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Dimensional Stability of Specialty Species

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FOREST GROWERS RESEARCH

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FOREST GROWERS RESEARCH

EXECUTIVE SUMMARY

Dimensional changes caused by changes in wood moisture content (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 this 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. The test using humid air is not complete, and only interim results are given here.

For the short term water soaking (swellometer) test, there was a wide range of different behaviours. 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).

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.

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.

Dimensional Stability can be evaluated over either short, or long time frames. In service wood will undergo changes in moisture content that last for varying lengths of time, some will only be short (a number of 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 of these 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).

This report covers the dimensional stability of wood following short term (3 day) exposure to liquid water. Testing of dimensional stability following long term exposure to humid air is ongoing, and interim results are presented here.

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 did 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 length of the tangential dimension is recorded again. We have found that 30 mins is not enough 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.

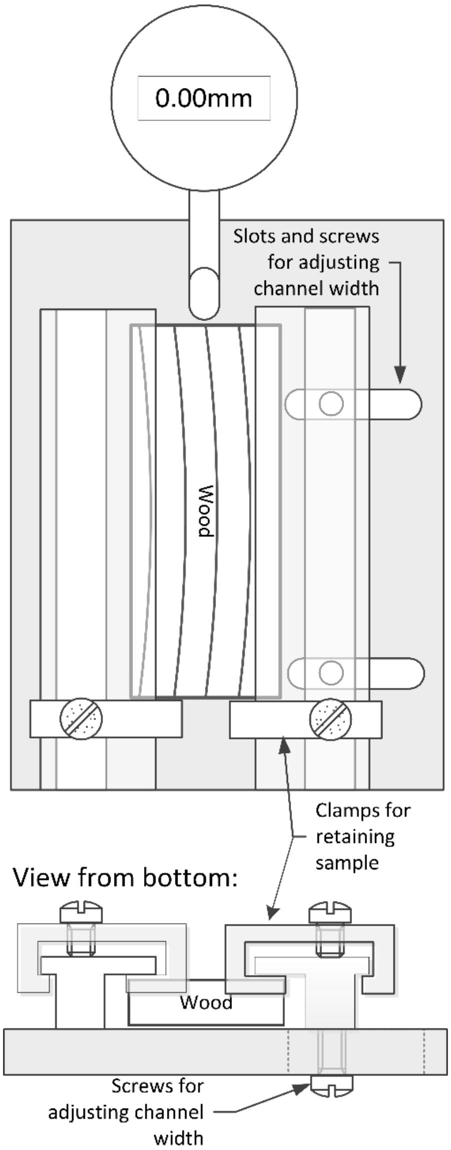

Figure 1. Front and bottom views of Swellometer jig.

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 compare 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).

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

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.

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

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) are cut from five boards of each species being assessed.

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

The dimensions of the blocks are then measured in the radial and tangential directions according to Figure 2. Dimensions are measured using a digital dial gauge (accurate to 0.001mm) which is firmly mounted to the bench to prevent movement during measurement. The block 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.

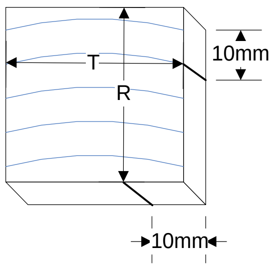

Figure 2. Location of dimension measurements in humidity cycling tests.

After the initial dimension measurement, the samples are 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 are completed, and then the blocks are oven dried at 105°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

$$\Delta R = \frac{R_{MC} - R_{OD}}{R_{OD}} \times 100 \tag{3}$$

Tangential dimensional change

$$\Delta T = \frac{T_{MC} - T_{OD}}{T_{OD}} \times 100 \tag{4}$$

Equilibrium moisture content (EMC)

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

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	(%)

The long term stability test generally takes around 12 months to complete, depending on how quickly the samples equilibrate at each condition. As of May 2019 testing is roughly 50% complete, so interim results are presented here.

As the samples have not yet been oven dried, the interim results compare the radial and tangential dimensions to their dimensions at the beginning of the test.

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 raidata 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. 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.

