exterior	15 mm	5 ply	Other	197, Black wrap	Not Finish	0.285	0.447	E0	E0
9-78-38-08	B Bond	Exterior	15 mm	5 ply	Other	197, Clear wrap	Not Finish	0.282	0.443	E0	E0
9-78-39-08	B Bond	Exterior	15 mm	5 ply	Other	213	Not Finish	0.134	0.210	E0	E0
9-78-40-08	B Bond	Exterior	15 mm	5 ply	Other	222	Not Finish	0.182	0.286	E0	E0
9-78-41-08	B Bond	Exterior	15 mm	5 ply	Other	233	Not Finish	0.272	0.427	E0	E0
9-78-42-08	B Bond	Exterior	15 mm	5 ply	Other	234	Not Finish	0.303	0.476	E0	E0
9-78-43-08	B Bond	Exterior	15 mm	5 ply	Other	237	Not Finish	0.197	0.309	E0	E0
9-78-44-08	B Bond	Exterior	15 mm	5 ply	Other	242	Not Finish	0.185	0.290	E0	E0
9-78-45-08	B Bond	Exterior	15 mm	5 ply	Other	244	Not Finish	0.246	0.386	E0	E0
9-78-46-08	B Bond	Exterior	15 mm	5 ply	Other	246	Not Finish	0.18	0.283	E0	E0
9-78-47-08	B Bond	Exterior	15 mm	5 ply	Other	250	Not Finish	0.318	0.499	E0	E0
9-78-48-08	B Bond	Exterior	15 mm	5 ply	Other	261	Not Finish	0.206	0.323	E0	E0

Sample Description					Species	Comments	Finish	Abosorbance	Emission	E-Class	Result
9-78-49-08	B Bond	Exterior	15 mm	5 ply	Other	271	Not Finish	0.25	0.393	E0	E0
9-78-50-08	B Bond	Exterior	15 mm	5 ply	Other	274	Not Finish	0.067	0.105	E0	E0
9-78-51-08	B Bond	Exterior	15 mm	5 ply	Other	281	Not Finish	0.103	0.162	E0	E0
9-78-52-08	B Bond	Exterior	15 mm	5 ply	Other	285	Not Finish	0.187	0.294	E0	E0
9-78-53-08	B Bond	Exterior	15 mm	5 ply	Other	289	Not Finish	0.17	0.267	E0	E0
9-78-54-08	B Bond	Exterior	15 mm	5 ply	Other	294	Not Finish	0.15	0.236	E0	E0
9-78-55-08	B Bond	Exterior	15 mm	5 ply	Other	299	Not Finish	0.16	0.251	E0	E0
9-78-56-08	B Bond	Exterior	15 mm	5 ply	Other	302	Not Finish	0.14	0.220	E0	E0
9-78-57-08	B Bond	Exterior	15 mm	5 ply	Other	305	Not Finish	0.11	0.173	E0	E0
9-78-58-08	B Bond	Exterior	15 mm	5 ply	Other	314	Not Finish	0.12	0.188	E0	E0
9-78-59-08	B Bond	Exterior	15 mm	5 ply	Other	316	Not Finish	0.22	0.345	E0	E0
9-78-60-08	B Bond	Exterior	15 mm	5 ply	Other	317	Not Finish	0.18	0.283	E0	E0
9-78-61-08	B Bond	Exterior	15 mm	5 ply	Other	320, Clear Wrap	Not Finish	0.07	0.110	E0	E0
9-78-62-08	B Bond	Exterior	15 mm	5 ply	Other	320, Black wrap	Not Finish	0.07	0.110	E0	E0
9-78-63-08	B Bond	Exterior	15 mm	5 ply	Other	329	Not Finish	0.18	0.283	E0	E0
9-78-64-08	B Bond	Exterior	15 mm	5 ply	Other	332	Not Finish	0.13	0.204	E0	E0
9-78-65-08	B Bond	Exterior	15 mm	5 ply	Other	343	Not Finish	0.15	0.236	E0	E0
9-78-66-08	B Bond	Exterior	15 mm	5 ply	Other	349	Not Finish	0.15	0.236	E0	E0
9-78-67-08	B Bond	Exterior	15 mm	5 ply	Other	357	Not Finish	0.16	0.251	E0	E0
9-78-68-08	B Bond	Exterior	15 mm	5 ply	Other	358	Not Finish	0.15	0.236	E0	E0
9-78-69-08	B Bond	Exterior	15 mm	5 ply	Other	365	Not Finish	0.12	0.188	E0	E0

Plywood House 3 Dunlop Street Newstead Qld Australia | PO Box 2108 Fortitude Valley BC Qld 4006
P: +617 3854 1228 | F: +617 3252 4769 | E: inbox@paa.asn.au | ABN 34 009 704 901

Sample Description	Species	Comments	Finish	Abosorbance	Emission	E-Class	Result

Total Samples : 69

Testing has been in accordance with methods outlined in the Australian Standard Test Method's AS/NZS2098.11 for Plywood or AS/NZS4357.4 for LVL. Measurement uncertainty is 0.035 mg/L. All LVL, I Beam and Formply samples are Edge Treated prior to testing.This report must not be reproduced except in full. This document is issued in accordance with NATA's accreditation requirements.

Regards

Susie Steiger
Technical Officer

Appendix A2: Glue bond quality results

Part A: Plywood manufactured from veneers sourced from lower billets

EWPAA

ENGINEERED WOOD PRODUCTS ASSOCIATION OF AUSTRALASIA

PRODUCT CERTIFIED paa ENGINEERED WOOD | JAS-ANZ | NATA Accredited for compliance with ISO/IEC 17025 NATA Accredited No. 765

EWPAA Test Report Ref : 17/09/2008 9-79

Dane Thomas
Forests NSW
PO Box J19

Results of Plywood Bond Quality Tests of Samples Recieved 17/09/2008 (Batch 9-79)

