Client Report :

Comparison of home grown and imported softwood for Timber Frame market – Final Report

Client report number 215 - 340

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30th March 2004

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Executive Summary

This is the final report for the following project, full title: "Home grown softwoods for UK timber frame construction”. The project work involves a critical, independent evaluation of home grown softwood for the UK timber frame construction sector. This involves selection and assessment by comparison of sample batches of home grown and imported material, together with panel production trials and conditioning tests on panel assemblies

Main Findings:

Low levels of distortion were found present in both imported and home grown timber as supplied, although the home grown timber showed a greater tendency to distort in bow and spring when allowed to dry unrestrained. This was due to the level of compression wood within the sample batch. Levels of twist observed were 20% higher on average in the UK timber following unrestrained conditioning compared with imported timber.

The home grown timber showed better performance in compression tests due to the greater frequency of knots. The greater frequency and size of the knots in the home grown timber is more likely to cause a problem with nail fouling. However during production trails at Stewart Milne Timber Systems no instances of nail fouling were observed, although the number of panels made was limited. In another BRE Project (DTi sponsored Pii on “Providing High Quality Timber for the UK Construction Sector”) a scanner based solution for knot fouling problems has been developed.

It was observed that the nails fixing the sheathing OSB had been over-driven on the panels manufactured in the trials and that for this reason racking resistance values were below the normal level expected. This is an important consideration for timber frame manufacturers. The level of pressure for nailing can be reduced.

During conditioning tests on panels fabricated by BRE from supplied moisture content to levels below that anticipated in service, no significant distortion was observed. This tends to confirm that timber frame construction provides a high level of restraint for timber undergoing a change in moisture content.

Stewart Milne Timber Systems Ltd were not willing to fabricate panels made from UK timber for inclusion into any full scale structure. The company currently obtain imported timber at a discount and for sizes other than 89mm x 38mm CLS, such as 140mm stud sizes and also joists.

On the basis of the above work, it can be concluded that UK grown timber is well-suited to timber frame panel manufacture, although economic factors and company policy may count against its uptake. Close regard should be given to improving quality control in the UK sawmilling sector. This could be achieved through the application of timber scanning technology.

Next output: BRE Information Paper based on this work, with draft for comment May 04

Contents

1. Introduction

General:

This report details the final report on the following project, full title: "Home grown softwoods for UK timber frame construction”

Project Details: PPD 26/02 (BRE project no. CV0256)

The BRE Project Manager is Mr Tim Reynolds, Senior Consultant (01923 664832, reynoldst@bre.co.uk)

Other key contributors: Mr Matthew Cornwell, Mr Gerald Moore and Mr Keye Liu.

Background and objectives:

The project work involves a critical, independent evaluation of home grown softwood for the UK timber frame construction sector. This involves selection and assessment by comparison of sample batches of home grown and imported material. The project involves a partnership approach by BRE, James Jones and Sons Ltd and Stewart Milne Timber Systems. The home grown material was supplied by James Jones and Sons Ltd, whilst the imported material was taken from Stewart Milne’s existing stock.

In Jan 2003 BRE requested 2 batches of 89x38mm CLS from UK and Swedish sources. Since its arrival this material has undergone a programme of testing and conditioning. Assessment of a random selection of 100 battens from each set is now fully complete.

1. Measurement of distortion (bow, spring, twist) at:

- Supplied moisture content (approx 20-22%).
- After 3 weeks at 25 deg C and RH 65%, unrestrained.
- After conditioning to low moisture content (approx 14%) unrestrained.

The distortion measurements made after unrestrained material has been conditioned or part conditioned are designed to determine the *propensity* to distort. It is recognised that timber studding in a timber frame house will be well restrained in service.

2. Assessment of level of compression wood

3. Measurement of knot size and frequency on one random face

4. Compression perpendicular to grain tests to BS EN 1193

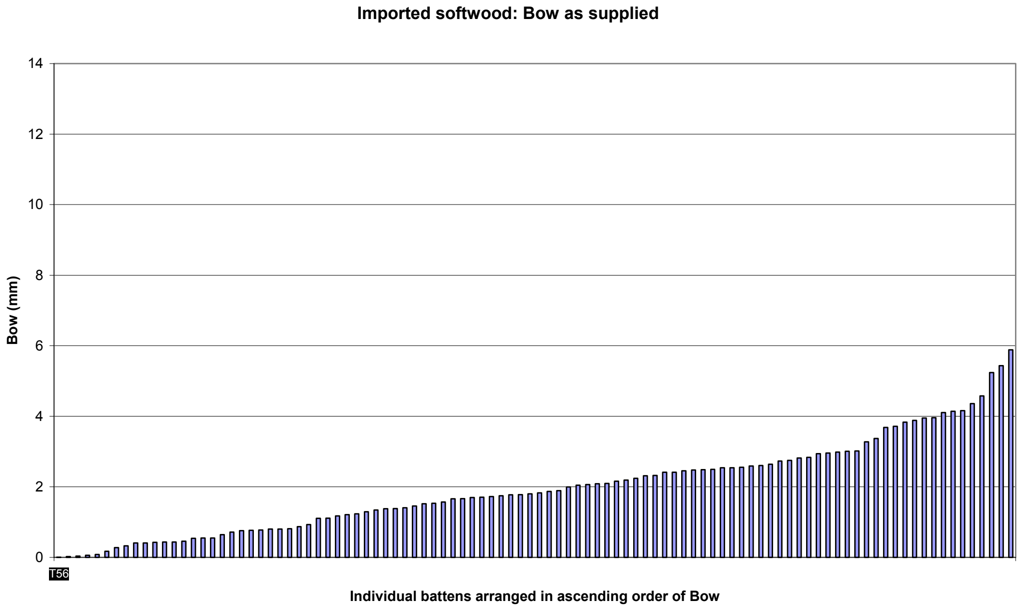
5. Production trials with UK grown timber at Stewart Milne Timber Systems Ltd.

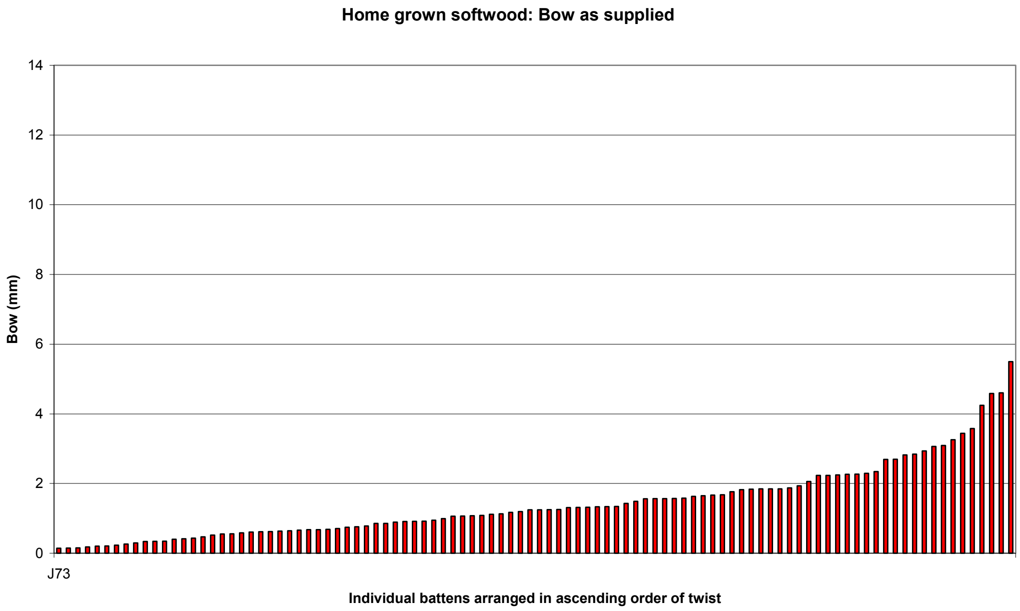
6. Racking resistance tests on panels manufactured with UK timber

7. Monitoring of distortion on partially restrained panels undergoing conditioning

2. Distortion Test Results

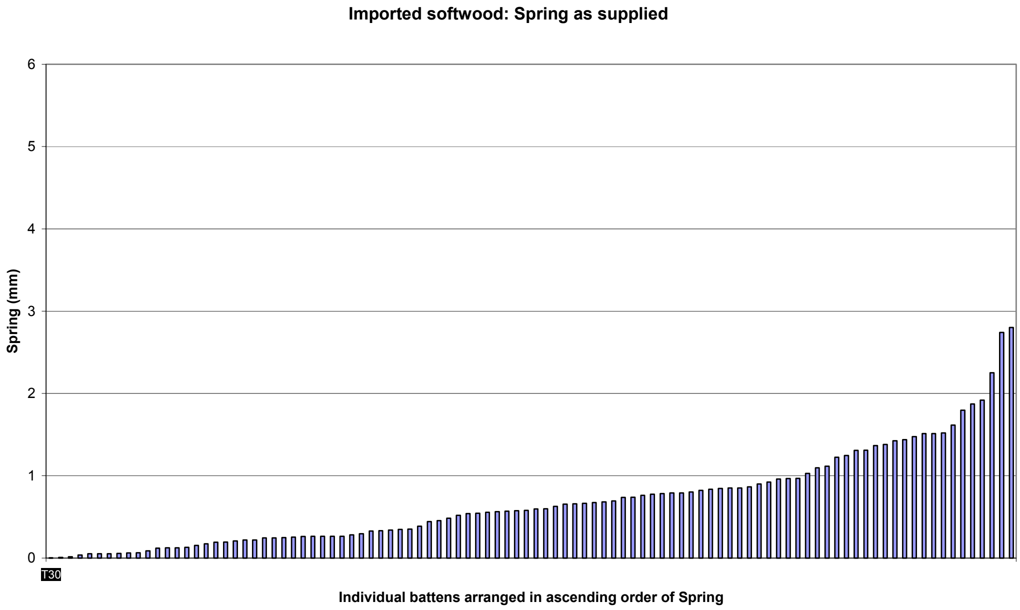
2.1 Distortion as supplied - Bow. Figures 1 and 2 (below) show the measured bow graphs of the Imported (coloured blue) and Home grown material (coloured red)

