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FIRST STATUS REPORT: TESTING OF AGED SOFTWOOD FIBERBOARD MATERIAL FOR THE 9975 SHIPPING PACKAGE

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First Status Report: Testing of Aged Softwood Fiberboard Material for the 9975 Shipping Package

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Summary

Samples have been prepared from a softwood fiberboard lower subassembly. Physical, mechanical and thermal properties have been measured following varying periods of conditioning in each of several environments. These tests have been conducted in the same manner as previous testing on cane fiberboard samples.

Overall, similar aging trends are observed for softwood and cane fiberboard samples. Some of the observed differences result from the limited exposure periods of the softwood fiberboard samples, and the impact of seasonal humidity levels. Testing following additional conditioning will continue and should eliminate this bias.

Post-conditioning data have been measured on a single softwood fiberboard assembly, and baseline data are also available from a limited number of vendor-provided samples. This provides minimal information on the possible sample-to-sample variation exhibited by softwood fiberboard. Data to date are generally consistent with the range seen in cane fiberboard, but much of the compression strength data tends toward the lower end of that range. Further understanding of the variability of softwood fiberboard properties will require testing of additional material.

Background

Cane fiberboard wall sheathing is specified for thermal insulation and impact resistance in 9975 shipping packages. Softwood fiberboard manufactured by Knight-Celotex was approved as an acceptable substitute for transportation in 2008. Data in the literature [1] show a consistent trend in thermal properties of fiberboard as a function of temperature, density and/or moisture content regardless of material source. Thermal and mechanical properties were measured for un-aged softwood fiberboard samples, and found to be sufficiently similar to those of un-aged cane fiberboard to support the acceptance of 9975 packages with softwood fiberboard overpack into KAMS for storage. The continued acceptability of aged softwood fiberboard to meet KAMS storage requirements was the subject of subsequent activities.

This is an interim status report for experiments carried out per Task Technical Plan WSRC-TR-2008-00024 [2], which is part of the comprehensive 9975 package surveillance program [3]. The primary goal of this task is to validate the preliminary assessment that Knight-Celotex softwood fiberboard is an acceptable substitute for cane fiberboard in the 9975 shipping package overpack, and that the long-term performance of these two materials in a storage environment is comparable.

Experimental Method

A lower fiberboard subassembly fabricated from softwood fiberboard for use in a 9975 shipping package was obtained from KAMS. Samples were removed from this subassembly for conditioning and testing to track the potential degradation in physical, thermal and mechanical properties. Samples were aged in 4 environments:

- 250F oven (nominal humidity of ~1%RH)
- 215F oven (nominal humidity of ~1%RH)

- 185F oven (nominal humidity of ~2%RH)
- 185F, 30%RH environmental chamber

The sample configurations and test methodologies are the same as used for aging and testing cane fiberboard samples [4, 5]. Samples for physical measurements (mass loss samples) are approximately 2 inch cubes, and receive periodic measurement of weight and dimensions. Two of these samples are conditioning in each of the 4 environments. Samples for compression testing are also approximately 2 inch cubes. These samples were placed in 3 of the environments (250F and 185F oven, and 185F 30%RH chamber). A few of these samples are removed periodically for testing. Since the compression test is destructive, these samples are not returned to the conditioning environment.

Testing for thermal properties includes both thermal conductivity and specific heat capacity. Thermal conductivity samples are approximately 7 x 7 x 1.3 inches. Two of these samples are conditioned in each of 3 environments (250F and 215F oven, and 185F 30%RH chamber) and tested periodically. In each sample pair, one is oriented for axial heat flow, and the other is oriented for radial heat flow. Thermal conductivity is measured at 3 mean temperatures – 25, 50 and 85C (77, 122 and 185F)

Specific heat capacity samples are cylindrical, approximately 1 inch diameter and 1.5 inch high. Three of these samples are conditioned in each of 2 environments (250F oven and 185F 30%RH chamber) and tested periodically. Specific heat capacity is measured for each of two mean temperatures – 25 and 50C (77 and 122F).

Conditioning of all samples began in November 2008. Thermal and mass loss samples were characterized before conditioning, and separate compression samples were tested without conditioning to document baseline properties. The three oven environments have been maintained on an almost continuous basis during the past year, while the environmental chamber has experienced significant down-time. Therefore, the samples in the 185F 30%RH environment have not accumulated as much total exposure time as the other samples.