ID	Type	Bond	Nom Thick	Plys	Species	Finish	Comments	Manufactured	Thickness Measured	Bond Quality: Bond Ratings	Avg	Result
9-79-1-08	Exterior	B Bond	15	5	Other	Not Finished	5		16.30	7 8 6.5 4	6.4	Pass
9-79-2-08	Exterior	B Bond	15	5	Other	Not Finished	11		13.94	8.5 6.5 6.5 5	6.6	Pass
9-79-3-08	Exterior	B Bond	15	5	Other	Not Finished	13		14.89	7.5 7.5 4.5 3.5	5.8	Pass
9-79-4-08	Exterior	B Bond	15	5	Other	Not Finished	14		14.84	0.5 8 7 8	5.9	Fail
9-79-5-08	Exterior	B Bond	15	5	Other	Not Finished	15		16.14	8.5 6 8.5 7.5	7.6	Pass
9-79-6-08	Exterior	B Bond	15	5	Other	Not Finished	25		15.30	3.5 7 7 7.5	6.3	Pass
9-79-7-08	Exterior	B Bond	15	5	Other	Not Finished	32		14.68	8.5 8.5 5 6.5	7.1	Pass
9-79-8-08	Exterior	B Bond	15	5	Other	Not Finished	33		16.20	6.5 6.5 7.5 8	7.1	Pass
9-79-9-08	Exterior	B Bond	15	5	Other	Not Finished	35		15.70	9.5 10 9.5 6	8.8	Pass
9-79-10-08	Exterior	B Bond	15	5	Other	Not Finished	42		15.32	7 5 8 6	6.5	Pass
9-79-11-08	Exterior	B Bond	15	5	Other	Not Finished	47		15.32	2.5 2.5 3.5 7	3.9	Fail
9-79-12-08	Exterior	B Bond	15	5	Other	Not Finished	57		15.73	5.5 8 3.5 7.5	6.1	Pass
9-79-13-08	Exterior	B Bond	15	5	Other	Not Finished	58		14.61	4 6.5 5 8	5.6	Pass
9-79-14-08	Exterior	B Bond	15	5	Other	Not Finished	79		15.24	7 7.5 7 5	6.6	Pass
9-79-15-08	Exterior	B Bond	15	5	Other	Not Finished	67		15.68	5.5 7 6.5 8	6.8	Pass
9-79-16-08	Exterior	B Bond	15	5	Other	Not Finished	82		15.99	9.5 6.5 7.5 2.5	6.5	Pass
9-79-17-08	Exterior	B Bond	15	5	Other	Not Finished	92		17.48	6 6 7.5 9	7.1	Pass
9-79-18-08	Exterior	B Bond	15	5	Other	Not Finished	95		15.53	8 3 7 3	5.3	Pass
9-79-19-08	Exterior	B Bond	15	5	Other	Not Finished	110		15.55	1 4.5 1.5 3.5	2.6	Fail
9-79-20-08	Exterior	B Bond	15	5	Other	Not Finished	106		16.18	6.5 7.5 5 8	6.8	Pass
9-79-21-08	Exterior	B Bond	15	5	Other	Not Finished	116		16.21	6.5 5 6 8	6.4	Pass
9-79-22-08	Exterior	B Bond	15	5	Other	Not Finished	118		15.53	4.5 5 6.5 4	5.0	Pass
9-79-23-08	Exterior	B Bond	15	5	Other	Not Finished	120		16.05	7.5 9 8 6.5	7.8	Pass
9-79-24-08	Exterior	B Bond	15	5	Other	Not Finished	123		14.50	9 6 5.5 5	6.4	Pass
9-79-25-08	Exterior	B Bond	15	5	Other	Not Finished	124		17.12	5.5 9 8 6	7.1	Pass
9-79-26-08	Exterior	B Bond	15	5	Other	Not Finished	146		14.24	6.5 8 7.5 2.5	6.1	Pass
9-79-27-08	Exterior	B Bond	15	5	Other	Not Finished	148		16.74	7 2.5 3.5 8	5.3	Pass
9-79-28-08	Exterior	B Bond	15	5	Other	Not Finished	152		14.50	6.5 8 8 3.5	6.5	Pass
9-79-29-08	Exterior	B Bond	15	5	Other	Not Finished	169		16.22	8 7 3.5 1	4.9	Fail
9-79-30-08	Exterior	B Bond	15	5	Other	Not Finished	173		15.37	7.5 8 9.5 9.5	8.6	Pass

Tuesday, 21 October 2008

Plywood House 3 Dunlop Street Newstead Qld Australia | PO Box 2108 Fortitude Valley BC Qld 4006
P: +617 3854 1228 | F: +617 3252 4769 | E: mbox@paa.asn.au | ABN 34 009 704 901

Page 1 of 3

Results of Plywood Bond Quality Tests of Samples Recieved 17/09/2008 (Batch 9-79)