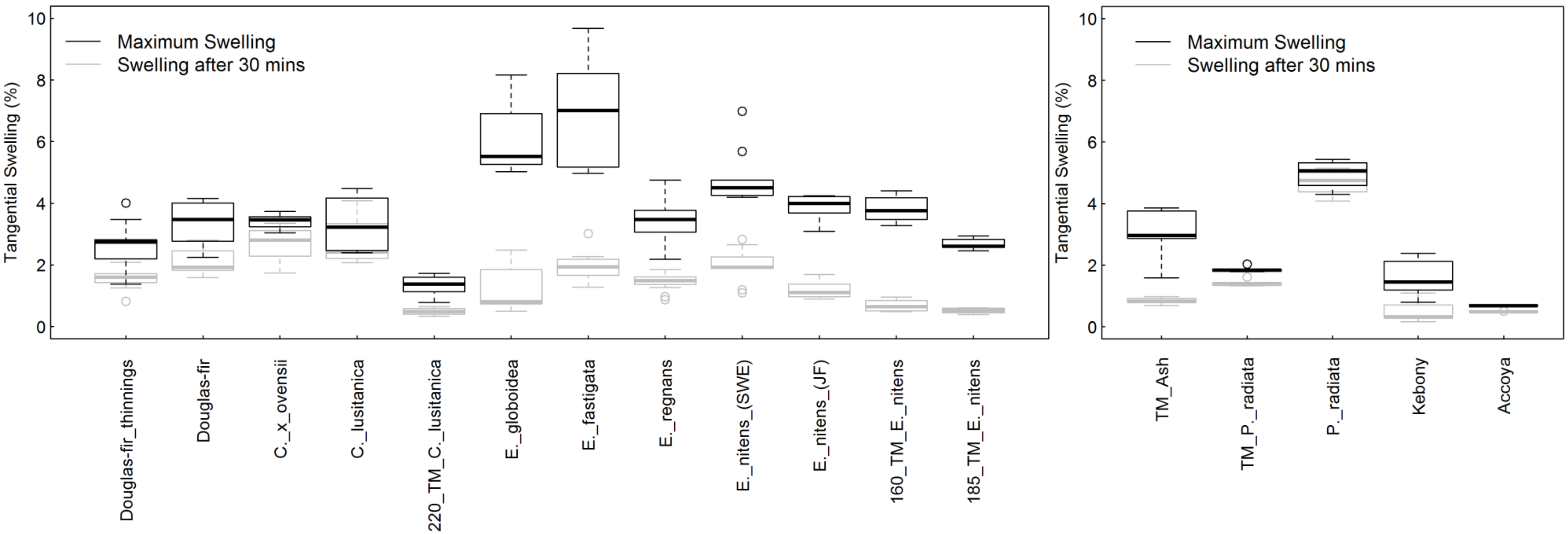

Figure 3. Swelling after 30 minutes (grey boxes) and 3 days (black boxes) of water soaking. The left hand panel shows SWP species (including thermal modifications), the right hand panel shows commercial benchmarks.

For the long term humidity cycling, 6 of the 13 humidity conditions are complete. Interim results are shown in Table 2. These have been sorted from smallest to largest tangential dimensional change (expressed as percentage change in the tangential direction for a 1% change in relative humidity). Generally these mirror the short term water soaking results. Not surprisingly Accoya has the lowest dimensional change, followed by the different species of thermally modified wood and the Kebony (commercial furfurylated wood). Similarly, *E. fastigata* and *E. globoidea* had the highest dimensional change. The Douglas-fir thinnings has a slightly lower dimensional change than the commercial Douglas-fir boards, and the *E. nitens* from SouthWood Exports has a slightly lower dimensional change to the *E. nitens* from John Fairweather.

Table 2.

Species	**Radial change (%/%RH)**	**Tangential change (%/%RH)**
Accoya	0.005	0.009
220°C TM *C. lusitanica*	0.013	0.014
210°C TM *E. nitens*	0.010	0.016
Kebony	0.012	0.017
TM Ash	0.013	0.019
TM Radiata pine	0.015	0.023
160°C TM *E. nitens*	0.012	0.025
185°C TM *E. nitens*	0.016	0.026
Douglas-fir thinnings	0.018	0.030
Douglas-fir	0.024	0.039
Radiata pine	0.021	0.040
C. x ovensii	0.022	0.044
C. lusitanica	0.024	0.045
E. nitens (SWE)	0.023	0.046
E. nitens (JF)	0.032	0.046
E. regnans	0.034	0.053
E. fastigata	0.037	0.056
E. globoidea	0.039	0.060

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. The humidity cycling tests are roughly 50% complete, and interim figures have been presented here.

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.

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.

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

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