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Dimensional changes of pine timber exposed to different environmental conditions

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SUMMARY

The moisture content of timber fluctuates with changes in atmospheric conditions, and because of the hygroscopic properties of timber, some changes in dimensions may occur. The change in moisture content and dimensions (length, width, thickness) of back-sawn 90 x 35 mm maritime pine (*Pinus pinaster*) and radiata pine (*P. radiata*) timber stored at 8 per cent or 18 per cent equilibrium moisture content (EMC) conditions were monitored for 40 days. Samples with sloping grain (equal to or greater than 7°) or straight grain (less than 7°) were compared.

All timber samples had been high-temperature dried to a moisture content of 10.5 ± 2.0 per cent. Timber stored in the 8 per cent EMC chamber shrank as it lost moisture and had a small decrease in width and thickness but negligible change in length, while timber in the 18 per cent EMC chamber absorbed moisture and showed small increases in width and thickness but a negligible change in length. Slope of grain showed no significant effect on changes in dimension.

Longitudinal shrinkage was negligible in the 8 per cent conditions. The greatest mean change in length owing to longitudinal movement was for straight grained radiata pine stored in the 18 per cent EMC chamber, where the increase was 0.09 per cent or 0.9 mm in a 1000 mm long sample, over a moisture content change of 5.5 per cent. This indicates that movement in-service (where the range about EMC may be perhaps 3 to 4 per cent) should be minimal. Movement of the timber may be a factor in 'inverted peaking' in ceiling and wall sheets, but a complete assessment of all factors is required.

INTRODUCTION

As green timber dries in the desorption process, it initially loses free water from the cell cavities, and then loses bound water from the cell walls. The moisture content level at which shrinkage commences is the fibre saturation point (f.s.p.) at approximately 30 per cent moisture content, and shrinkage continues from f.s.p. to equilibrium moisture content (EMC) and below. If its moisture content is below EMC, wood has adsorptive properties which give it the ability to extract water vapour from the surrounding air until it is in moisture equilibrium with the air, i.e. it is a hygroscopic material (Haygreen and Bowyer 1982). Adsorption of water results in swelling of the timber.

As the atmospheric conditions in any one place vary from day to day and season to season, the moisture content of timber constantly changes, even in a sheltered position, but at a much slower rate than the changes in atmospheric conditions. Wood used where humidity fluctuates continually changes in moisture content, and therefore dimension (Haygreen and Bowyer 1982).

Problems can arise when timber is used in widely varying humidity and temperature conditions, if the design and application of the timber product have not anticipated changes in dimension. For satisfactory performance of timber in-service, it is essential to use timber with moisture contents close to the appropriate EMC. Shrinkage can result in checking and warping of timber, and swelling in humid conditions can result in jammed doors and windows, and in buckled table tops.

The amount of shrinkage varies with orientation of the grain, and as a general rule the ratio of tangential to radial to longitudinal shrinkage is 100:50:1. Longitudinal shrinkage in any piece of straight-grained timber cut from mature wood is negligible, e.g. 0.2 to 0.3 per cent from f.s.p. to EMC, a difference in moisture content of about 15 per cent. Compression wood, which can be found in pine trees, is undesirable in timber owing to the high longitudinal shrinkage which is commonly 1.0 to 2.0 per cent and may be as great as 6.0 or 7.0 per cent (Haygreen and Bowyer 1982). Cown and McConchie (1980) quoted a mean longitudinal shrinkage of 0.02 per cent from green to 12 per cent moisture content for 52-year-old radiata pine (*Pinus radiata* D.Don). Any greater increase in length of a piece of timber may be owing to the occurrence of sloping grain, spiral grain in juvenile wood or compression wood.

A study of the shrinkage of 90 x 35 mm pine timber (*P. pinaster* Ait. and *P. radiata*), with straight or sloping grain having an initial moisture content of 10.5 ± 2.0 per cent and stored under 8 or 18 per cent EMC conditions was undertaken by the Timber Utilisation Centre (TUC) (now CALM Timber Technology) following a request from the Timber Advisory Centre. The topic is also relevant to the Association of Wall and Ceiling Contractors of Western Australia. There have been occasional problems with 'inverted peaking' in ceiling and wall fixings when radiata pine studs and rafters are used, with movement of the sheeting and perhaps nail popping. Changes in the moisture content of the pine which, because of timber's hygroscopic properties, can result in swelling or shrinking with increases or decreases in moisture content, may be a factor causing 'inverted peaking'.

The trial was designed to assess lengths of maritime or radiata pine with either straight or sloping grain to quantify the variations in length occurring when timber is stored at either 8 per cent or 18 per cent EMC.

