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SECOND 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, with a few differences. On the positive side, the softwood fiberboard data to date shows less sample-to-sample variation in physical properties than cane fiberboard, and the thermal conductivity decreases at a slower rate at 250F for softwood fiberboard than for cane fiberboard. On the other hand, the softwood fiberboard physical property samples generally show degradation rates greater than cane fiberboard samples in the 185F 30%RH environment. Testing following additional conditioning will continue and the addition of samples in other elevated humidity environment(s) will be pursued to identify the extent of these trends.

Post-conditioning data have been measured on samples from 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 some portions of the data trends are skewed 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 to verify whether the long-term performance of these two materials in a storage environment is comparable.

A first status report on softwood fiberboard testing was issued previously [4] with test data following up to 48 weeks exposure in accelerated aging environments. Subsequent data and additional analysis are presented herein.

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 [5, 6]. 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. Several additional compression samples were added to each environment in December 2009 to provide replicate data points and longer exposures. A few of these samples remain in their 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 (relative to the package geometry). 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 inches 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 52C (77 and 125F).

Conditioning of 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, 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 mass loss samples are measured on an approximately weekly basis. These data (for one of each pair of samples) 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 of degradation between samples with different starting values. The rates of change in the weight, density and dimensions of these samples are summarized in Table 1 for all samples. Comparable rates 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. Typical stress-strain curves for softwood fiberboard samples tested in the parallel orientation are shown in Figure 2. 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 Figure 3, along with comparable data for cane fiberboard samples, for samples tested in the parallel orientation.

Typical stress-strain curves for softwood fiberboard samples tested in the perpendicular orientation are shown in Figure 4. Data on the area under the stress-strain curve to a strain of 40% are summarized in Figure 5, along with comparable data for cane fiberboard samples, for samples tested in the perpendicular orientation.

Thermal conductivity data for each sample are presented in Figure 6. 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 7, 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 7.

Specific heat capacity results are summarized in Figure 8. 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 8 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 which warrant further observation.

Softwood fiberboard samples conditioned at 185F 30%RH generally show a greater rate of degradation than cane fiberboard samples in the same environment. This has been seen in the following properties:

- The mass loss samples show a rate of weight and height loss of 0.3 to 0.6 %/year greater than the maximum rate seen for cane fiberboard samples. One of the two mass loss samples in this environment shows a rate of length & width loss of 0.3 %/year greater than the maximum rate seen for cane fiberboard samples. See Table 1.

- The compression test data for parallel orientation samples (Figure 3) show a greater decrease in strength for softwood fiberboard samples. Both compression test metrics decrease faster over time in this environment for softwood fiberboard samples than for cane fiberboard samples. This orientation is of greater relevance to storage of packages in KAMS, since it is the primary direction of impact in the postulated forklift impact scenario.
- The thermal conductivity of softwood fiberboard decreases slightly faster than that for cane fiberboard in the axial orientation (Figure 7b) in this environment.

The specific impact of these differences observed at 185F 30%RH is currently unknown. Since this is the only elevated humidity environment used for conditioning softwood fiberboard samples, it is possible that similar behavior may occur in other elevated humidity environments as well. Therefore, it is proposed that additional samples begin conditioning in additional elevated humidity environments. The specific additional environment(s) will be recommended through revision to the task technical plan [2]. It is also possible that these differences will decrease with longer exposure times. Therefore, existing softwood fiberboard samples will continue conditioning and testing.

In contrast to the behavior of samples conditioning at 185F 30%RH, the thermal conductivity samples (both orientations) conditioning at 250F have degraded at a slower rate than the corresponding cane fiberboard samples (Figure 7).

An apparent bias between softwood and cane fiberboard degradation is also seen in the specific heat capacity data at a mean temperature of 77F, but not in the data at a mean temperature of 125F. There is a greater degree of scatter in the specific heat capacity data for both materials at 77F, which results from the temperature of the water bath for each mean test temperature. For a mean temperature of 125F, the water bath is at ambient temperature and is less affected by heat loss to the room (the water bath is ~40F for a mean test temperature of 77F). Accordingly, the 125F data are considered more reliable, as reflected in their reduced scatter. These data show no difference in specific heat capacity behavior between softwood and cane fiberboard.

