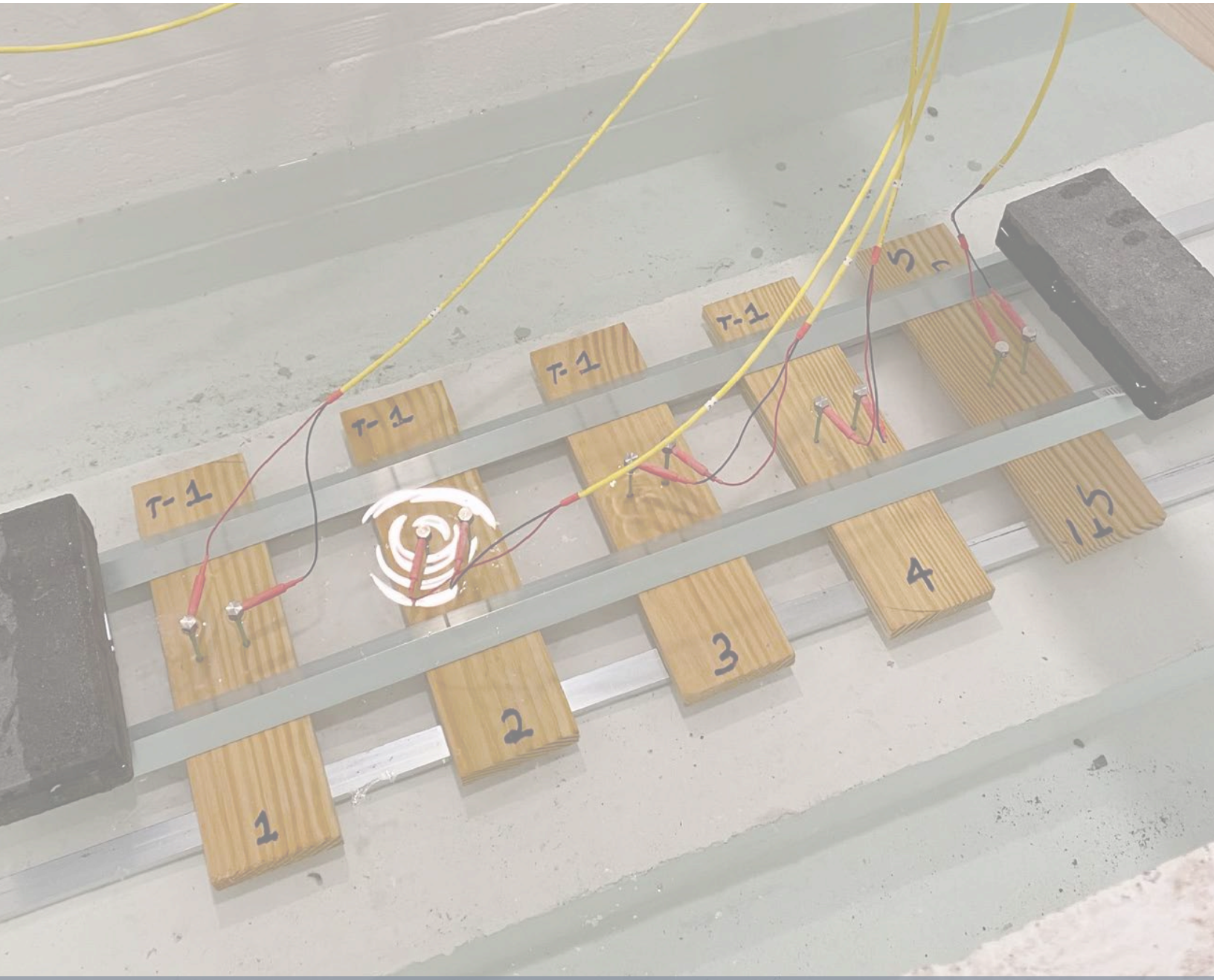
Testing the Flood Resiliency of Historic Wood Flooring Material Using Test Protocol BRS 1-22

Protocol 1 Report

October 2022



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PURPOSE

This report documents the methodology, results, and conclusions of testing undertaken by Building Resilient Solutions (BRS) to study the durability and survivability of historic wood flooring materials that have been exposed to limited duration water inundation, as is commonly experienced during tidal flooding events. These tests were performed in accordance with "BRS 1-22: Test Protocol for Flood Testing of Wood Floors," which was developed by Georg Reichard, Ph.D., P.E. for BRS. "BRS 1-22" was developed to create a consistent assessment method regarding the durability and survivability of wood floors after flooding events. The Protocol adopted processes from various testing standards to create a standard process for controlled testing of wood flooring materials in an environmentally controlled test chamber. Specifically, this testing was intended to replicate flood events and drying periods typical to the conditions seen in Tidewater, Virginia in order to analyze their effects on species of old and modern growth wood commonly used in finished flooring. The consistent testing methods and observations made during the Protocol 1 testing will allow for the development of a replicable way to assess the survivability of historic wood materials during a flood event.

The testing examined two principal areas of potential damage to wood flooring, with data collected for two primary purposes, listed below.

1. Establish thresholds of damage states based on moisture content, volumetric changes, and surface appearance in wood floor systems.
2. Determine the impact on the mechanical and visual properties of wood floor systems after inundation and a controlled drying cycle.

This testing was not intended to address all possible flooding scenarios. The purpose was to examine the effects of controlled flooding and drying cycles on modern and historic floor boards. Typical flood events were replicated multiple times to reveal the impact to tested materials.

TEST METHODS

MATERIALS FOR TESTING

Materials were selected based on the type of historic materials used in pre-1940 construction in Tidewater Virginia and the modern materials that have replaced them in later construction. Samples were selected based on species, grain orientation, and growth density. Samples were cut to a uniform size for individual tests to provide consistent data samples. Samples were of Southern Yellow Pine, *Pinus sp.*, and White Oak, *Quercus sp.* Sections of old, dense growth Southern Yellow Pine, modern growth Southern Yellow Pine, and dense growth White Oak were used for testing. Samples were selected for consistency in density and mechanical characteristics of thickness, length, width, and flatness. The selected samples were 12" long, ¾" thick, and 3 ¼" wide, nominal. The precise dimensions of each sample were recorded prior to and upon completion of each test.

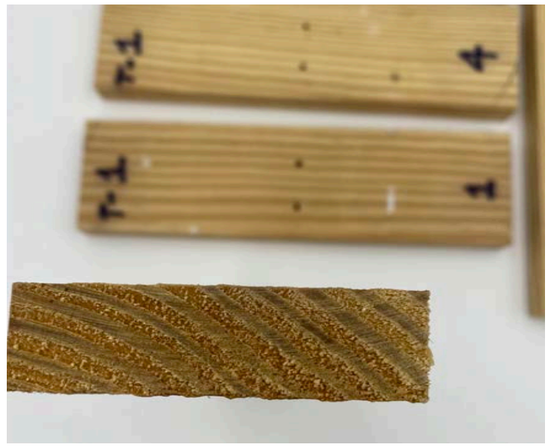


Figure 1 - Test 1 Wood material samples.

