A Structural Comparison of the Glasswood Fusion Product TimberSIL and Regular Lumber

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Figure 1: 3-point Loading Testing

Introduction:

For the purpose of product evaluation the company TimberSIL provided the FDOT Structures Research Center with twelve beam specimens each being 12 feet in length. TimberSIL is a non-toxic, non-leaching wood sealant and protectant that is of interest to the department for its structural timbers used for impact railings and wales for boat paths under bridges. Half the specimens had cross-section dimensions of 4"x6" and the other half had cross-section dimensions of 6"x8". Out of the six 4"x6" specimens and six 6"x8" specimens three of each had been fused with glass in a process that infuses flexible glass layers around the wood fibers. These three specimens were the actual TimberSIL product; the other remaining specimens were regular pine wood which are referred to as control or untreated specimens. Testing of the beams was performed on April 6th – 9th of 2010. All beams were simply supported and tested in 3-point bending with the load being applied at midspan as shown in Figures 1 and 2. The test setup and all testing procedures followed were in accordance with ASTM D198.

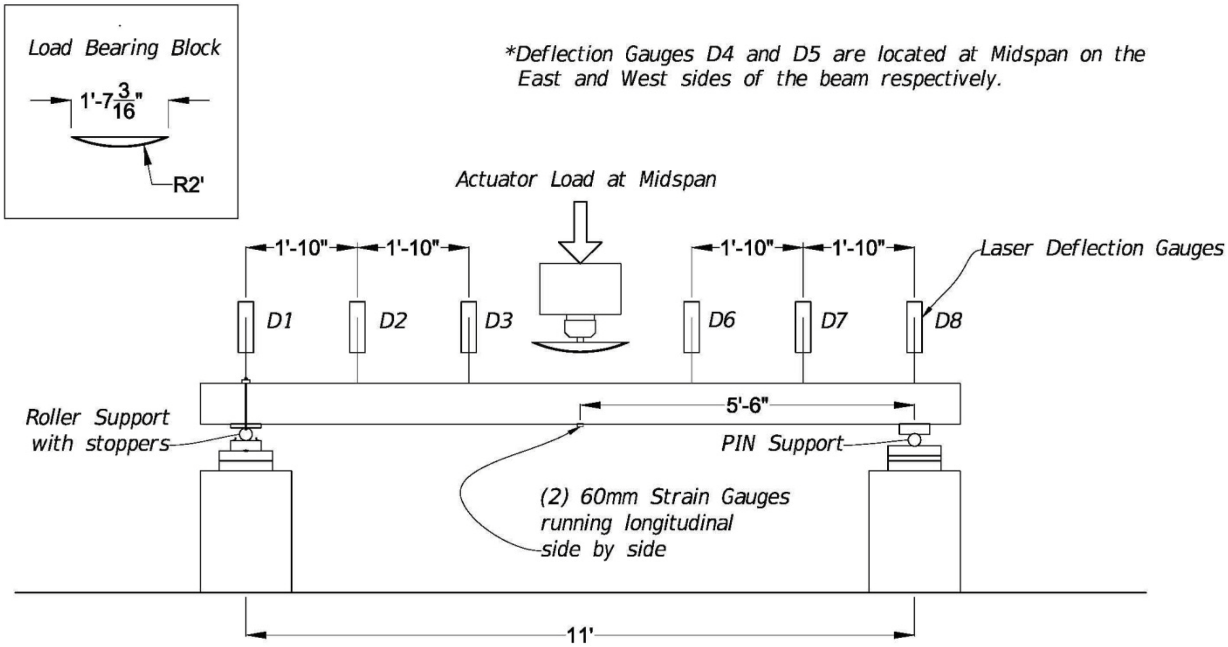


Figure 2: 3-point Loading Test Setup

Figure 3: North Roller Support (left) and South Rocker Support (right)

Results:

The tests were performed in the FDOT Research Center Laboratory using a deflection controlled load rate. The rate of loading for all specimens was approximately 0.004 inch per second. The six 4"x6" specimens were cycled to a load just over 2 kips five times before being loaded a sixth time to failure. The six 6"x8" specimens were loaded once only and they were all taken to failure. The failure data as well as the Modulus of Rupture (S_r) and Apparent Modulus of Elasticity (E_f) are listed in Tables 1 & 2. The pertinent graphs from the data that was collected are shown in Figures 4-16. Raw data can be furnished upon request.

Table 1: Test Data and Structural Results of 4”x6” Specimens

Sample #	Ultimate Load F_u (kip)	Deflection at Ultimate Load (in)	Strain* at Ultimate Load	Modulus of Rupture (psi)	Modulus of Elasticity** (psi)
Control 1	7.829	3.121	6855	1.076×10^4	2.412×10^6
Control 2	6.144	5.032	8647	8.448×10^3	1.438×10^6
Control 3	6.342	4.387	9187	8.721×10^3	2.074×10^6
TimberSIL 1	6.513	4.878	11970	8.956×10^3	1.505×10^6
TimberSIL 2	7.14	3.054	6072	9.818×10^3	2.204×10^6
TimberSIL 3	6.568	4.700	11700	9.031×10^3	1.642×10^6