MATERIALS AND METHODS

Sixty-two pieces of back-sawn 90 x 35 mm pine timber were randomly selected from production at Wespine's sawmill at Dardanup. The timber was a mixture of maritime pine and radiata pine. Maritime pine samples were high-temperature dried at 140°C and radiata pine at 150°C, with drying times of 14 h or 10 h respectively. Samples were reconditioned by steaming at 100°C for 3 to 4 h. Ninety per cent of the timber produced at Wespine's factory is radiata pine, however, at the time of selection a considerable volume of maritime pine had been dressed and was available for sampling. Similar shrinkage figures have been reported for both species (Kingston and Risdon 1961).

The timber was delivered to the TUC in Harvey where species, initial moisture contents, weight, slope of grain, air-dry density, and the dimensions of width, thickness and length were measured. Slope of grain was determined at two positions on the board by scribing the individual pieces of timber, and calculating slope using the method described in AS 1080.2.1 - 1981 (Standards Association of Australia 1981). The samples with a slope of grain of less than 7 degrees were classified as straight-grained, and those with a slope of grain equal to or greater than 7 degrees as sloping grained.

Fifteen samples with straight grain and fifteen with sloping grain were stored in the 8 per cent EMC chamber, and sixteen straight grain samples and sixteen sloping grain samples in the 18 per cent EMC chamber. The actual conditions in the 8 per cent EMC chamber were: 35°C dry bulb temperature (DBT) and 45 per cent relative humidity (RH) and; in the 18 per cent EMC chamber: 30°C DBT and 85 per cent RH. Twice weekly for the next six weeks, the samples were assessed for change in weight (moisture content variation) and dimensions. Thirty-nine samples were maritime pine (22 with straight grain and 17 with sloping grain) and 23 radiata pine (9 straight grain and 14 sloping grain), and these were randomly distributed between the 18 and 8 per cent EMC chambers. The samples that contained pith or 'heart-in' samples were noted and their shrinkages compared with the samples without pith. Ninety per cent of the 'heart-in' samples were radiata pine, of which two-thirds were stored in the 18 per cent EMC chamber and one-third in the 8 per cent chamber.

RESULTS AND DISCUSSION

The air-dried densities and the slope of grain were assessed before placing the samples into the EMC chambers. The results are given in Table 1.

Air-dry densities measured in this trial for maritime pine were similar to the mean density of 596 $kg.m^{-3}$ (after reconditioning) determined by Kingston and Risdon (1961), but the range was slightly greater. The air-dry densities for radiata pine were similar to the mean of 485 $kg.m^{-3}$ and range for 10- to 20-year-old trees determined by Kingston and Risdon (1961), but smaller than the mean figure of 593 $kg.m^{-3}$ for 30- to 40-year-old trees. There is a highly significant positive correlation between shrinkage and basic density (Kininmonth and Whitehouse 1991). The densities assessed in this trial were similar to density figures quoted by Kingston and Risdon (1961) suggesting that shrinkages should be representative for pine timber grown in Western Australia.

Analysis of variance was used to determine any significant differences in density between maritime pine and radiata pine, and within each species between samples with straight or sloping grain. Maritime pine was significantly higher in density than radiata pine, but no significant differences in density were found between

TABLE 1

Air-dried density and slope of grain of maritime pine and radiata pine.

SPECIES	GRAIN ORIENTATION	AIR-DRIED DENSITY ($kg.m^{-3}$) MEAN	S.D.	RANGE	SLOPE OF GRAIN (°) MEAN	S.D.	RANGE
Maritime pine	Sloping grain	605	70	490-735	7.6	1.8	8-12
Maritime pine	Straight grain	595	40	510-665	4.9	1.9	1-7
Radiata pine	Sloping grain	490	60	400-595	8.4	2.1	8-14
Radiata pine	Straight grain	485	55	420-580	5.4	1.7	2-7

Note: Air-dried density was assessed at a moisture content of 10.5 ± 2.0 per cent.

maritime pine with straight grain or sloping grain and radiata pine with straight grain or sloping grain. For grain orientation, grain angle was significantly greater in sloping grain than straight grained samples, for both species.

After determining the initial dimensions, moisture contents and weights, the timber was stored in either the 8 per cent or 18 per cent EMC chamber. The initial and final measurements of each parameter in sloping grain and straight grain timber over the 40 day assessment period are listed in Tables 2 and 3.

Figures 1 to 4 show the trends in moisture content, length, width and thickness changes for maritime pine or radiata pine with either sloping or straight grain. Samples were back-sawn, any change in width would indicate a tangential movement and any change in thickness a radial movement. Figure 1 shows moisture content variations, and that the samples stabilized at about 17 per cent in the 18 per cent chamber, or 10 per cent in the 8 per cent chamber after 40 days exposure. Figure 2 shows negligible change in length, with the straight grained radiata pine stored in the 18 per cent EMC chamber having the largest mean change of 0.09 per cent, more than the samples with sloping grain. Samples are approximately 1000 mm long, therefore a 0.01 per cent change in length is equivalent to 0.1 mm.