TEST CHAMBER

The chamber is insulated with 4" of polystyrene rigid insulation, and the tub is built of CMU coated in vinyl water proofing material designed to allow the porous masonry to maintain an even water level. The overall size of the chamber is 7'8" wide by 8'8" tall and 16' long. The tub is 6' wide by 2'8" deep and 2'8" wide. The test chamber was designed to allow for controlled flooding and drying by providing a controlled environment and consistent depth of water over the samples.

Chamber temperature, humidity, and water levels were all established and maintained within set values. Environmental conditions were monitored through use of remote sensors and recorded through a data logging system. Temperature was maintained using a small 1500-watt electric heater and a fan coil, provided with chilled circulated water via a water tank and pump. The water tank and pump system were located on the exterior of the chamber. The fan coil unit provided air circulation to prevent stagnat temperature and Relative Humidity (RH). The fan, chiller, heater, and circulation pump were controlled by thermostatic probes set to specific high and low measurements that allowed for no more than five degrees of deviation. RH was controlled using both a humidifier and dehumidifier at the same setting to maintain consistent humidity levels.

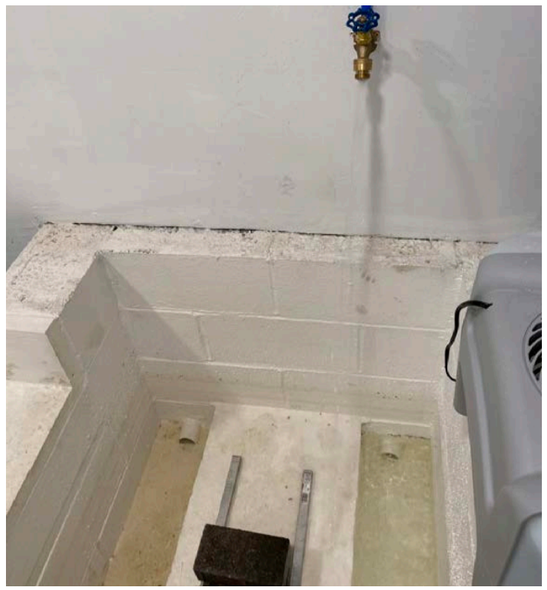


Figure 2 - Test chamber being filled with water.

The water used for flooding the samples was municipal tap water, supplied by a spigot located directly over the tub. Water depth was measured with a simple ruler affixed to the sidewall of the tub. Water temperature was not controlled, but it was monitored and was the only environmental variable in the chamber.

Each test run was monitored with a Lignomat data collection system that sent data to a local laptop computer for recordation; information is stored in the computer and in the BRS dropbox file system for staff use. Data was collected using probes inserted into the test material. The probes collected RH and moisture content levels for each sample.

The entire chamber and environs were also captured on CCTV so that conditions and progress could be monitored off-site.

TESTING METHODOLOGY

Tests 1-3 were each conducted using a single species with the same growth characteristics (either old growth or new growth). Test 4 included a mixture of two species and growth characteristics (both old growth and new growth). Prior to running each test, all environmental systems in the test chamber were activated; systems were set to an approximate stable temperature of 70 degrees Fahrenheit and 70% RH.

The exact data points were recorded in Testing Observations Report (TOR) forms (TORs for each test are included in Appendices A1, B1, C1, and D1). Other recorded data included water level, data sampling interval, date, time, and data probe numbers for each sample. TORs were also used to record general observations about the chamber, conditions inside the chamber, and times for start and stop of the testing.

Prior to starting each test run, samples selected for each test were allowed to rest inside the laboratory for three days to reach equilibrium with the current conditions inside the laboratory. Each sample was photographed to record visual characteristics prior to testing. Each sample was assigned a test number and

sample number specific to the individual test. In preparation for each test, data from each sample was recorded on an individual Test Specimen Record Sheet (see Appendices A2, B2, C2, and D2). The data points collected included the assigned number for each specimen, test number, and physical attributes of each sample. Weight was measured in kilograms, while length, width, and thickness were measured in inches. Width and thickness were measured in four locations on each sample. Moisture content was measured with a pin-less probe, using eight points of collection for each sample. The measurement points varied in orientation and location and were taken on both of the wide surfaces of each sample.

Geometric deformations, or changes to the shape or physical character of a sample, were recorded for each test specimen. Specimens were assessed for deformations such as cupping (when a board's edges are higher than its center), crowning (when a board's center is higher than its edges), buckling (when a board bends or becomes uneven), or other distortions as compared to a flat uniform sample. The distortions were judged using a standard machinists straight edge and any deviations from a flat and uniform sample were noted. Specific measurements of these deviations were not recorded; instead visual observations were made. All of this data was recorded on the Test Specimen Record Sheet for data analysis.

To monitor the moisture content of each sample, two 0.187-inch holes were drilled approximately along the centerline lengthwise of each sample. The holes were 1 1/12-inches apart and 3/8' deep, so that the probes from the Lignomat system could be inserted into the sample.

Testing was performed by placing each sample on two 1" stainless-steel angles that rested on the chamber floor and elevated the samples slightly. The appropriate leads for the moisture monitoring pins were then attached to the samples, and weights were placed across two additional stainless-steel angles situated on top of the sample material. This allowed for the minimum amount of surface contact while keeping the samples submerged.

Before testing was initiated, all recording systems were checked for operation. The Lignomat system was then activated and began recording measurements prior to flooding the tub. The tub was then flooded to a consistent

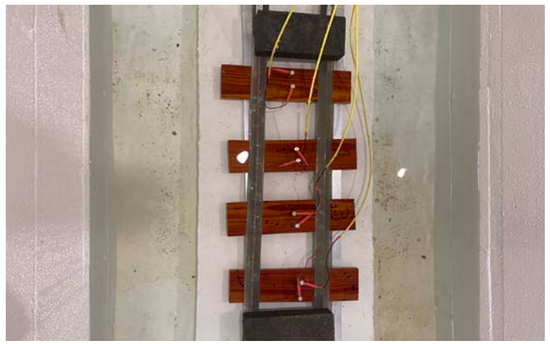


Figure 3 - Test 3 in progress.

level, the date and time recorded, and the chamber was sealed. At regular intervals the environmental conditions were checked and corrected where necessary to maintain conditions as close to the set points as possible (see Test Results section for additional details).

Initially the test period was established as wetting for 72 hours and drying for seven days; however, this was interrupted by some equipment failures which are described in more detail in Test 1 - Modern Southern Yellow Pine. The initial testing was adjusted as necessary to ensure necessary data was gathered accurately. When the test period was completed, the chamber was drained of water, time and conditions were recorded, and the drying period was started. The chamber was held at 70 degrees Fahrenheit and 70% RH during the drying phase. Moisture in the samples was continuously monitored through the Lignomat system along with temperature. When the drying phase was complete the same data points were collected for each sample and recorded on the Test Specimen Record Sheet. With this method, samples were weighed, dried in a convection lab oven to remove all water, reweighed, and a calculation completed to determine the moisture content.

DATA COLLECTION METHODS

- Weight was measured using a laboratory scale measuring to the nearest .0001kg.
- Length was measured along both edges, using a flat machinist scale, to the nearest .031 inch.
- Thickness and width were measured in four locations, using digital calipers to the nearest .001 inch.
- Moisture content was measured using a pin-less Wagner moisture meter to the nearest .01 percent.
- Post-test moisture was measured using the oven dry method; Moisture Content = (Initial Weight - Dry Weight) / Oven Weight.

