Dimensional Stability of Specialty Species

Authors: Rosie Sargent, Gavin Durbin

Date: December 2019

Publication No: SWP-T090

TABLE OF CONTENTS

Dimensional Stability of Specialty Species 1
EXECUTIVE SUMMARY 1
INTRODUCTION 2
METHODS 3
Short Term Dimensional Stability (Swellometer) 3
Long Term Dimensional Stability (Humidity Cycling) 5
RESULTS 6
Short term dimensional stability 6
Long Term Dimensional Stability 8
CONCLUSION 10
ACKNOWLEDGEMENTS 11
REFERENCES 11
APPENDICES 12
Appendix: 1 Source of test material 12
Appendix 2: Data for each species 13

Disclaimer

This report has been prepared by Scion for Forest Growers Research Ltd (FGR) subject to the terms and conditions of a research services agreement dated 1 January 2016.

The opinions and information provided in this report have been provided in good faith and on the basis that every endeavour has been made to be accurate and not misleading and to exercise reasonable care, skill and judgement in providing such opinions and information.

Under the terms of the Services Agreement, Scion's liability to FGR in relation to the services provided to produce this report is limited to the value of those services. Neither Scion nor any of its employees, contractors, agents or other persons acting on its behalf or under its control accept any responsibility to any person or organisation in respect of any information or opinion provided in this report in excess of that amount.

supported by forestgrowers commodity levy

FOREST GROWERS RESEARCH

EXECUTIVE SUMMARY

Changes in the moisture content of wood changes its dimensions. The magnitude of these changes (dimensional stability) can have a large impact on how the wood performs in service. Poor dimensional stability can lead to cracking, poor paint adhesion and problems with clearances in moving parts like doors and windows. To better understand how wood will behave in service, the dimensional stability of 16 different wood types were compared (8 species, plus variations such as modified wood, or different tree ages).

Two tests were used, one using short term contact with liquid water, and one exposing the wood to different air humidities.

For the short-term water soaking (swellometer) test, there was a wide range of different behaviours between the different wood types. The hardwood samples tended to swell the most, but did so quite slowly. The softwood samples swelled less, but did so quite quickly, so after 30 minutes soaking, they had similar, or higher, levels of swelling than the hardwoods. Radiata pine had the third-to-highest level of swelling, behind *E. globoidea* and *E. fastigata*. It also had the highest level of swelling after 30 minutes. Thermal modification reduced both the degree of swelling and the rate of swelling for all the species included in this testing (*C. lusitanica, E. nitens*, radiata pine).

For the long-term humidity cycling test, all the wood species had similar equilibrium moisture contents at each of the humidity levels. The thermally modified *E. nitens* and *C. lusitanica* had significantly reduced moisture contents compared to the unmodified wood from the same species Their moisture contents were also similar to some of the commercially available modified wood products (Kebony, thermally modified radiata pine). Dimensional changes were lower in softwood species (including radiata pine) compared to hardwood species. *E. fastigata* and *E. globoidea* had particularly large dimensional changes (around 0.06 % change in dimension for every 1% change in relative humidity) so were less dimensionally stable than radiata pine. The thermally modified wood had similar dimensional changes to the commercial modified products.

Understanding differences in dimensional stability between different species makes it easier to understand how each species would behave in service and makes it easier to specify timbers that will work well in a particular application. It is promising to see the thermally modified specialty species are performing similarly to commercially available modified wood products.

INTRODUCTION

Dimensional stability is defined as the amount that wood dimensions change as the wood moisture content changes, either in response to contact with liquid water, or through changes in relative humidity in the surrounding air. Dimensional stability is an important property for predicting how the wood will behave in service - problems caused by large dimensional changes include coatings cracking prematurely, and cracking and deformation around joins.

There are no consistently-used methods for assessing dimensional stability, leading to a variety of ways of expressing dimensional stability, many of which cannot be compared between different data sources. Some common methods of describing dimensional stability (e.g. shrinkage from green to 12% MC) do not necessarily describe the way wood will behave in service (wood is unlikely to be used in the green condition, and shrinkage from green to 12% is generally not linear). Additionally this method cannot be used for modified, or engineered wood, or for comparing behaviour with non-wood products. Because of these limitations Scion has investigated better ways of quantifying dimensional stability.