Variation has been seen in the properties of cane fiberboard, as illustrated in the comparative data shown in Table 1 (physical properties) and Figures 3 and 5 (compression strength). Similar variation has also been seen in thermal conductivity [7]. This reflects the inherent variability of this heterogeneous material. One would expect to find a similar variability in the properties of softwood fiberboard, although softwood fiberboard is more consistent in its range of fiber size and overall texture. For the current task, all softwood fiberboard samples were obtained from a single assembly, and do not provide any indication of the degree of variation that might exist in other assemblies.

Previous baseline testing [8] provides some indication of variation in softwood fiberboard properties. 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 samples from the current effort. Since the baseline compression strength of the softwood fiberboard from the current effort is similar to the average from cane fiberboard assemblies, the indication from these data is that softwood fiberboard may be weaker, on average, than cane fiberboard. It is recommended that softwood fiberboard samples from additional assemblies be tested (with and without aging) when they become available.

Conclusions

Overall, similar aging trends are observed for softwood and cane fiberboard samples, with a few differences. On the positive side, the softwood fiberboard data to date shows less sample-to-sample variation in physical properties than cane fiberboard, and the thermal conductivity decreases at a slower rate at 250F for softwood fiberboard than for cane fiberboard. On the other hand, the softwood fiberboard physical property samples conditioning at 185F 30%RH generally show degradation rates greater than cane fiberboard samples in this environment. The differences seen in the 185F 30%RH environment are large enough to warrant continuation of the current testing of softwood fiberboard. The additional conditioning of softwood fiberboard samples in other elevated humidity environment(s) is recommended. Current samples will also remain in test to accumulate longer exposure times.

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 from additional softwood fiberboard assemblies should 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] SRNL-TR-2009-00475, "First Status Report: Testing of Aged Softwood Fiberboard Material for the 997 Shipping Package", W. L. Daugherty, January 2010.

[5] 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.

[6] 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.

[7] SRNL-SCS-2008-00054, "Statistical Analysis Fiberboard Thermal Conductivity Test Results", S. P. Harris, August 27, 2008.

[8] 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 (2 samples) vs cane fiberboard (range of 7 - 12 samples per environment) over the stated duration

			Softwood Fiberboard	Cane Fiberboard
Property	Environment	Duration of Data (days)	Rate of Change (%/yr)	Rate of Change (%/yr)
Weight	250F, dry	687	-14.84, -14.68	-18.24 to -13.74
	215F, dry	679	-3.89, -3.72	-3.99 to -3.15
	185F, dry	697	-1.37, -1.34	-2.71 to -1.01
	185F, 30%RH	458	**-6.71, -6.45**	-6.15 to -3.74
Density	250F, dry	687	-7.79, -7.32	-11.00 to -7.32
	215F, dry	679	-1.31, -1.17	-2.93 to +1.02
	185F, dry	697	+0.06, +0.28	-1.29 to +1.19
	185F, 30%RH	452	-1.87, -1.40	-3.57 to -1.18
Height	250F, dry	687	-6.93, -6.53	-6.98 to -4.81
	215F, dry	679	-1.79, -1.54	-2.95 to -1.00
	185F, dry	697	-1.09, -0.76	-1.50 to -0.29
	185F, 30%RH	470	**-2.79, -2.66**	-2.18 to -1.06
Length, Width	250F, dry	687	-0.89, -0.77	-3.00 to -0.62
	215F, dry	673	-0.57, -0.54	-1.31 to +0.36
	185F, dry	697	-0.91, -0.34	-0.91 to +0.18
	185F, 30%RH	470	**-0.94**, -0.48	-0.58 to +0.19