Results

The physical properties of the weight loss samples are measured on an approximately weekly basis. These data are shown in Figure 1 on a normalized basis (each datum is divided by its corresponding value after the first conditioning period). This normalization allows for a direct comparison between samples with different starting values. The rates of change in the weight, density and dimensions of these samples are summarized in Table 1. Comparable data for cane fiberboard samples are also shown in Table 1, for comparison.

Compression testing is performed with the load applied either parallel or perpendicular to the fiberboard layers. Stress-strain curves for softwood fiberboard samples are shown in Figures 2 and 3 for these two orientations, respectively. Because of variation in the shape of the stress-strain curve from one sample to another, two metrics have been used to provide a comparison of compression test performance. For samples of both orientations, the area under the stress-strain curve up to a strain of 40% provides a metric that is roughly proportional to the energy absorbed by the material. In addition, samples tested in the parallel orientation experience an initial stress peak as the layers start to buckle. This buckling strength provides a second metric for comparison of the parallel orientation samples. These metrics are summarized in Tables 2 and 3, along with the data for cane fiberboard samples.

Thermal conductivity data for each sample are presented in Figure 4. Similar trends are seen for each of the three test temperatures – 25, 50 and 85C. Since the baseline thermal conductivity varies for each sample, normalized data are shown in Figure 5, and show the relative change from the first data point after 8 weeks conditioning. For comparison, comparable normalized data for cane fiberboard samples are also shown in Figure 5.

Specific heat capacity results are summarized in Figure 6. Due to the degree of scatter in individual results, results from each trial for all 3 samples in a given environment are averaged for each conditioning period. Comparable data for cane fiberboard samples are also shown in Figure 6 for comparison.

Discussion

Overall, similar aging trends are observed for softwood and cane fiberboard samples. No significant differences have been observed in the behavior of the two materials. However, there are some differences in some properties, which warrant further observation.

In comparing the physical property data for the two materials (softwood and cane fiberboard), the results for the softwood fiberboard samples may not be fully representative since they have been conditioned for less than 1 year. Seasonal variation in ambient moisture level will also affect the physical properties, and this effect will superimpose on any change due to degradation. This is most pronounced for samples in the 185F oven, and has minimal effect in the other environments.

In calculating the rate of change for the density and dimension data in Table 1, the first 70 days of data were ignored, due to a significant degree of scatter during this period. That leaves ~8 months of data collected between February and September 2009 to consider. The environmental chamber (185F, 30%RH environment) was off for ~2 ½ months during this period. Since this time frame extends from a period of relatively low ambient humidity to one of maximum ambient humidity, seasonal variation may impact the observed change in properties. This is seen in the reported positive increase in density for the softwood fiberboard samples in the 185F oven. By comparison, rates of change for cane fiberboard in the 185F environments are reported for periods of ~8 months as well as for multi-year periods. The 8 month periods represent exposure from February through September during the first year of conditioning, to be comparable to the softwood fiberboard exposure. The cane fiberboard samples do not show an increase in density for either period, but they do show a net increase in height during the 8 month interval, and a decrease in height over the longer 3 year period. The other properties also show variation between the 8 month rates and the multi-year rates. Additional data from softwood fiberboard samples will help eliminate this bias and demonstrate whether there is a significant difference in the physical behavior of the two materials.

For the mass loss samples in the 185F 30%RH environment, the weight, density and height have decreased faster for softwood fiberboard than for cane fiberboard. The rate of weight loss for softwood samples in the 250F oven was greater than the rate for cane fiberboard (17%/yr vs 14 %/yr. However, the weight loss for cane fiberboard during its first year was 21%. It is likely that the reported differences between the two materials will decrease as additional data are collected.

The compression test data are compared to two groups of cane fiberboard data in Tables 2 and 3. The first cane fiberboard group represents data for samples removed from LD1 and LD2 source packages. These two sources are generally the weaker among the material tested. The second group represents data for samples removed from MSC and New source packages, which tend to have average strength and above-average strength, respectively. Several of the compression test metrics (buckling strength, and area under the stress-strain curve to 40% strain) for softwood fiberboard fall below the comparable ranges reported for cane fiberboard, while many of the metrics fall within the range for cane fiberboard. At this point, it appears that the softwood fiberboard tested has compressive strength properties similar to some of the weaker (but not necessarily the weakest) cane fiberboard material.