Dimensional Stability can be evaluated over either short, or long timeframes. In service wood will undergo changes in moisture content that last for varying times, some will only be short (a few hours) and sometimes the conditions will continue until the wood is in equilibrium with its surroundings. Wood can behave differently over these short and long timeframes, so in this work two tests are used, one measuring dimensional stability of short time periods, and one at equilibrium conditions. Additionally, one test looks at contact with liquid water, and one with changes in the humidity in the air. For both tests, the dimensional stability metrics used can be directly linked to the behaviour of the wood, as a percentage change in the wood dimensions under certain conditions (30 minutes water soaking, or after a 1% change in relative humidity).

Using the tests outlined above, the dimensional stability of 7 specialty wood species have been compared to benchmarks such as radiata pine and commercially available modified wood products. For some of the specialty species, additional variations have been included, such as different tree ages, or thermal modification treatments.

METHODS

The following species were used in this study:

- *E. fastigata*
- *E. regnans*
- *E. globoidea*
- *E. nitens* (from SouthWood Exports)
- *C. ovensii*
- Douglas-fir (thinnings or top logs)
- Douglas-fir (commercial framing timber)

Additional species and commercial wood products have been measured in Scion SSIF funded studies and have been included in this report:

- Radiata pine
- Thermally modified radiata pine
- *C. lusitanica*
- Thermally modified *C. lusitanica*
- *E. nitens* (from John Fairweather)
- Thermally modified *E. nitens*
- Accoya (acetylated radiata pine)
- Kebony (furfurylated radiata pine)
- Thermally modified ash

Details of the source of the different species can be found in the Appendix.

Short Term Dimensional Stability (Swellometer)

The swellometer test is based on the test method specified by the US Window and Door Manufacturers Association (WDMA, 2009). Two 38 × 100 × 6 mm (Radial x Tangential x Longitudinal) samples were cut from each board and equilibrated at 25°C, 65% RH for 5 weeks. The standard specifies samples 127 mm or 254 mm in the tangential direction, but wood from such wide boards is hard to obtain consistently, so shorter dimensions have been used here.

Samples were loaded into a swellometer jig (Figure 1), which consists of a rigid back which supports a digital dial gauge, and a channel that the wood slides into. The wood was fixed against the end of the dial gauge by a pair of brass stops that slide into the channel and can be fixed in place via a screw. One side of the channel can be adjusted sideways to accommodate different widths of samples. The channel restrained the sample sufficiently, so it remained in the correct orientation during the test but left enough space for the sample to swell during testing and not become jammed in the channel.

In the WDMA method the initial tangential dimension is recorded, then jig is immersed in distilled water at 24 ± 3°C and after 30 mins the test is stopped, and the tangential dimension is recorded again. We have found that 30 mins is not enough time for significant swelling to occur in some wood types, so in this study the tangential dimension was measured continuously during immersion (every 5ms) and the test was continued for three days, by which time all the samples had stopped swelling.

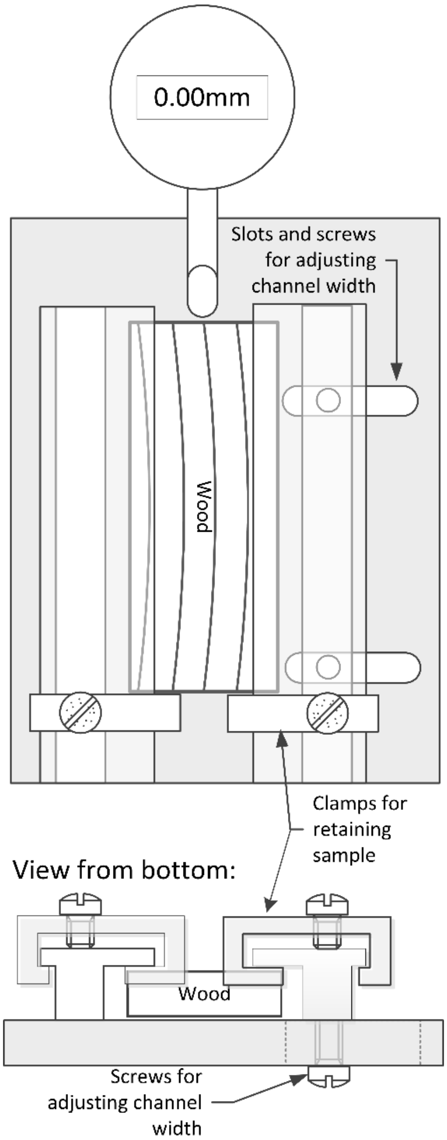

Figure 1. Front and bottom views of Swellometer jig.