Figure 4 - Test material being weighed.

Figure 5 - Test material being measured.

TEST RESULTS

TEST 1 - MODERN SOUTHERN YELLOW PINE

The specimens for Test 1 were composed of rift sawn, modern growth Southern Yellow Pine, *Pinus sp*. This was the first complete run of testing in the newly constructed test chamber, and as such there were some exceptions to the standard testing parameters that were established. These deviations/ variations in testing parameters were quickly addressed as outlined below. Samples were initially measured, weighed, and examined for physical anomalies. These pre-testing measurements were recorded and samples were photographed. The five samples used in Test 1 were approximately 3.25-inches in width, 0.75-inches thick, 12-inches long, and weighed 0.40kg. Specific dimensions are recorded in the chart below. No geometric deformations were noted on any of the samples. Moisture content ranged from 11.1% - 14.1% within the samples for an average of 12% moisture content.

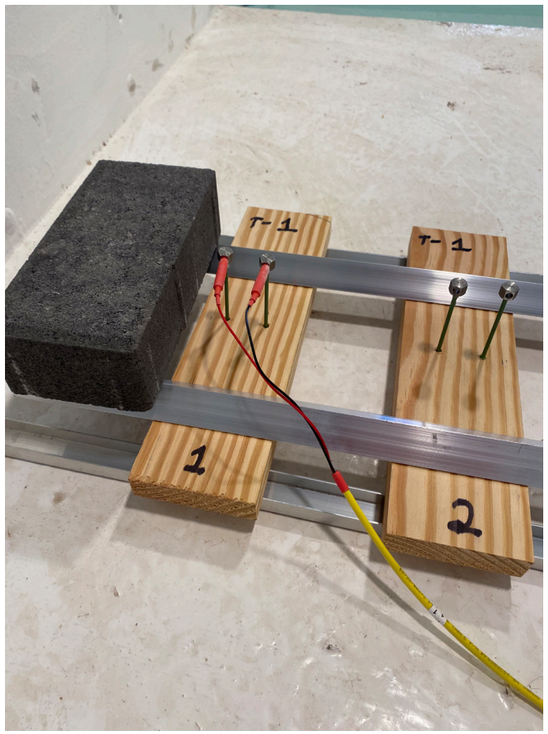


Figure 6 - Test 1 materials pre-testing with moisture pins being attached.

TABLE 1 - Test 1 Average Measurements by Specimen - Pre-Testing

	Specimen 1.1	*Specimen 1.2*	*Specimen 1.3*	*Specimen 1.4*	*Specimen 1.5*
Length (in)	11.93	11.93	12.00	11.93	12.00
Width (in)	3.24	3.23	3.26	3.22	3.24
Thickness (in)	0.85	0.85	0.84	0.84	0.85
Weight (kg)	0.3155	0.3220	0.3215	0.3200	0.3080
Moisture Content (%)	12.0%	12.0%	12.0%	12.0%	13.0%

Several equipment problems within this test sequence resulted in additional run time for wetting and drying. Initially the floor tank developed a leak, which required the test to be moved to the wall tank section of the chamber. The water levels remained constant after that move. The chilled water holding tank then developed a leak and had to be repaired. This was done quickly, and temperature remained within the guidelines for the remainder of the test. On the second day, a Lignomat probe monitoring the moisture content for one of the samples failed (MC 5) and was replaced (MC 6). Although some data was lost, this interruption only occurred during the wetting period when moisture content was steady as measured by each probe. The water level dropped for approximately 3 hours on the second day during a pump installation; this was quickly corrected. At the beginning of the test, only a dehumidifier set to 70% was running, as it was believed that controlling the high side of the RH would be required. However, keeping the RH to a minimum of 70% proved more difficult, and the RH within the chamber fluctuated between 70% and 40% during initial testing. To address this fluctuation, a humidifier was added to the chamber to maintain control. With both the dehumidifier and humidifier running the RH was stabilized to 70%. Due to these equipment issues, the overall wetting period was six days as opposed to the planned three, and the drying period ran for 30 days instead of the planned seven days.

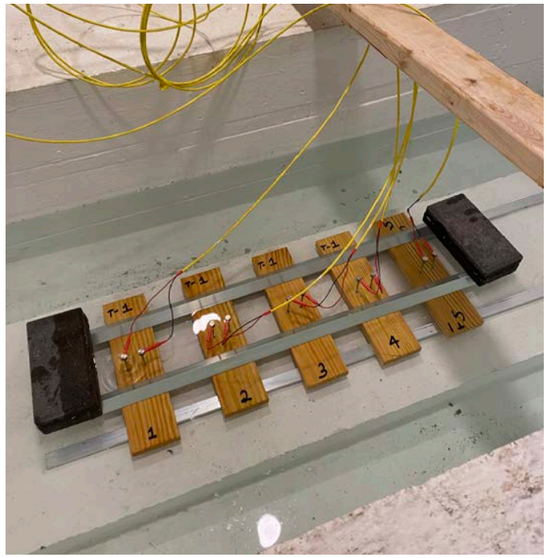
Measurements taken immediately upon draining revealed that the samples had increased in thickness by an average of 3%, width by 8%, and weight by 17%. The length of the samples did not increase by any measurable amount. No geometric deformations were noted in the samples at the draining point.

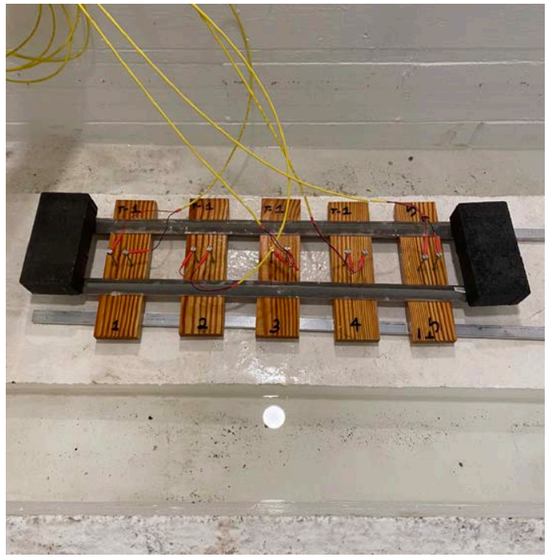
TABLE 2 - Test 1 Average Measurements by Specimen - Post-Draining

	Specimen 1.1	*Specimen 1.2*	*Specimen 1.3*	*Specimen 1.4*	*Specimen 1.5*
Length (in)	11.93	11.93	12.00	11.93	11.93
Width (in)	3.29	3.33	3.33	3.31	3.31
Thickness (in)	0.91	0.92	0.92	0.91	0.92
Weight (kg)	0.3858	0.3858	0.3858	0.3858	0.3858

Upon completion of the drying process the samples varied from their initial measurements by an average of 2.8% in thickness, width by 0.88% and weight by less than 1%. The samples contained an average moisture content of 14.6%, but when calculated by oven dry method the moisture was 11%.