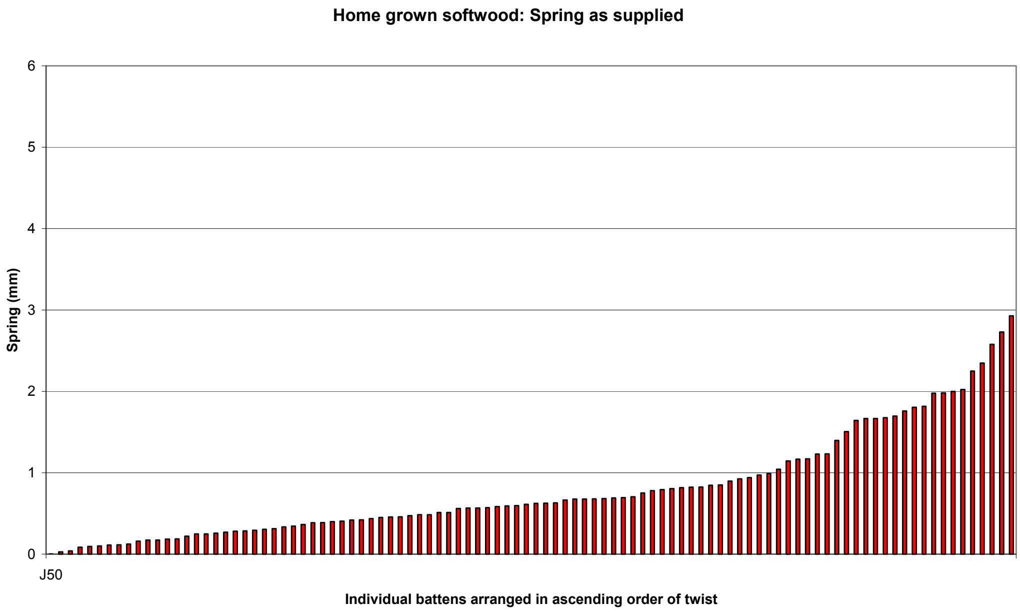




Figures 1 and 2 Comparison of Bow at supplied moisture content

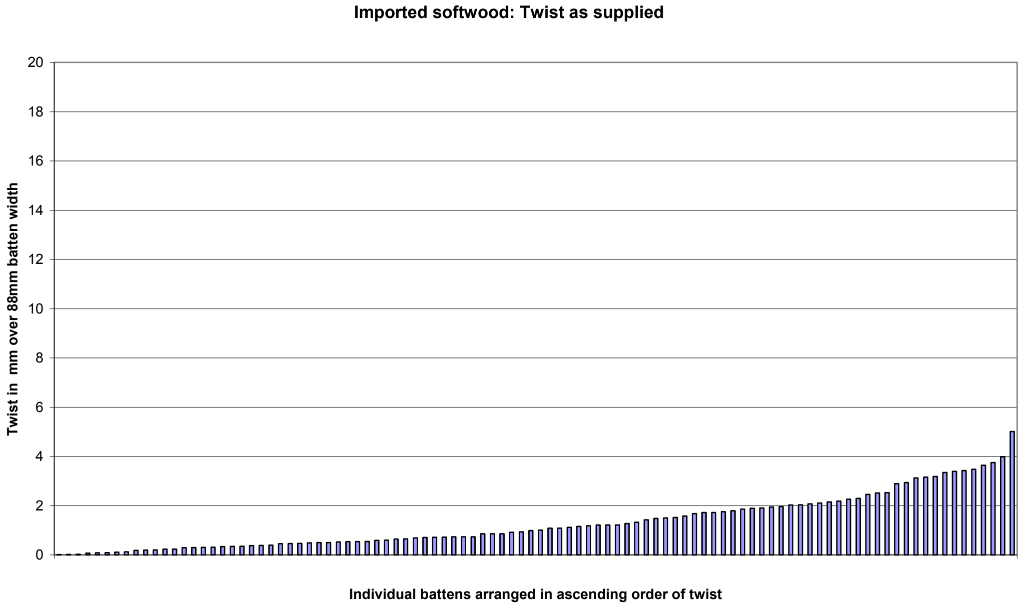
2.2 Distortion as supplied - Spring. Figures 3 and 4 (below) show the measured spring graphs of the Imported (coloured blue) and Home grown material (coloured red)

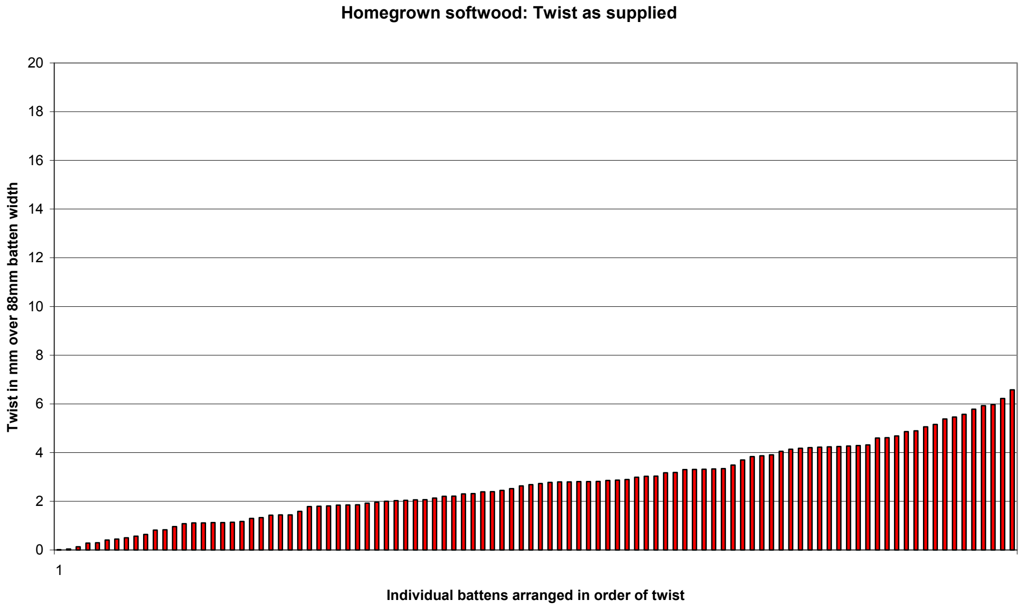




Figures 3 and 4 Comparison of Bow at supplied moisture content

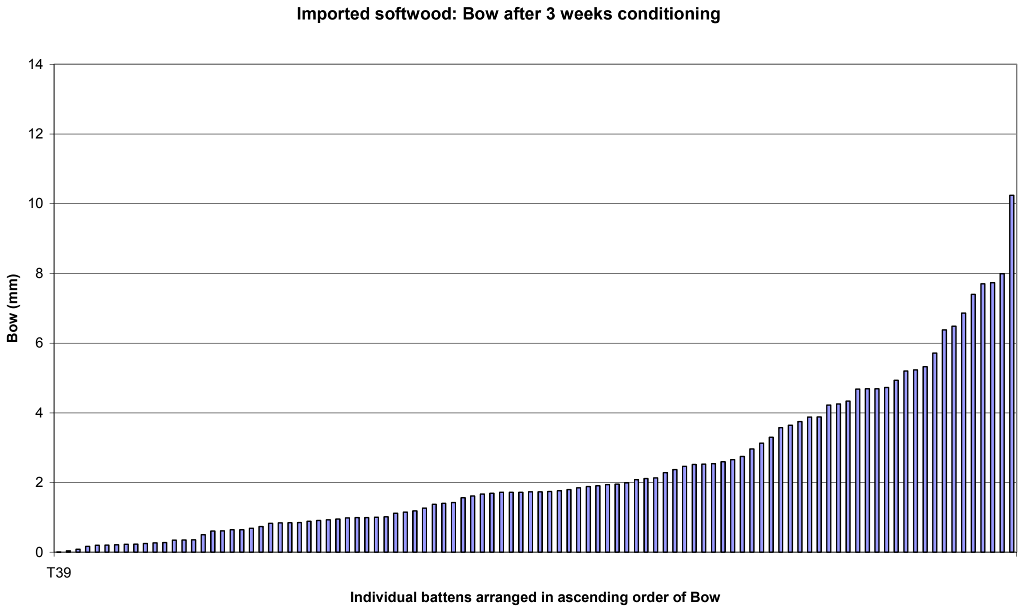
2.3 Distortion as supplied - Twist. Figures 5 and 6 (below) show the measured twist graphs of the Imported (coloured blue) and Home grown material (coloured red)

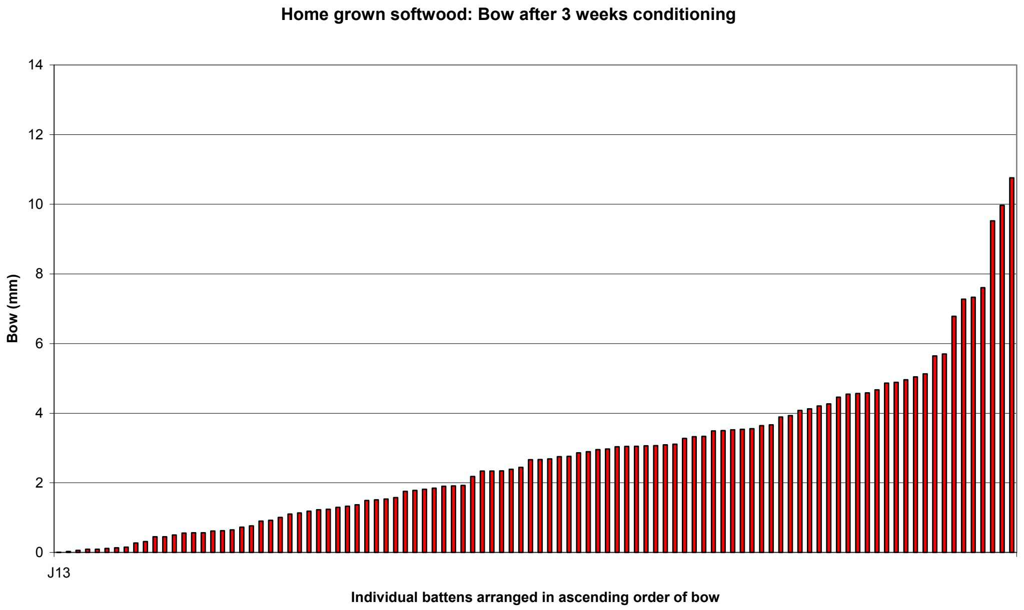




Figures 5 and 6 Comparison of twist at supplied moisture content

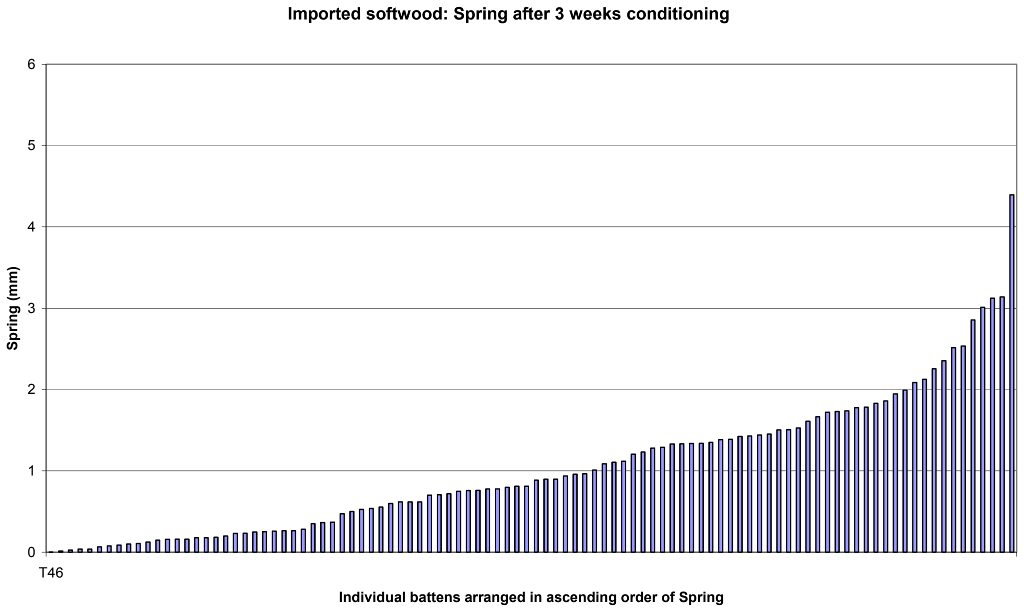
2.4 Distortion after 3 weeks conditioning - Bow. Figures 7 and 8 (below) show the measured bow graphs of the Imported (coloured blue) and Home grown material (coloured red)