The standard WDMA calculations are used to determine the effectiveness of wood treatments, so the calculations specified describe the level of swelling in terms of the percentage improvement over the swelling of untreated wood. This is obviously not suitable for comparing behaviour of different wood species. We have chosen two more suitable metrics for the data analysis: Maximum swelling, and the swelling that has occurred after 30 minutes of soaking. These are intended to quantify the overall levels of swelling of the samples, and the rate at which they swell.

Maximum swelling is defined as the percentage difference between the initial sample dimension and the final sample dimension (i.e. the maximum dimension it achieves after 3 days soaking).

$$SW_{max} = \frac{(T_{final} - T_0)}{T_0} \times 100 \quad (1)$$

Where: SW_{max} is the maximum swelling (% of initial tangential dimension)
T_{final} is the final tangential dimension (mm)
T_0 is the initial tangential dimension (mm)

Swelling after 30 minutes is the same, but uses the dimension after 30 minutes of soaking.

$$SW_{30} = \frac{T_{30} - T_0}{T_0} \times 100 \quad (2)$$

Where: SW_{30} is the Percentage swelling after 30 mins
T_{30} is the tangential dimensions after 30 minutes
and the remaining parameters are defined in Equation 1.

Long Term Dimensional Stability (Humidity Cycling)
This test is based on the European standard (DIN 52 184, 1979). Two blocks 35x35x10mm (RxTxL) were cut from five boards of each wood type being assessed.

The blocks were placed in a controlled environment at 25°C 60-70% RH, until constant mass was attained (defined as less than 0.1% change in mass over 24 hours).

The dimensions of the blocks were then measured in the radial and tangential directions according to Figure 2. Dimensions were measured using a digital dial gauge (accurate to 0.001mm) which is firmly mounted to the bench to prevent movement during measurement. The block to be measured sits flat against the base of the measurement jig and is held firmly against two measurement pins opposite the dial gauge. The block can then be moved sideways until the dial gauge is aligned with a line marked in felt-tipped pen 10mm from one corner of the block. This method enables accurate and repeatable measurement of the same locations on each block for every measurement.

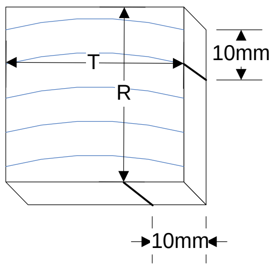

Figure 2. Location of dimension measurements in humidity cycling tests.

After measuring the initial dimensions, the samples were placed in each of the controlled environments listed in Table 1 until their weight has stabilised, and dimensions were measured again according to the method above, then moved to the next condition in the table. This constitutes one full humidity cycle. Two further humidity cycles were completed, and then the blocks were oven dried at 103°C to constant weight, and the weight and dimensions recorded again.

Table 1. Conditions used for long-term humidity cycling

Step	Temperature	Humidity
1	25°C	Medium (60-70% RH)
2	25°C	High (90-95% RH)
3	25°C	Medium (60-70% RH)
4	25°C	Low (30-40% RH)

From this data, the following calculations can be made for each humidity step.

Radial dimensional change

$$\Delta R = \frac{R_{MC}-R_{OD}}{R_{OD}} \times 100 \qquad (3)$$

Tangential dimensional change

$$\Delta T = \frac{T_{MC}-T_{OD}}{T_{OD}} \times 100 \qquad (4)$$

Equilibrium moisture content (EMC)

$$EMC = \frac{m_{MC} - m_{OD}}{m_{OD}} \times 100 \qquad (5)$$

Where:

R_{MC}	radial dimension at the specified humidity	(mm)
R_{OD}	radial dimension when oven dry	(mm)
ΔR	percentage change in radial dimension from oven dry	(%)
T_{MC}	tangential dimension at the specified humidity	(mm)
T_{OD}	tangential dimension when oven dry	(mm)
ΔT	percentage change in tangential dimension from oven dry	(%)
m_{MC}	mass at specified humidity	(g)
m_{OD}	Mass when oven dry	(g)
EMC	Equilibrium moisture content	(%)

