Density and shrinkage of four low-rainfall plantation-grown eucalypts

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Summary

Density and shrinkage values are presented for four eucalypt species (27-y-old *Eucalyptus cladocalyx* F.Muell. (sugar gum), 42-y-old *E. occidentalis* Endl. (swamp yate), 41-y-old *E. astringens* (Maiden) Maiden (brown mallet) and 40-y-old *E. leucoxylon* F.Muell. (yellow gum)) grown in low-rainfall plantations near Horsham in western Victoria. The mean basic densities for the four species were 752–827 kg m^{-3}. The mean unit shrinkages were 0.37–0.41% for tangential shrinkage and 0.22–0.29% for radial shrinkage. These values are more or less comparable with those of wood sampled from mature trees of the same species.

Density and shrinkage values were also compared with published data for *E. delegatensis* R.Baker (alpine ash). The four low-rainfall species have much higher densities than *E. delegatensis* (511 kg m^{-3}), but their unit shrinkages are only slightly higher than those for *E. delegatensis* (0.35% tangential and 0.22% radial) and should be manageable with appropriate design allowances.

Recoverable collapse, measured as the difference between shrinkage values (from green to 12% MC) before reconditioning (BR) and after reconditioning (AR), was evident in all four plantation-grown species (tangential, 2.4–4.1%; radial, 0.4–1.3%). Despite this, steam reconditioning to recover collapse is not generally recommended because existing surface checks may re-open or become worse after steam reconditioning. In addition, the volume lost by not steaming is not large and ‘washboarding’ (localised earlywood collapse that results in a corrugated radial surface) does not occur with these species.

Keywords: wood properties; wood density; shrinkage; dry conditions; forest plantations; eucalypts

Introduction

Density and shrinkage are two of the most important properties influencing the suitability of a species for a timber product (Hillis 1984): density because of its strong relationship with most physical properties such as strength and hardness; shrinkage because of its importance in movement and stability of timber products while being processed and in service. These two properties therefore strongly affect many sawing, drying, machining and design characteristics (Ashley and Ozarska 2000; Ozarska 2000).

Density and shrinkage data were obtained from logs harvested for a sawing and drying project (Blakemore *et al.* 2001) aimed at evaluating the potential of the four eucalypt species to produce high-value appearance-grade products from farm forestry plantations in the low-rainfall (400–600 mm y^{-1}) regions of south-eastern Australia.

Methods

The four eucalypt species sampled were *Eucalyptus cladocalyx* F.Muell. (sugar gum), *E. occidentalis* Endl. (swamp yate), *E. astringens* (Maiden) Maiden (brown mallet) and *E. leucoxylon* F.Muell. (yellow gum). All four species were sampled from plantations in low-rainfall (400–450 mm y^{-1}) areas north-west of Horsham, western Victoria (Table 1).

The procedures used for determining densities and shrinkages were consistent with those described by Kingston and Risdon (1961). For the sawing study by Blakemore *et al*. (2001), 3-m-long butt logs were harvested and sawn predominantly into nominal 105 mm x 43 mm dimension boards. Test specimens for density and shrinkage measurements were prepared from one board of each log. The test specimens were cut approximately

Table 1. Plantation details for each species

Species	Location	Latitude	Longitude	Plantation age (y)	Number of trees sampled
E. cladocalyx	Wail State Forest	36°31'S	142°05'E	27	10
E. leucoxylon	Wail State Forest	36°30'S	142°04'E	40	11
E. occidentalis	The Barrett Reserve	36°25'S	142°19'E	42	11
E. astringens	Glenlee State Forest	36°16'S	141°50'E	41	11

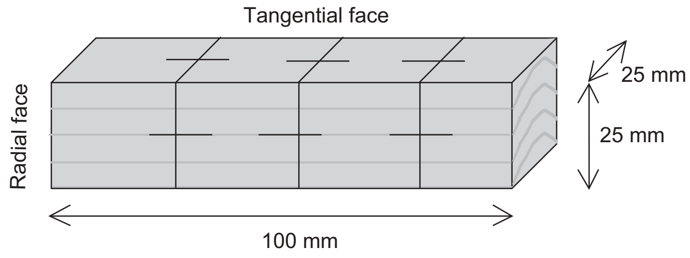

Figure 1. Test specimen showing location of measuring points

600 mm from the stump end of the boards. The boards were selected at various distances from the pith, but as much outer heartwood was sampled as possible. The dimensions of the test specimens were 25 mm (radial) x 25 mm (tangential) x 100 mm (longitudinal), trying for truly radial and tangential faces (Figure 1).

The test specimens were measured and weighed in the following conditions:

1. green,
2. after drying in a conditioned chamber (at 65% relative humidity and 25°C) to a uniform moisture content (MC) of about 12%,
3. after reconditioning (two hours in saturated steam at >98°C) and redrying to a uniform MC in the 12% EMC conditions (65% relative humidity and 25°C),
4. after drying in a conditioned chamber (at 25% relative humidity and 40°C) to a uniform MC of about 5%,
5. reweighed after drying in an oven at 103 ± 2°C until a constant dry weight was obtained.