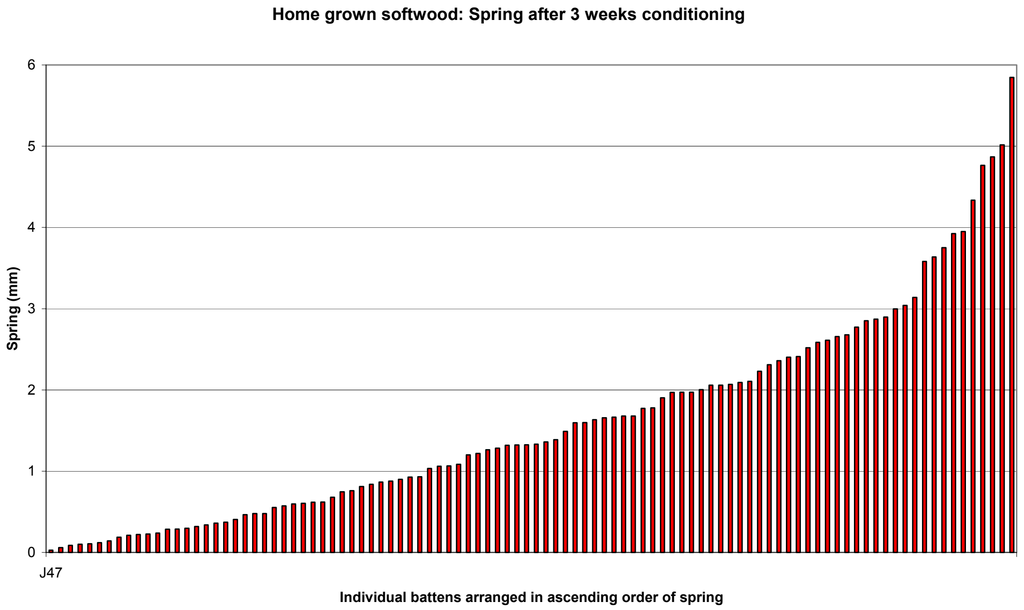




Figures 7 and 8 Comparison of Bow after 3 weeks conditioning

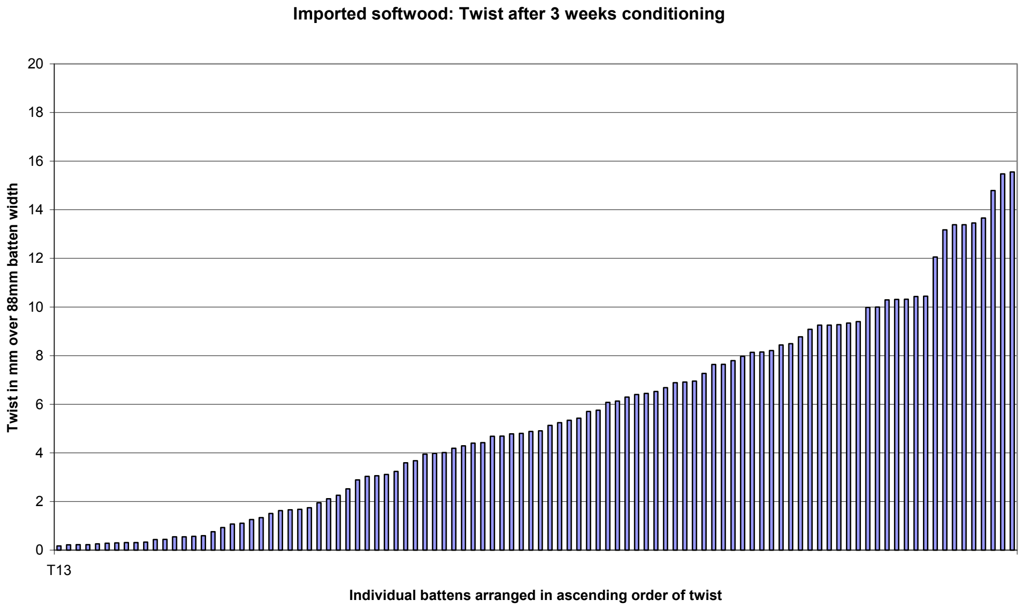
2.5 Distortion after 3 weeks conditioning - Spring. Figures 9 and 10 (below) show the measured spring graphs of the Imported (coloured blue) and Home grown material (coloured red)

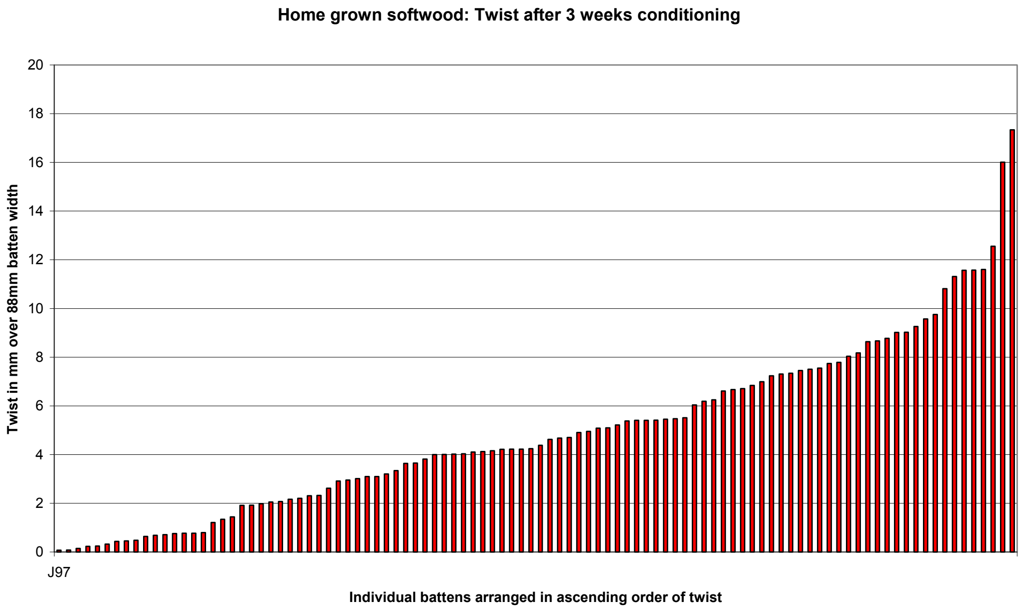




Figures 9 and 10 Comparison of Spring after 3 weeks conditioning

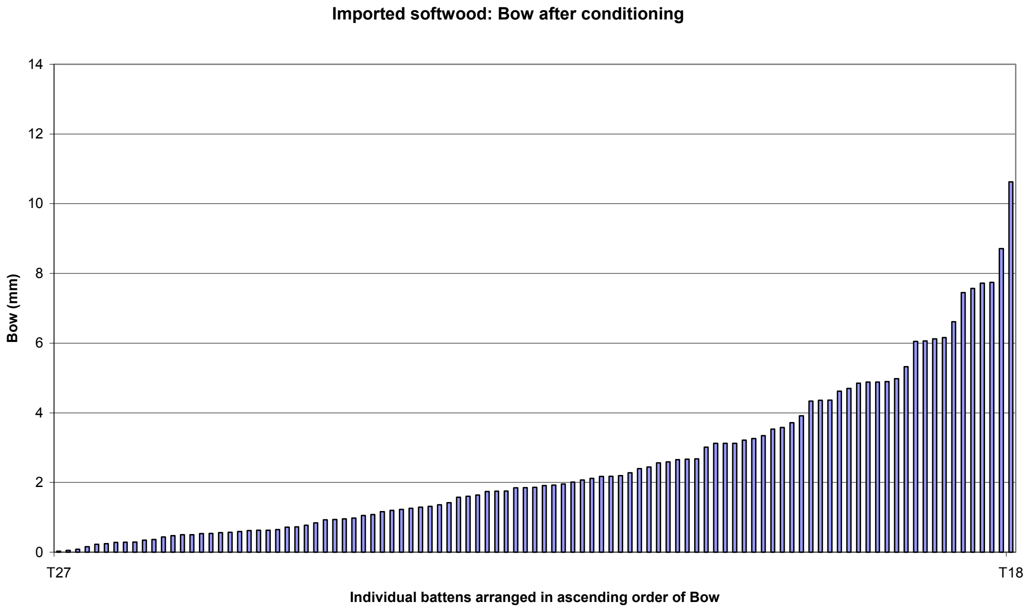
2.6 Distortion after 3 weeks conditioning - Twist. Figures 11 and 12 (below) show the measured bow graphs of the Imported (coloured blue) and Home grown material (coloured red)