TABLE 3 - Test 1 Average Measurements by Specimen - Post-Drying					
	Specimen 1.1	*Specimen 1.2*	*Specimen 1.3*	*Specimen 1.4*	*Specimen 1.5*
Length (in)	11.93	11.93	12.00	11.93	12.00
Width (in)	3.25	3.26	3.28	3.30	3.26
Thickness (in)	0.87	0.87	0.87	0.89	0.87
Weight (kg)	0.3165	0.3235	0.3225	0.3225	0.3095
Moisture Content (%)	12.6%	13.2%	13.0%	13.0%	21.0%
Moisture Content by Oven Dry Method (%)	10.0%	12.0%	12.0%	12.0%	7.0%





Figures 7 & 8 - Test 1 materials during flooding of tank (at left) and during post-draining (at right).

TEST 2 - OLD GROWTH SOUTHERN YELLOW PINE, RIFT SAWN

Test specimens for Test 2 were composed of rift sawn, old growth Southern Yellow Pine, *Pinus sp.*, often referred to as heart pine. The samples were dense growth, and laden with resin. The samples were examined and pre-testing data points were recorded. The samples were approximately 3.25-inches in width, 0.75-inches in thickness, and 12-inches long. The samples weighed an average of 0.42 kg. Moisture content within the samples averaged 15%. No geometric deformations were observed.

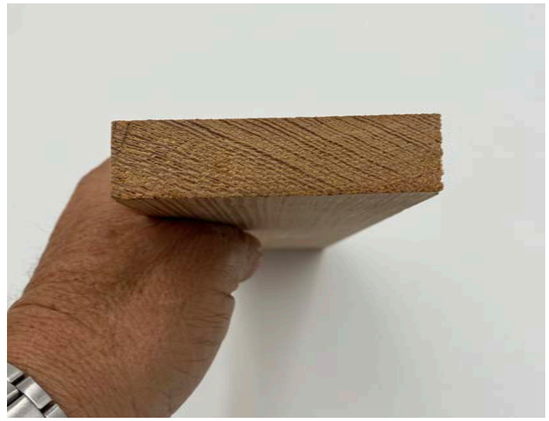


Figure 9 - Test 2 materials showing typical density.

TABLE 4 - Test 2 Average Measurements by Specimen - Pre-Testing				
	Specimen 2.1	*Specimen 2.2*	*Specimen 2.3*	*Specimen 2.4*
Length (in)	11.93	12.06	11.88	11.88
Width (in)	3.24	3.25	3.27	3.26
Thickness (in)	0.78	0.77	0.77	0.77
Weight (kg)	0.3120	0.3170	0.3125	0.3150
Moisture Content (%)	11.0%	11.0%	11.0%	11.0%

During this test the chamber operated well with no equipment problems or anomalies. The chamber was flooded, and the wetting period ran for three days and drying ran for fifteen days. Temperature and RH were held within the guidelines of 70 degrees and 70% RH during the wetting and drying period.

Data samples taken immediately after draining were 0.06% gain in width, 4% gain in thickness, and 6% gain in weight.

TABLE 5 - Test 2 Average Measurements by Specimen - Post-Draining				
	Specimen 2.1	*Specimen 2.2*	*Specimen 2.3*	*Specimen 2.4*
Length (in)	11.93	12.06	11.90	11.89
Width (in)	3.25	3.26	3.29	3.29
Thickness (in)	0.83	0.84	0.85	0.84
Weight (kg)	0.3300	0.3435	0.3321	0.3321

Measurements taken after the drying period was complete revealed that the samples had retained gains in width of 0.154%, thickness of 1.275%, and 4.05% in weight. The samples contained an average of 16.3% moisture content after the drying period; however, when calculated by oven dry method the average moisture content was 11%. No noticeable geometric deformations were observed on the dry samples.

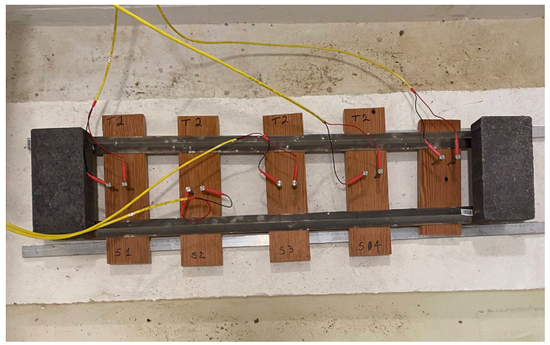


Figure 10 - Test 2 materials during post-draining.

TABLE 6 - Test 2 Average Measurements by Specimen - Post-Drying				
	Specimen 2.1	*Specimen 2.2*	*Specimen 2.3*	*Specimen 2.4*
Length (in)	11.93	12.06	11.88	11.88
Width (in)	3.25	3.25	3.27	3.27
Thickness (in)	0.79	0.78	0.78	0.78
Weight (kg)	0.3125	0.3300	0.3265	0.3295
Moisture Content (%)	16.6%	16.5%	16.0%	16.0%
Moisture Content by Oven Dry Method (%)	9.0%	12.0%	11.0%	12.0%

TEST 3 - OLD GROWTH SOUTHERN YELLOW PINE, FLAT SAWN

Test 3 samples were composed of recycled old growth Southern Yellow Pine, *Pinus sp.* The specimens were flat sawn and slightly wider growth than those of Test 2; however, the Test 3 samples were more resinous in nature. Pre-testing data points for each sample were collected as listed in the design protocol and recorded. Each sample was photographed, and a visual inspection of any geometric deformations were recorded. The samples were approximately 3.25-inches in width, 0.75-inches in thickness, 12-inches long, and weighed 0.40kg. The moisture content prior to flooding was 15%. The samples were flat, square, and showed no noticeable geometric deformations.

Figure 11 - Test 3 materials showing typical density.

TABLE 7 - Test 3 Average Measurements by Specimen - Pre-Testing				
	Specimen 3.1	*Specimen 3.2*	*Specimen 3.3*	*Specimen 3.4*
Length (in)	11.94	11.94	11.80	11.88
Width (in)	3.26	3.25	3.27	3.24
Thickness (in)	0.77	0.78	0.77	0.77
Weight (kg)	0.4020	0.4195	0.4075	0.4120
Moisture Content (%)	16.0%	15.0%	15.0%	15.0%

It was discovered prior to Test 3 that the chilled water system was not working properly, and the system was replaced before Test 3 began. During this test, the system was running at 69% RH and a temperature of 69 degrees Fahrenheit, and, once flooded, water levels remained constant. The chamber had nominal changes in temperature and RH during the flooding and drying periods, but remained within the desired range described in the design protocol.

TABLE 8 - Test 3 Average Measurements by Specimen - Post-Draining				
	Specimen 3.1	*Specimen 3.2*	*Specimen 3.3*	*Specimen 3.4*
Length (in)	11.89	12.06	12.06	12.06
Width (in)	3.29	3.28	3.29	3.28
Thickness (in)	0.84	0.84	0.84	0.84
Weight (kg)	0.4210	0.4290	0.4240	0.4290

Draining occurred after three days, and the drying period was eight days. Measurements taken after draining revealed that the samples had gained 3.2% in width, 8% in thickness, and 13% in weight.

After the drying period, the same data points showed an overall gain of 0.442% in width, 1.14% in thickness, and 0.406% in weight. No geometric deformations were noticeable on the dry samples.