*** Strain is reported in microstrain averaged from the side by side 60mm foil gauges at midspan**

**** This Modulus of Elasticity is the Apparent Modulus of Elasticity (E_f), includes some shear distortion**

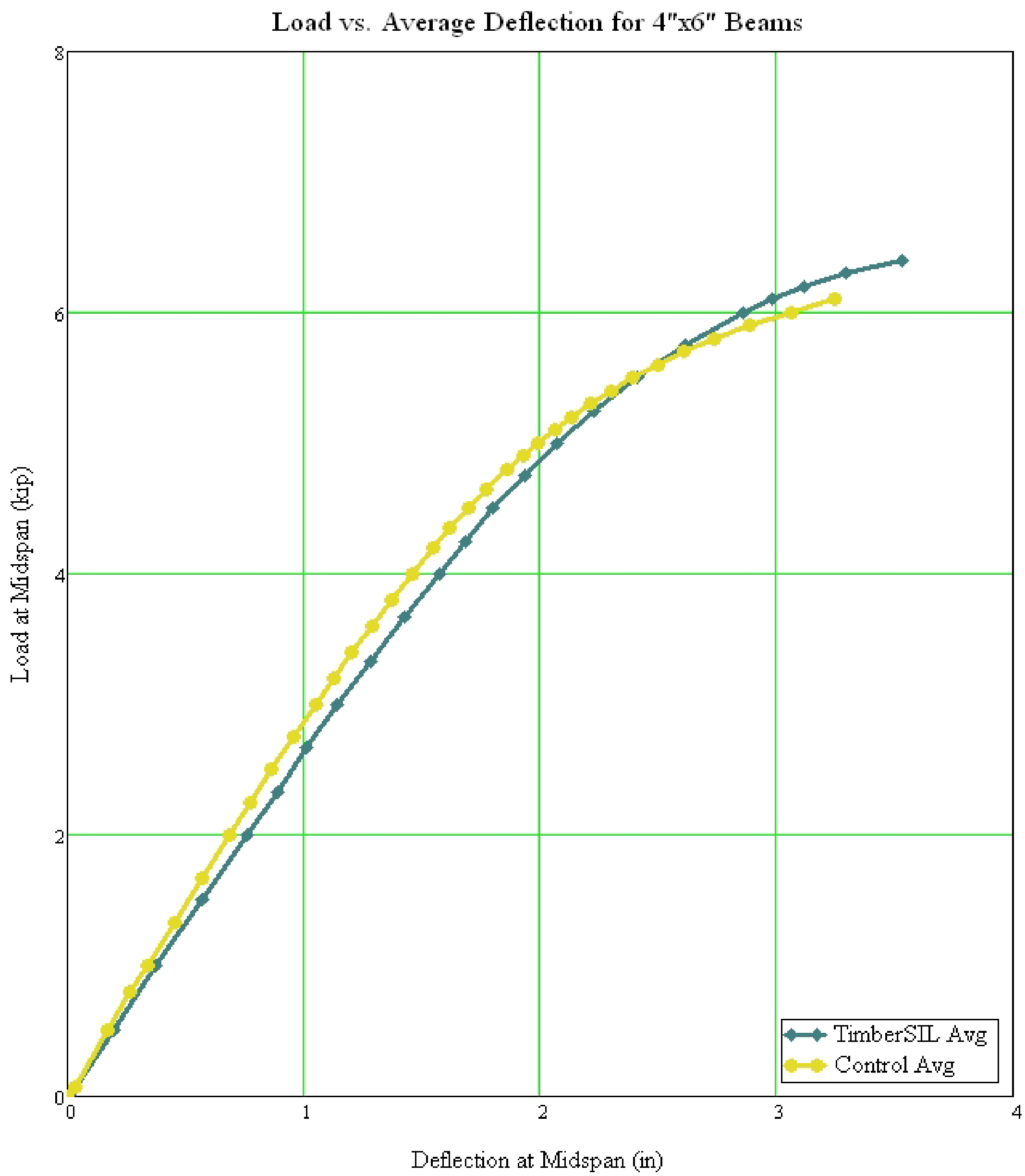


Figure 4: Average Load vs. Deflection Curves for 4x6 Beams

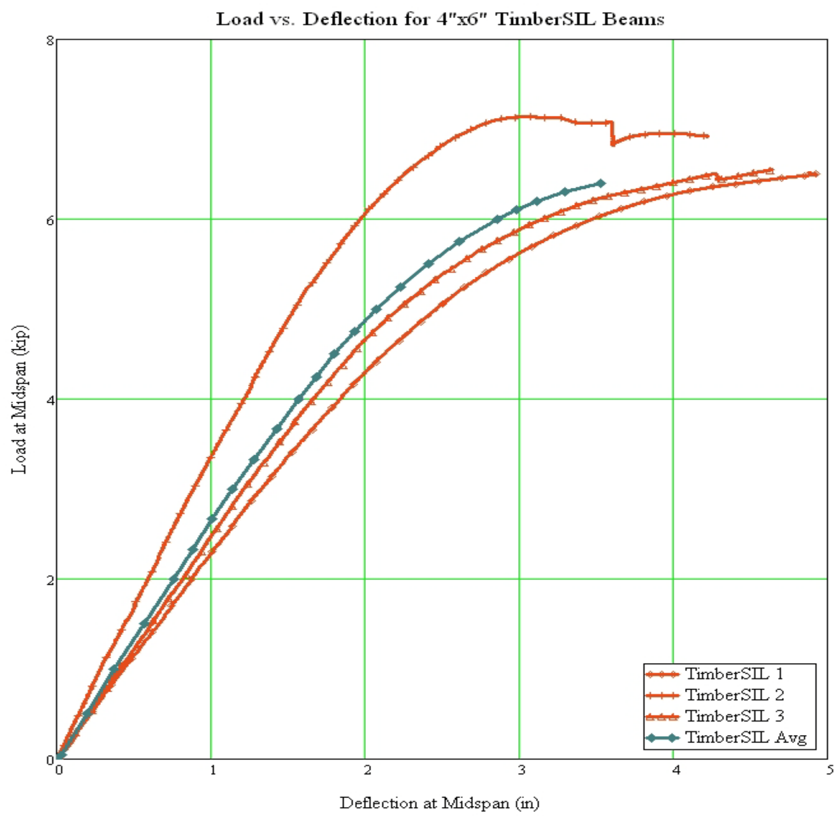


Figure 5: Deflection Curves for 4x6 TimberSIL Specimens

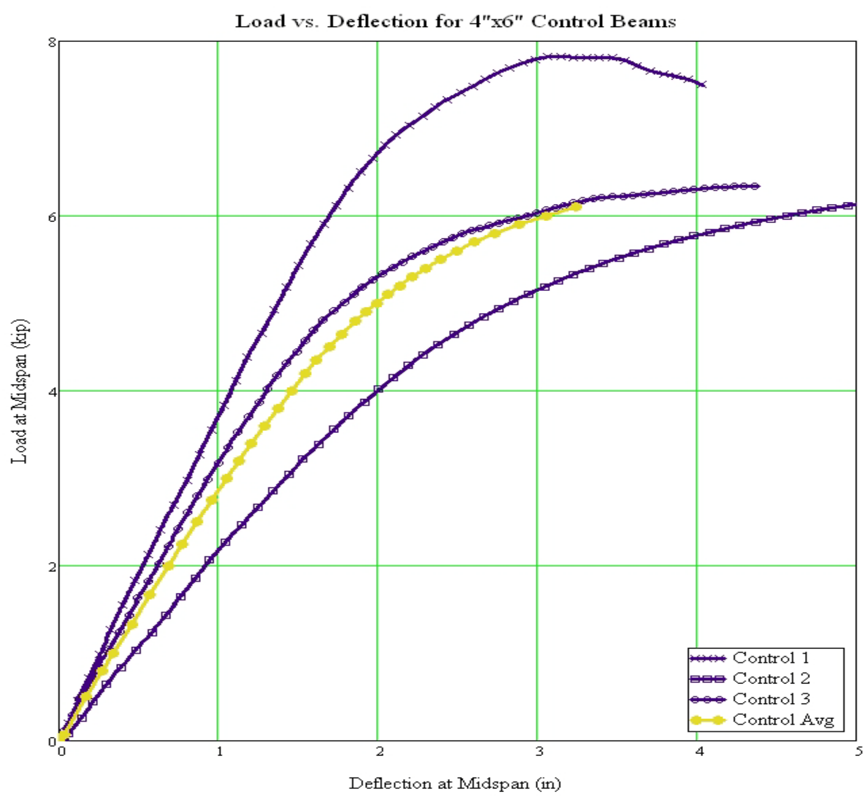


Figure 6: Deflection Curves for 4x6 Control Specimens

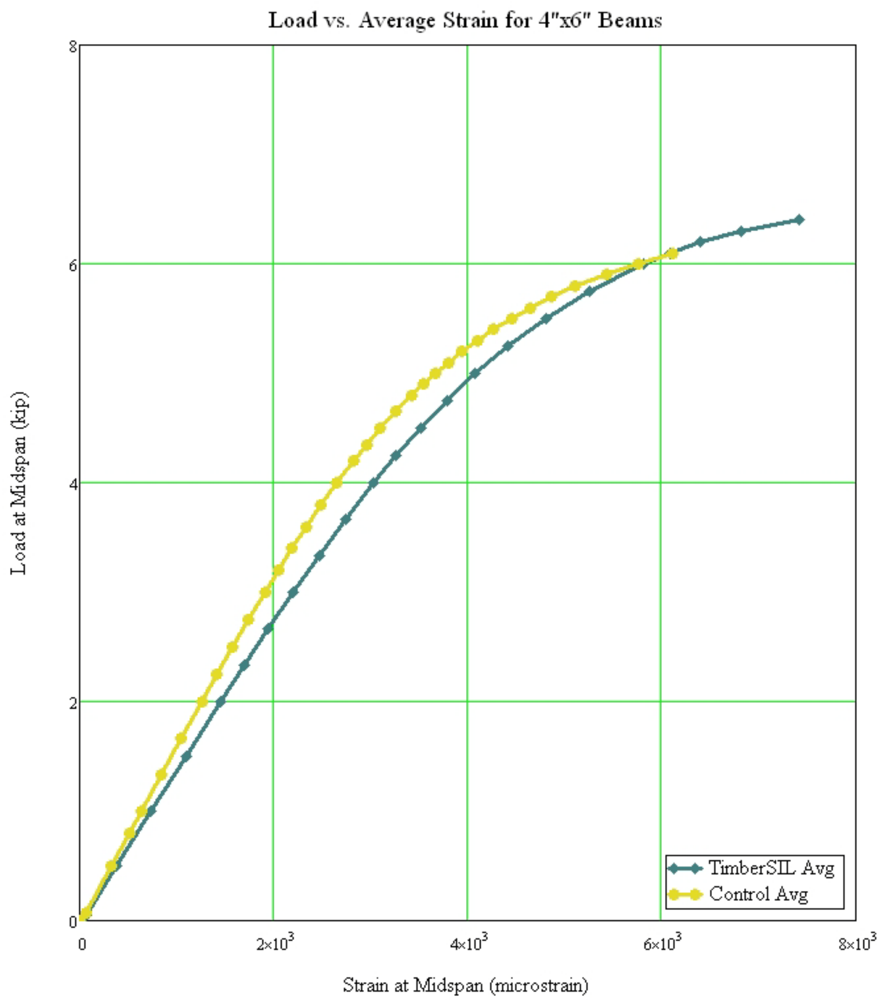


Figure 7: Average Load vs. Strain Curves for 4x6 Beams

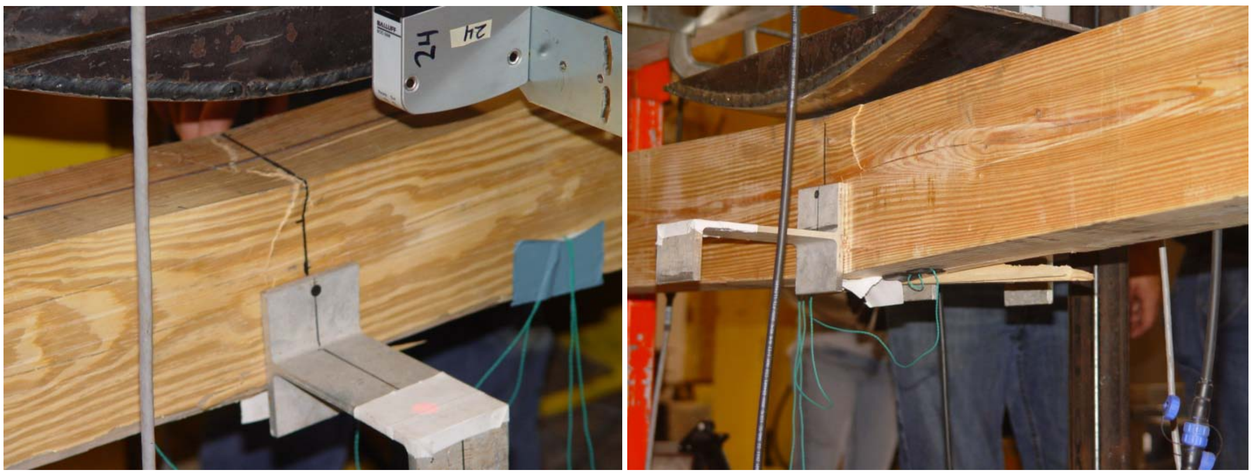


Figure 8: Failure of a 4x6 Beam