									Thickness	Bond Quality		
ID	Type	Bond	Nom Thick	Plys	Species	Finish	Comments	Manufactured	Measured	Bond Ratings	Avg	Result
9-79-31-08	Exterior	B Bond	15	5	Other	Not Finished	176		15.94	1 4.5 3.5 4	3.3	Fail
9-79-32-08	Exterior	B Bond	15	5	Other	Not Finished	178		15.60	3 4 3.5 7.5	4.5	Fail
9-79-33-08	Exterior	B Bond	15	5	Other	Not Finished	181		15.28	8 6.5 8.5 8	7.8	Pass
9-79-34-08	Exterior	B Bond	15	5	Other	Not Finished	185		15.70	7 5.5 6.5 6.5	6.4	Pass
9-79-35-08	Exterior	B Bond	15	5	Other	Not Finished	190		15.32	9.5 6.5 8 6	7.5	Pass
9-79-36-08	Exterior	B Bond	15	5	Other	Not Finished	194		15.86	8.5 7.5 8 4.5	7.1	Pass
9-79-37-08	Exterior	B Bond	15	5	Other	Not Finished	197		15.65	0.5 4 6 7.5	4.5	Fail
9-79-38-08	Exterior	B Bond	15	5	Other	Not Finished	197		16.46	6 8 8.5 0	5.6	Fail
9-79-39-08	Exterior	B Bond	15	5	Other	Not Finished	213		15.72	4.5 8 6 4	5.6	Pass
9-79-40-08	Exterior	B Bond	15	5	Other	Not Finished	222		15.70	9 10 7.5 9.5	9.0	Pass
9-79-41-08	Exterior	B Bond	15	5	Other	Not Finished	233		15.85	8 8.5 7 5	7.1	Pass
9-79-42-08	Exterior	B Bond	15	5	Other	Not Finished	234		16.16	4 3.5 6.5 1.5	3.9	Fail
9-79-43-08	Exterior	B Bond	15	5	Other	Not Finished	237		16.07	5 7.5 7.5 2	5.5	Pass
9-79-44-08	Exterior	B Bond	15	5	Other	Not Finished	242		15.56	7.5 6.5 7 2.5	5.9	Pass
9-79-45-08	Exterior	B Bond	15	5	Other	Not Finished	244		15.74	8.5 8.5 6 3.5	6.6	Pass
9-79-46-08	Exterior	B Bond	15	5	Other	Not Finished	246		16.02	8 6.5 7.5 0	5.5	Fail
9-79-47-08	Exterior	B Bond	15	5	Other	Not Finished	250		15.94	3.5 7 5.5 0.5	4.1	Fail
9-79-48-08	Exterior	B Bond	15	5	Other	Not Finished	261		15.69	6 4.5 2.5 0.5	3.4	Fail
9-79-49-08	Exterior	B Bond	15	5	Other	Not Finished	271		15.79	1.5 2 4.5 6	3.5	Fail
9-79-50-08	Exterior	B Bond	15	5	Other	Not Finished	274		14.60	2.5 3.5 6 8.5	5.1	Pass
9-79-51-08	Exterior	B Bond	15	5	Other	Not Finished	284		15.36	6 5 2.5 6.5	5.0	Pass
9-79-52-08	Exterior	B Bond	15	5	Other	Not Finished	285		14.02	6 8 5.5 5.5	6.3	Pass
9-79-53-08	Exterior	B Bond	15	5	Other	Not Finished	289		14.48	3.5 7 4.5 7.5	5.6	Pass
9-79-54-08	Exterior	B Bond	15	5	Other	Not Finished	294		14.16	2 2.5 6 7	4.4	Fail
9-79-55-08	Exterior	B Bond	15	5	Other	Not Finished	299		14.81	3.5 8 5 8.5	6.3	Pass
9-79-56-08	Exterior	B Bond	15	5	Other	Not Finished	302		13.94	5.5 6.5 5.5 9	6.6	Pass
9-79-57-08	Exterior	B Bond	15	5	Other	Not Finished	305		14.86	4 4 6 7	5.3	Pass
9-79-58-08	Exterior	B Bond	15	5	Other	Not Finished	314		14.90	8 6 8 6.5	7.1	Pass
9-79-59-08	Exterior	B Bond	15	5	Other	Not Finished	316		14.79	4 7 3.5 7	5.4	Pass
9-79-60-08	Exterior	B Bond	15	5	Other	Not Finished	317		14.75	9 6.5 7 4.5	6.8	Pass
9-79-61-08	Exterior	B Bond	15	5	Other	Not Finished	320		14.42	2.5 6 5.5 7.5	5.4	Pass
9-79-62-08	Exterior	B Bond	15	5	Other	Not Finished	320		14.57	4.5 6.5 5.5 5.5	5.5	Pass
9-79-63-08	Exterior	B Bond	15	5	Other	Not Finished	329		14.78	8.5 7.5 8 5	7.3	Pass
9-79-64-08	Exterior	B Bond	15	5	Other	Not Finished	332		15.21	2 6.5 4 7.5	5.0	Pass
9-79-65-08	Exterior	B Bond	15	5	Other	Not Finished	343		14.86	5 6.5 4 8	5.9	Pass
9-79-66-08	Exterior	B Bond	15	5	Other	Not Finished	349		15.13	5 4.5 4.5 5.5	4.9	Fail
9-79-67-08	Exterior	B Bond	15	5	Other	Not Finished	357		14.99	6 5.5 6 7	6.1	Pass
9-79-68-08	Exterior	B Bond	15	5	Other	Not Finished	365		14.43	4.5 4 7.5 7.5	5.9	Pass
9-79-69-08	Exterior	B Bond	15	5	Other	Not Finished	358		15.15	2 5 7 6.5	5.1	Pass

Plywood House 3 Dunlop Street Newstead Qld Australia | PO Box 2108 Fortitude Valley BC Qld 4006
P: +617 3854 1228 | F: +617 3252 4769 | E: inbox@paa.asn.au | ABN 34 009 704 901

Results of Plywood Bond Quality Tests of Samples Recieved 17/09/2008 (Batch 9-79)

									Thickness	Bond Quality		
ID	Type	Bond	Nom Thick	Plys	Species	Finish	Comments	Manufactured	Measured	Bond Ratings	Avg	Result

Total Samples : 69 **Samples Passed :** 54 **Batch Bond Quality Average :** 5.71

The bond qualities and thicknesses of the above samples were determined in accordance with AS/NZS 2098.2-2006 (except section 8.1) and AS/NZS 2098.4-2006 respectively. Bond quality pass criteria used as per clause 3.3C, AS/NZS 2269. The minimum and maximum thickness have not been reported. This report must not be reproduced except in full. This document is issued in accordance with NATA's accreditation requirements.

Regards

Susie Steiger
Technical Officer

Plywood House 3 Dunlop Street Newstead Qld Australia | PO Box 2108 Fortitude Valley BC Qld 4006
P: +617 3854 1228 | F: +617 3252 4769 | E: inbox@paa.asn.au | ABN 34 009 704 901

Part B: Plywood manufactured from veneers sourced from lower billets

EWPAA

ENGINEERED WOOD PRODUCTS ASSOCIATION OF AUSTRALASIA

PRODUCT CERTIFIED paa ENGINEERED WOOD JAS-ANZ NATA Accredited for compliance with ISO/IEC 17025 NATA Accredited No. 765

EWPAA Test Report Ref : 4/02/2009 2-17

Dane Thomas
Forests NSW
PO Box J19

Results of Plywood Bond Quality Tests of Samples Recieved 4/02/2009 (Batch 2-17)