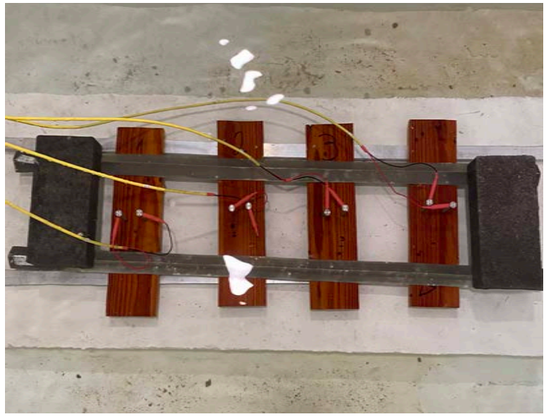


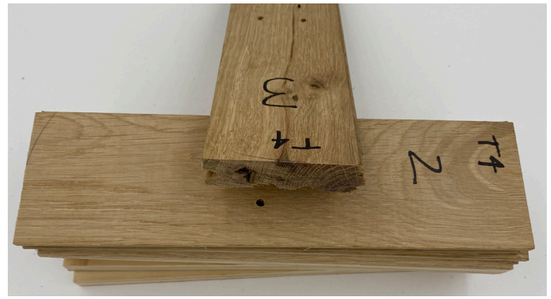
Figure 12 - Test 3 materials during flooding of tank.

TABLE 9 - Test 3 Average Measurements by Specimen - Post-Drying				
	Specimen 3.1	*Specimen 3.2*	*Specimen 3.3*	*Specimen 3.4*
Length (in)	11.88	11.88	11.88	11.88
Width (in)	3.27	3.26	3.28	3.26
Thickness (in)	0.78	0.79	0.78	0.78
Weight (kg)	0.4015	0.4125	0.4150	0.4185
Moisture Content (%)	15.5%	16.6%	15.0%	15.0%
Moisture Content by Oven Dry Method (%)	9.0%	12.0%	12.0%	13.0%

TEST 4 - MODERN WHITE OAK & MODERN SOUTHERN YELLOW PINE

The fourth test was done using a mixture of two species, White Oak, *Quercus sp.* and Southern Yellow Pine, *Pinus sp.* Three samples of the White Oak flooring and four samples of the Southern Yellow Pine flooring were used in the test. Samples were initially measured, weighed, and examined for physical anomalies.

The White Oak samples (Samples 1-3) were cut to a tongue and groove flooring pattern, rift sawn, and of moderate growth density. Samples weighed an average of 0.3603kg, were 0.75-inches thick, 12-inches long, and 3.43-inches in width. Moisture content within the samples averaged 13%. Samples 1 and 2 both had slight geometric deformations of crowning on one broad face of each sample. The Southern Yellow Pine samples (Samples 4-7) were an average of 3.5-inches in width, 0.745-inches in thickness, 12-inches long, and weighed 0.2235kg. No noticeable geometric deformations were observed on the samples. All samples were numbered, photographed, and drilled for probes.



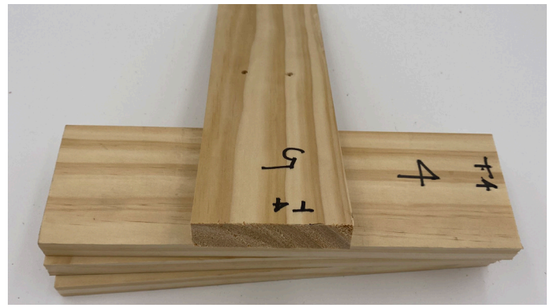


Figure 13 - Test 4 materials showing variation in materials.

TABLE 10 - Test 4 Average Measurements by Specimen - Pre-Testing							
	Specimen 4.1	*Specimen 4.2*	*Specimen 4.3*	*Specimen 4.4*	*Specimen 4.5*	*Specimen 4.6*	*Specimen 4.7*
Length (in)	11.94	11.94	12.00	11.94	11.94	11.94	11.94
Width (in)	3.47	3.40	3.44	3.50	3.50	3.50	3.50
Thickness (in)	0.75	0.76	0.75	0.74	0.75	0.76	0.75
Weight (kg)	0.3930	0.3440	0.3440	0.2130	0.2200	0.2170	0.2260
Moisture Content (%)	11.0%	14.0%	14.0%	9.0%	10.0%	10.0%	11.0%

Prior to installing the samples, the chamber was running with a temperature of 69 degrees Fahrenheit and RH of 80%. The temperature and RH inside the chamber quickly stabilized and remained within normal range during the testing period. Draining occurred after three days and post-draining data was collected. The drying period then spanned five days.

Data collected after draining revealed that the White Oak sample had average gains of 2% in width, 11% in thickness, and 1.8% in weight.

Post-drying data points revealed the White Oak samples had average gains of 1% in width, 1.8% in thickness and 8% in weight. Geometric deformations of crowning on White Oak samples 1 and 2 that were recorded prior to testing were still noticeably visible, and there was now cupping on sample 2. Post-drying moisture content averaged 14.6% measured by a pin-less meter; however, when calculated by oven dry method the moisture content was assessed as 9.7%.

Post-draining data points revealed that the Southern Yellow Pine samples averaged a gain of 6% in width, 11.9% in thickness, and 17% in weight.

Data points collected post-drying revealed that the Southern Yellow Pine samples had an average gain of 2.3% in width, 2.3% in thickness, and 2.0% in weight. Moisture content measured by pin-less meter averaged 12.25%, and moisture content calculated by oven dry method revealed a moisture content of 12.8%. No noticeable geometric deformations were recorded.

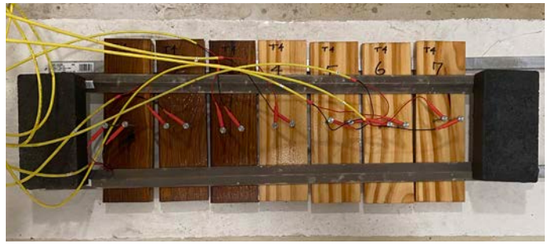


Figure 14 - Test 4 materials during post-drying.

TABLE 11 - Test 4 Average Measurements by Specimen - Post-Draining

	Specimen 4.1	*Specimen 4.2*	*Specimen 4.3*	*Specimen 4.4*	*Specimen 4.5*	*Specimen 4.6*	*Specimen 4.7*
Length (in)	12.00	12.06	12.03	12.06	12.06	12.00	12.00
Width (in)	3.26	3.47	3.49	3.73	3.79	3.69	3.69
Thickness (in)	0.84	0.85	0.85	0.85	0.85	0.84	0.85
Weight (kg)	0.4210	0.3610	0.3980	0.2780	0.2670	0.2650	0.2750

TABLE 12 - Test 4 Average Measurements by Specimen - Post-Drying

	Specimen 4.1	*Specimen 4.2*	*Specimen 4.3*	*Specimen 4.4*	*Specimen 4.5*	*Specimen 4.6*	*Specimen 4.7*
Length (in)	11.94	11.94	12.00	12.08	11.94	11.94	11.94
Width (in)	3.50	3.42	3.46	3.59	3.61	3.59	3.55
Thickness (in)	0.77	0.76	0.77	0.75	0.76	0.77	0.77
Weight (kg)	0.4020	0.3500	0.4020	0.2200	0.2270	0.2240	0.2330
Moisture Content (%)	16.3%	11.7%	16.0%	12.0%	12.0%	12.1%	12.9%
Moisture Content by Oven Dry Method (%)	5.0%	5.0%	9.0%	7.0%	10.0%	8.0%	13.0%

ANALYSIS

MATERIAL PROPERTIES

Samples were chosen to represent some of the most common flooring materials utilized in pre-1940 structures in the Tidewater area of Virginia, as well as the modern materials that replaced them in later construction. These samples were intentionally varied in order to illustrate and examine the performance of the variation in growth patterns, grain orientation, and species within the flooring types. The samples of modern materials of White Oak, *Quercus sp.*, and Southern Yellow Pine, *Pinus sp.*, came from standing timber that was cut, kiln dried, and milled to a specific pattern or thickness and width. The old growth samples of Pine were taken from recycled timbers that were cut during the 19th century and had been utilized in the construction of commercial buildings from that time period. These timbers were re-sawn and the sawn planks were milled to a specific pattern or thickness and width for this testing. Samples were selected to represent flat (plain) sawn and rift sawn materials.