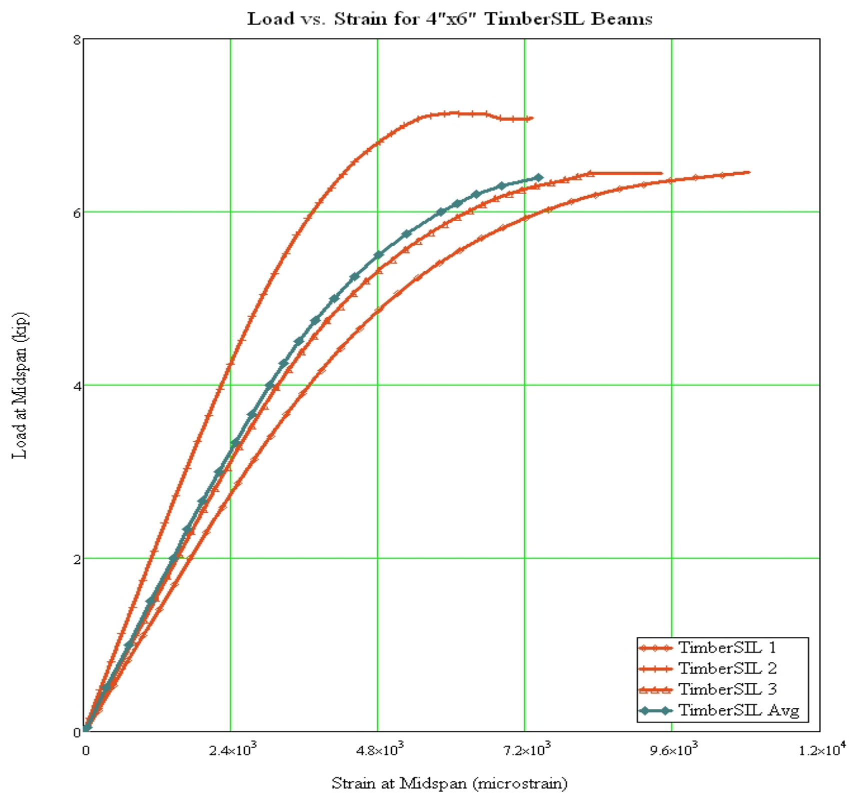


Figure 9: Strain Curves for 4x6 TimberSIL Beams

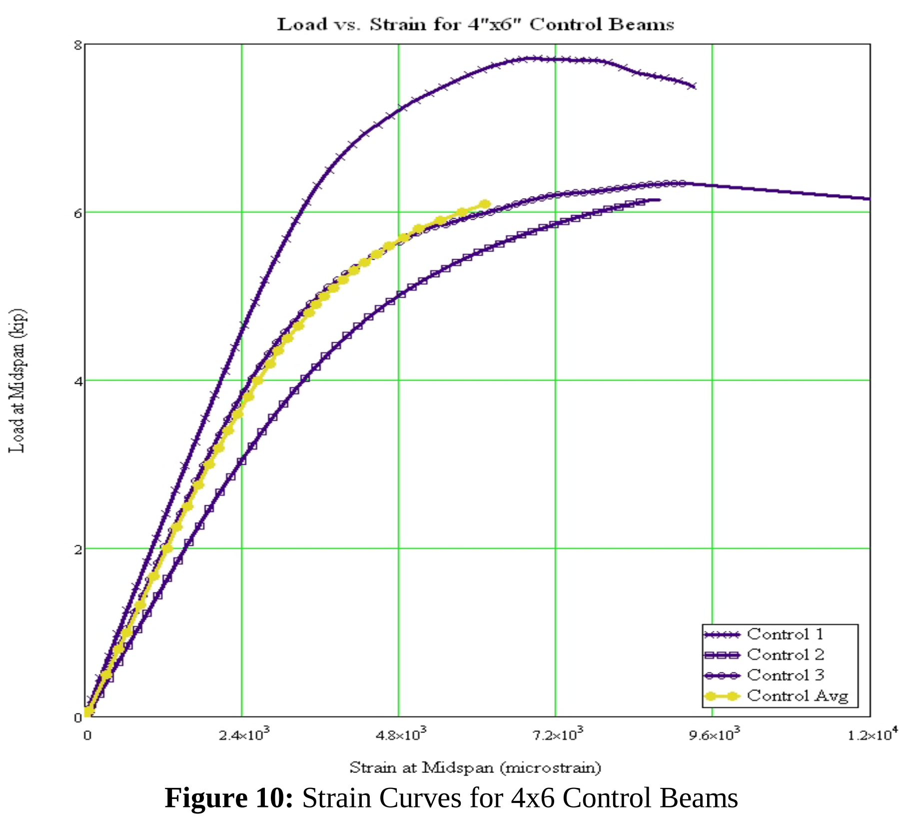


Figure 10: Strain Curves for 4x6 Control Beams

Table 2: Test Data and Structural Results of 6”x8” Specimens

Sample #	Ultimate Load F_u (kip)	Deflection at Ultimate Load (in)	Strain* at Ultimate Load	Modulus of Rupture (psi)	Modulus of Elasticity** (psi)
Control 1	19.279	2.541	6477	9.941×10^3	2.036×10^6
Control 2	16.14	4.015	9149	8.322×10^3	1.553×10^6
Control 3	11.056	1.663	- -	5.701×10^3	1.430×10^6
TimberSIL 1	16.991	3.284	8931	8.761×10^3	1.558×10^6
TimberSIL 2	18.861	2.935	8301	9.725×10^3	1.714×10^6
TimberSIL 3	14.167	2.309	5555	7.305×10^3	1.601×10^6