									Thickness	Bond Quality		
ID	Type	Bond	Nom Thick	Plys	Species	Finish	Comments	Manufactured	Measured	Bond Ratings	Avg	Result
2-17-1-09	Exterior	B Bond	15	5	Other	Not Finished	187		15.82	4 6.5 4.5 7	5.5	Pass
2-17-2-09	Exterior	B Bond	15	5	Other	Not Finished	172		15.68	3.5 4.5 5.5 7	5.1	Pass
2-17-3-09	Exterior	B Bond	15	5	Other	Not Finished	191		15.46	7 7.5 6.5 7	7.0	Pass
2-17-4-09	Exterior	B Bond	15	5	Other	Not Finished	238		15.88	0 1 1 5	1.8	Fail
2-17-5-09	Exterior	B Bond	15	5	Other	Not Finished	182		15.56	8 8.5 8.5 7.5	8.1	Pass
2-17-6-09	Exterior	B Bond	15	5	Other	Not Finished	243		400.96	2 6 7 7.5	5.6	Pass
2-17-7-09	Exterior	B Bond	15	5	Other	Not Finished	278		14.39	5.5 5 4.5 5	5.0	Pass
2-17-8-09	Exterior	B Bond	15	5	Other	Not Finished	287		14.79	8.5 8.5 8 6.5	7.9	Pass
2-17-9-09	Exterior	B Bond	15	5	Other	Not Finished	258		15.90	2 2 4 3	2.8	Fail
2-17-10-09	Exterior	B Bond	15	5	Other	Not Finished	249		16.09	5.5 2.5 2.5 3.5	3.5	Fail
2-17-11-09	Exterior	B Bond	15	5	Other	Not Finished	223		15.61	6 7 7 8.5	7.1	Pass
2-17-12-09	Exterior	B Bond	15	5	Other	Not Finished	231		15.71	3 6 7.5 6.5	5.8	Pass
2-17-13-09	Exterior	B Bond	15	5	Other	Not Finished	208		15.61	6.5 7 7.5 6	6.8	Pass
2-17-14-09	Exterior	B Bond	15	5	Other	Not Finished	199		15.87	3 5 6.5 7.5	5.5	Pass
2-17-15-09	Exterior	B Bond	15	5	Other	Not Finished	330		14.77	6 6.5 7 6	6.4	Pass
2-17-16-09	Exterior	B Bond	15	5	Other	Not Finished	254		15.52	2.5 4.5 6.5 6	4.9	Fail
2-17-17-09	Exterior	B Bond	15	5	Other	Not Finished	319		14.46	8 9 8.5 7	8.1	Pass
2-17-18-09	Exterior	B Bond	15	5	Other	Not Finished	240		16.11	0 3.5 2.5 2.5	2.1	Fail
2-17-19-09	Exterior	B Bond	15	5	Other	Not Finished	276		14.35	10 10 8 6.5	8.6	Pass
2-17-20-09	Exterior	B Bond	15	5	Other	Not Finished	239		15.56	6.5 8 6 6.5	6.8	Pass
2-17-21-09	Special	B Bond	15	5	Other	Not Finished	163		15.60	2.5 5 4.5 6	4.5	Fail
2-17-22-09	Exterior	B Bond	15	5	Other	Not Finished	307		14.29	7 8 8 4.5	6.9	Pass
2-17-23-09	Exterior	B Bond	15	5	Other	Not Finished	165		15.63	5 5.5 6 6.5	5.8	Pass
2-17-24-09	Exterior	B Bond	15	5	Other	Not Finished	189		15.61	0.5 3 3 7	3.4	Fail
2-17-25-09	Exterior	B Bond	15	5	Other	Not Finished	179		15.81	2.5 8 4.5 8.5	5.9	Pass
2-17-26-09	Exterior	B Bond	15	5	Other	Not Finished	215		15.68	3 5.5 6 7.5	5.5	Pass
2-17-27-09	Exterior	B Bond	15	5	Other	Not Finished	85		15.84	7 8.5 7 3.5	6.5	Pass
2-17-28-09	Exterior	B Bond	15	5	Other	Not Finished	2		15.18	7 6.5 2.5 4	5.0	Pass
2-17-29-09	Exterior	B Bond	15	5	Other	Not Finished	3		15.29	8.5 9.5 8.5 2	7.1	Pass

Monday, 30 March 2009

Plywood House 3 Dunlop Street Newstead Qld Australia | PO Box 2108 Fortitude Valley BC Qld 4006
P: +617 3250 3700 | F: +617 3252 4769 | E: inbox@paa.asn.au | ABN 34 009 704 901

Page 1 of 2

Results of Plywood Bond Quality Tests of Samples Recieved 4/02/2009 (Batch 2-17)

ID	Type	Bond	Nom Thick	Plys	Species	Finish	Comments	Manufactured	Thickness Measured	Bond Quality Bond Ratings	Bond Quality Avg	Result
2-17-30-09	Exterior	B Bond	15	5	Other	Not Finished	122		16.64	**4 7.5 6 6.5**	6.0	Pass

Total Samples : 30 **Samples Passed :** 23 **Batch Bond Quality Average :** 5.68

The bond qualities and thicknesses of the above samples were determined in accordance with AS/NZS 2098.2-2006 (except section 8.1) and AS/NZS 2098.4-2006 respectively. Bond quality pass criteria used as per clause 3.3C, AS/NZS 2269. The minimum and maximum thickness have not been reported. This report must not be reproduced except in full. This document is issued in accordance with NATA's accreditation requirements.

Regards

Susie Steiger
Technical Officer

Appendix A3. In-grade MOR & MOE test results

Individual results tested to Australian and New Zealand Standard *Plywood – Structural, Part 1: Determination of structural properties – Test methods. AS/NZ 2269.1:2008*. Standards Australia (2008).

Testing Machine: Avery UTM (Grade A)
Test facililty: Forests NSW, Sydney
Test type & configuration: 4-point bending test loaded at third points
Test span: 720 mm
Nominal thickness: 15 mm   Nominal width: 300 mm
Plywood construction: 15-30-5