The samples performed independently and were evaluated based on three general characteristics: species, density of growth, and grain orientation. The tests were divided into five basic categories of materials; (1) rift sawn old growth Pine, (2) flat sawn old growth Pine, (3) modern low-density rift sawn Pine, (4) modern moderate density rift sawn Pine, and (5) modern moderate density rift sawn White Oak. Tests 2 and 3 examined samples of dense old growth Pine that were rift and flat sawn. Although one was rift sawn and one was flat sawn, these old growth samples only differed slightly in growth density. The modern growth samples of Pine selected for Tests 1 and 4 were both rift sawn, but were otherwise quite different from each other. The Pine samples from Test 4 were very soft, low-density, and contained only four years of growth. The Test 1 Pine samples, however, were of a more moderate growth density and contained nine years of growth in the same sample width. Additionally, the grain orientation in the Test 1 Pine samples was much closer to vertical (perpendicular to the broad face of the plank) than the Test 4 samples. Test 4 also included modern White Oak samples of moderate density growth, which were tested in conjunction with the Test 4 Pine samples.

Figures 15 & 16 - Example of differences in wood density;
Top:Test 1 modern growth southern yellow pine.
Bottom: Test 3 recycled old growth heart pine.

MATERIAL PERFORMANCE

The performance of the materials varied significantly from one to another, which was especially evident between samples of different species and growth characteristics. Performance was judged by how much or little the samples gained in width, thickness, and weight after testing as compared to their pre-testing measurements.

The most important of these measurements is width since the movement of flooring as its width expands is most often the ultimate cause of flooring failure after flooding. The modern growth Pine samples exhibited little dimensional stability, expanding 0.21 inches per 3.5-inch width. This means that a floor system of modern growth Pine that is 12 feet in width would have expanded over 8 inches in total width. The expansion of the fibers would have caused much stress on fasteners when nailed in place, leading the floor to buckle and the fasteners to fail, even on rift sawn samples such as these. The modern White Oak samples expanded 2.87 inches, which would cause much of the same damage as the modern Pine. Comparatively, the dense growth Pine samples only expanded 0.016 inches in width, which would create a total expansion of 0.70 inches in width over a 12 foot span.

Changes in thickness due to wetting and drying were less significant between materials. Overall, the dense growth Pine out performed the low-density Pine during both wet and dry conditions for all categories except thickness. In this category, low-density Pine performed better in wet conditions, while dense Pine performed better after drying. Immediately after draining, the dense growth Pine (Test 3) showed 1% more relative gain in thickness than the low-density Pine (Test 1). However, the low-density Pine retained most of the gained thickness after drying, whereas the dense Pine returned close to its original thickness. The overall gains in thickness during the wetting period for the dense Pine was 0.06 inches compared to 0.02 inches for the low-density Pine, and although this is a significant difference, it would cause little damage to the floor system if it returned close to its original thickness after drying. The differences in thickness between the Pine samples may have been partially related to the swollen fibers of the softer spring growth, or lighter color portion of the annual rings. These fibers often swell more than the harder summer growth, which can result in a distortion termed “raised grain” that may be measured as an overall thickness without being a true change in thickness.

Performance in the category of weight again exhibited some variety across the samples. Test results from the same basic samples of Pine from Test 1 and Test 4 gained and retained very different weights, leaving the data inconclusive. After drying, the samples of

dense growth Pine generally held less weight compared to all other samples; however, the difference between low-density Pine and dense Pine was not conclusive. There is a direct correlation between the weight gain and water absorption; this gain manifests in significantly increased width and nominally increased thickness.

EFFECTS OF CHAMBER CONDITIONS ON SAMPLES

The chamber conditions were, for the most part, steady throughout the testing period. The expanded drying period of Test 1 may have contributed to the difference between tests in the measurements taken at the completion of the drying period. Test 1 had a drying period of 30 days, while Test 4 only had five days. The Pine in Test 1 exhibited better performance in final drying than the Test 4 pine by returning to a value closer to the original measurements. Although it is important that the material return as close as possible to its original size, if high expansion occurred during the wetting period then the floor materials will have likely already failed before completely drying. This failure is caused when the moisture content exceeds the saturation pressure in a sample's cavities and causes the fibers to break. Other changes such as the tank's lowered water levels for a few hours during Test 1 and changes in heating and cooling seem to have had little effect on the samples.

Conditions within the test chamber during the drying period were held at a constant temperature of 70 degrees Fahrenheit and 70% RH with little significant change. The constant environment and modest conditions allowed for reasonably slow drying. Variations in drying conditions would perhaps bring about additional changes to the samples.

Figure 17 - Test chamber

CONCLUSIONS

Testing carried out in a controlled environment can never replicate exactly the flooding found in the natural environment. The purpose of the tests conducted in this investigation was to measure and compare the performance of the samples under completely controlled conditions that could be replicated on any number of other samples. This approach allowed for the examination of specific performance characteristics that would cause floor system failure, and for the comparison of those performance characteristics across all samples. Performance for these tests was judged by the gained values of each of the recorded measurements. Any gain of the measured data points is an indicator of lowered performance, and a retained gain after drying lowers the performance and durability of the floor system even more. The best overall performance from the samples came from the old growth dense Southern Yellow Pine. Some samples of low-density Southern Yellow Pine and modern White Oak performed slightly better in some categories, but overall, the dense growth Southern Yellow Pine outperformed the other investigated species.

Grain orientation was an additional factor that influenced performance. Those samples with growth rings running parallel to the sample's broad face performed poorer than those with rings running perpendicular to the broad face. The difference in performance was the most noticeable in the width and thickness data. Weight, or water absorption, was little affected by grain orientation.

In general, the results of this test indicate that a floor system laid from dense, old growth Southern Yellow Pine, like many of the floors found in pre-1940 structures in the Tidewater region of Virginia, will outperform a floor system laid from modern low-to-moderate density Southern Yellow Pine or White Oak. The old growth Southern Yellow Pine floors can and will survive a flood event with little repair or replacement.

FUTURE TESTING

While the tests performed in this study have confirmed the survivability of historic Southern Yellow Pine floor materials, more testing is needed. Samples of a complete flooring system of these same materials should be subjected to additional testing. In addition, the environment of the chamber should be altered to simulate quicker and slower drying scenarios in order to evaluate the effects of the varied drying rates that could be experienced after real world flood events. The addition or exclusion of a subfloor should also be included in future testing.