RESULTS

Short term dimensional stability

Results for the swellometer testing are shown in Figure 3. There are a wide range of results, *E. fastigata* and *E. globoidea* swelled the most (an average of 6-8% swelling after 3 days, much greater than radiata pine at ~5%). *E. regnans* and *E. nitens* swelled less than radiata pine, and were similar to the cypresses and Douglas-fir (average of 2-4% tangential swelling after 3 days).

For both the Douglas-fir and the *E. nitens*, two sources of wood were used, allowing comparisons between different tree ages. The Douglas-fir thinnings swelled less than the commercial Douglas-fir framing, but the pruned *E. nitens* from John Fairweather (JF) swelled less than the younger pulp regime trees from SouthWood Exports (SWE).

The difference between the swelling after 30 minutes, and the swelling after 3 days gives an idea of how quickly the wood starts to swell when it first comes into contact with liquid water. Radiata pine swells very quickly, nearly achieving full swelling after 30 minutes. All the other wood species swell much less in the first 30 minutes, at most only swelling half as much as the radiata pine over that period. This slower rate of swelling is likely to have an impact on the in-service behaviour of the wood, because wood can be in contact with water for varying periods of time, ranging from less than an hour, to a number of days. A wood species that swells rapidly will spend more of this time in a very swollen state, potentially leading to surface checking, reduced paint adhesion etc. A wood species that swells more slowly (e.g. *E. globoidea*) may only reach a very swollen state occasionally, so may not have as many swelling-related issues as the radiata pine.

For radiata pine, *C. lusitanica* and *E. nitens,* thermally modified boards were also tested. For all species, the thermal modification reduced the overall levels of swelling, but also slowed the rate of swelling, so the samples that had swelled the least after 30 minutes tended to be those that had been thermally modified, even if their total amount of swelling was little different to the unmodified samples of the same species.

The commercial Accoya boards swelled very little, but also swelled quite quickly, with almost all the swelling occurring in the first 30 minutes. Accoya is known to be highly dimensionally stable, so the low overall swelling is not surprising, but it is interesting that it also swells so quickly.