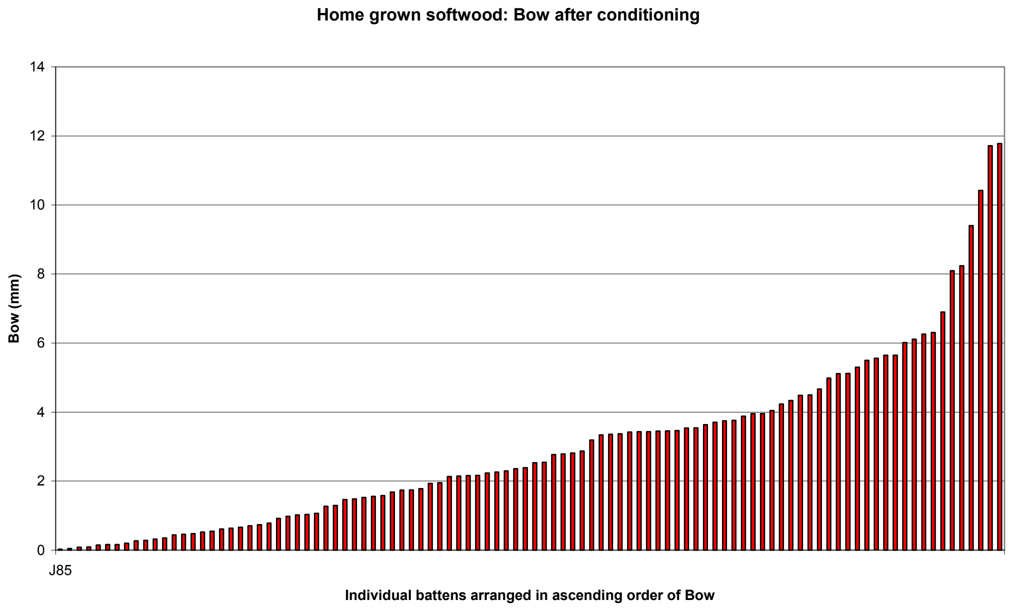




Figures 11 and 12 Comparison of Twist after 3 weeks conditioning

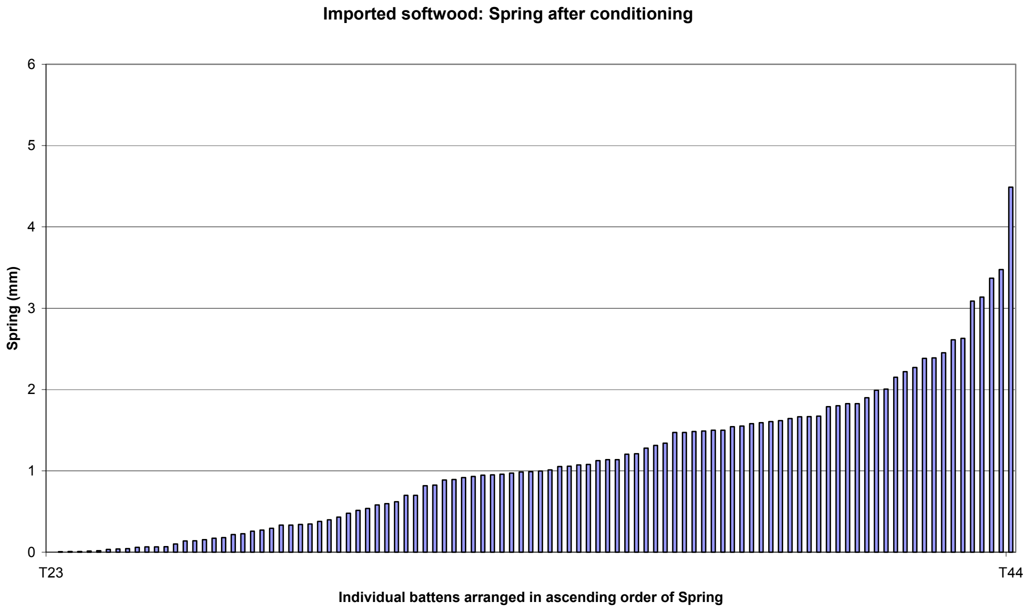
2.7 Distortion after full conditioning - Bow Figures 13 and 14 (below) show the measured bow graphs of the Imported (coloured blue) and Home grown material (coloured red)

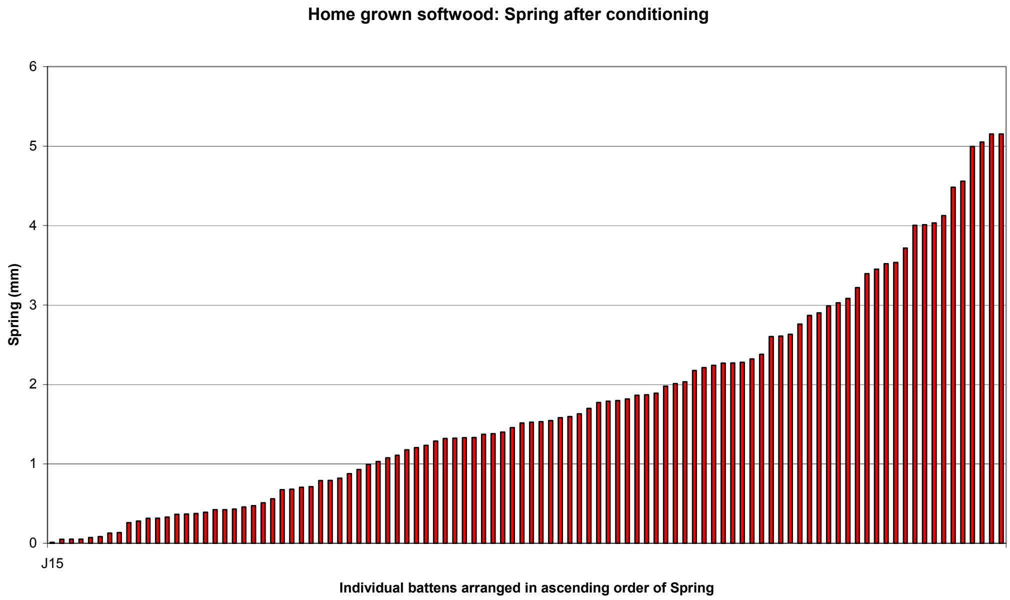




Figures 13 and 14 Comparison of Bow after full conditioning

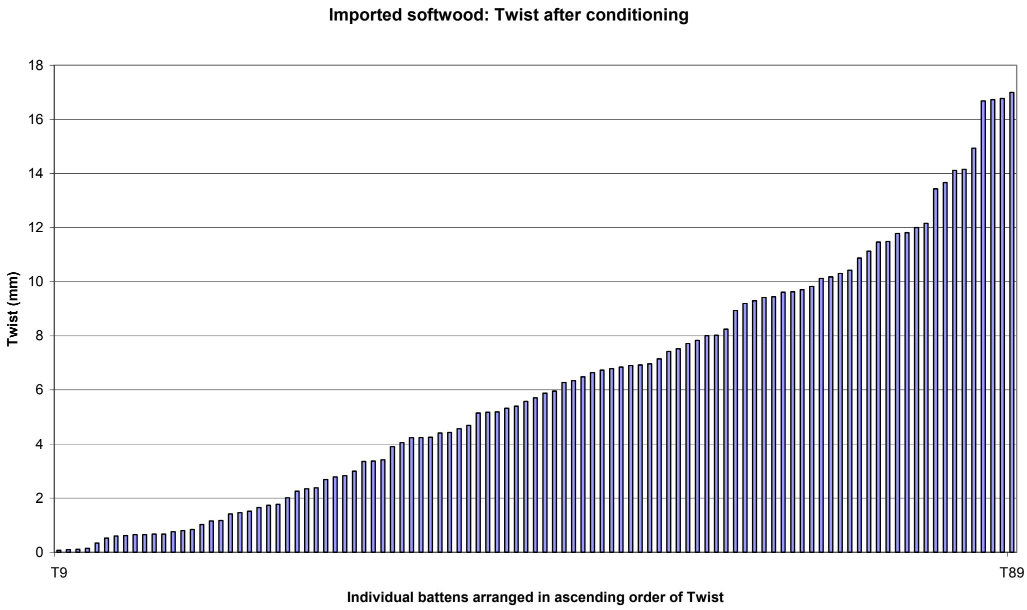
2.8 Distortion after full conditioning - Spring Figures 15 and 16 (below) show the measured spring graphs of the Imported (coloured blue) and Home grown material (coloured red)

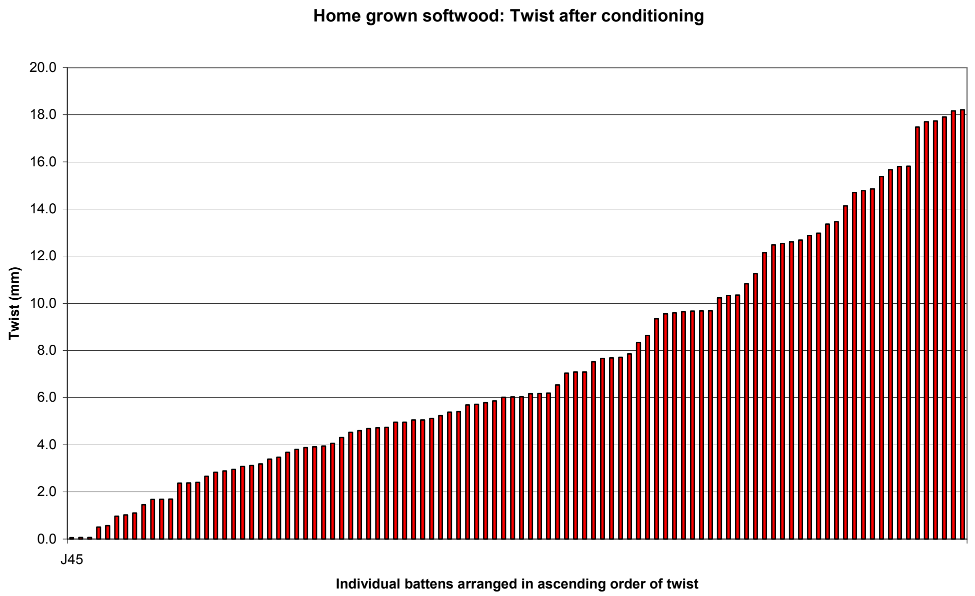




Figures 15 and 16 Comparison of Spring after full conditioning

2.9 Distortion after full conditioning - Twist Figures17 and 18 (below) show the measured twist graphs of the Imported (coloured blue) and Home grown material (coloured red)





Figures 17 and 18 Comparison of Twist after full conditioning

2.10 Distortion Averages

Table 1 (below) shows the average distortion values for both sets of timber

		Average values (mm)				
		Twist	Bow	Spring	Cup	Moisture (%H_2O)
Imported	High m.c.	1.31	1.98	0.7	0.14	22
	Medium m.c.	5.49	2.37	1.03	0.32	16.9
	Low m.c.	6.24	2.53	1.12	0.35	14
Home grown	High m.c.	2.76	1.44	0.81	0.02	22.6
	Medium m.c.	4.97	2.78	1.61	0.32	16.8
	Low m.c.	7.44	2.99	1.75	0.3	14

Table 1: Average Distortion data

The higher bow and spring at conditioned (low) moisture content in the home-grown timber was determined to be caused by the presence of significant levels of compression wood in about 30% of the samples. The level of twist was 20% higher in the home grown timber after unrestrained conditioning.

3.0 Compression Wood

The home grown samples measured for distortion at the various moisture contents were also visually assessed and put into the following three compression wood categories;

1. No compression wood;
2. Slight compression wood
3. Significant compression wood.

Figures 19, 20 and 21 (below) show bow, spring and twist at low moisture content, arranged into three compression wood categories and ascending order of distortion.