It is likely that package-to-package variation exists with softwood fiberboard. Previous baseline testing [6] provides some indication of such variation. Baseline softwood fiberboard samples were tested from material laminated by Knight-Celotex at their Danville and Marrero plants. The metrics for these baseline samples indicate this material is weaker and absorbed less energy than the baseline sample from the current effort. Since the compression strength of the softwood fiberboard from the current effort is similar to the weaker cane fiberboard assemblies, the preliminary indication from these data is that softwood fiberboard may be weaker, on average, than cane fiberboard.

Compression testing has been performed on softwood fiberboard samples aged through 32 weeks. Additional testing is planned for exposures through 64 weeks for each environment. These additional data will be more meaningful in the comparison to aging of cane fiberboard since the cane fiberboard samples experienced a more significant decrease in strength between 32 and 64 weeks at 250F. In addition, additional samples have begun conditioning to provide replicate results for some of the existing data.

The thermal data collected to date on softwood fiberboard appears similar to that for cane fiberboard. The normalized thermal conductivity data (Figure 5) show very similar trends for both materials in each environment. The biggest difference is seen at 250F, where the thermal conductivity of the softwood has not decreased quite as fast as that of the cane fiberboard. There is significant scatter in the specific heat capacity data for both materials, especially when measured at 25C. The scatter is reduced at a mean temperature of 50C. This improvement stems from the temperature of the water bath for each mean test temperature. For a mean temperature of 50C, the water bath is at ambient temperature and is less affected by heat loss to the room. Accordingly, the 50C data are considered more reliable, and they indicate no significant difference between the two materials.

Conclusions

Overall, similar aging trends are observed for softwood and cane fiberboard samples. Some of the observed differences result from the limited exposure periods of the softwood fiberboard samples, and the impact of seasonal humidity levels. Testing following additional conditioning will continue and should eliminate this bias.

While the compression strength of the two materials generally falls within an overlapping range, the softwood fiberboard samples tested as part of this current effort tend to be at the weaker end of that range. The limited source for softwood fiberboard material to date provides little data to understand the range of scatter that might be inherent in this material. Data on additional softwood fiberboard material can be obtained as the material becomes available.

References

[1] WSRC-STI-2008-00329, "Review of Data Comparing Softwood Fiberboard and Cane Fiberboard Properties Relevant to 9975 Shipping Packages", W.L. Daugherty, June 2008.

[2] WSRC-TR-2008-00024, "Task Technical and Quality Assurance Plan for Testing to Support Acceptance into KAMS of Model 9975 Packages with Softwood Fiberboard Overpack (U)", January 2008.

[3] WSRC-TR-2001-0286, Rev. 2, "SRS Surveillance Program for Storage of Pu Material in KAMS".

[4] PVP2007-26114, "Properties of Fiberboard Overpack Material in the 9975 Shipping Package following Thermal Aging", W. L. Daugherty, Proceedings of PVP 2007 Conference, July 2007, ASME

[5] WSRC-STI-2006-00121, "Degradation of Fiberboard in Model 9975 Package Following Environmental Conditioning – First Interim Report", W. L. Daugherty and S. P. Harris, May 2007

[6] SRNL-MST-2008-00043, "Properties of Un-Aged Knight-Celotex Softwood Fiberboard for Thermal Modeling", W. L. Daugherty, February 27, 2008.