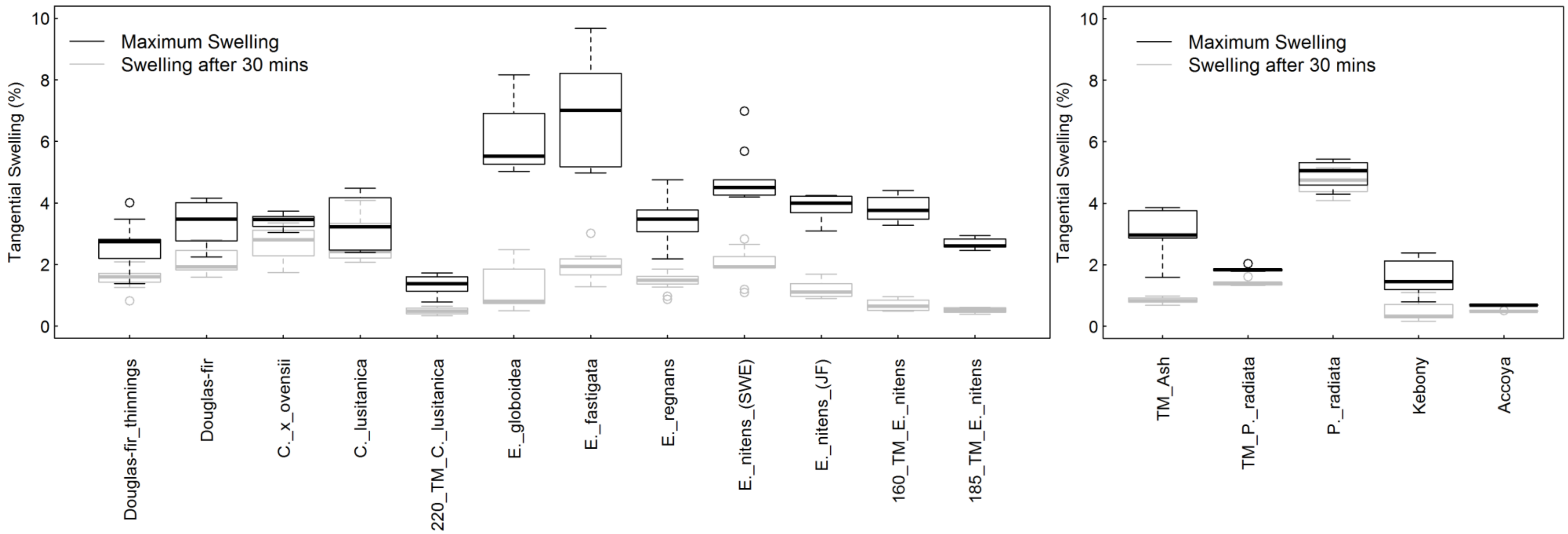

Figure 3. Swelling after 30 minutes (grey boxes) and 3 days (black boxes) of water soaking. The left hand panel shows SWP species (including thermal modifications), the right hand panel shows commercial benchmarks.

Long Term Dimensional Stability

Figure 4a. shows the moisture content of the samples at each humidity condition. Reduced moisture content generally corresponds to increased dimensional stability and can give samples some protection from fungal attack in certain situations, as the moisture content may remain below the threshold level required for decay. The moisture contents for each species are similar, with some species showing more variation in MC (*C. lusitanica*, older *E. nitens*), and some showing a bit less variation (Douglas-fir). The three thermal modification treatments show substantial reductions in EMC compared to unmodified wood from the same species. At 90% RH, most of the species had a similar EMC to radiata pine, but at lower humidity levels the radiata pine had a higher EMC. The thermally modified *C. lusitanica*, and the *E. nitens* thermally modified at 185°C had similar EMC values to many of the commercially available modified wood products (thermally modified radiata pine, thermally modified Ash, Kebony).

Figure 4b shows shrinkage (radial and tangential) for every 1% change in the relative humidity surrounding the sample. Generally, shrinkage is greater in the tangential dimension, but some species (such as *E. regnans*) have similar levels of shrinkage in the radial and tangential directions. Not surprisingly the modified wood samples (both commercial products, and those thermally modified at Scion) show small changes in dimension with changing relative humidity, but the unmodified wood shows much larger changes. The softwood species tend to have lower dimensional changes (i.e. higher dimensional stability) compared to the eucalypt species. Even within the eucalypt species there are variations – *E. nitens* and *E. regnans* are significantly more stable than *E. fastigata* and *E. globoidea*.