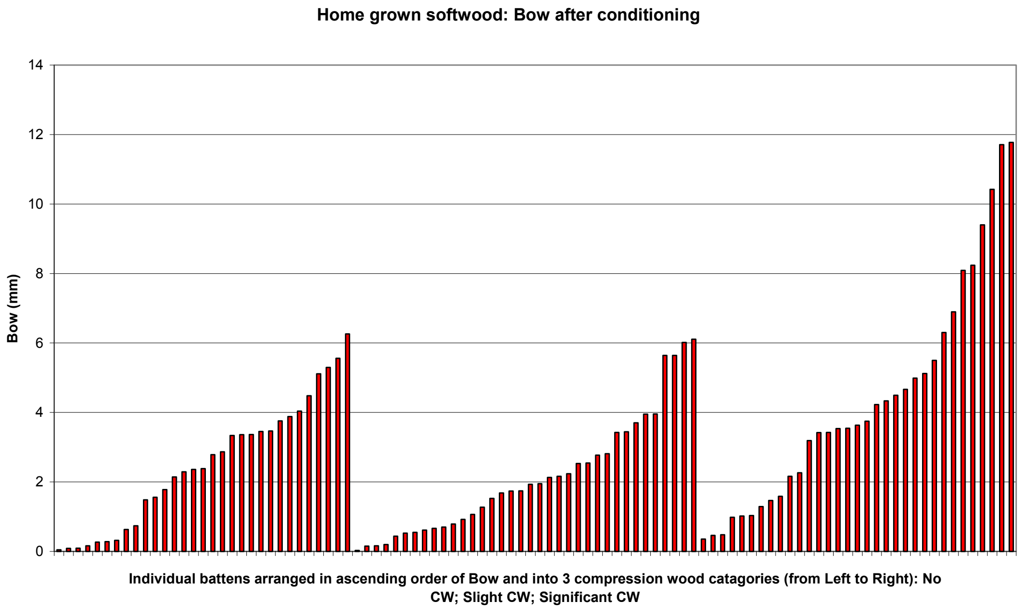


Figure 19: Compression Wood Content and Bow

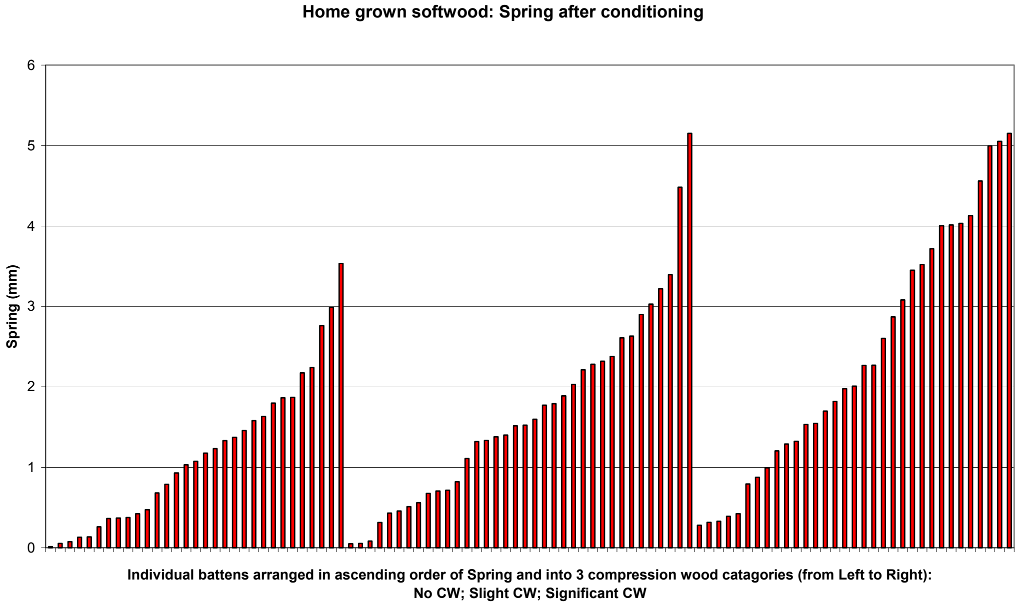


Figure 20: Compression Wood Content and Spring

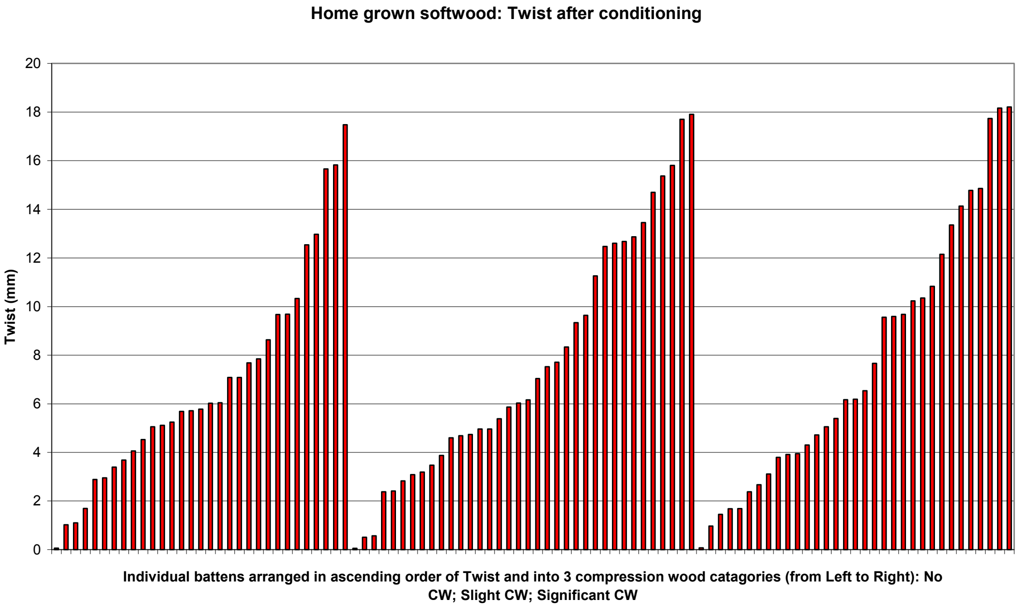


Figure 21: Compression Wood Content and Twist

It is clear that compression wood is the factor in both bow and spring, but not twist as would be expected.

It was not possible to determine with sufficient confidence the compression wood content in the imported timber because of the preservative treatment colouration. However, the levels of bow and spring as shown in graphs 1 to 18 indicate a lower level of compression wood.

4.0 Knot Content

Table 2 (below) summarises the knot measurements and analysis:

	Average Knot area for one face of batten (mm^2)	Area of 1 batten face (2400*88mm) (mm^2)	Knot proportion of 1 batten face (%)	Average No. of Knots per batten	Average Knot size (mm^2)
Imported	1092.88	211200	0.517462121	6.1	184.7295
Home grown	1733.30	211200	0.820691288	8.4	206.3447

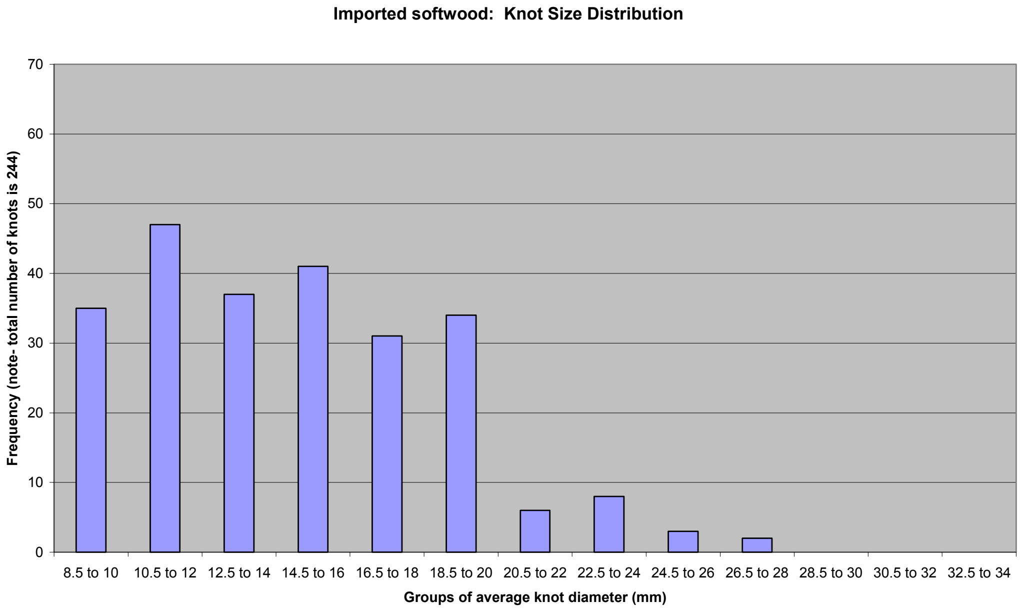
Table 2: Knot data

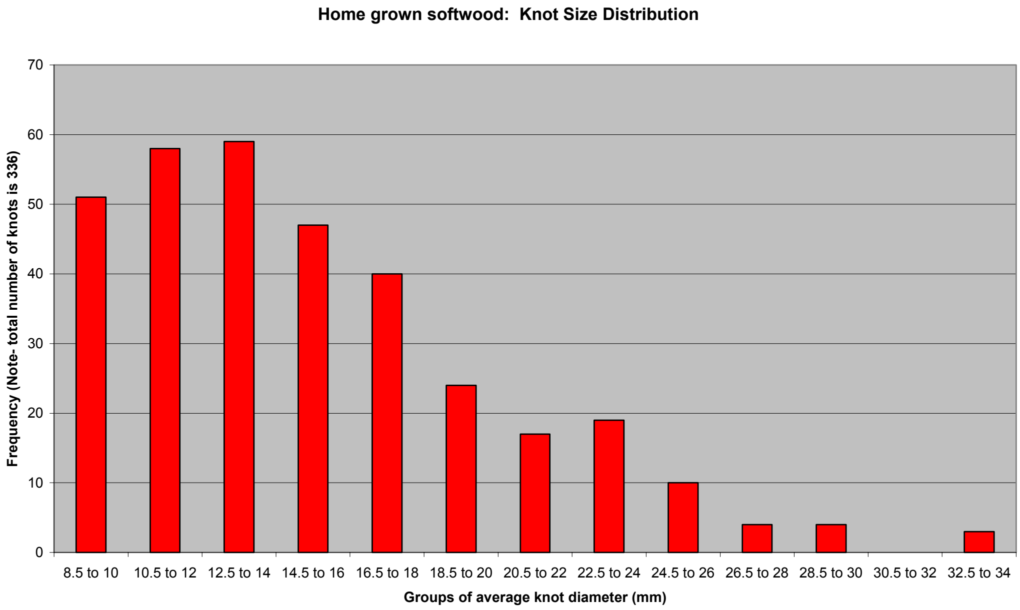
NB/ Only knots with diameter above 10mm are included.

The above results show:

- The proportion of knots in terms of total knot area on one face of the home grown timber was 60% greater than that of the imported material.
- The UK timber contains 38% more knots over 10mm in size than the imported material.
- The average knot size is 12% larger in the home grown timber compared with the imported.