Table 1. Physical property changes in softwood vs cane fiberboard

		Softwood Fiberboard		Cane Fiberboard	
Property	Environment	Duration of Data (days)	Rate of Change (%/yr)	Duration of Data (days)	Rate of Change (%/yr)
Weight	250F, dry	303	-17.05	1104	-13.94
	215F, dry	307	-3.76	1116	-3.60
	185F, dry	314	-1.04	231 / 1106	-1.16 / -1.08
	185F, 30%RH	201	-7.70	224 / 666	-3.35 / -3.46
Density	250F, dry	230	-7.85	1104	-7.66
	215F, dry	234	-0.69	1116	-1.89
	185F, dry	241	+1.00	231 / 1106	-0.99 / -0.18
	185F, 30%RH	128	-4.20	224 / 666	-0.34 / -1.35
Height	250F, dry	230	-6.86	1104	-5.48
	215F, dry	234	-1.55	1116	-1.07
	185F, dry	241	-1.04	231 / 1106	+0.06 / -0.49
	185F, 30%RH	128	-2.87	224 / 666	-1.26 / -1.05
Length, Width	250F, dry	230	-0.60	1104	-1.81
	215F, dry	234	-0.58	1116	-0.40
	185F, dry	241	-0.52	231 / 1106	-0.12 / -0.21
	185F, 30%RH	128	-0.86	224 / 666	-0.92 / -0.58

Table 2. Summary of compression test metrics – parallel orientation

	Buckling Strength (psi)			Area under σ - ε Curve to 40% Strain (psi)		
Time at Temperature (weeks)	**Softwood Fiberboard**	Cane Fiberboard - LD1 & LD2 source packages	Cane Fiberboard - MSC & New source packages	**Softwood Fiberboard**	Cane Fiberboard - LD1 & LD2 source packages	Cane Fiberboard - MSC & New source packages
Baseline						
0	**254**	156 – 214	164 – 410	**55**	42 – 46	46 – 78
185F, dry						
8	**190**	155 – 212	196	**28**	37 – 38	37
32	**226**	80 – 227	222 – 348	**15**	19 – 31	46 – 67
64	- - -	184 – 269	217	- - -	24 – 36	46
185F, 30% RH						
8	**201**	269	226 – 314	**30**	27	40 – 67
31 / 32	**139**	229	201 – 290	**15**	28	42 – 43
250F, dry						
8	**156**	125 – 132	222 – 257	**14**	11 – 20	36 – 41
16	**107**	109 – 121	- - -	**8**	11 – 18	- - -
32	**133**	95	94 – 135	**14**	16	16 – 21
64		71	49	- - -	11	9

Table 3. Summary of compression test metrics – perpendicular orientation

	Area under σ - ε Curve to 40% Strain (psi)		
Time at Temp. (weeks)	**Softwood Fiberboard**	Cane Fiberboard - LD1 & LD2 source packages	Cane Fiberboard - MSC & New source packages
Baseline			
0	**38**	31	33 – 53
185F, dry			
8	**48**	54 – 55	- - -
32	**50**	- - -	40
64	- - -	33 – 57	46
185F, 30% RH			
8	**39**	48	50 - 53
31 / 32	**35**	43	28 – 56
250F, dry			
8	**41**	43 – 45	52 - 54
16	**36**	21 – 26	- - -
32	**31**	23	21 – 40
64	- - -	15	16