Species	Site	Age (yr)	Sample No	MC	MOR (MPa)	MOE (MPa)	Assigned Grade
E. agglomerata	WCC	34	19	8.4	131.0	26329	34
E. agglomerata	WCC	34	20	8.6	121.1	25630	34
E. agglomerata	WCC	34	23	8.5	107.5	24330	34
E. agglomerata	WCC	34	25	8.5	108.9	20506	27
E. agglomerata	WCC	34	26	9.4	100.6	24693	34
E. agglomerata	WCC	34	27	8.9	71.8	22157	34
E. agglomerata	WCC	34	28	9.3	100.0	22459	34
E. agglomerata	WCC	34	47	10.0	143.8	24320	34
E. agglomerata	WCC	34	89	8.5	131.9	24184	34
E. agglomerata	WCC	34	90	9.7	121.3	28483	34
E. agglomerata	WCC	34	91	9.5	127.1	28045	34
E. agglomerata	WCC	34	92	10.2	128.1	32146	34
E. agglomerata	WCC	34	93	9.6	118.6	24388	34
E. agglomerata	WCC	34	100	8.4	150.5	32559	34
E. agglomerata	WCC	34	120	10.5	146.5	28565	34
E. agglomerata	WCC	34	121	9.1	153.9	23811	34
E. agglomerata	WCC	34	128	9.8	117.5	27887	34
E. agglomerata	WCC	34	129	11.2	143.2	26134	34
E. agglomerata	WCC	34	130	10.8	104.2	25424	34
E. agglomerata	WCC	34	131	11.5	125.1	24103	34
E. agglomerata	WCC	34	132	11.2	111.5	23097	34
E. agglomerata	WCC	34	133	10.8	107.0	24257	34
E. agglomerata	WCC	34	134	10.8	104.3	22935	34
E. agglomerata	WCC	34	135	11.0	136.7	32429	34
E. agglomerata	WCC	34	136	10.5	130.0	25472	34
E. agglomerata	WCC	34	137	10.1	72.9	18086	22
E. agglomerata	WCC	34	138	10.0	113.5	30740	34
E. agglomerata	WCC	34	139	9.1	98.1	27307	34
E. agglomerata	WCC	34	147	9.8	79.6	20264	27
E. agglomerata	WCC	34	148	11.2	100.6	25342	34
E. agglomerata	WCC	34	149	10.6	105.0	22057	34

Species	Site	Age (yr)	Sample No	MC	MOR (MPa)	MOE (MPa)	Assigned Grade
E. agglomerata	WCC	34	300	8.4	116.3	22014	34
E. agglomerata	WCC	34	301	8.5	112.1	22199	34
E. agglomerata	WCC	34	302	8.5	102.5	17435	22
E. agglomerata	WCC	34	303	8.5	96.9	20774	27
E. agglomerata	WCC	34	329	7.5	84.6	16295	22
E. agglomerata	WCC	34	337	7.2	70.2	15941	17
E. agglomerata	WCC	34	338	7.1	70.2	17004	22
E. agglomerata	WCC	34	339	7.3	90.7	16327	22
E. agglomerata	WCC	34	340	7.8	112.2	19879	27
E. agglomerata	WCC	34	342	8.1	122.3	19656	27
E. agglomerata	WCC	34	343	8.2	103.7	17792	22
E. agglomerata	WCC	34	344	8.4	104.8	17106	22
E. agglomerata	WCC	34	345	8.2	99.6	17041	22
E. agglomerata	WCC	34	346	8.2	84.2	17492	22
E. agglomerata	WCC	34	361	7.8	97.6	17937	22
E. dunnii	Boambee	12	159	9.7	118.9	20260	27
E. dunnii	Boambee	12	160	9.5	138.1	26028	34
E. dunnii	Boambee	12	161	8.9	85.8	17095	22
E. dunnii	Boambee	12	162	8.9	141.8	22327	34
E. dunnii	Boambee	12	169	9.2	83.8	17649	22
E. dunnii	Boambee	12	170	8.7	85.5	17089	22
E. dunnii	Boambee	12	171	8.0	85.5	19404	27
E. dunnii	Boambee	12	172	8.1	108.4	19518	27
E. dunnii	Boambee	12	173	8.5	108.1	22210	34
E. dunnii	Boambee	12	174	7.9	104.2	21025	27
E. dunnii	Boambee	12	178	8.8	80.5	14360	17
E. dunnii	Boambee	12	179	8.0	121.4	22988	34
E. dunnii	Boambee	12	180	7.9	72.7	17560	22
E. dunnii	Boambee	12	186	7.9	98.0	19889	27
E. dunnii	Boambee	12	187	7.4	84.9	20237	27
E. dunnii	Boambee	12	188	7.3	106.6	20965	27
E. dunnii	Boambee	12	197	10.0	109.6	19292	27
E. dunnii	Boambee	12	198	9.6	128.1	22589	34
E. dunnii	Boambee	12	199	9.3	120.6	19803	27
E. dunnii	Boambee	12	200	9.2	94.8	18080	22
E. dunnii	Boambee	12	209	8.4	79.8	14497	17
E. dunnii	Boambee	12	210	8.1	89.5	18930	27
E. dunnii	Boambee	12	211	8.6	68.8	14328	17
E. dunnii	Boambee	12	212	9.0	130.4	21393	27
E. dunnii	Boambee	12	222	8.4	119.6	22141	34
E. dunnii	Boambee	12	223	8.1	80.6	21369	27
E. dunnii	Boambee	12	224	8.5	92.8	19207	27
E. dunnii	Boambee	12	225	9.0	111.4	22518	34
E. dunnii	Boambee	12	226	8.5	89.6	19620	27
E. dunnii	Boambee	12	227	8.5	106.9	21546	34
E. dunnii	Boambee	12	234	10.3	95.3	19841	27
E. dunnii	Boambee	12	235	10.8	115.9	18824	27
E. dunnii	Boambee	12	236	11.0	85.6	20367	27