The radial and tangential dimensions were measured using a digital displacement gauge with readings graduated to 0.001 mm. A pneumatic ram was used to apply 300 kPa of pressure to the measuring contact points, which were flat 10 mm diameter discs. The tangential and radial measurements were taken at three equidistant points along each sample in the middle of the faces, as shown in Figure 1. The three measurements for each dimension were averaged for each test specimen. The lengths of the test specimens were measured with digital vernier callipers with 0.01 mm increments. For the density calculations, volumes were estimated from the measurements of the three dimensions. The scales used to weigh the test specimens were graduated to 0.001 g.

The densities measured were basic density (oven dry mass/green volume) and air dry density (mass at 12% MC/volume at 12% MC before and after steam reconditioning). Shrinkage values from green to 12% MC are expressed as a percentage of green dimensions. Unit shrinkages were calculated by dividing the difference in shrinkage between 12% and 5% MC by the change in moisture content.

Shrinkage in most eucalypt species has two components (Chafe *et al*. 1993): normal shrinkage (due to the removal of water from cell walls, which occurs below the fibre saturation point (FSP)), and collapse or abnormal shrinkage (which occurs above FSP and results in cells flattening or 'collapsing'). Steam reconditioning can 'recover' most of this collapse shrinkage (Chafe *et al*. 1993). Shrinkage is measured before reconditioning (BR) as a measure of total shrinkage (normal and collapse), then after reconditioning (AR) as a measure of normal shrinkage; the difference between BR and AR shrinkages is a measure of recoverable collapse.

Variation in timber properties within and between different species means that most wood will be close to, but not exactly reach, the predicted equilibrium moisture content (EMC) for the given conditions. In this case, most of the test specimens equilibrated close to 14–15% in the intended 12% EMC conditions. Therefore, individual densities and shrinkages were adjusted to 12% using the unit shrinkages for the individual test specimens. The unit shrinkage is a good indicator of the potential for the timber to move in service.

Results and discussion

Table 2 shows the density and shrinkage values for the four plantation-grown eucalypt species. For comparison, the limited data from Kingston and Risdon (1961) for timber from mature trees of *E. leucoxylon*, *E. astringens* and *E. cladocalyx* are shown in Table 3. Due to sampling issues (size and representativeness), the differences between species, and between mature and plantation timber of the same species, need to be interpreted cautiously. For example, as only one sample was used to generate the density and shrinkage values for mature *E. cladocalyx* timber, no meaningful comparisons can be made with the values presented here for plantation-grown timber.

Generally, it is expected that plantation-grown timber will have lower density than mature timber of the same species (Hillis 1984), as is the case with *E. leucoxylon*. Surprisingly, the plantation-grown *E. astringens* had markedly higher density than the mature *E. astringens* and this observation is likely to be related to the sampling issues noted above.

Table 3 also shows the density and shrinkage values from Kingston and Risdon (1961) for *E. delegatensis* R.Baker (alpine ash), a typical native timber species currently processed into appearance products in south-eastern Australia as part of the 'ash' group of species. This clearly illustrates the relatively high density of the species grown in low-rainfall areas. High densities are usually associated with high strength and high shrinkage properties (Hillis 1984). In this case, however, the unit shrinkages for the four low-rainfall species are only marginally greater than for *E. delegatensis*.

The levels of recoverable collapse in the four species are comparable to that of *E. delegatensis*, a species for which steam reconditioning is common industrial practice (Rozsa and Mills 1991). However, steam reconditioning is mostly used to ameliorate pronounced 'washboarding' (localised earlywood collapse, that results in a corrugated radial surface), which is not necessarily reflected in the difference between the BR and AR shrinkage values. Despite the moderate levels of recoverable collapse, steam reconditioning is not generally recommended for these four species, because no 'washboarding' was reported by Blakemore *et al*. (2001) in drying studies with this material, and attempts at steam reconditioning with this material initially reopened existing surface checks or possibly made them worse.

Table 2. Density and shrinkage values for *Eucalyptus leucoxylon*, *E. astringens*, *E. occidentalis* and *E. cladocalyx*. Mean values are shown in bold in the top line for each species, the number of samples and standard error of the mean are shown in the next line, and the third line shows the 95% confidence interval for individual values.