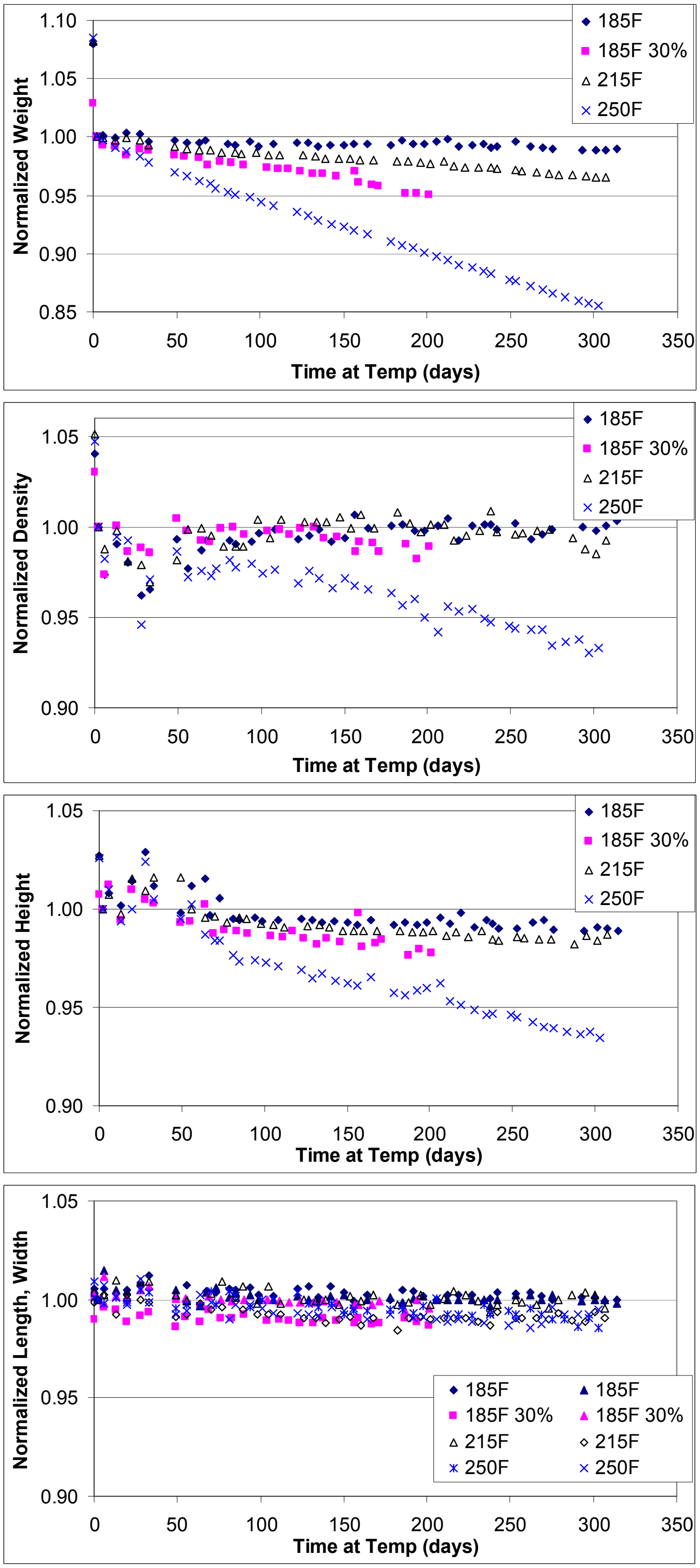


Figure 1. Normalized physical data for softwood fiberboard mass loss samples.