Figures 22 and 23 (below) show the knot size/distribution graphs for both sets of timber:





Figures 22 (top) and 23: Comparison of knot size and frequency

5.0 Compression perpendicular to grain

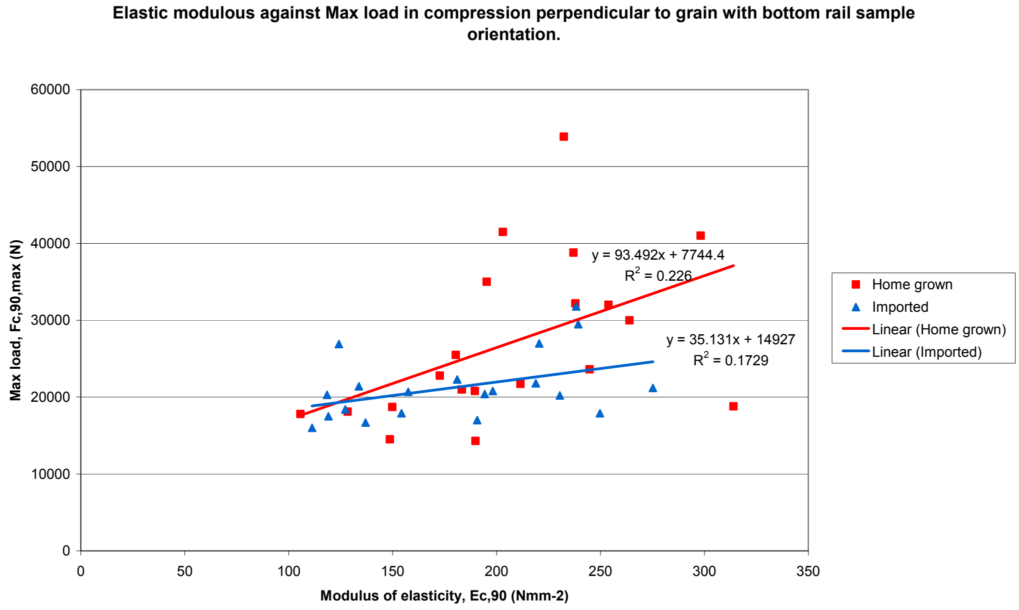
Samples were tested in accordance with BS EN 1193:1998. (ref = 1) The timber samples were selected from the ends of battens at random and samples which contained defects were not deliberately avoided. This was so that the tests were more representative of the compressive loading experienced in a typical timber frame.

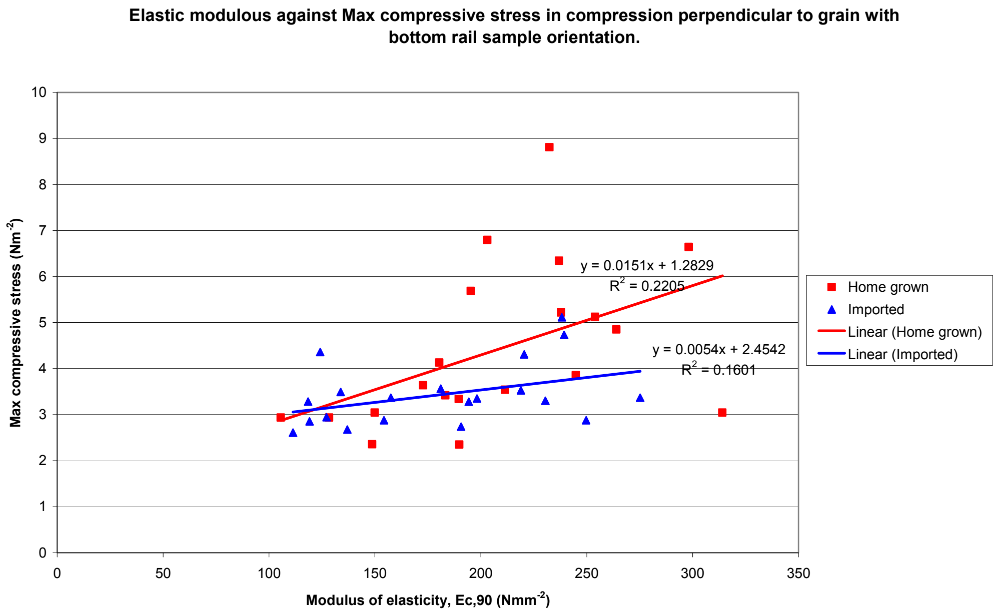
Table 3 (below) details the results in summary form.

Figures 24 and 25 (below) show comparative results of Load v MOE and Compressive stress v MOE, respectively, for both sets of timber.

Sample type	Sample Code	Density (Kgm^{-3})	Moisture content (H_2O%)	Fc,90,max (N)	Ec,90 (N/mm^2)	fc,90 (N/mm^2)
Imported	T98A	454.7	14.47	17900	154.3	2.88
Imported	T42A	447.1	14.68	20800	198.2	3.35
Imported	T22A	686.4	13.58	26900	124.2	4.36
Imported	T10A	463.1	14.66	20400	194.3	3.28
Imported	T68A	476.8	14.98	21400	133.8	3.49
Imported	T81A	494.1	14.39	27000	220.5	4.31
Imported	T19A	594.9	13.45	31800	238.3	5.12
Imported	T94A	450.4	14.58	16700	137	2.68
Imported	T92A	522.1	14.70	17000	190.7	2.74
Imported	T76A	471.4	14.41	20700	157.5	3.36
Imported	T89A	455.9	14.70	18400	127.2	2.95
Imported	T2A	497.1	14.17	17500	119.1	2.85
Imported	T45A	465.7	13.30	29500	239.3	4.73
Imported	T5A	512.6	14.92	21800	218.9	3.53
Imported	T53A	442.8	14.46	22300	181.1	3.56
Imported	T64A	507	13.65	21200	275.2	3.36
Imported	T1A	488.4	15.05	20200	230.5	3.30
Imported	T13A	444.6	14.67	20300	118.5	3.28
Imported	T92B	523.2	14.27	17900	249.7	2.88
Imported	T44A	441.2	14.96	16000	111.3	2.61
Imported	Average	491.98	14.4	21285	180.98	3.43
Home grown	J98A	431	14.65	22800	172.7	3.64
Home grown	J76B	545.5	14.78	41500	203.1	6.79
Home grown	J87A	427.5	14.42	30000	264	4.85
Home grown	J92A	455	14.87	18700	149.9	3.04
Home grown	J25A	617.9	15.14	53900	232.4	8.81
Home grown	J52A	445.7	15.35	25500	180.4	4.13
Home grown	J61A	472.9	14.53	21000	183.3	3.42
Home grown	J53A	365.8	11.29	14500	148.7	2.35
Home grown	J21A	438.3	14.89	21700	211.5	3.54
Home grown	J32B	400.3	14.80	20800	189.6	3.34
Home grown	J74A	478.5	14.73	32000	253.9	5.12
Home grown	J92B	547.8	14.83	41000	298.2	6.64
Home grown	J48A	455.1	14.90	17800	105.6	2.94
Home grown	J50A	542.3	14.35	35000	195.3	5.69
Home grown	J77A	609.6	14.82	38800	237	6.34
Home grown	J30A	458.1	14.53	18800	314	3.04
Home grown	J32A	455	15.67	23600	244.8	3.86
Home grown	J44A	484.2	14.62	32200	237.9	5.22
Home grown	J51CN	385.9	15.00	14300	189.9	2.35
Home grown	J74B	408.4	14.55	18100	128.4	2.94
Home grown	Average	471.24	14.64	27100	207.03	4.4

Table 3: Compression Test Results





Figures 24 (top) and 25: Compression Test Results

The high modulus of elasticity and maximum compressive stress found for the UK spruce is likely to be due to high knot contents. Both sets of samples were conditioned to 14% moisture content.

6.0 Production trials at Stewart Milne Timber Systems Ltd.

BRE despatched 50 randomly selected UK battens to Stewart Milne Timber Systems Ltd. for their assessment and comment. The studs were sent at the saw mill supplied moisture content of 18 to 20%. Stewart Milne considered the level of twist and knots to be unacceptably high but were prepared to carry out a limited production run of four panels, with BRE present.

During the production run no problems such as nail fouling occurred, although the number of panels made was quite limited. However, it was noted that the majority of the nails fixing the sheathing were over-shot (ie they had penetrated the timber too far), resulting in shearing of the OSB around the nail head. The nail heads were 3 to 4mm below the general level of the sheathing. This is most likely the result of the setting on the nail gun being too high. Whilst this setting may result in few instances of nail fouling, it was found to have a deleterious effect on the structural performance of the panel (see section 7.0).

7. Racking resistance tests on panels manufactured from UK timber

Racking resistance tests to BS 5268 part 6 were carried out on the panels manufactured from UK grown timber, with the following results (Table 4):

Racking Test Results	Stiffness R (N/mm)	Fmax (kN)
Test 1	591	6.85
Test 2	646	6.95

Table 4: Racking resistance tests

Table 5 gives the test reduction and calculation of basic racking resistance (BRR). The test results for the two panels are shown graphically in Figures 26 and 27.

The panels were found to fall below the required racking resistance by about 20%, with the most likely explanation that the sheathing fixing nails had been over-driven.

Reduction of Results

	Abbr.	Panel Number		
		Test 1	Test 2	
Vertical load (kN)	F_v	0		
Racking stiffness (N/mm)	R	591	646	-
Maximum load (kN)	F	6.85	6.95	-
DESIGN STIFFNESS				
Average stiffness (N/mm)	R_{mean}	619		
No. of tests		2		
Modification factor	K_{109}	0.87		
Design stiffness load (kN)[1)]	R_1	**3.23**		
DESIGN STRENGTH				
Lowest failure	F_{min}	6.85		
No. of tests		3		
Modification factor	K_{109}	0.93		
Factor of Safety	FofS	1.6		
Design strength[2)]	R_2	**3.98**		
BASIC RACKING RESISTANCE				
Design load (kN)[3)]	R_3	3.23		
Design resistance (kN/m)[4)]	DRR	1.35		
Vertical load modification factor	K_{111}	1		
Basic racking resistance (kN/m)[5)]	BRR	**1.35**		

1) *$R_1 = R_{mean} \times 0.002 \times H_{WP} \times 1.25 \times K_{109}$*
2) *$R_2 = F_{min} \times K_{109}$ / Factor of Safety*
3) *Lower of R_1 and R_2*
4) *R_3 / Length of partition*
5) *BRR= DRR/ K_{111}*

For a 9.0mm OSB[1] sheathed timber frame wall
BS 5268: 6.1 quotes a basic racking resistance (BRR) of 1.68kN/m

Note 1: OSB fixed using 3.0mm wire nails at least 50mm long at a maximum spacing 150mm on perimeter and 300mm on internal lengths.