Species	Site	Age (yr)	Sample No	MC	MOR (MPa)	MOE (MPa)	Assigned Grade
E. dunnii	Boambee	12	240	10.1	92.6	21409	27
E. dunnii	Boambee	12	241	10.5	66.4	13797	14
E. dunnii	Boambee	12	242	10.5	76.2	14138	17
E. dunnii	Boambee	12	243	9.9	41.5	13021	14
E. dunnii	Boambee	12	246	10.8	103.2	17701	22
E. dunnii	Boambee	12	247	11.0	116.1	20656	27
E. dunnii	Boambee	12	248	11.0	84.1	21016	27
E. dunnii	Boambee	12	249	11.2	95.7	20479	27
E. dunnii	Boambee	12	250	10.6	126.2	22207	34
E. dunnii	Boambee	12	251	10.9	92.0	17756	22
E. dunnii	Boambee	12	254	10.9	109.1	21037	27
E. dunnii	Boambee	12	255	11.2	125.2	24838	34
E. dunnii	Boambee	12	262	11.0	99.0	25821	34
E. dunnii	Boambee	12	263	10.1	89.6	19435	27
E. dunnii	Boambee	12	264	9.8	77.9	18563	27
E. dunnii	Boambee	12	265	10.3	77.3	14094	17
E. dunnii	Boambee	12	266	10.3	59.3	13369	14
E. dunnii	Boambee	12	267	9.8	58.6	12962	14
E. dunnii	Boambee	12	268	12.6	103.4	19006	27
E. dunnii	Boambee	12	269	10.1	121.0	22206	34
E. dunnii	Boambee	12	270	10.3	126.7	24263	34
E. dunnii	Boambee	12	271	10.6	120.3	23853	34
E. dunnii	Boambee	12	272	11.3	88.6	18320	22
E. dunnii	Boambee	12	273	11.5	98.5	17120	22
E. dunnii	Newry	17	158	10.9	125.4	22887	34
E. dunnii	Newry	17	163	9.1	101.2	18758	27
E. dunnii	Newry	17	164	8.8	126.8	20244	27
E. dunnii	Newry	17	165	9.2	126.9	24683	34
E. dunnii	Newry	17	166	9.5	95.1	18446	22
E. dunnii	Newry	17	167	9.2	130.9	26788	34
E. dunnii	Newry	17	168	9.5	98.3	20199	27
E. dunnii	Newry	17	175	8.6	126.6	26635	34
E. dunnii	Newry	17	176	9.1	100.8	23094	34
E. dunnii	Newry	17	177	8.8	108.9	22216	34
E. dunnii	Newry	17	181	7.7	87.6	19682	27
E. dunnii	Newry	17	182	7.4	91.6	18963	27
E. dunnii	Newry	17	183	7.9	92.5	18368	22
E. dunnii	Newry	17	184	8.2	69.5	20611	27
E. dunnii	Newry	17	185	8.4	44.1	13399	14
E. dunnii	Newry	17	189	8.1	76.1	19180	27
E. dunnii	Newry	17	190	8.0	73.6	16967	22
E. dunnii	Newry	17	191	7.5	101.8	23225	34
E. dunnii	Newry	17	192	7.9	116.5	25202	34
E. dunnii	Newry	17	193	9.6	122.1	22152	34
E. dunnii	Newry	17	194	10.9	116.0	20055	27
E. dunnii	Newry	17	195	10.0	110.9	24855	34
E. dunnii	Newry	17	196	10.5	118.1	23242	34
E. dunnii	Newry	17	201	9.8	63.8	18814	27

Species	Site	Age (yr)	Sample No	MC	MOR (MPa)	MOE (MPa)	Assigned Grade
E. dunnii	Newry	17	202	9.5	78.7	16155	22
E. dunnii	Newry	17	203	9.0	78.4	20363	27
E. dunnii	Newry	17	204	8.2	114.1	25765	34
E. dunnii	Newry	17	205	8.8	117.1	23609	34
E. dunnii	Newry	17	206	8.9	101.4	23264	34
E. dunnii	Newry	17	207	8.8	83.0	19588	27
E. dunnii	Newry	17	208	8.6	67.4	16827	22
E. dunnii	Newry	17	213	9.6	110.7	20809	27
E. dunnii	Newry	17	214	9.7	101.9	23597	34
E. dunnii	Newry	17	215	9.7	125.6	26080	34
E. dunnii	Newry	17	216	9.3	120.9	27829	34
E. dunnii	Newry	17	217	9.4	94.6	22245	34
E. dunnii	Newry	17	218	7.8	136.4	24879	34
E. dunnii	Newry	17	219	7.8	77.8	19821	27
E. dunnii	Newry	17	220	7.5	73.5	19526	27
E. dunnii	Newry	17	221	7.8	84.2	21463	27
E. dunnii	Newry	17	228	8.5	87.6	18687	27
E. dunnii	Newry	17	229	9.3	93.2	20028	27
E. dunnii	Newry	17	230	10.3	126.8	25017	34
E. dunnii	Newry	17	231	10.5	133.6	25981	34
E. dunnii	Newry	17	232	10.8	105.0	27084	34
E. dunnii	Newry	17	233	11.4	97.4	21878	34
E. dunnii	Newry	17	237	10.6	97.4	21364	27
E. dunnii	Newry	17	238	10.9	98.4	20640	27
E. dunnii	Newry	17	239	10.8	91.6	19110	27
E. dunnii	Newry	17	244	9.4	82.8	17232	22
E. dunnii	Newry	17	245		109.1	20400	27
E. dunnii	Newry	17	252	11.9	86.4	16722	22
E. dunnii	Newry	17	253	11.6	102.2	17963	22
E. dunnii	Newry	17	256	11.3	99.6	20532	27
E. dunnii	Newry	17	257	11.7	69.7	18070	22
E. dunnii	Newry	17	258	12.2	81.2	19330	27
E. dunnii	Newry	17	259	12.1	113.6	22752	34
E. dunnii	Newry	17	260	12.0	59.2	13398	14
E. dunnii	Newry	17	261	11.4	73.7	15981	17
E. dunnii	WCC	34	2	9.1	76.1	19303	27
E. dunnii	WCC	34	3	8.6	75.6	19470	27
E. dunnii	WCC	34	4	8.6	104.2	22841	34
E. dunnii	WCC	34	5	7.8	94.5	25636	34
E. dunnii	WCC	34	80	8.2	111.5	25312	34
E. dunnii	WCC	34	81	8.0	149.2	27716	34
E. dunnii	WCC	34	82	7.7	155.3	30354	34
E. dunnii	WCC	34	83	8.5	119.1	25574	34
E. dunnii	WCC	34	85	8.2	90.6	24308	34
E. dunnii	WCC	34	86	8.2	76.1	18060	22
E. dunnii	WCC	34	87	7.8	144.5	28142	34
E. dunnii	WCC	34	88	7.9	131.0	26472	34
E. dunnii	WCC	34	122	9.4	161.4	36922	34