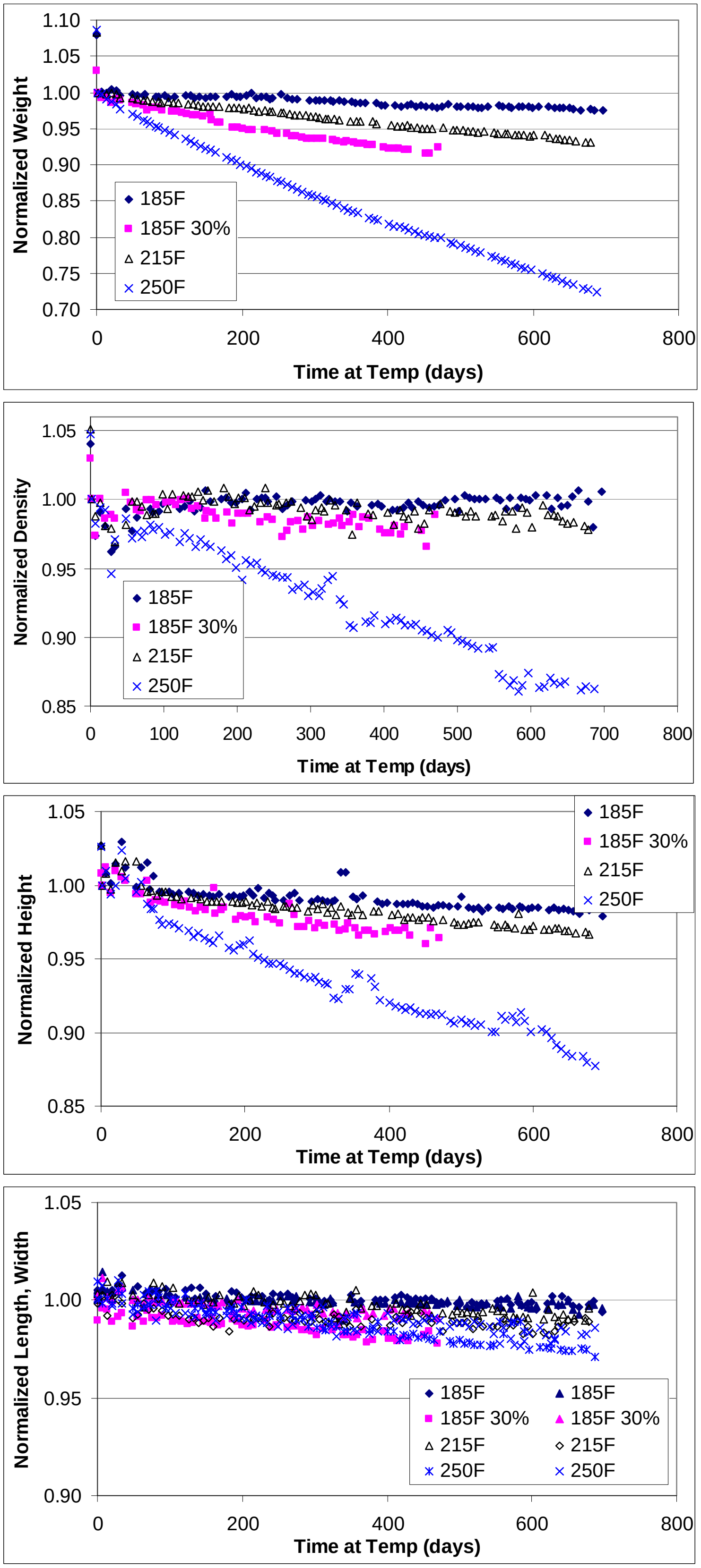


Figure 1. Normalized physical data for softwood fiberboard mass loss samples.

(a) Weight change

(b) Density change

(c) Height change

(d) Length / width change

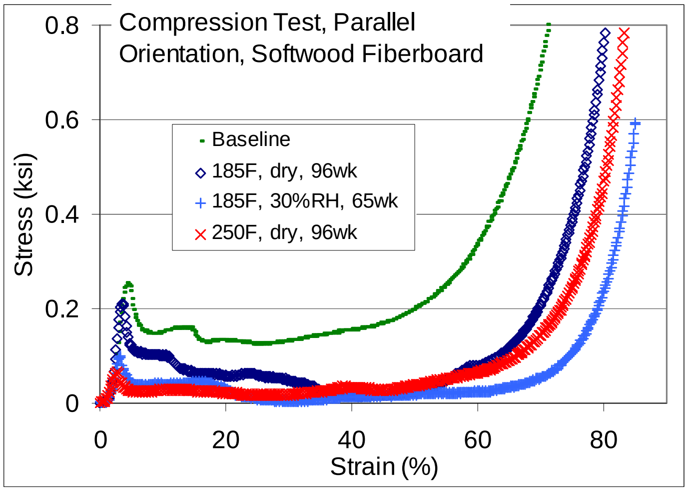


Figure 2. Typical compression stress-strain curves for softwood fiberboard samples, parallel orientation