*** Strain is reported in microstrain averaged from the side by side 60mm foil gauges at midspan**

**** This Modulus of Elasticity is the Apparent Modulus of Elasticity (E_f), includes some shear distortion**

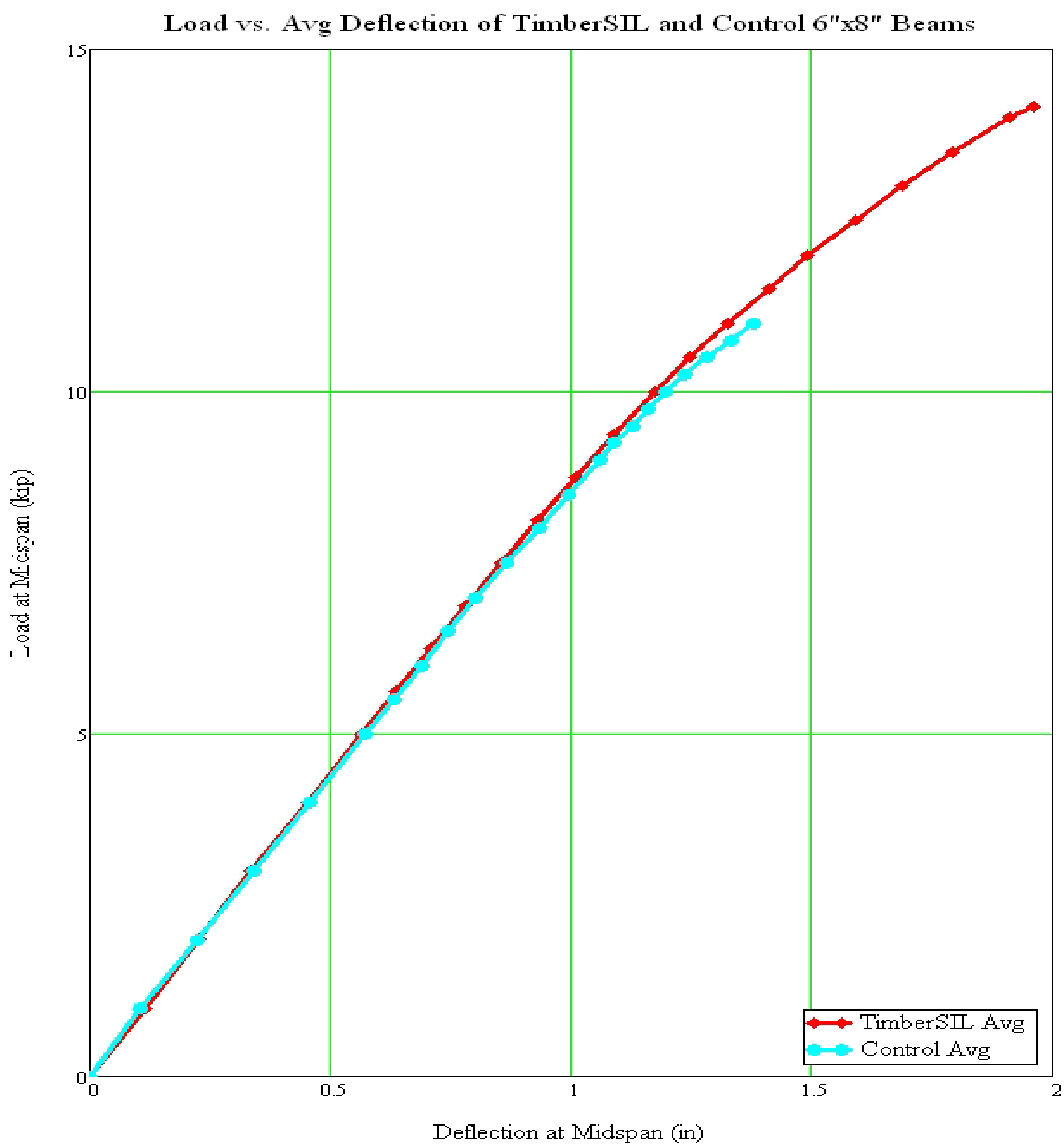


Figure 11: Load vs. Deflection Curves for 6x8 Beams

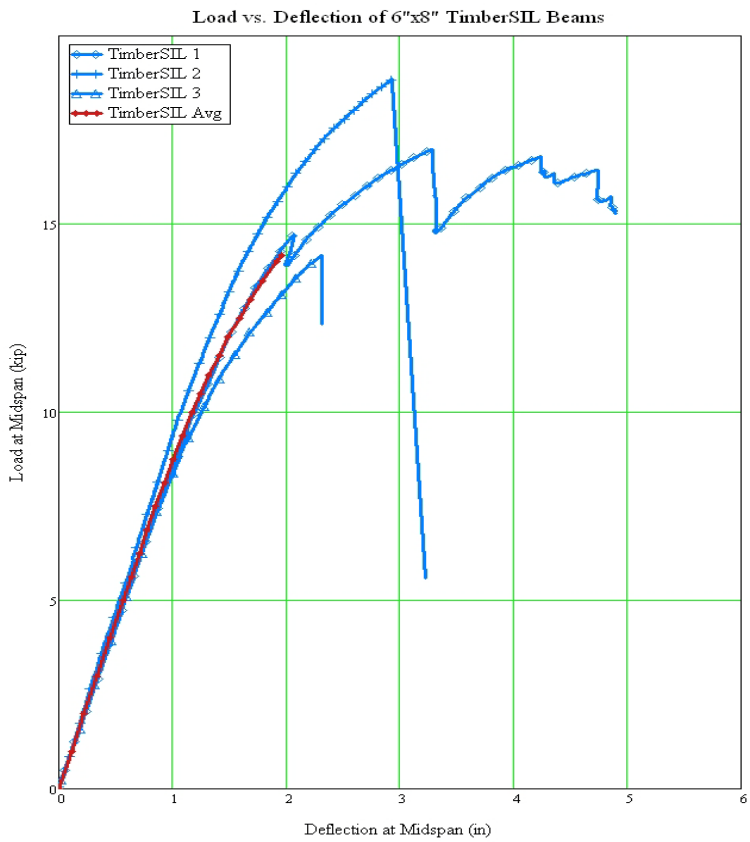


Figure 12: Deflection Curves for 6x8 TimberSIL Beams

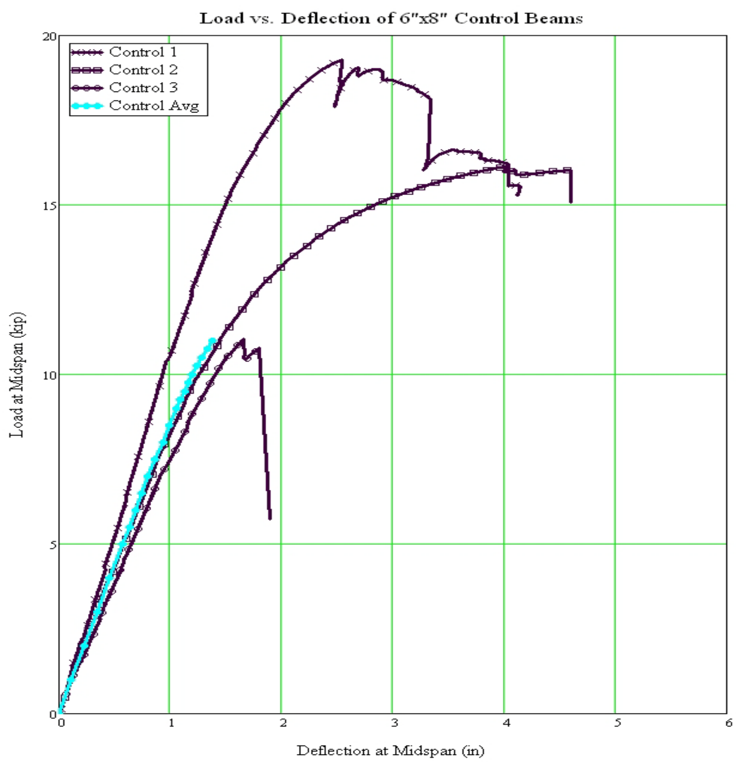


Figure 13: Deflection Curves for 6x8 Control Beams

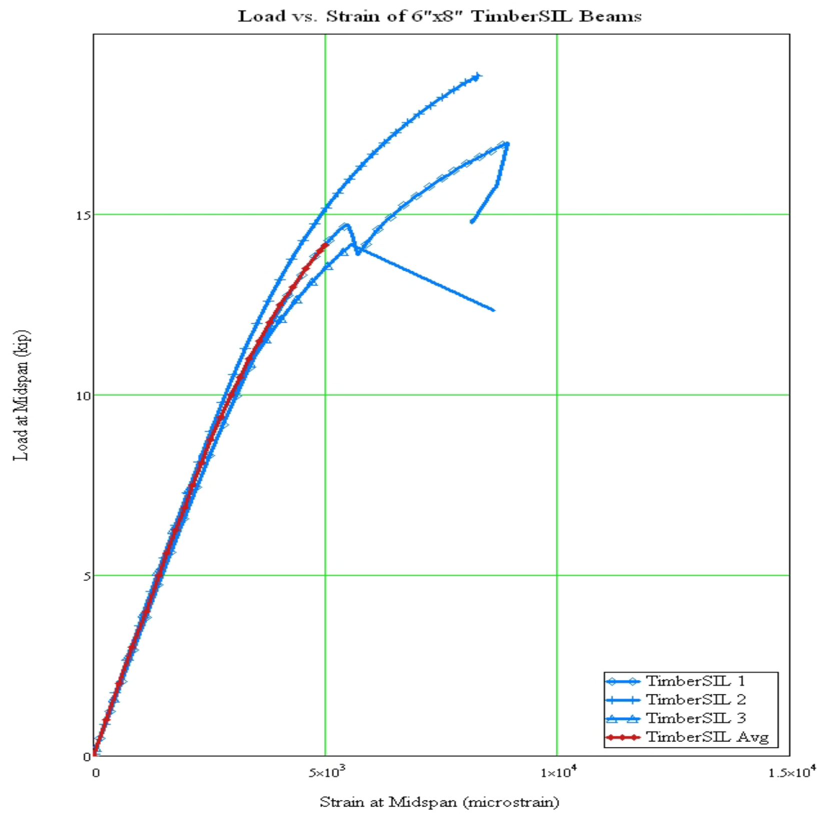


Figure14: Strain Curves for 6x8 TimberSIL Beams

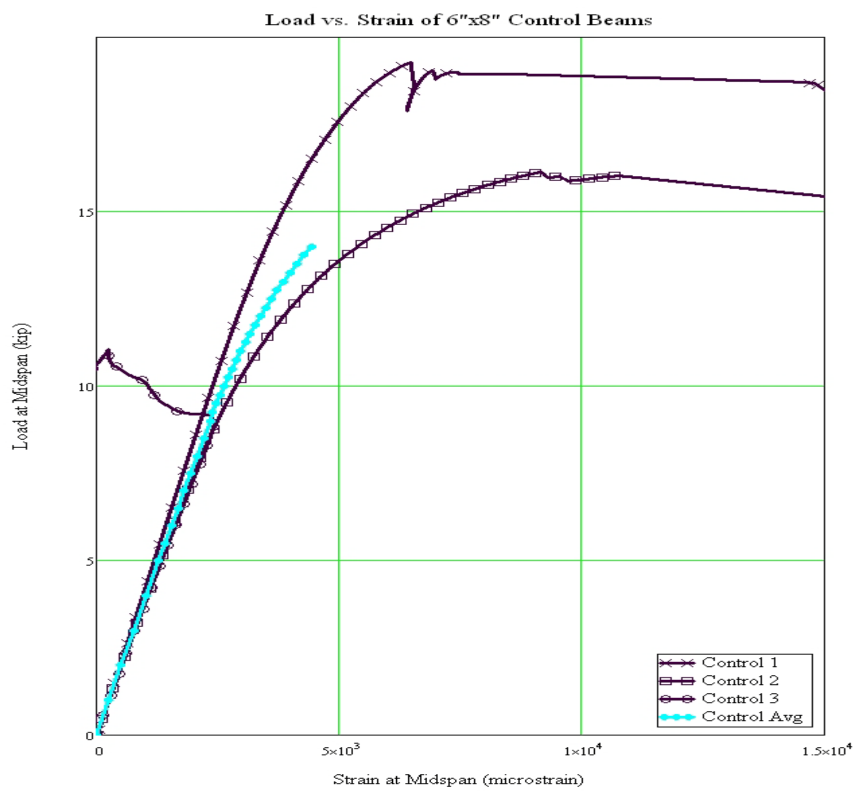


Figure 15: Strain Curves for 6x8 Control Beams

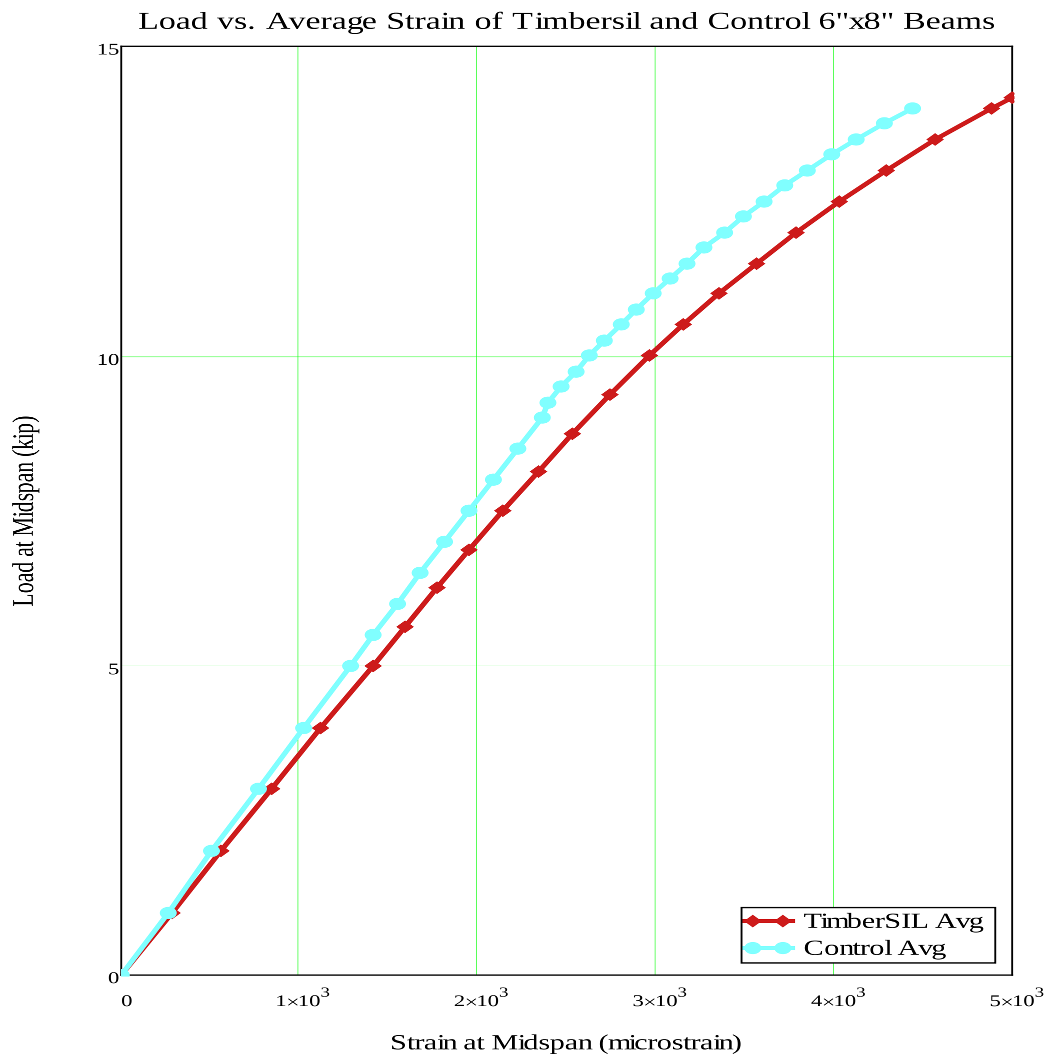


Figure 16: Average Load vs. Strain Curves for 6x8 Beams

<u>Discussion</u>:

The graphs and data show that the addition of the TimberSIL glass fusion to wood beams results in no identifiable increase of structural properties in a flexure setting. It is also obvious that the addition of the glass fusion sealant has no detrimental effects to the structural integrity of the wood. From a structural stand point the only difference between the TimberSIL specimens and the regular control specimens was that the mechanical properties of the TimberSIL appeared to be more consistent but more extensive testing would need to be done to confirm this. Table 3 shows the standard deviation and coefficient of variance for the data given in Tables 1 & 2. In Figure 15 the Control 3 sample shows that its strain gauges debonded during testing which is why strain data for Control 3 was left off of Tables 2 & 3. The strain data from the remaining two samples was still used in the averaging curve seen in Figure 16. Most likely since Control samples 2 & 3 were so close to each other before the gauge on Control 3 debonded the second half of the averaging curve in Figure 16 would actually be closer to the TimberSIL curve.