Species	Density (kg m^{-3})				Shrinkage (% of green dimension)			
	Basic	Green	Air dry (12%)		Dimension	Green to 12% MC		Unit
			BR[a]	AR[b]		BR[a]	AR[b]	shrinkage[c]
Gum, yellow	**802**	**1178**	**1023**	**969**	Tangential	**9.5**	**5.4**	**0.38**
E. leucoxylon	11 14.0	11 5.7	11 13.3	11 16.0		11 0.64	11 0.26	11 0.012
(40 y old)	699–906	1136–1221	925–1122	851–1087		4.8–14.2	3.4–7.3	0.30–0.47
					Radial	**3.0**	**2.1**	**0.22**
						11 0.25	11 0.19	11 0.009
						1.2–4.9	0.7–3.5	0.16–0.29
Mallet, brown	**827**	**1119**	**1044**	**1013**	Tangential	**7.7**	**5.3**	**0.41**
E. astringens	11 14.7	11 10.2	11 13.1	11 14.4		11 0.3	11 0.3	11 0.007
(41 y old)	718–935	1044–1194	947–1141	906–1119		5.4–10.0	3.5–7.2	0.35–0.46
					Radial	**3.9**	**3.5**	**0.28**
						11 0.48	11 0.49	11 0.007
						0.4–7.5	–0.2–7.1	0.23–0.34
Yate, swamp	**784**	**1129**	**1019**	**969**	Tangential	**9.4**	**6.0**	**0.40**
E. occidentalis	11 16.8	11 9.3	11 15.7	11 18.5		11 0.78	11 0.45	11 0.009
(42 y old)	660–908	1060–1197	903–1135	832–1105		3.7–15.2	2.7–9.3	0.33–0.46
					Radial	**4.8**	**3.5**	**0.29**
						11 0.42	11 0.29	11 0.009
						1.6–7.9	1.3–5.7	0.22–0.35
Gum, sugar	**752**	**1119**	**952**	**913**	Tangential	**8.5**	**5.3**	**0.37**
E. cladocalyx	10 25.4	10 13.0	10 2.0	10 28.2		10 0.83	10 0.32	10 0.008
(27 y old)	571–934	1026–1212	787–1116	711–1115		2.5–14.4	3.0–7.5	0.32–0.43
					Radial	**3.4**	**2.6**	**0.24**
						10 0.17	10 0.12	10 0.012
						2.2–4.6	1.8–3.5	0.15–0.33

[a]BR = before reconditioning
[b]AR = after reconditioning
[c]Unit shrinkage = calculated by dividing the difference in shrinkage between 12% and 5% MC by the change in moisture content (i.e. by 7)

Conclusion

Compared with data previously published (Kingston and Risdon 1961) relating to three low-rainfall species from mature native forests, the densities of plantation-grown material of the same species were mostly comparable or slightly lower, while the shrinkages were comparable or slightly higher. The comparison with *E. delegatensis* shows that while the four low-rainfall plantation eucalypts have high densities, shrinkage problems should not be significantly worse than those which industry already copes with through design considerations. While the high densities may cause some initial problems with sawing, machining and gluing, these should be readily resolvable. The advantages of these timbers should be their high strength and durability properties, possibly making them suited to applications such as outdoor furniture and decking, as well as interior furniture and flooring.

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Table 3. Density and shrinkage values for mature *Eucalyptus leucoxylon*, *E. astringens*, *E. cladocalyx*, and for *E. delegatensis* (Kingston and Risdon 1961). The timber sampled was from native forests. Mean values are shown in bold in the top line for each species, the number of samples and standard error of the mean are shown in the line below, and the third line shows the 95% confidence interval for individual values*.

Species	Density (kg m^{-3})			Shrinkage (%)			
	Basic	Air dry (12%)		Dimension	Green to 12% MC		Unit
		BR[a]	AR[b]		BR[a]	AR[b]	shrinkage[c]
Gum, yellow	**811**	**1008**	**974**	Tangential	**6.3**	**4.5**	**0.32**
E. leucoxylon	16 27.4	25 23.2	25 22.3		16 0.32	16 0.14	4
Victoria	607–1044	777–1262	758–1217		2.8–10.2	3.2–6.0	
				Radial	**2.8**	**2.1**	**0.19**
					16 0.21	16 0.14	4
					0.7–4.9	1.0–3.3	
Mallet, brown	**770**	**974**	**948**	Tangential	**7.1**	**5.5**	
E. astringens	14 7.5	14 9.5	14 9.3		14 0.15	14 0.17	
Western Australia	708–833	895–1054	871–1027		5.8–8.4	3.2–6.0	
				Radial	**4.4**	**3.6**	
					14 0.13	14 0.13	
					3.3–5.5	2.6–4.7	
Gum, sugar	**753**	**1105**	**1035**	Tangential	**10.5**	**6.2**	
E. cladocalyx	1	5 27.7	5 54.8		1	1	
Victoria		916–1294	663–1406				
				Radial	**6.2**	**2.6**	
					1	1	
Ash, alpine	**511**	**663**	**655**	Tangential	**8.5**	**6.3**	**0.35**
E. delegatensis	41 5.9	47 9.0	74 7.5		47 0.27	46 0.13	9 0.012
NSW–Victoria	397–573	498–756	478–773		4.1–12.2	4.2–8.8	0.27–0.43
				Radial	**5.2**	**3.5**	**0.22**
					57 0.24	56 0.11	17 0.010
					1.1–7.7	1.7–4.8	0.13–0.33

[a]BR = before reconditioning; [b]AR = after reconditioning
[c]Unit shrinkage = calculated by dividing the difference in shrinkage between 12% and 5% MC by the change in moisture content (i.e. by 7)
*The 95% confidence intervals from Kingston and Risdon (1961) appear to be maximum and minimum values

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