(a) Weight change

(b) Density change

(c) Height change

(d) Length / width change

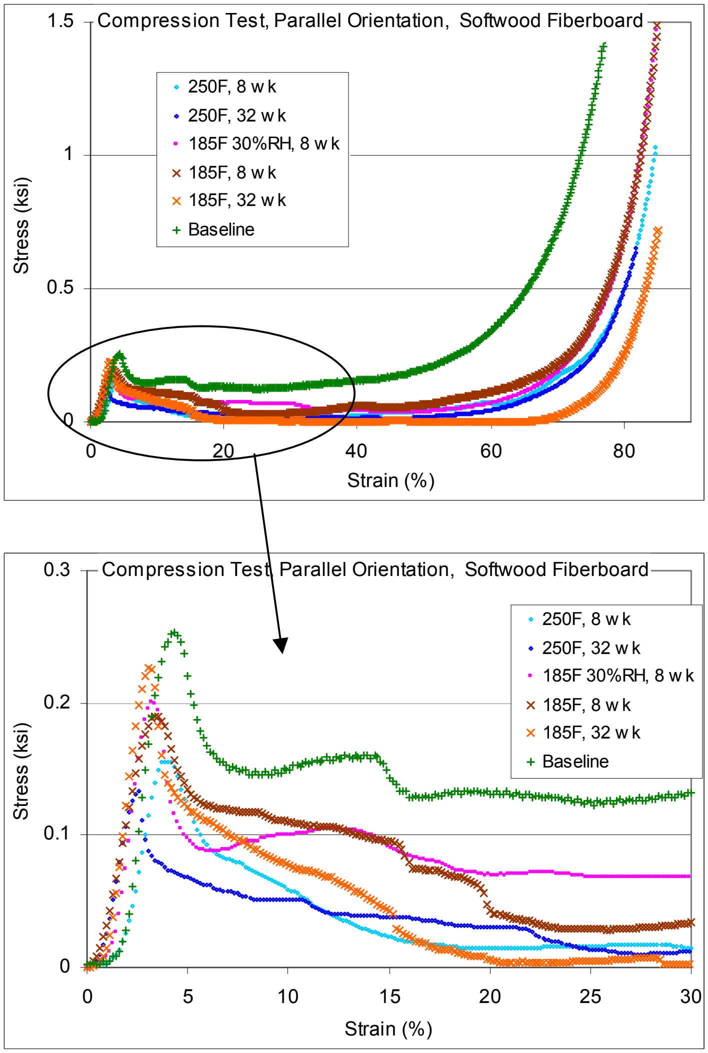


Figure 2. Compression stress-strain curves for softwood fiberboard samples, parallel orientation

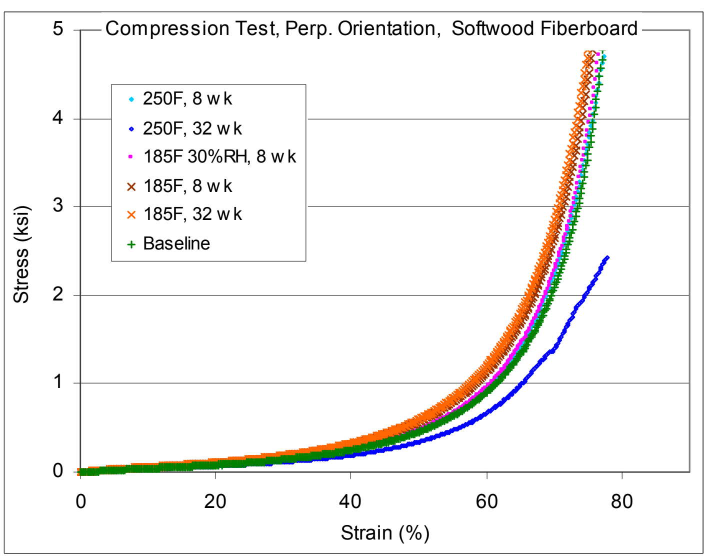
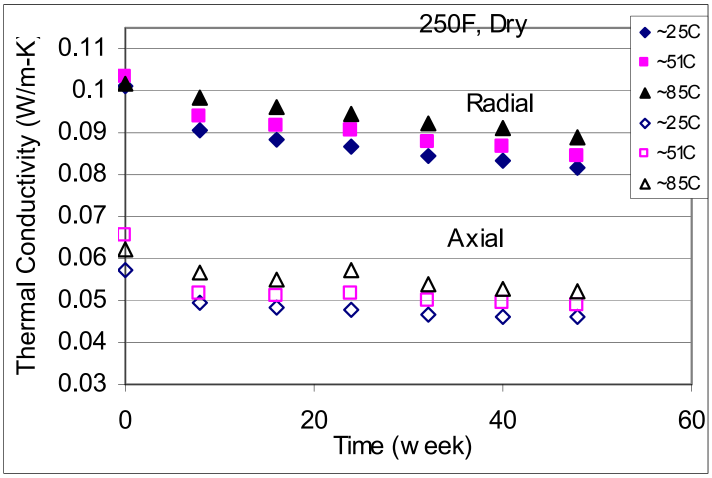
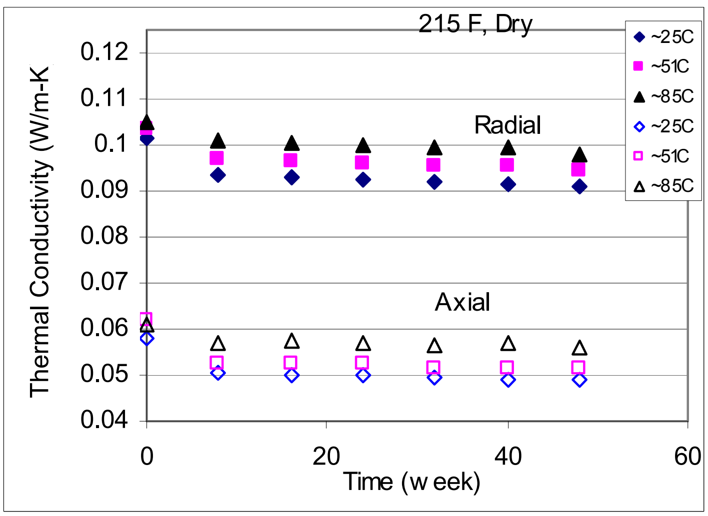