APPENDICES

APPENDIX A: TEST 1 - MODERN SOUTHERN YELLOW PINE

The following pages include the Testing Observations Report for Test 1, the Testing Specimens Record Sheet for each Test 1 specimen, Test 1 Results Graphs, and Test 1 photographs.

Appendix A1: Test 1 Testing Observation Report

TESTING OBSERVATIONS REPORT	
Test Protocol	Flood Test Protocol #1
Test #	Test 1
Test Duration	04/04/2022 - 05/12/2022
Starting Time Stamp	04/04/2022 - 02:53pm
Draining Time Stamp	04/11/2022 - 11:10am
Starting Environmental Conditions • **Tempreature** • **Relative Humidity**	 70.0°F 40%
Setpoint Environmental Conditions • **Tempreature** • **Relative Humidity**	 70.0°F 40%
Water Level (above sample) • **Min** • **Max**	 3.00 in 3.14 in
Drying Duration • **Start** • **End**	 04/11/2022 - 11:10am 05/12/2022 - 09:49am
General Observations:	• Used wall tank as the floor tank is leaking when completely filled • Heating on/no cooling, cooling tank leaking • Mid testing data collected 4/5/22 • Cooling tank repaired 4/5/22, cooling normal. • Lignomat system set for data collection at 60 min intervals. • MC5 on the Lignomat system failed on 4/14/22, changed to MC6 • Tank was drained accidentally on 4/5/22 12:56 pm and filled at 3:56 pm same day. • Test was allowed to run longer as an initial test on the tank and systems to get everything normalized. • All heating and cooling operating normal. • Samples were KD Southern Yellow Pine, Pinus sp. Very fast growth pine

Appendix A2: Test 1 Specimen Record Sheets

Test Specimen Record Sheet									
Test Protocol #	1		**Test**	1	Date	04/04/2022			
Specimen #	1		**Type of Material**		SYP		**Species**	*Pinus sp.*	
Grain Orientation	Rift			**Probe**		MC1			
Pre-Test Characteristics									**AVG**
Length	**1**	**2**							
	11.93	11.93							**11.93**
Width	**1**	**2**	**3**	**4**					
	3.24	3.23	3.23	3.24					**3.24**
Thickness	**1**	**2**	**3**	**4**					
	0.85	0.84	0.85	0.84					**0.85**
Moisture Content	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
	11.6	11.8	12.5	11.4	12.1	12.9	12.8	12.2	**12.0%**
Weight									**0.3155**
Post-Draining Test Characteristics									**AVG**
Length	**1**	**2**							
	11.93	11.93							**11.93**
Width	**1**	**2**	**3**	**4**					
	3.30	3.28	3.29	3.30					**3.29**
Thickness	**1**	**2**	**3**	**4**					
	0.90	0.92	0.91	0.91					**0.91**
Weight									**0.3858**
Post-Test Characteristics									**AVG**
Length	**1**	**2**							
	11.93	11.93							**11.93**
Width	**1**	**2**	**3**	**4**					
	3.25	3.25	3.24	3.24					**3.25**
Thickness	**1**	**2**	**3**	**4**					
	0.86	0.86	0.88	0.88					**0.87**
Moisture Content	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
	12.9	12.4	12.9	12.7	12.6	12.7	12.6	12.3	**12.6%**
Weight									**0.3165**
Moisture content by Oven Dry Method				**Oven**	**0.288**				**10.0%**
Geometric Deformation									
		Cupping	Crown	Buckling	Other		Notes:		
Pre-Test		X	X	X	X				
Post-Test		X	X	X	X				

Test Specimen Record Sheet									
Test Protocol #	1		**Test**	1	Date	04/04/2022			
Specimen #	2		**Type of Material**		SYP		**Species**	*Pinus sp.*	
Grain Orientation	Rift			**Probe**		MC2			
Pre-Test Characteristics									**AVG**
Length	**1**	**2**							
	11.93	11.93							**11.93**
Width	**1**	**2**	**3**	**4**					
	3.23	3.23	3.22	3.22					**3.23**
Thickness	**1**	**2**	**3**	**4**					
	0.85	0.85	0.84	0.84					**0.85**
Moisture Content	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
	12.2	11.9	11.8	11.7	14	13.5	11.4	11.5	**12.0%**
Weight									**0.3220**
Post-Draining Test Characteristics									**AVG**
Length	**1**	**2**							
	11.93	11.93							**11.93**
Width	**1**	**2**	**3**	**4**					
	3.29	3.30	3.29	3.30					**3.33**
Thickness	**1**	**2**	**3**	**4**					
	0.91	0.92	0.91	0.93					**0.918**
Weight									**0.3858**
Post-Test Characteristics									**AVG**
Length	**1**	**2**							
	11.93	11.93							**11.93**
Width	**1**	**2**	**3**	**4**					
	3.25	3.26	3.25	3.27					**3.26**
Thickness	**1**	**2**	**3**	**4**					
	0.86	0.86	0.88	0.87					**0.87**
Moisture Content	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
	12.8	12.9	12.5	12.9	14.3	14.0	2.0	13.3	**13.2%**
Weight									**0.3235**
Moisture content by Oven Dry Method				**Oven**	**0.288**				**12.0%**
Geometric Deformation									

		Cupping	Crown	Buckling	Other		Notes: Some raised grain after testing.
Pre-Test		X	X	X	X		
Post-Test		X	X	X	X		

Test Specimen Record Sheet									
Test Protocol #	1		**Test**	1	Date	04/04/2022			
Specimen #	3		**Type of Material**		SYP		**Species**	*Pinus sp.*	
Grain Orientation	Rift			**Probe**		MC5			
Pre-Test Characteristics									**AVG**
Length	**1**	**2**							
	12.00	12.00							**12.00**
Width	**1**	**2**	**3**	**4**					
	3.26	3.26	3.26	3.26					**3.26**
Thickness	**1**	**2**	**3**	**4**					
	0.83	0.83	0.85	0.83					**0.84**
Moisture Content	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
	13.6	12.8	11.2	12.3	12.7	11.6	11.5	12.8	**12.0%**
Weight									**0.3215**
Post-Draining Test Characteristics									**AVG**
Length	**1**	**2**							
	12.00	12.00							**12.00**
Width	**1**	**2**	**3**	**4**					
	3.33	3.34	3.33	3.32					**3.33**
Thickness	**1**	**2**	**3**	**4**					
	0.92	0.92	0.90	0.93					**0.92**
Weight									**0.3858**
Post-Test Characteristics									**AVG**
Length	**1**	**2**							
	12.00	12.00							**12.00**
Width	**1**	**2**	**3**	**4**					
	3.27	3.28	3.28	3.29					**3.28**
Thickness	**1**	**2**	**3**	**4**					
	0.87	0.87	0.86	0.88					**0.87**
Moisture Content	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
	13.0	12.8	14.2	15.0	11.0	10.9	13.7	13.2	**13.0%**
Weight									**0.3225**
Moisture content by Oven Dry Method				**Oven**	**0.288**				**12.0%**
Geometric Deformation									