Table 5: Reduction of racking test results

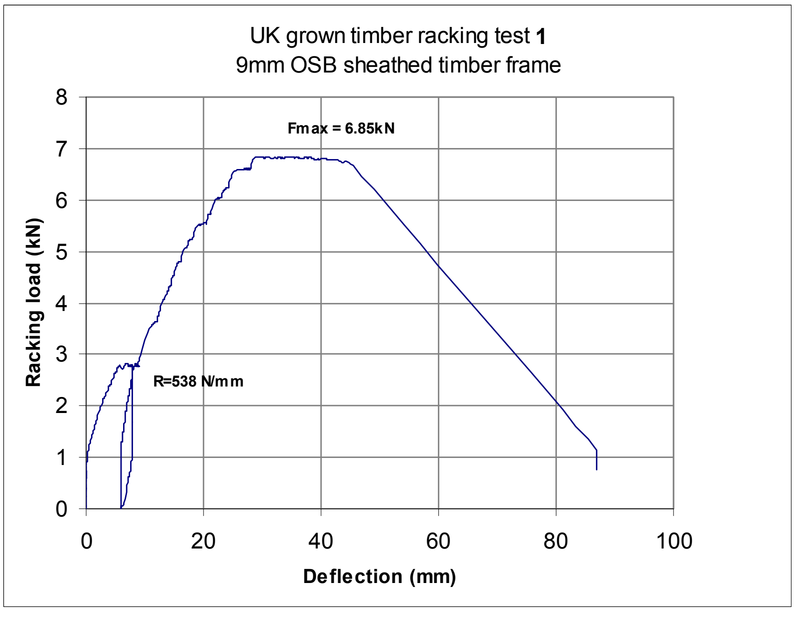


Figure 26: Test results panel 1

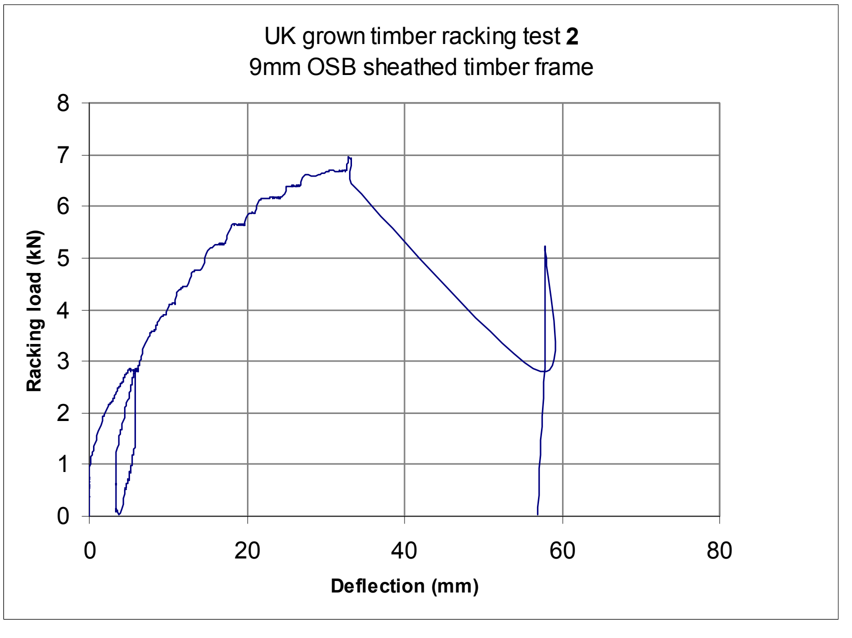


Figure 27: Test results panel 2

8. Monitoring of distortion on partially restrained panels undergoing conditioning

The aim of the test was to compare the distortion of wall panels constructed using imported and UK grown timber. The panels were manufactured at BRE with identical nailing patterns, and then fitted into rigs which simulated partial restraint with the top and bottom of the panel fixed; whilst the mid section was free to move. Particularly in brick clad timber frame much greater restraint of the mid section of the panel would be afforded by the wall ties.

Two timber frame panels were constructed for each set-up and joined as shown in Figure 28. The panel construction was designed to simulate the joint between adjacent panels, with overlapping top rail and sole plate. The timber moisture content of the time of panel fabrication was around 18% ie typical of fabrication levels. The conditioning trials took place in a heated engineering laboratory which, although not precisely temperature and humidity controlled, facilitated the drying down of the timber to levels which are probably below the in service conditions, and which represent a worst case scenario.

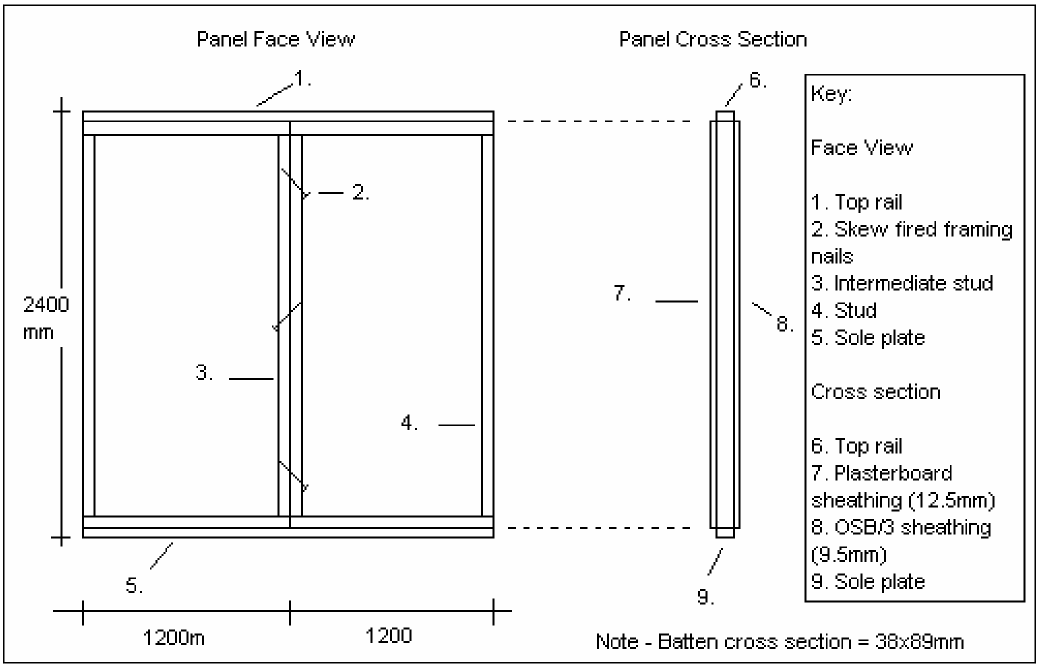


Figure 28: Panel construction joint (note that intermediate studs are omitted from the diagram)

The fixing specification for the panel construction shown above was as follows:

The panel frame joints were fixed using two 100mm long screw shank framing nails. The intermediate stud was fixed by three skew fired framing nails as shown in Figure 28. The bottom rail was fixed to the sole plate by the same framing nails, again skew fired at 600mm centres.

The plasterboard and OSB/3 sheathing were fixed by 3mm diameter and 50mm long wire nails. The plasterboard fixings were at 150mm centres around the board perimeter whilst the OSB/3 fixings were at 150mm centres around the perimeter and 300mm centres along the intermediate studs.

Measurement points and directions are shown in Figure 29 and 30

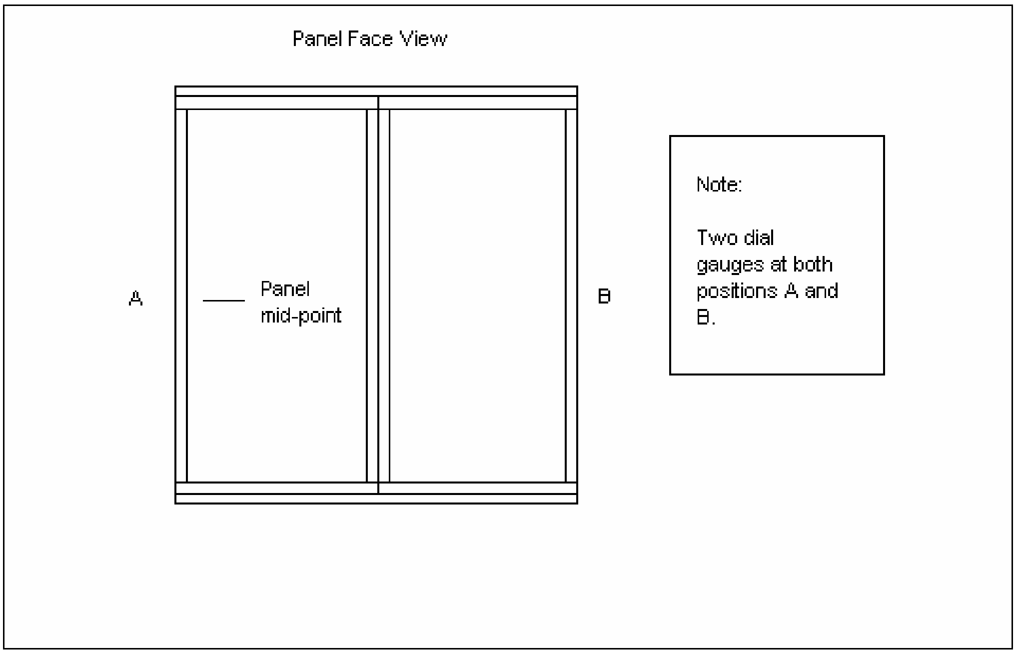


Figure 29: Dial gauge positions

Panel movement relative to the points indicated were measured periodically together with the timber moisture content and laboratory conditions

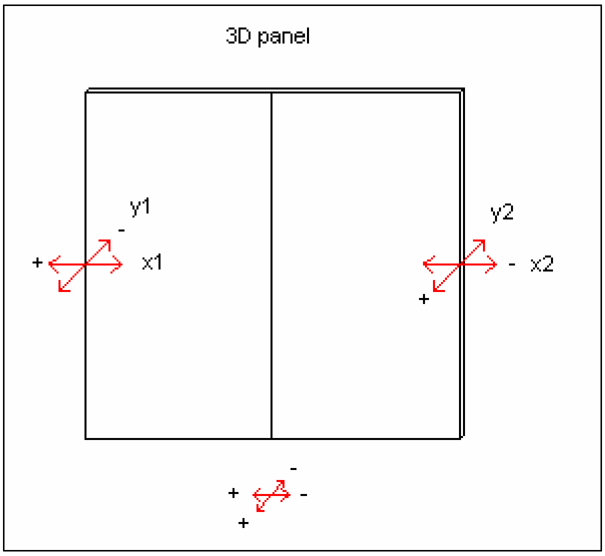


Figure 30: Dial gauge directions

Table 6 (below) details the directions of the measurement taken:

Data Set	**Series 1**	**Series 2**	**Series 3**	**Series 4**
Side of panel (left or right relative to front view)	LHS	LHS	RHS	RHS
Direction of movement (refer to Figure 30)	↔ x1	↕ y1	↕ y2	↔ x2

Figures 31 and 32 (below) show the results of the conditioning tests with data series as defined in Table 6:

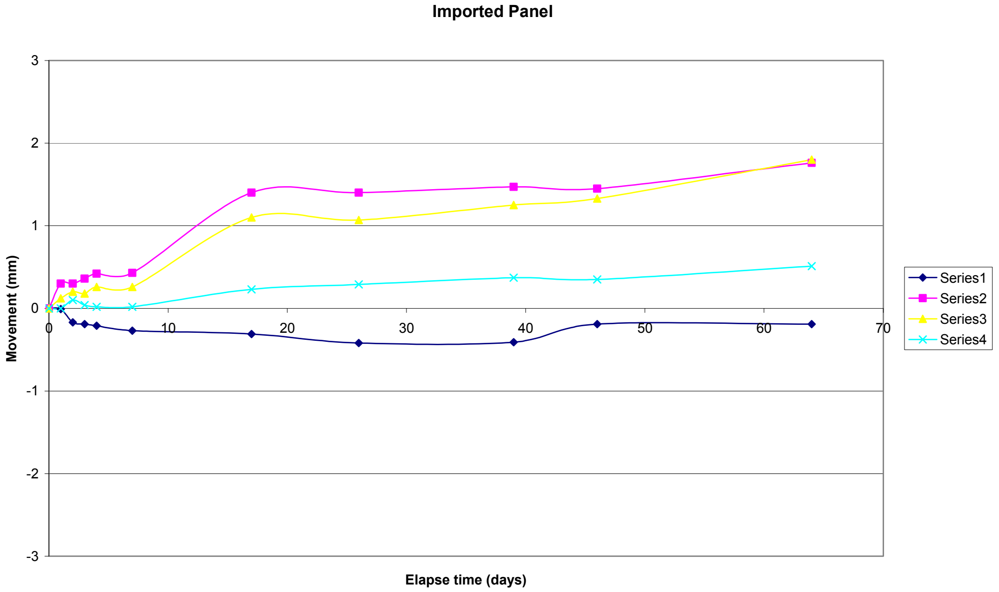


Figure 31: Imported timber panel test results

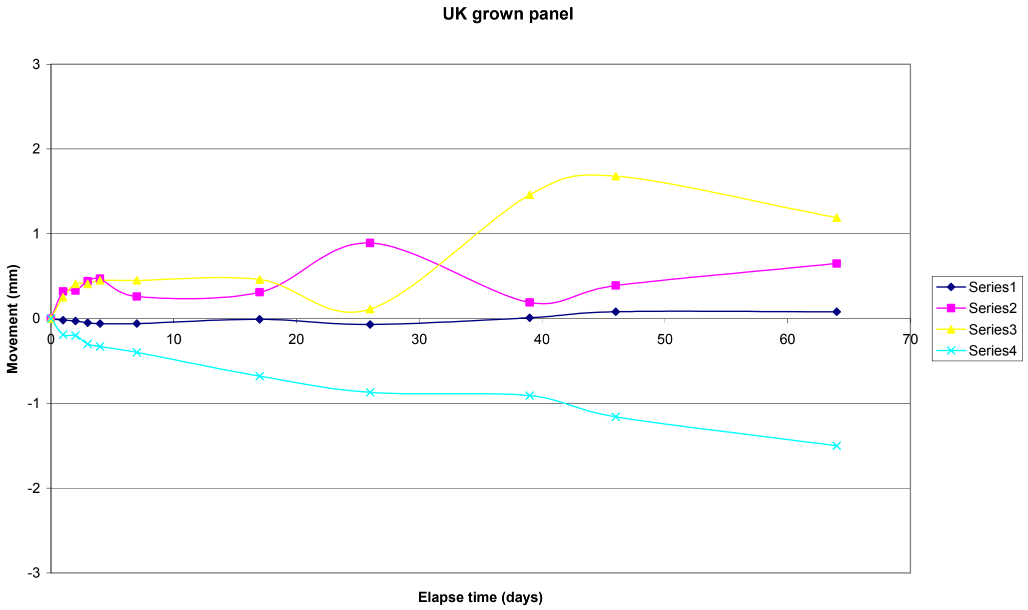


Figure 32: UK timber panel test results

Both the imported and UK timber panels were observed to have positive movement for series 1 and 2 data (which means that on the left hand side of the panel there was movement to the left and outward). However, the level of movement is so low as to make it impossible to draw any firm conclusions on the nature of the distortion, other than to say that it is in practical terms negligible. Clearly, and as expected, the restraint afforded by the panel construction prevents the distortion observed on unrestrained battens for bow, spring and twist.

Figure 33 (below) shows the recorded timber moisture contents, with the anticipated fall from supplied moisture content ie about 18% to 10% which is normal for timber inside a continuously heated building but actually below that expected for a timber frame inner leaf.

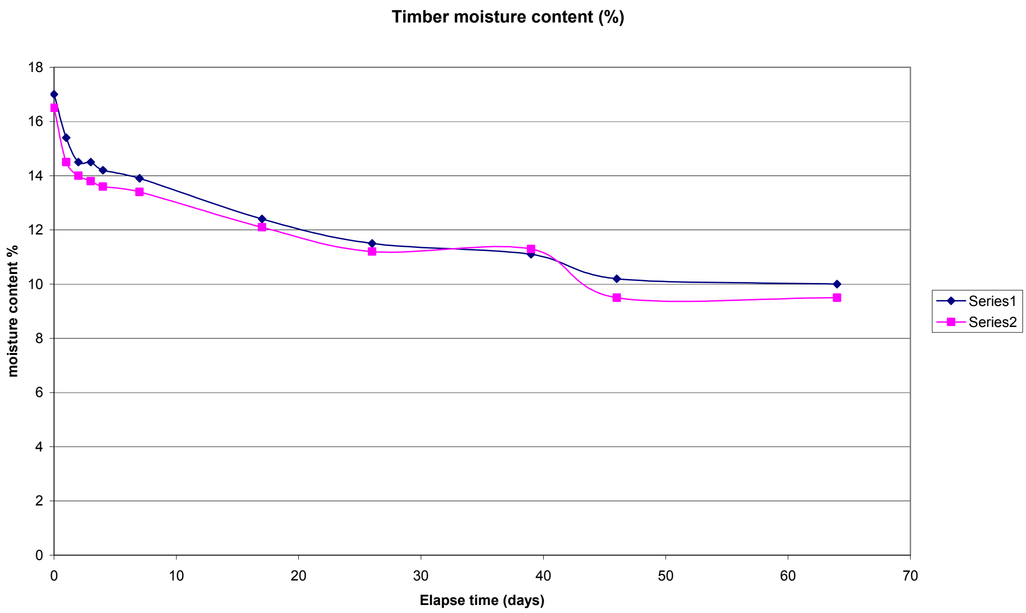


Figure 33: Timber moisture contents during the test

Figure 34 (below) shows the fairly constant laboratory conditions during the experiment:

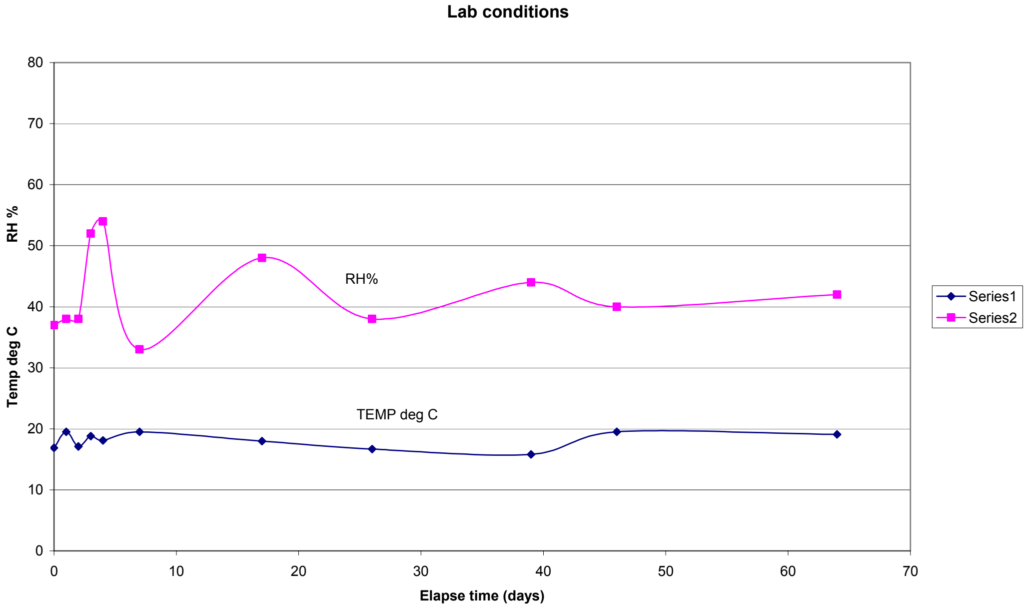


Figure 34: Laboratory conditions

9. Conclusions

Low levels of distortion were present in both imported and home grown timber as supplied, although the home grown timber showed a greater tendency to distort in bow and spring when allowed to dry unrestrained. This was due, in part, to the level of compression wood within the sample batch. Levels of twist observed were 20% higher on average in the UK timber following unrestrained conditioning compared with imported timber, which can be considered quite favourable. However, in a timber frame building distortion will be limited by:

- Restraint afforded by the sheathing board, plasterboard, brickwork outer leaf and noggins
- Studs at panel ends and corners will be fixed back to back with other studs
- Sole plates, headers and footers will be under constant dead load from floor and roof
- Distortion will be limited by the lower change in moisture content from supplied to the expected service condition, in comparison with joists for example.
- In panel production timber will have little time to dry out unrestrained
- Most bow present in supplied timber is caused by poor support (stickering)

In a timber frame building most of the vertical movement comes from cross grain shrinkage in the floor zones and take up of construction slack (Grantham and Enjily, 2003 [ref = 2]), with cross grain shrinkage of sole plates, bottom and top rails contributing much less. Longitudinal shrinkage of studding is negligible. It follows that the shrinkage differential when comparing imported and home-grown stud material is minimal.

The home grown timber showed better performance in compression tests due, in part, to the greater frequency of knots. The greater frequency and size of the knots in the home grown timber is more likely to cause a problem with nail fouling. However, during production trails at Stewart Milne Timber Systems no instances of nail fouling were observed, although the number of panels made was limited. In another BRE Project (DTi sponsored Pii on “Providing High Quality Timber for the UK Construction Sector”) a scanner based solution for knot fouling problems has been developed.

It was observed that the nails fixing the sheathing OSB had been over-driven on the panels manufactured in the trials and that for this reason racking resistance values were below the normal level expected. This is an important consideration for timber frame manufacturers.

During conditioning tests on panels fabricated by BRE from supplied moisture content to levels below that anticipated in service, no significant distortion was observed. This tends to confirm that timber frame construction provides a high level of restraint for timber undergoing change in moisture content.

Stewart Milne Timber Systems Ltd were not willing to fabricate panels made from UK timber for inclusion into any full scale structure. The company currently obtain imported timber at a discount and for sizes other than 89mm x 38mm CLS, such as 140mm stud sizes and also joists.

On the basis of the above work, it can be concluded that UK grown timber is well-suited to timber frame panel manufacture, although economic factors and company policy may count against its uptake.

Close regard should be given to improving quality control in the UK sawmilling sector. This could be achieved through the application of timber scanning technology.

References

1. British Standards Institution BS EN 1193:1998 *Timber structures- Determination of shear strength and mechanical properties perpendicular to the grain*. BSI, London.

2. Grantham, R., Enjily, V. (2003) *Multi-storey Timber Frame Buildings*, BRE Report BR 454, CRC London.