Table 3: Standard Deviation and Coefficient of Variance for Structural Data

Specimen Type		Ultimate Load		Deflection at Ultimate Load		Strain at Ultimate Load		Modulus of Rupture		Modulus of Elasticity	
		Std Dev (kip)	COV	Std Dev (in)	COV	Std Dev (microstrain)	COV	Std Dev (psi)	COV	Std Dev (psi)	COV
4x6	Control	0.921	0.136	0.972	0.233	1221	0.148	1263	0.136	494539	0.250
	TimberSIL	0.347	0.051	1.005	0.239	3330	0.336	478	0.052	370408	0.208
6x8	Control	4.149	0.268	1.188	0.434	1889*	0.242*	2140	0.268	320326	0.191
	TimberSIL	2.363	0.142	0.494	0.174	1795	0.236	1218	0.142	80575	0.05

* only two data points were used in the creation of these numbers

Figure 17: Use of Phenol Red in Identification of TimberSIL Product vs. Regular Wood
TimberSIL below regular wood (left), Regular Wood corner view (middle), TimberSIL corner view (right)

Identification:

Identification of the TimberSIL product in the field can be a problem because the sealant does not stain the wood or change the appearance of the wood. This can leave contractors and engineers wondering if timbers delivered to a job site have actually been treated with TimberSIL or are just regular wood. Figure 17 shows an example of a simple field test that was suggested by the manufacturer to identify that the product received is actually TimberSIL. The pH indicator solution Phenol Red was dripped on both control and TimberSIL specimens. In the left picture of Figure 17 the top beam is untreated wood and the bottom beam is TimberSIL. The Phenol Red soaks into the untreated wood and turns an orange-yellow color. On the TimberSIL product the Phenol Red will turn from its initial red color to a dark magenta as it dries. The dot in the middle of the two beams in Figure 17 (left) was applied three days prior to the picture being taken. The dots on either side were applied about a minute before the picture was taken. Care must be taken not to apply the Phenol Red to a damaged or cut portion of a timber when testing for the existence of TimberSIL. Looking at the middle and right pictures of Figure 17 it is hard to tell from the corner cut if TimberSIL is present or not. This is because cutting or scrapping the wood can damage or remove the fused glass at the surface of that location allowing the Phenol Red to penetrate the bare wood fibers.

Further investigation with Phenol Red led to varied results. Figure 18 shows two 6”x8” beams sitting side by side. The beam on the left was labeled as being TimberSIL from the manufacturer and the beam on the right was labeled as control. It is shown that both beams appear to identify as TimberSIL on the left, longitudinal half of the beams and as untreated wood on the right half. The Phenol Red was applied to these two wood pieces at the same time and about 15 minutes prior to the photograph being taken. The two beams have been sitting next to each other in an air conditioned room for three months. Therefore the relative moisture levels in the beams should be the same; there was also no foreign water on these beams at time the Phenol Red was applied.

Figure 18: Variable Phenol Red Results: TimberSIL (left), Control (Right)

Because the experimental results of all tested beams failed to show any definitive difference between TimberSIL and untreated wood and the Phenol Red test produced varied results another method was utilized to prove the beams marked Test had indeed been treated with TimberSIL. Verification of the TimberSIL product was achieved by the use of a scanning electron microscope (SEM) courtesy of the Florida Geological Survey located in Tallahassee, FL.

Using a box cutter shavings were taken from four beams and were later turned into samples to be scanned by the SEM. Two of the sampled beams had a 4”x6” cross-section the other two were 6”x8”. Of the 4x6 and 6x8 beams one was marked TimberSIL and the other was marked as Control. A small portion of the shavings were coated in carbon and scanned in the SEM. Figures 19-26 show the results and verify that the TimberSIL treated beams were received.