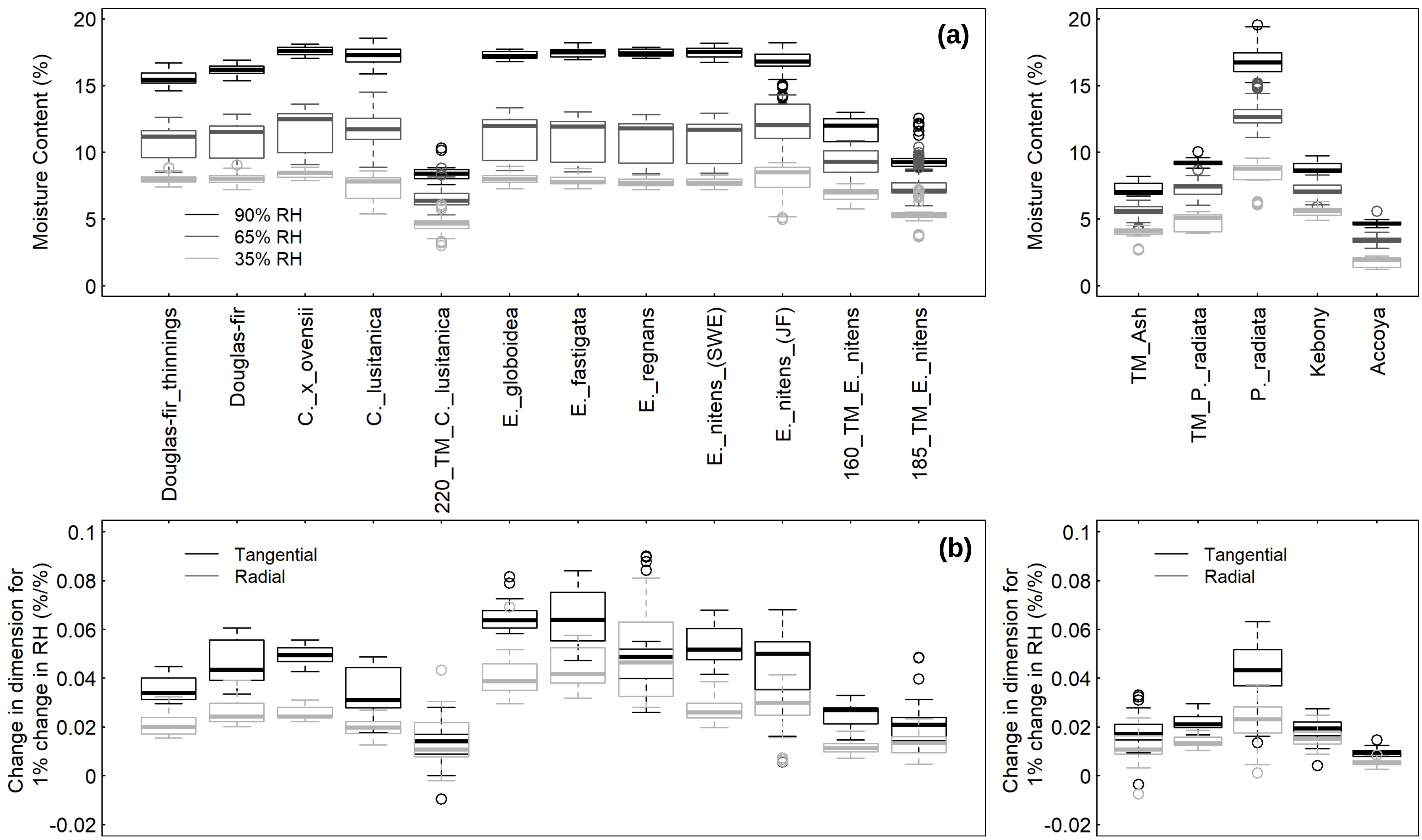

Figure 4: Equilibrium moisture content (a) at three different humidity levels and (b) change in radial and tangential dimensions with change in relative humidity

CONCLUSION

The dimensional stability of a wide range of SWP species, as well as commercially available benchmarks, was measured under both short-term water soaking, and long-term humidity cycling.

For the water soaking tests, there were a wide range of behaviours between the different wood species. Radiata pine swells a lot (~5% swelling) and does so very quickly, so a large proportion of the time the timber spent wet would be at, or close to, maximum swelling. Conversely some of the eucalypts (e.g. *E. globoidea*) swell more than radiata pine, but do so quite slowly, so for these species, a smaller proportion of the time they spent wet would be at maximum swelling, possibly leading to less in-service swelling than radiata pine. The cypresses, Douglas-fir, and two eucalypts (*E. nitens* and *E. regnans*) swelled less than the radiata pine. The softwoods tended to swell relatively quickly, and the hardwoods much more slowly. For the three species investigated (radiata pine, *C. lusitanica, E. nitens*) thermal modification tended to reduce both the total amount of swelling, and the rate of swelling.

For the humidity cycling tests the softwoods (cypress, Douglas-fir, radiata pine) tended to have a slightly higher dimensional stability compared to the eucalypt species, however there were no large differences in moisture content between the hardwoods and softwoods. Thermal modification increased the dimensional stability *in C. lusitanica* and E. nitens to similar levels to some of the commercial modified wood products. Two of the eucalypts (*E. globoidea* and *E. fastigata*) had lower dimensional stability than radiata pine, the other species were similar to radiata pine, or more dimensionally stable.

Having comparative data between a range of species like this (including commercial modified wood) is an important resource for understanding how different wood species are likely to behave in service. For some applications (e.g. exterior painted surfaces) frequent rapid swelling may cause paint to crack and flake prematurely. In applications where clearances are important (e.g. windows and doors) species that swell a lot may not be suitable, even if they swell very slowly, so will only reach maximum dimensions.