Species	Site	Age (yr)	Sample No	MC	MOR (MPa)	MOE (MPa)	Assigned Grade
E. dunnii	WCC	34	123	8.8	91.2	20913	27
E. dunnii	WCC	34	274	8.9	136.7	23352	34
E. dunnii	WCC	34	275	8.2	107.5	20924	27
E. dunnii	WCC	34	276	7.4	92.7	18635	27
E. dunnii	WCC	34	277	7.5	165.4	26366	34
E. dunnii	WCC	34	278	7.5	141.0	23048	34
E. dunnii	WCC	34	279	7.5	151.2	24503	34
E. dunnii	WCC	34	280	7.5	160.5	25808	34
E. dunnii	WCC	34	287	6.7	102.5	20383	27
E. dunnii	WCC	34	288	6.7	110.5	19954	27
E. dunnii	WCC	34	289	7.8	97.2	18227	22
E. dunnii	WCC	34	290	6.8	94.7	19608	27
E. dunnii	WCC	34	293	7.2	123.3	21301	27
E. dunnii	WCC	34	299	8.6	81.3	17195	22
E. dunnii	WCC	34	307	7.2	75.8	17539	22
E. dunnii	WCC	34	308	7.4	82.8	17649	22
E. dunnii	WCC	34	309	7.5	69.2	15194	17
E. dunnii	WCC	34	310	7.5	80.0	13594	14
E. dunnii	WCC	34	317	8.1	99.6	21413	27
E. dunnii	WCC	34	318	8.1	97.0	18608	27
E. dunnii	WCC	34	319	7.9	105.2	19502	27
E. dunnii	WCC	34	327	8.1	75.8	20093	27
E. dunnii	WCC	34	328	7.9	81.3	20735	27
E. dunnii	WCC	34	330	7.5	105.9	22100	34
E. dunnii	WCC	34	331	7.0	112.3	20719	27
E. dunnii	WCC	34	332	6.8	74.7	19217	27
E. dunnii	WCC	34	333	6.9	51.4	16457	22
E. dunnii	WCC	34	334	7.0	105.6	20768	27
E. dunnii	WCC	34	347	8.7	71.8	19440	27
E. dunnii	WCC	34	348	7.6	107.0	21330	27
E. dunnii	WCC	34	353	7.2	68.6	16110	22
E. dunnii	WCC	34	357	7.6	87.3	19981	27
E. dunnii	WCC	34	364	8.2	91.0	15508	17
E. dunnii	WCC	34	367	8.6	83.8	14018	17
E. grandis	WCC	34	6	8.4	97.2	18142	22
E. grandis	WCC	34	21	7.9	117.6	25975	34
E. grandis	WCC	34	22	8.1	97.4	20528	27
E. grandis	WCC	34	29	8.4	96.9	17355	22
E. grandis	WCC	34	30	8.7	71.2	15790	17
E. grandis	WCC	34	31	9.2	81.8	14834	17
E. grandis	WCC	34	32	8.8	56.6	11072	11
E. grandis	WCC	34	33	8.7	99.5	19939	27
E. grandis	WCC	34	34	9.3	126.6	25882	34
E. grandis	WCC	34	35	8.5	130.9	21951	34
E. grandis	WCC	34	36	8.4	122.8	24387	34
E. grandis	WCC	34	37	8.3	104.2	17614	22
E. grandis	WCC	34	38	8.4	107.0	17042	22
E. grandis	WCC	34	39	9.0	83.8	14337	17

Species	Site	Age (yr)	Sample No	MC	MOR (MPa)	MOE (MPa)	Assigned Grade
E. grandis	WCC	34	43	8.2	98.5	19692	27
E. grandis	WCC	34	44	8.7	77.8	18252	22
E. grandis	WCC	34	45	9.4	104.7	20229	27
E. grandis	WCC	34	48	9.3	93.6	17673	22
E. grandis	WCC	34	49	8.9	85.3	14698	17
E. grandis	WCC	34	50	9.3	89.1	18262	22
E. grandis	WCC	34	51	9.9	88.1	16999	22
E. grandis	WCC	34	58	9.9	41.1	12071	14
E. grandis	WCC	34	59	9.6	81.0	18892	27
E. grandis	WCC	34	60	9.7	69.0	15267	17
E. grandis	WCC	34	61	9.6	86.7	19723	27
E. grandis	WCC	34	62	9.2	79.7	14779	17
E. grandis	WCC	34	63	9.2	109.5	22859	34
E. grandis	WCC	34	64	9.3	109.0	19503	27
E. grandis	WCC	34	65	9.6	96.8	17896	22
E. grandis	WCC	34	66	9.9	87.6	17856	22
E. grandis	WCC	34	67	9.6	106.9	19441	27
E. grandis	WCC	34	74	9.2	75.0	15445	17
E. grandis	WCC	34	75	9.3	84.7	16332	22
E. grandis	WCC	34	76	9.2	51.8	11657	11
E. grandis	WCC	34	113	8.1	76.7	16355	22
E. grandis	WCC	34	114	8.1	94.3	17448	22
E. grandis	WCC	34	115	8.1	98.0	14837	17
E. grandis	WCC	34	116	7.8	103.1	23943	34
E. grandis	WCC	34	152	9.4	56.9	15499	17
E. grandis	WCC	34	291	6.8	86.6	19022	27
E. grandis	WCC	34	305	7.6	80.4	17509	22
E. grandis	WCC	34	306	4.5	62.4	15748	17
E. grandis	WCC	34	311	7.1	64.8	13547	14
E. grandis	WCC	34	312	7.5	90.1	15308	17
E. grandis	WCC	34	313	7.8	67.9	13925	14
E. grandis	WCC	34	314	7.9	60.9	14105	17
E. grandis	WCC	34	359	7.3	81.0	14533	17
E. grandis	WCC	34	360	7.5	95.9	15433	17
E. grandis	WCC	34	365	8.5	86.3	17108	22
E. grandis	WCC	34	366	7.9	85.2	13470	14
E. pilularis	WCC	34	1	9.3	123.9	25216	34
E. pilularis	WCC	34	40	9.4	128.5	27264	34
E. pilularis	WCC	34	41	8.5	103.5	22793	34
E. pilularis	WCC	34	42	8.2	107.5	23025	34
E. pilularis	WCC	34	46	10.3	93.1	19590	27
E. pilularis	WCC	34	52	9.8	153.9	30497	34
E. pilularis	WCC	34	53	10.1	124.4	24511	34
E. pilularis	WCC	34	54	9.9	85.3	21491	27
E. pilularis	WCC	34	55	10.4	105.5	26477	34
E. pilularis	WCC	34	56	10.4	107.3	23809	34
E. pilularis	WCC	34	57	10.2	88.6	22644	34
E. pilularis	WCC	34	68	8.5	132.2	24667	34