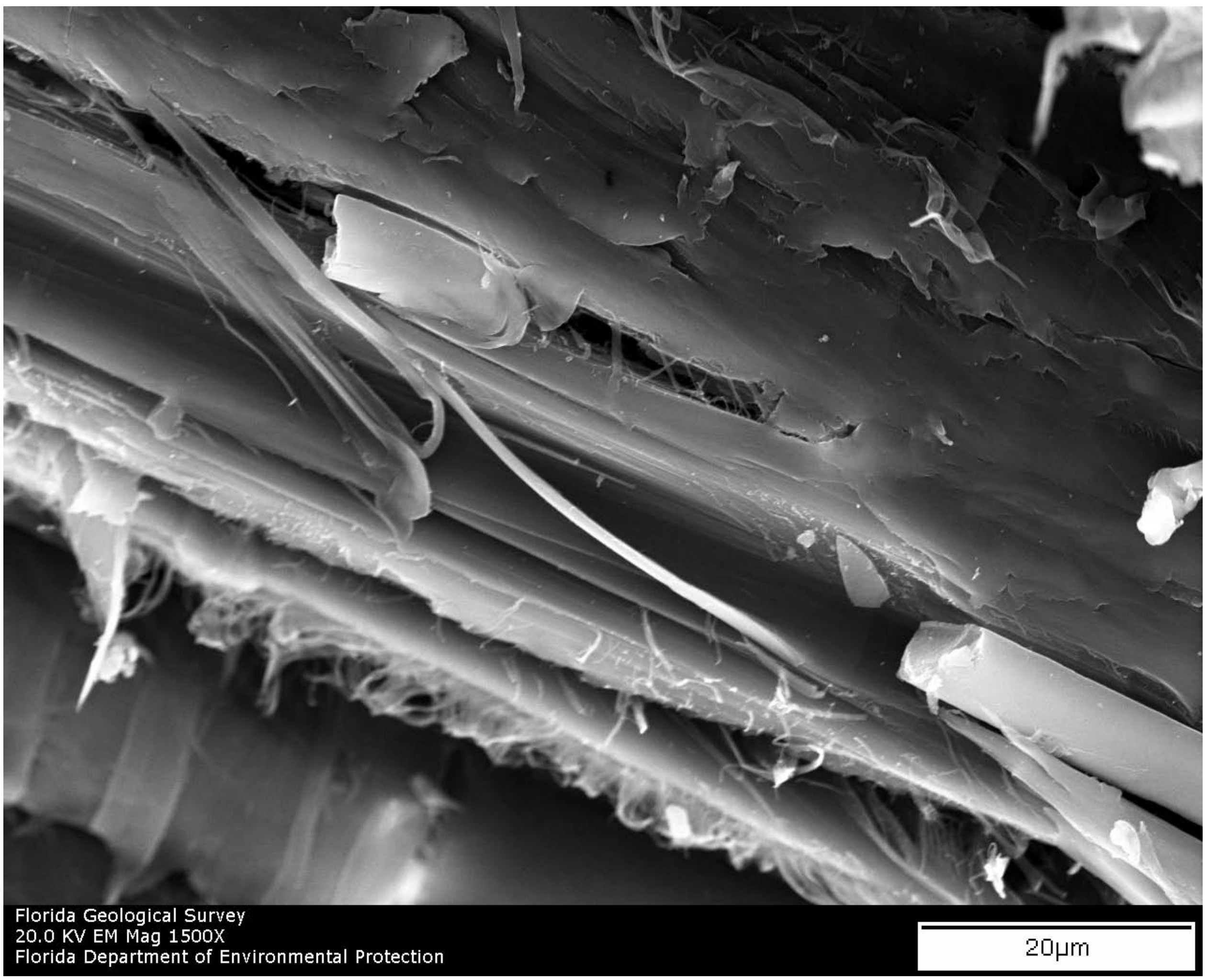


Figure 19: Untreated Wood at 1500x Magnification

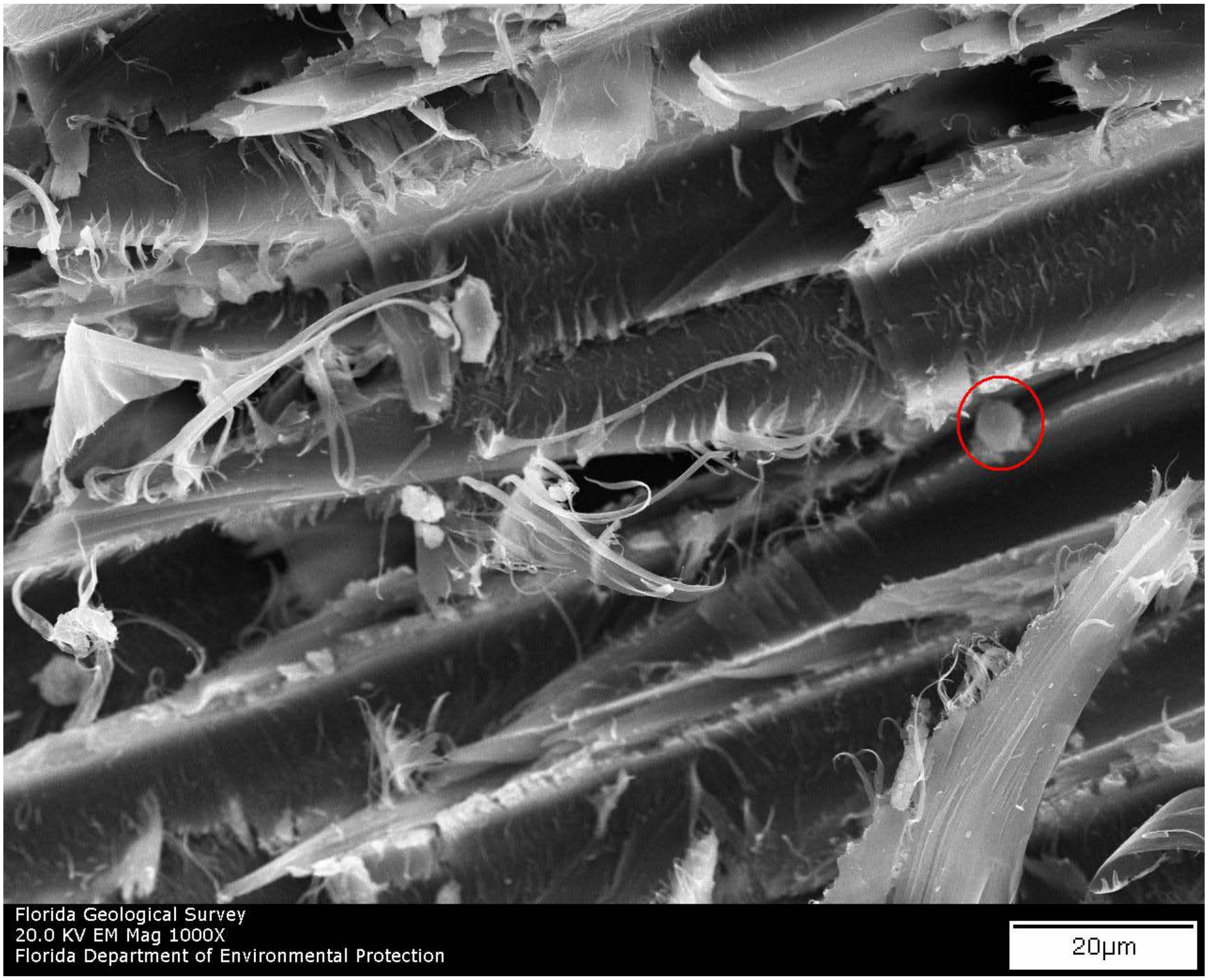


Figure 20: TimberSIL Wood at 1000x Magnification

Looking at Figure 20 versus Figure 19 light colored fibers/sheets can be seen wrapping around the wood fibers. Also the nodule circled in red on Figure 20 is silica. Other examples of TimberSIL can be seen in Figures 21, 22 & 23. In Figure 21 what appear to be holes in the wood are not caused by the TimberSIL treatment but are actually round cells called tracheids that function in water conduction and support of softwoods such as pine. In Figure 21 one can see within the circled region that a section of the lighter colored TimberSIL was broken away when sampling this piece from the beam. Impressions of the tracheid cells are seen in the broken section of the TimberSIL showing that the TimberSIL product bonds at the cellular level.

Figures 24, 25 & 26 are graphs of the elements present during the SEM scan. Figure 24 is a representative sampling of any random location within the control sample. Figure 25 is the bulk analysis that belongs to Figure 22 and Figure 26 is the bulk analysis that belongs to Figure 23. The Ca on the carbon (C) spike of Figure 26 can be disregarded.