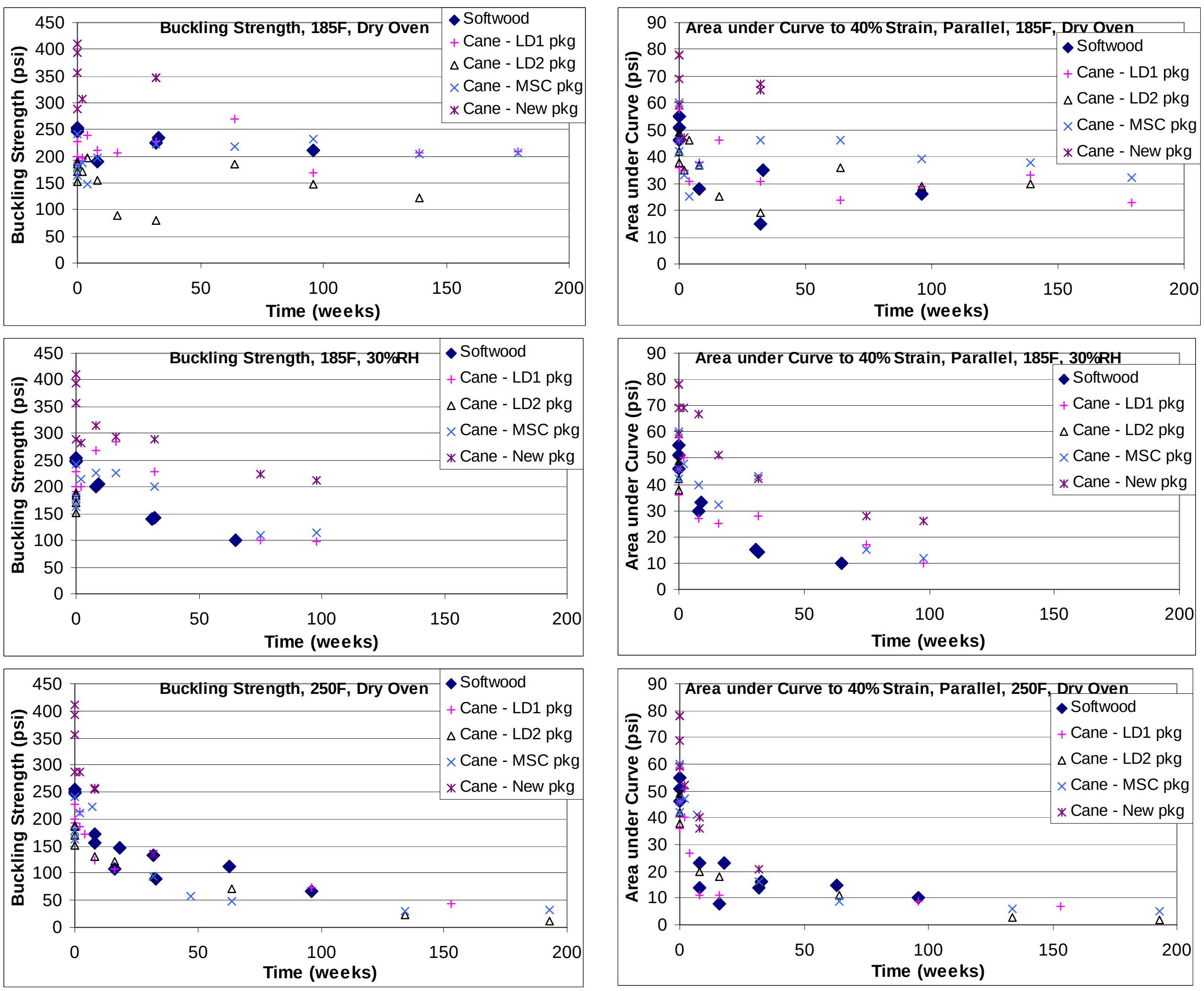


Figure 3. Compression test metrics (buckling strength, area under curve to 40% strain) for parallel orientation samples.