Other examples of overall changes in length are given in Tables 2 and 3. For example, sloping grained maritime pine stored in the 8 per cent EMC chamber actually showed a mean increase in length of 0.01 per cent and a mean moisture content decrease of 2 per cent over the 40 days exposure (Table 2). The radiata pine in this chamber decreased in length by 0.01 per cent. In the 18 per cent EMC chamber, maritime pine had a mean increase of 0.06 per cent while the mean moisture content increased 5.7 per cent, and radiata pine had a 0.08 per cent increase for a 7.5 per cent moisture content increase over the 40 days exposure.

Straight grained timber stored in the 8 per cent chamber showed a mean decrease in length of 0.01 per cent with radiata pine, but a similar increase for maritime pine over the 40 days, a fact that is difficult to explain. The respective mean moisture content decreases were 1.6 per cent for the radiata pine and 1.7 per cent for maritime pine over the 40 days exposure (Table 3). This represents a mean decrease in board length of 0.06 mm for each 1 per cent change in moisture content. Timber in the 18 per cent chamber showed increases in length of 0.06 per cent for maritime pine and 0.09 per cent for radiata pine, and moisture contents had mean increases of 6.5 per cent and 5.5 per cent respectively. This represents mean increases of 0.09 mm per 1 per cent change in moisture content for maritime pine or 0.16 mm per 1 per cent change in moisture content for radiata pine.

Figure 3 shows that the mean width of the samples in the 18 per cent EMC chamber increased from 90 mm to between 90.5 mm and 91.25 mm, a mean increase of 0.5 mm to 1.25 mm or 0.5 to 1.4 per cent. Samples in the 8 per cent EMC chamber also had a mean width of 90 mm and after 40 days exposure they had a mean shrinkage of between 0.25 mm and 1 mm, or 0.28 and 1.1 per cent.

Within species, the grain orientation showed little effect on swelling or shrinkage and differences between maritime pine and radiata pine were insignificant. This result could possibly be explained by the considerable variation in grain in each piece of timber, e.g. sloping grain is also found around knots, and the samples in this trial were selected based on sloping grain in the clear wood sections between the knots.

Figure 4 gives the change in thickness of the samples stored in both EMC chambers. The samples stored in the 18 per cent chamber had a mean thickness of 35.2 mm and increased in size after 40 days exposure by 0.2 mm to 0.4 mm, or 0.6 to 1.2 per cent. Samples in the 8 per cent chamber had an original mean thickness of 35.2 mm, except for the maritime pine with sloping grain, which had a mean thickness of 35.0 mm. The results indicated shrinkages of less than 0.2 mm, or 0.6 per cent. Species and grain orientation had no effect on the change in thickness.

Samples that contained pith ('heart-in') did not have excessive changes in dimension and were similar to the samples without pith.

There are various anatomical characteristics which may affect longitudinal shrinkage. Compression wood has a different cell structure from that of normal wood because of the much greater angle of fibrils to the cell axis and discontinuities between the microfibrils of the S2 layer, giving it a greater longitudinal shrinkage (Kininmonth and Whitehouse 1991). Longitudinal shrinkage is commonly 1 to 2 per cent and may be as great as 6 to 7 per cent (Haygreen and Bowyer 1982). Juvenile wood (which occurs in the first 10 to 12 growth rings) has a greater tendency for spiral grain, which can also give a higher degree of longitudinal shrinkage than normal wood. Haygreen and Bowyer (1982) quote longitudinal shrinkage figures from green to 12 per cent moisture content for loblolly pine (*P. taeda* L.) as 0.57 per cent for juvenile wood and less than 0.1 per cent for mature wood. The longitudinal shrinkages measured in this trial were between 0.01 per cent and 0.02 per cent, while the highest amount of swelling was 0.09 per cent for straight grained radiata pine stored in the 18 per cent EMC chamber.

Mean shrinkage values may be used to predict average dimensional changes in batches of material, but there is considerable variability within and between trees and also between plantation sites. Variation in the shrinkage of different samples of the same species exposed to the same treatments and conditions results primarily from three factors :

(1) *size and shape* - this affects the grain orientation in the timber and the uniformity of moisture through the thickness;
(2) *wood density* - the higher the density of the specimen, the more it will tend to shrink;
(3) *rate of drying* - under rapid drying conditions, internal stresses are set up because of differential shrinkage: this often results in less final shrinkage than would otherwise occur. By contrast, some species shrink more than normal when dried rapidly under high-temperature conditions (Haygreen and Bowyer 1982).