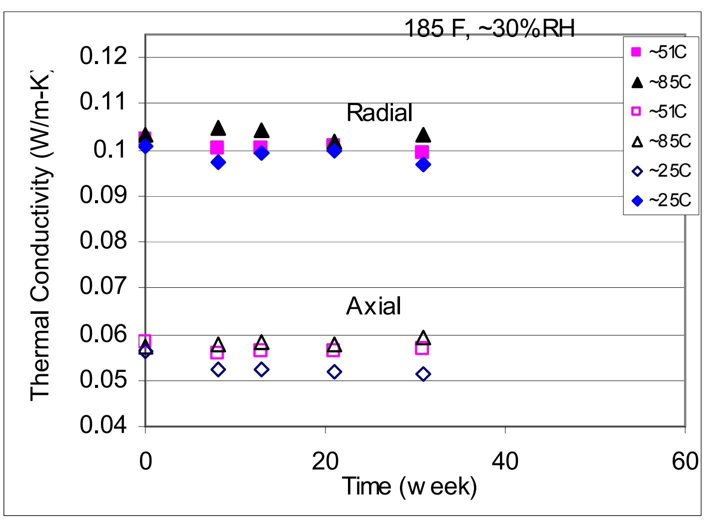
Figure 3. Compression stress-strain curves for softwood fiberboard samples, perpendicular orientation



(a)

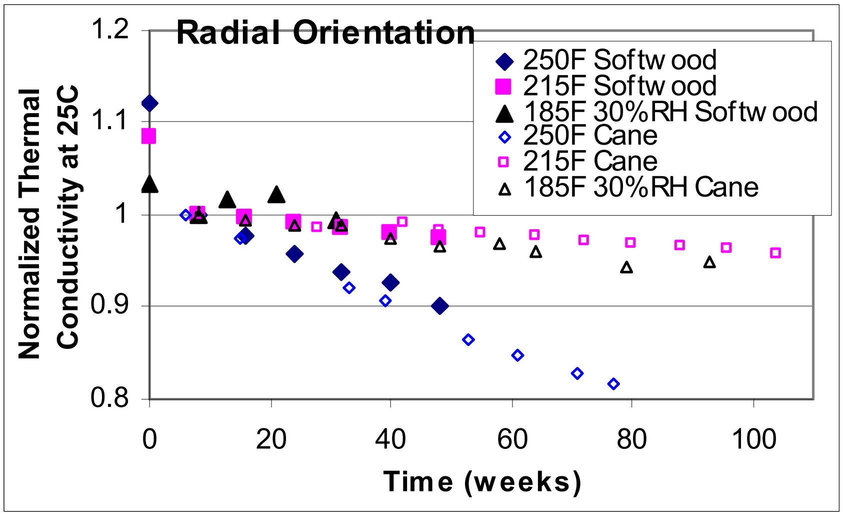


(b)

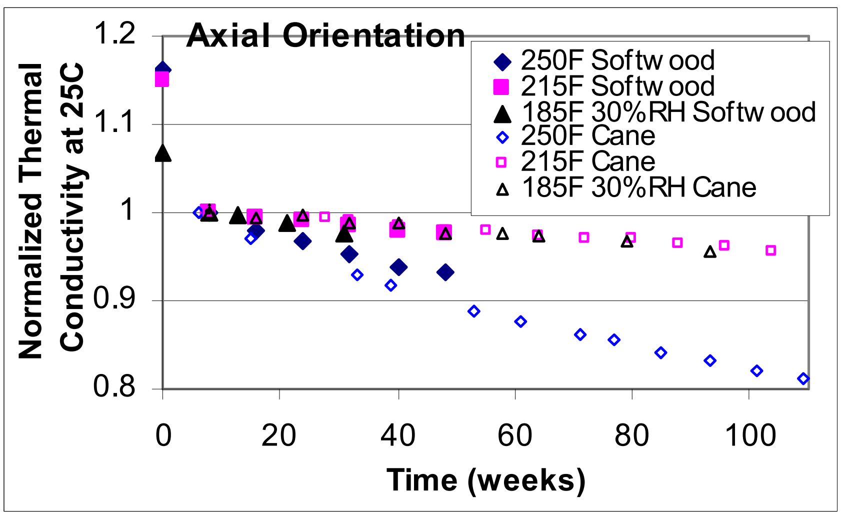


(c)