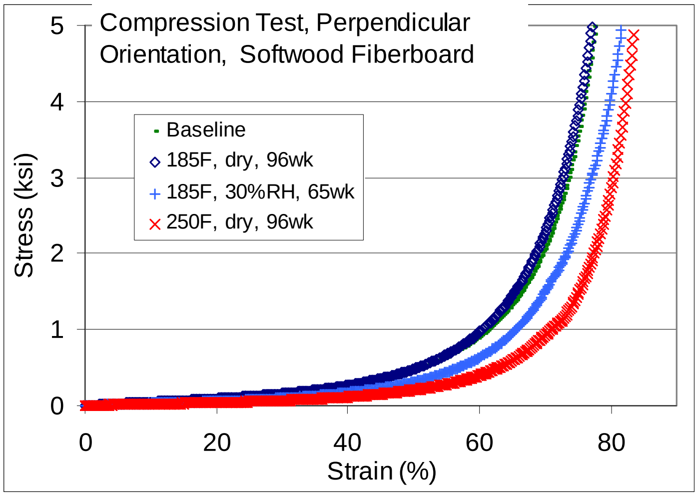


Figure 4. Typical compression stress-strain curves for softwood fiberboard samples, perpendicular orientation

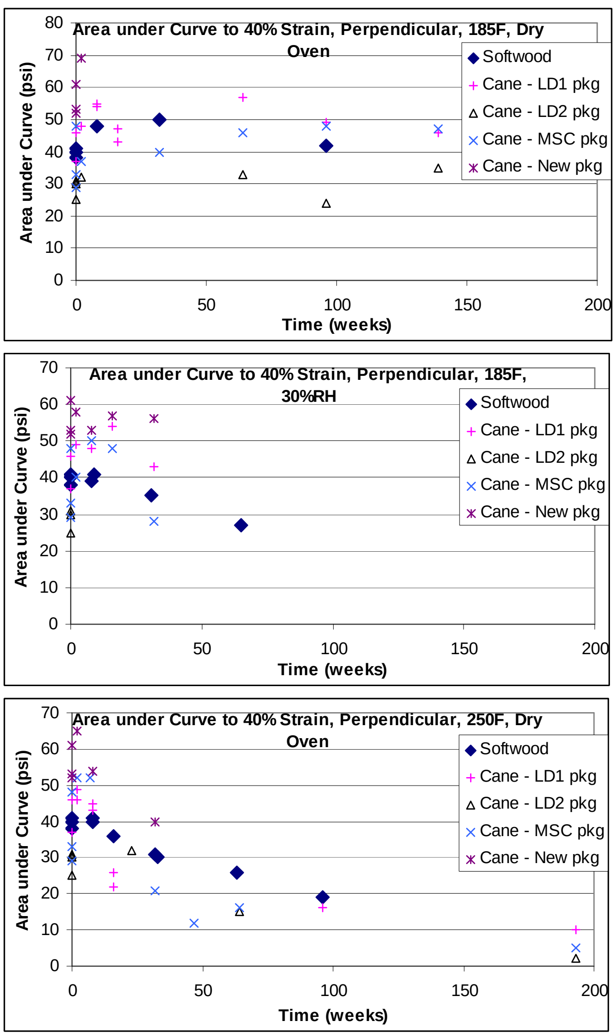


Figure 5. Compression test metric (area under curve to 40% strain) for perpendicular orientation samples.