SWP-T090 Dimensional Stability of Specialty Species_G11

ACKNOWLEDGEMENTS

Many of the samples for this work were kindly supplied by Dean Satchell, Paul Millen and Mark Dean.

Maxine Smith (Scion) performed all the testing. The swellometer jig was designed by Gavin Durbin (Scion) and built by Jurgen Fiedler.

REFERENCES

DIN 52 184. (1979). Testing of wood; determination of swelling and shrinkage.

WDMA. (2009). T.M. 2- 1999 Test Method to Determine the Short Term Anti-swell Effectiveness of Treating Systems. Chicago, IL: The Window & Door Manufacturers Association.

SWP-T090 Dimensional Stability of Specialty Species_G11

APPENDICES

Appendix: 1 Source of test material

Species	Source	Grown (if known)	Age (if known)	# trees/boards	Thickness	Width
Old D. fir	Scion	Otago/Southland, ex Blue Mountains lumber		6	40	200
Thinnings D. fir	Mark Dean	Conical Hill forest, Otago		6	50	100
Southwood E. nitens	Scion	SouthWood Exports, Southland	18	5	25	100
JF nitens	Scion	Farms in North Canterbury	25-30	8	25	100
E. regnans	Dean Satchell		19	6	25	100
E. regnans	Paul Millen			2	50	100
C. x ovensii	Dean Satchell			4	30	100
E. globoidea	Scion	Rotoehu forest	25	5	50	100
E. fastigata	Scion	Rotoehu forest	25	4	50	100
E. fastigata	Paul Millen			2	50	100
C. lusitanica	MacDirect			3	50	100
Radiata pine	McAlpines			4	50	100
Accoya	Timspec			2	50	150
Kebony	Fridells Timber Sweden			4	25	150
Kebony	Mafi, Australia			4	25	100
TM radiata pine	Tunnicliffes			2	50	150
TM Ash	Timspec			2	50	150
160°C TM *E. nitens*	Scion, ex. John Fairweather	Farms in North Canterbury	25-30	4	25	100
185°C TM *E. nitens*	Scion, ex. John Fairweather	Farms in North Canterbury	25-30	4	25	100
220°C TM *C. lusitanica*	Scion, ex. MacDirect			2	50	100

Appendix 2: Data for each species

MC	EMC (%) 35 % RH	65% RH	90% RH	% change with 1% change in RH Moisture content	Radial change	Tangential change	% Swelling after 3 days water soaking	% Swelling after 30 minutes water soaking
Douglas-fir_thinnings	8.0	10.8	15.5	0.126	0.018	0.031	2.7	1.6
Douglas-fir	8.0	11.0	16.2	0.135	0.023	0.040	3.4	2.1
C._x_ovensii	8.4	11.9	17.6	0.154	0.022	0.043	3.4	2.7
C._lusitanica	7.4	11.7	17.2	0.170	0.024	0.044	3.3	2.8
220_TM_*C._lusitanica*	4.5	6.6	8.5	0.071	0.013	0.014	1.3	0.5
E._globoidea	8.0	11.4	17.3	0.155	0.038	0.060	6.1	1.2
E._fastigata	7.9	11.3	17.5	0.159	0.038	0.058	6.9	1.9
E._regnans	7.7	11.2	17.5	0.161	0.044	0.045	3.5	1.5
*E._nitens*_(SWE)	7.7	11.1	17.5	0.160	0.023	0.047	4.8	2.0
*E._nitens*_(JF)	8.0	12.0	16.6	0.154	0.034	0.053	3.9	1.2
160_TM_*E._nitens*	6.9	9.2	11.7	0.087	0.012	0.025	3.8	0.7
185_TM_*E._nitens*	5.3	7.5	9.8	0.080	0.016	0.026	2.7	0.5
TM_Ash	4.2	5.5	6.9	0.080	0.014	0.022	1.9	1.4
TM_*P._radiata*	4.8	7.3	9.2	0.059	0.012	0.019	3.3	0.8
P._radiata	8.2	12.7	16.8	0.064	0.016	0.021	1.5	0.4
Kebony	5.6	7.2	8.8	0.180	0.028	0.050	5.0	4.7
Accoya	1.8	3.4	4.7	0.052	0.005	0.009	0.7	0.5