Figure 4. Thermal conductivity data for softwood fiberboard samples conditioned in 250F oven (a), 215F oven (b) and 185F 30%RH chamber (c)



(a) radial orientation



(b) axial orientation

Figure 5. Normalized thermal conductivity data for softwood fiberboard compared to data for cane fiberboard.

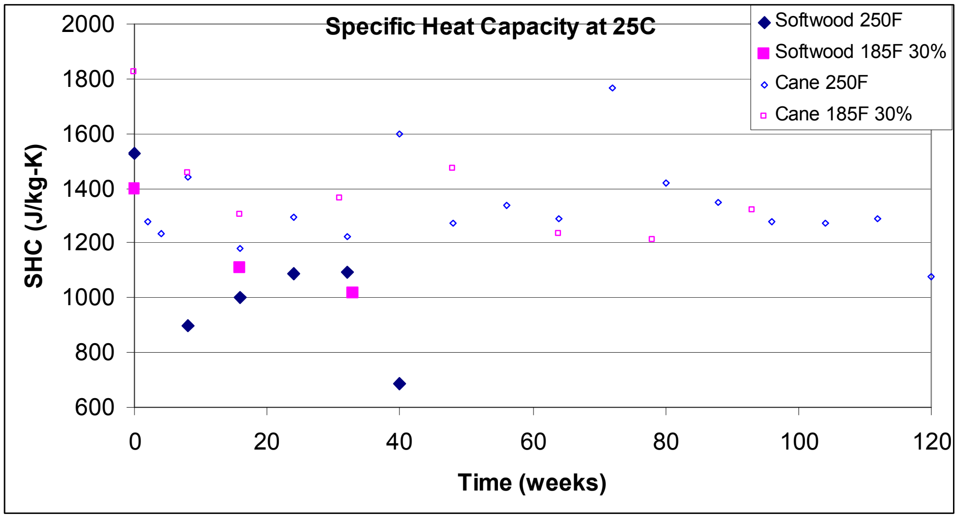
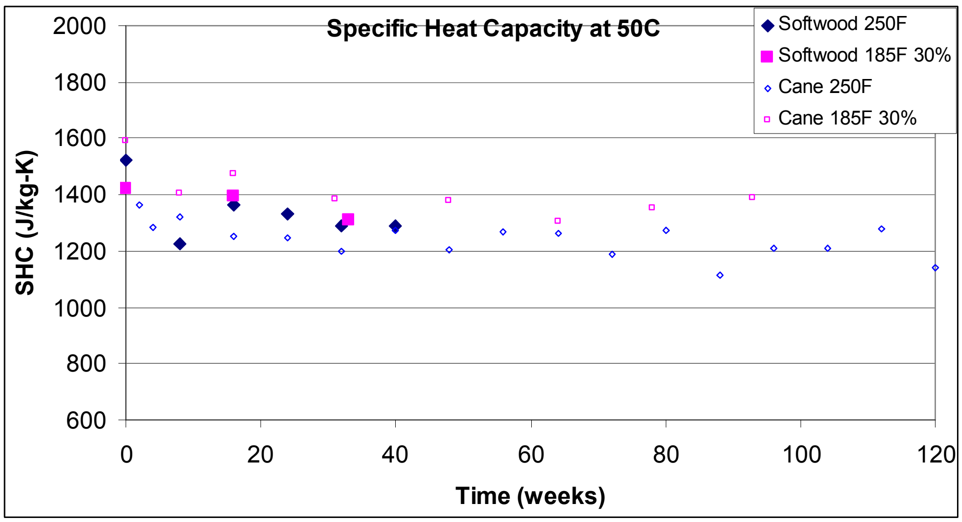


Figure 6. Specific heat capacity data for softwood fiberboard compared with cane fiberboard

(a) 25C mean temperature



(b) 50C mean temperature

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