Species	Site	Age (yr)	Sample No	MC	MOR (MPa)	MOE (MPa)	Assigned Grade
E. pilularis	WCC	34	69	8.7	109.3	22232	34
E. pilularis	WCC	34	70	8.4	140.4	26718	34
E. pilularis	WCC	34	71	8.3	138.9	25740	34
E. pilularis	WCC	34	72	8.7	91.1	24707	34
E. pilularis	WCC	34	73	8.9	82.5	21246	27
E. pilularis	WCC	34	77	8.7	143.9	29470	34
E. pilularis	WCC	34	78	8.3	122.9	21709	34
E. pilularis	WCC	34	79	9.2	119.9	21126	27
E. pilularis	WCC	34	101	7.9	114.9	21492	27
E. pilularis	WCC	34	102	7.8	124.2	24176	34
E. pilularis	WCC	34	103	7.7	123.9	27596	34
E. pilularis	WCC	34	104	7.8	133.8	24831	34
E. pilularis	WCC	34	105	7.6	125.7	25541	34
E. pilularis	WCC	34	106	8.1	146.9	29490	34
E. pilularis	WCC	34	111	8.2	101.5	24793	34
E. pilularis	WCC	34	112	8.1	103.0	24222	34
E. pilularis	WCC	34	140	9.0	129.4	25028	34
E. pilularis	WCC	34	141	8.2	99.9	24218	34
E. pilularis	WCC	34	142	7.9	160.0	29864	34
E. pilularis	WCC	34	143	7.7	80.9	25226	34
E. pilularis	WCC	34	144	7.5	130.0	26576	34
E. pilularis	WCC	34	145	7.9	135.3	28186	34
E. pilularis	WCC	34	153	9.6	160.0	30621	34
E. pilularis	WCC	34	154	9.7	146.9	29853	34
E. pilularis	WCC	34	155	9.7	134.2	28020	34
E. pilularis	WCC	34	156	10.1	112.8	24799	34
E. pilularis	WCC	34	157	10.5	107.4	22251	34
E. pilularis	WCC	34	281	9.0	120.5	22841	34
E. pilularis	WCC	34	282	7.6	77.7	16389	22
E. pilularis	WCC	34	283	7.1	95.7	18269	22
E. pilularis	WCC	34	284	7.2	120.2	19447	27
E. pilularis	WCC	34	294	7.3	114.2	19531	27
E. pilularis	WCC	34	295	7.2	104.0	19313	27
E. pilularis	WCC	34	296	7.1	100.5	19133	27
E. pilularis	WCC	34	297	7.1	108.9	18716	27
E. pilularis	WCC	34	298	7.2	86.2	17624	22
E. pilularis	WCC	34	304	8.1	105.0	18718	27
E. pilularis	WCC	34	315	8.3	100.8	19782	27
E. pilularis	WCC	34	316	7.9	71.9	17453	22
E. pilularis	WCC	34	323	7.9	108.1	19449	27
E. pilularis	WCC	34	324	7.6	70.4	14725	17
E. pilularis	WCC	34	325	7.6	93.2	18019	22
E. pilularis	WCC	34	335	7.4	58.9	16378	22
E. pilularis	WCC	34	336	7.0	75.8	18317	22
E. pilularis	WCC	34	341	7.8	113.7	17651	22
E. pilularis	WCC	34	349	7.2	127.1	22674	34
E. pilularis	WCC	34	350	7.4	61.6	13747	14
E. pilularis	WCC	34	351	7.6	75.4	14144	17

Species	Site	Age (yr)	Sample No	MC	MOR (MPa)	MOE (MPa)	Assigned Grade
E. pilularis	WCC	34	352	7.4	105.5	17945	22
E. pilularis	WCC	34	354	7.3	97.6	18534	27
E. pilularis	WCC	34	355	7.4	96.6	21121	27
E. pilularis	WCC	34	358	8.0	64.4	16396	22
E. pilularis	WCC	34	362	7.8	100.5	18253	22
E. pilularis	WCC	34	363	8.1	82.3	15074	17
E. saligna	WCC	34	7	7.7	126.7	22350	34
E. saligna	WCC	34	8	6.6	138.9	27880	34
E. saligna	WCC	34	9	6.7	121.5	22390	34
E. saligna	WCC	34	10	6.7	135.5	26404	34
E. saligna	WCC	34	11	7.3	70.5	13155	14
E. saligna	WCC	34	12	7.0	69.8	13307	14
E. saligna	WCC	34	13	7.6	94.9	17954	22
E. saligna	WCC	34	14	7.8	79.1	17589	22
E. saligna	WCC	34	15	7.7	99.8	20186	27
E. saligna	WCC	34	16	6.6	103.5	22199	34
E. saligna	WCC	34	17	7.1	82.1	14535	17
E. saligna	WCC	34	18	7.2	140.6	26445	34
E. saligna	WCC	34	24	9.0	88.5	15320	17
E. saligna	WCC	34	84	8.5	92.1	20601	27
E. saligna	WCC	34	94	9.2	55.2	16073	22
E. saligna	WCC	34	95	7.7	126.2	22431	34
E. saligna	WCC	34	96	7.5	121.2	24275	34
E. saligna	WCC	34	97	7.5	83.6	17296	22
E. saligna	WCC	34	98	7.6	81.3	15840	17
E. saligna	WCC	34	99	7.8	83.0	16813	22
E. saligna	WCC	34	107	7.9	115.9	30487	34
E. saligna	WCC	34	108	8.0	88.3	16307	22
E. saligna	WCC	34	109	7.9	64.5	14142	17
E. saligna	WCC	34	110	8.3	62.9	15087	17
E. saligna	WCC	34	117	8.1	82.0	18280	22
E. saligna	WCC	34	118	8.2	99.5	22447	34
E. saligna	WCC	34	119	9.6	85.2	16192	22
E. saligna	WCC	34	124	8.6	104.6	25269	34
E. saligna	WCC	34	125	9.0	70.0	16721	22
E. saligna	WCC	34	126	10.0	114.5	21113	27
E. saligna	WCC	34	127	9.4	57.4	12243	14
E. saligna	WCC	34	146	9.2	71.6	14246	17
E. saligna	WCC	34	150	10.1	80.8	14724	17
E. saligna	WCC	34	151	9.2	100.0	18483	22
E. saligna	WCC	34	285	7.3	64.0	12538	14
E. saligna	WCC	34	286	6.9	55.2	13743	14
E. saligna	WCC	34	320	7.8	88.3	15662	17
E. saligna	WCC	34	321	7.8	71.5	14143	17
E. saligna	WCC	34	322	7.7	79.5	16350	22
E. saligna	WCC	34	326	7.9	71.7	14413	17
E. saligna	WCC	34	356	7.8	82.4	15179	17