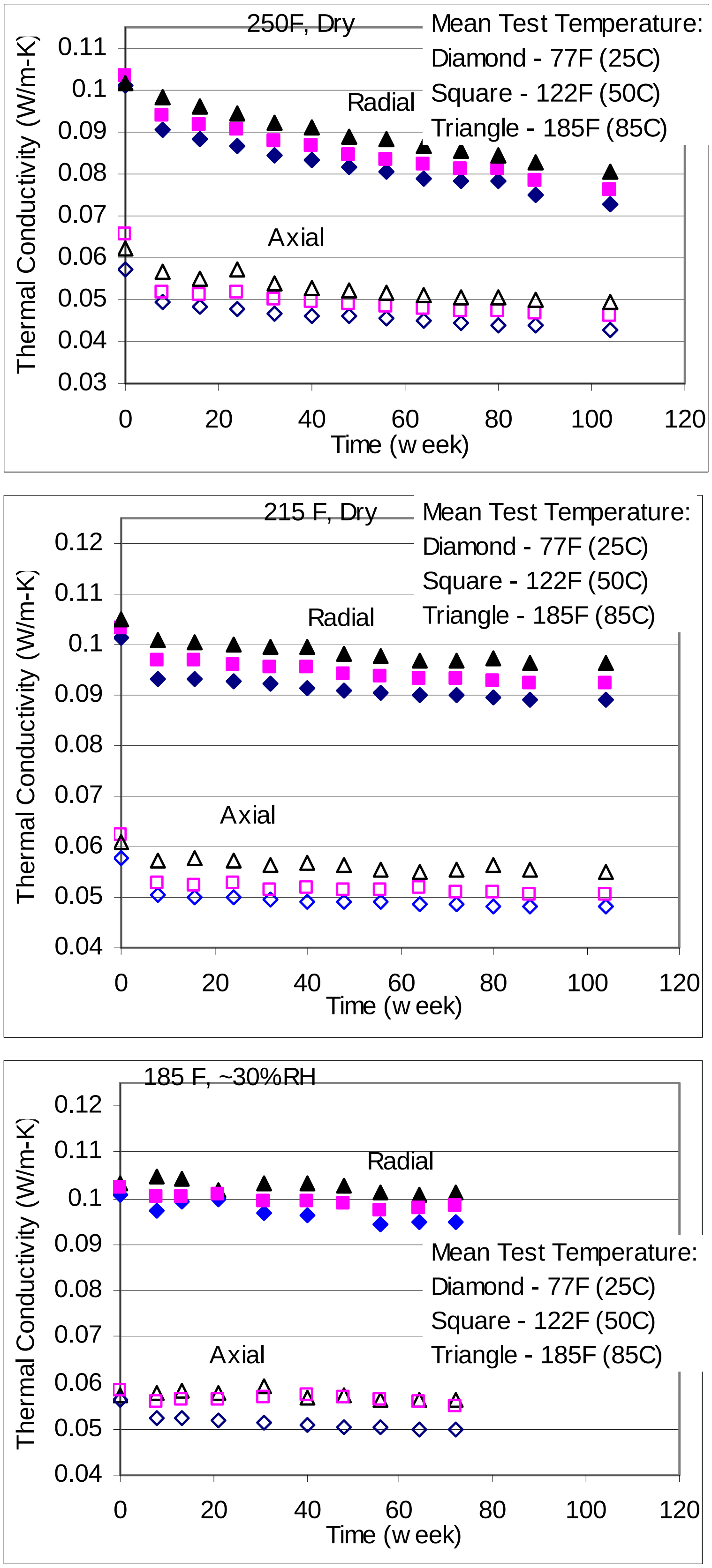
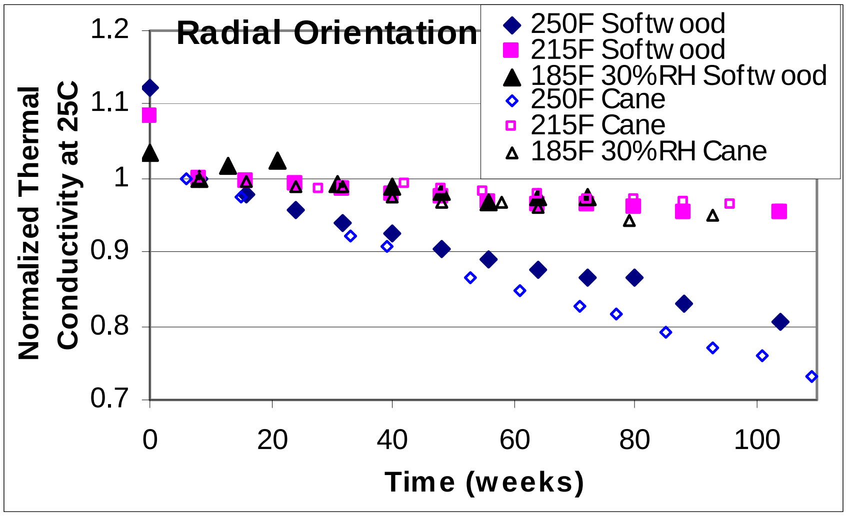


Figure 6. Thermal conductivity data for softwood fiberboard samples conditioned in:

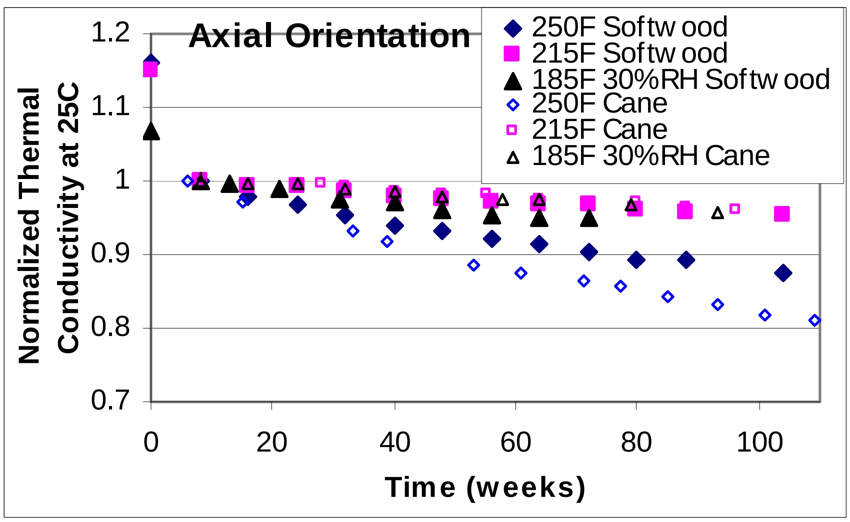
(a) 250F oven,

(b) 215F oven, and

(c) 185F 30%RH chamber



(a) radial orientation



(b) axial orientation

Figure 7. Normalized thermal conductivity data for softwood fiberboard compared to data for cane fiberboard.

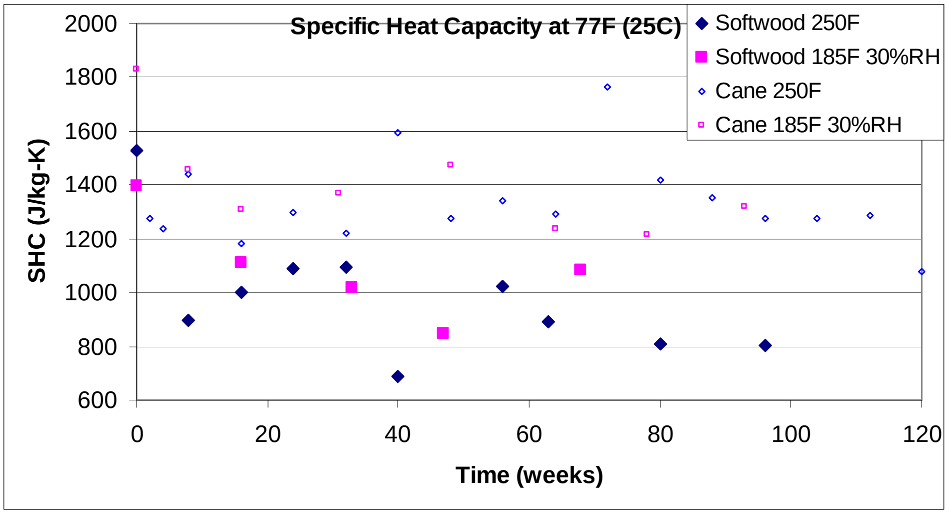
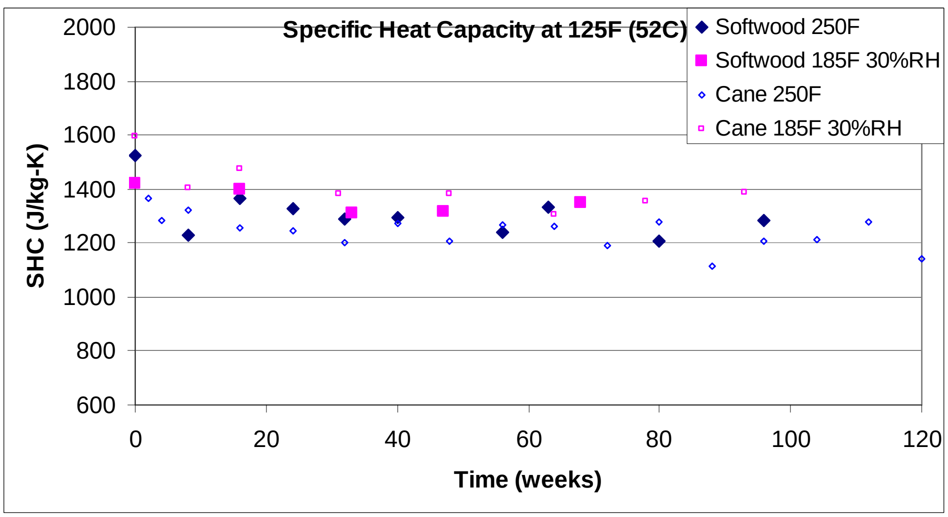


Figure 8. Specific heat capacity data for softwood fiberboard compared with cane fiberboard

(a) 25C mean temperature



(b) 52C mean temperature

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