Figure 21: TimberSIL Wood at 220x Magnification

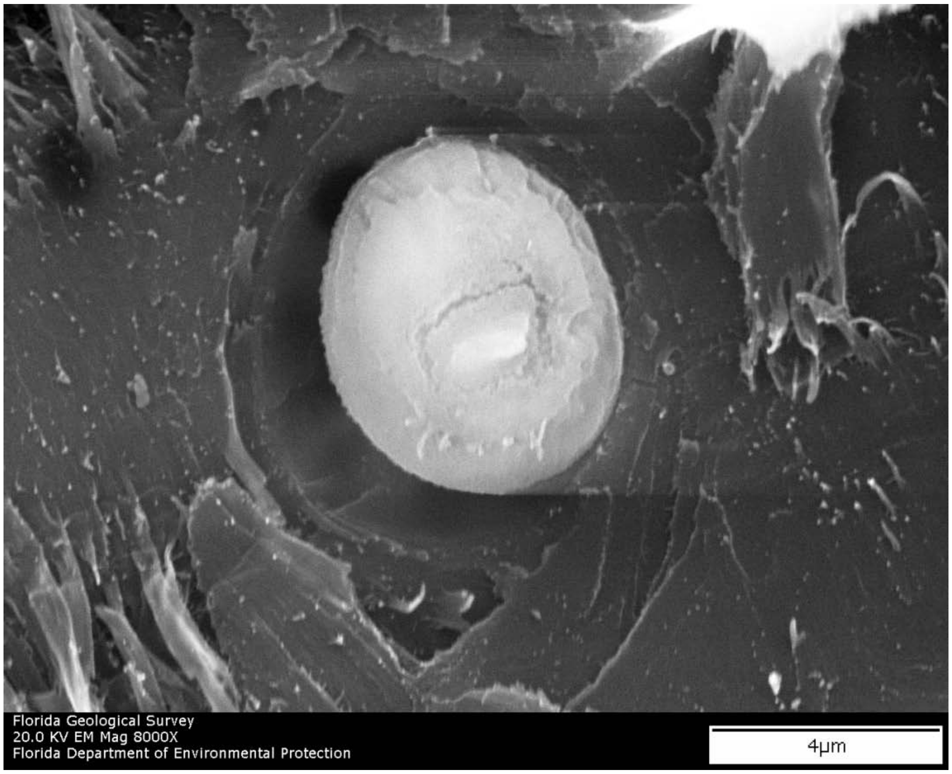


Figure 22: TimberSIL Wood at 8000x Magnification, Filled Tracheid

Figure 23: Microscopic Quartz Crystal in between Wood Fibers

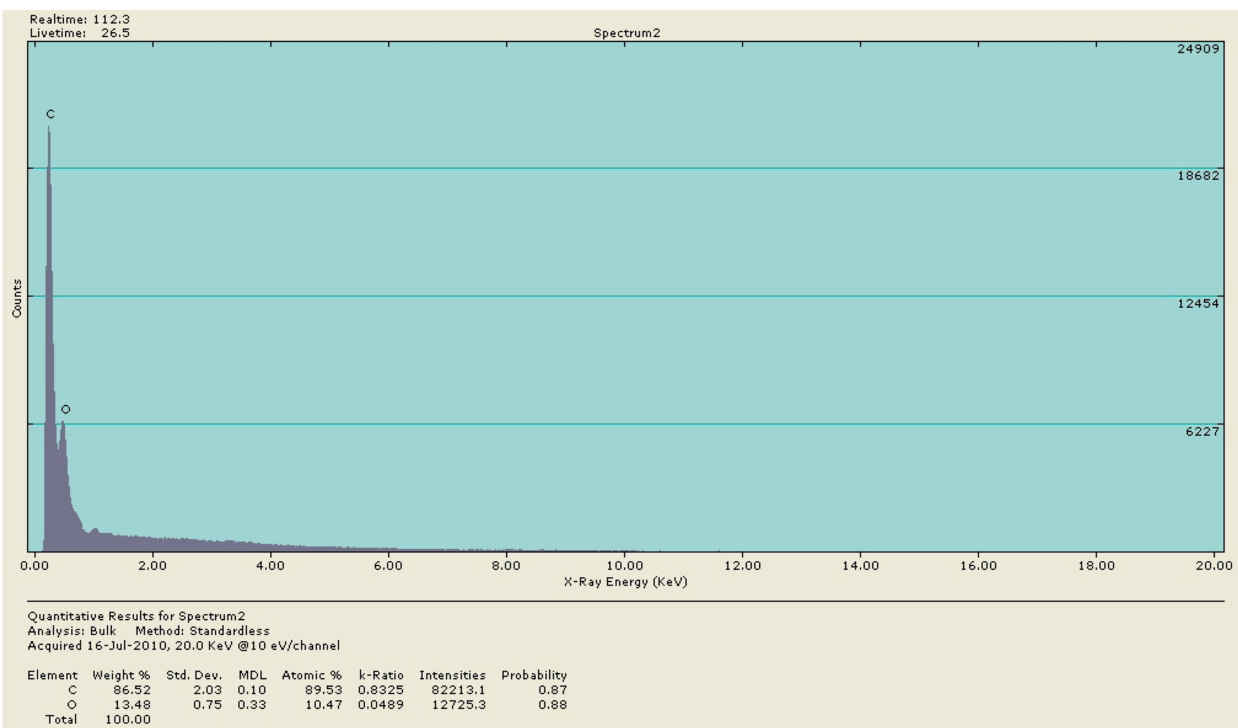
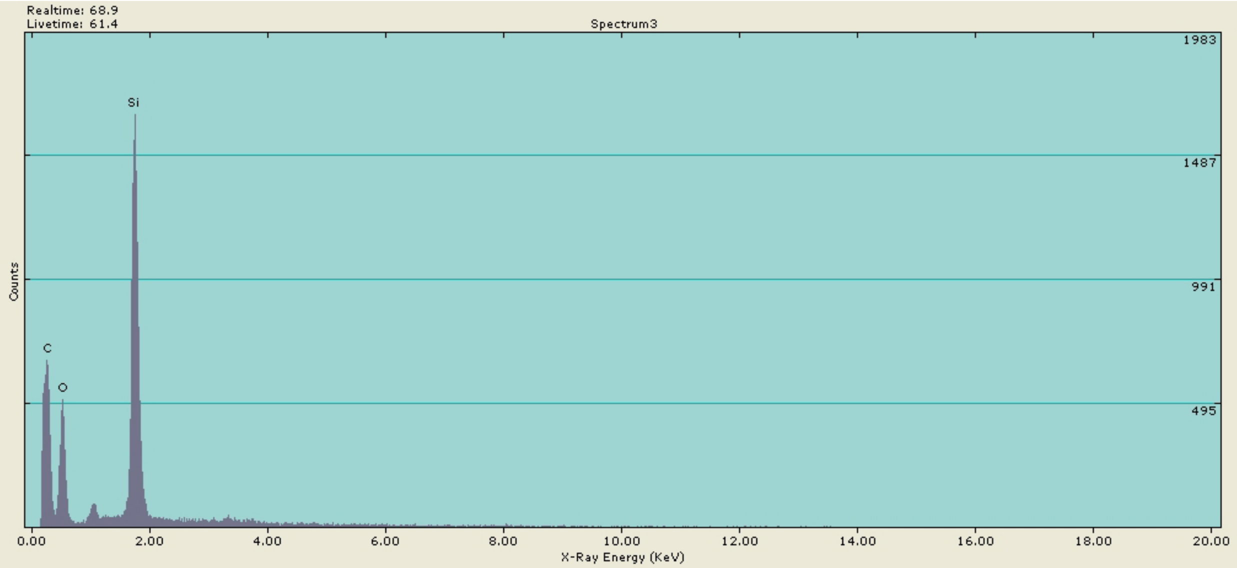


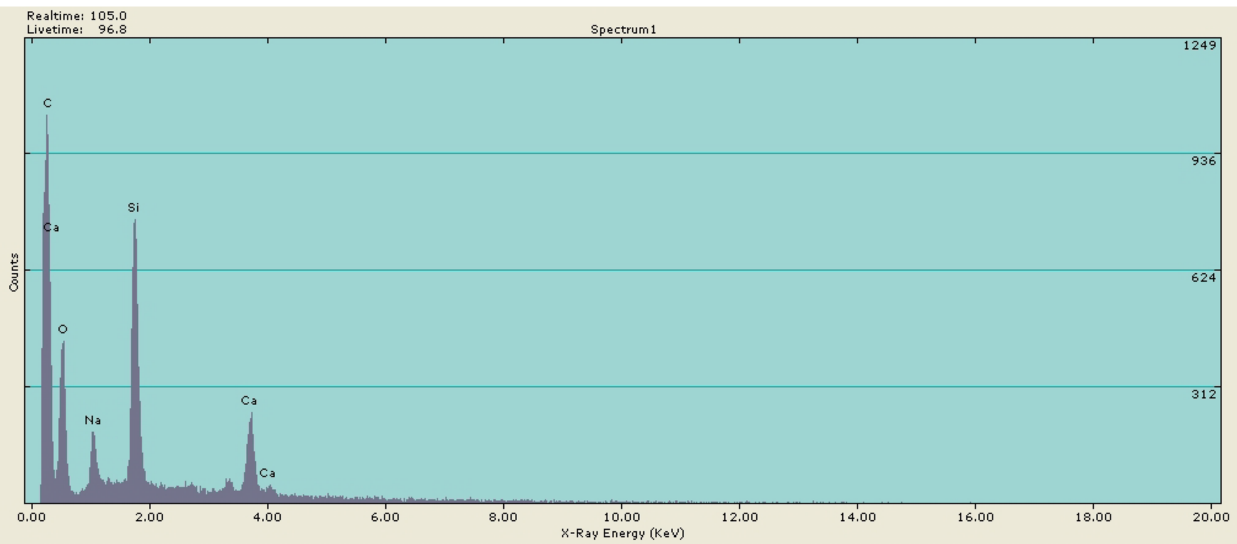
Figure 24: Graphical Representation of Elements for Untreated Wood



Quantitative Results for Spectrum3
Analysis: Bulk Method: Standardless
Acquired 16-Jul-2010, 20.0 KeV @10 eV/channel

Element	Weight %	Std. Dev.	MDL	Atomic %	k-Ratio	Intensities	Probability
C	47.89	1.82	0.28	60.06	0.3307	3102.4	0.89
O	29.61	1.44	0.58	27.87	0.1230	3046.4	0.95
Si	22.50	1.06	0.29	12.07	0.1902	11312.4	0.89
Total	100.00						

Figure 25: Graphical Representation of Elements for Figure 22



Quantitative Results for Spectrum1
Analysis: Bulk Method: Standardless
Acquired 16-Jul-2010, 20.0 KeV @10 eV/channel

Element	Weight %	Std. Dev.	MDL	Atomic %	k-Ratio	Intensities	Probability
C	62.53	2.09	0.28	73.12	0.4891	5572.5	0.91
O	22.06	1.27	0.60	19.37	0.0846	2542.1	0.93
Na	3.15	0.91	1.65	1.93	0.0148	936.3	0.90
Si	8.63	0.91	0.43	4.31	0.0708	5110.3	0.88
Ca	3.63	0.96	0.65	1.27	0.0340	1746.1	0.86
Total	100.00						

Figure 26: Graphical Representation of Elements for Figure 23

Conclusion:

Although the addition of the TimberSIL glass fusion treatment created no increase in strength or stiffness in a flexural situation it also didn't appear to have any detriment to the mechanical properties either. Therefore the TimberSIL product cannot be denied as an alternative to the lumber already used in construction based on structural capacity. One reason for the numbers in Tables 1 & 2 not being closer could be that the beams are not all of the same species of pine. The lumber provided to us was milled, "southern yellow pine". "Southern yellow pine" is a generic name for several species of pine the most common of which are Longleaf pine, Slash pine, Shortleaf pine and Loblolly pine. The lumber all came from the same source so it is likely that all the beams are of the same species but there is a chance the provided lumber was a mixture of several species. Each species of wood has accepted values for mechanical properties published in the USDA Wood Handbook, Ch.4. Some pine species are stronger than others. A more likely explanation of the variability of data is simply the fact that wood is a natural, organic material and therefore subject to many unknown factors.

Because TimberSIL looks identical to regular, untreated wood the contractor or engineer of record should verify that the lumber received is indeed the TimberSIL product. Because the Phenol Red field test seemed to be unreliable in the lab setting it is suggested that other cost efficient methods of identification be developed and utilized. Sampling lumber having the samples shipped to a lab to be scanned with an SEM will produce definitive results but this method is not thought to be time or cost efficient. Perhaps a standard method testing the fire retardant properties of TimberSIL or a permeability test could be developed for reliable and efficient identification.