		Cupping	Crown	Buckling	Other		Notes: Moved from MC5 to MC6 9:58am on 04/14/2022
Pre-Test		X	X	X	X		
Post-Test		X	X	X	X		

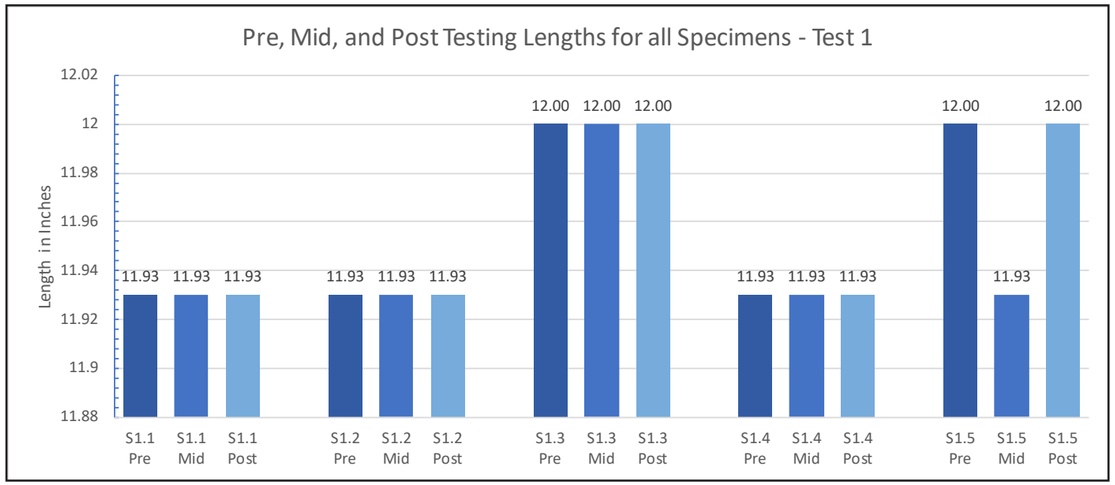
Test Specimen Record Sheet									
Test Protocol #	1		**Test**	1	Date	04/04/2022			
Specimen #	4		**Type of Material**		SYP		**Species**	*Pinus sp.*	
Grain Orientation	Rift			**Probe**		MC4			
Pre-Test Characteristics									**AVG**
Length	**1**	**2**							
	11.93	11.93							**11.93**
Width	**1**	**2**	**3**	**4**					
	3.22	3.22	3.22	3.22					**3.22**
Thickness	**1**	**2**	**3**	**4**					
	0.84	0.84	0.84	0.84					**0.84**
Moisture Content	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
	14.1	14.0	11.2	12.1	12.5	12.3	10.8	11.1	**12.0%**
Weight									**0.3200**
Post-Draining Test Characteristics									**AVG**
Length	**1**	**2**							
	11.93	11.93							**11.93**
Width	**1**	**2**	**3**	**4**					
	3.33	3.34	3.35	3.22					**3.31**
Thickness	**1**	**2**	**3**	**4**					
	0.92	0.92	0.91	0.90					**0.91**
Weight									**0.3858**
Post-Test Characteristics									**AVG**
Length	**1**	**2**							
	11.93	11.93							**11.93**
Width	**1**	**2**	**3**	**4**					
	3.29	3.30	3.31	3.29					**3.30**
Thickness	**1**	**2**	**3**	**4**					
	0.90	0.89	0.89	0.88					**0.89**
Moisture Content	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
	12.8	13.1	14.1	13.9	12.8	11.5	13.4	12.4	**13.0%**
Weight									**0.3225**
Moisture content by Oven Dry Method				**Oven**	**0.288**				**12%**
Geometric Deformation									

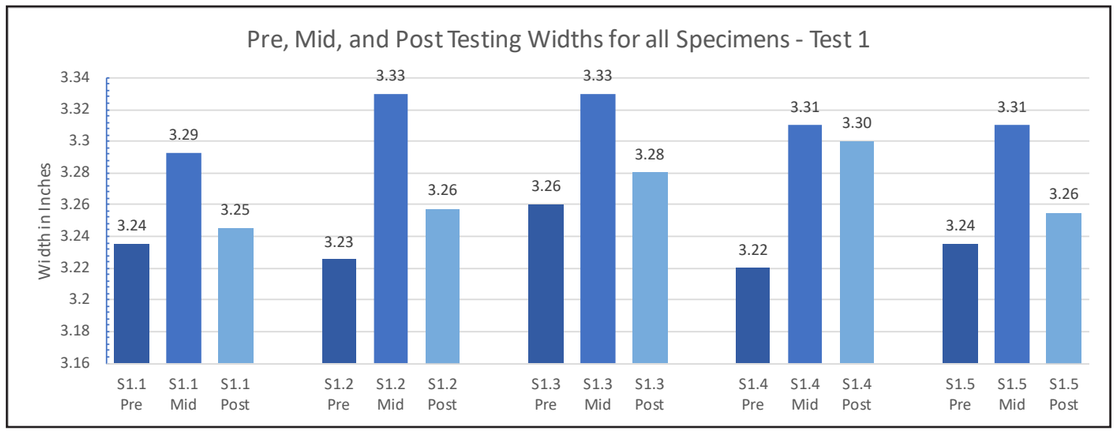
		Cupping	Crown	Buckling	Other		Notes:
Pre-Test		X	X	X	X		
Post-Test		X	X	X	X		

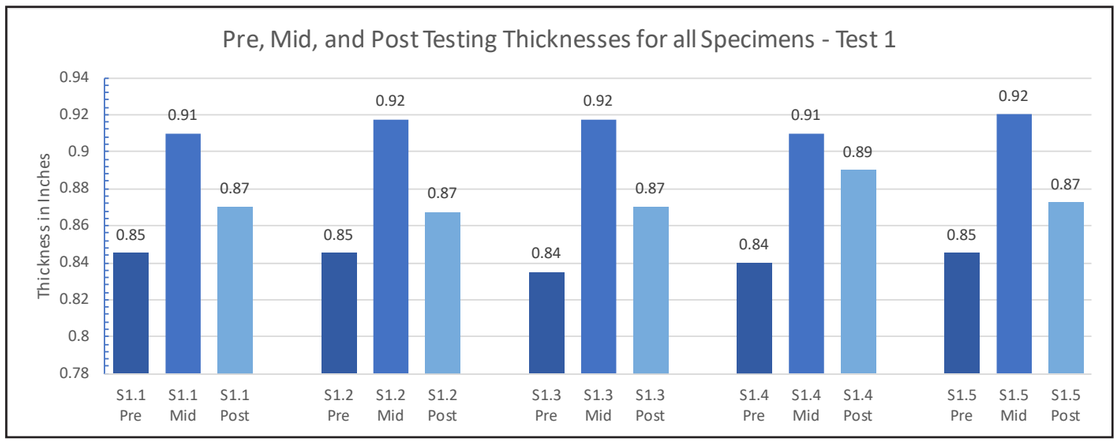
Test Specimen Record Sheet									
Test Protocol #	1		**Test**	1	Date	04/04/2022			
Specimen #	5		**Type of Material**		SYP		**Species**	*Pinus sp.*	
Grain Orientation	Rift			**Probe**		MC3			
Pre-Test Characteristics									**AVG**
Length	**1**	**2**							
	12.00	12.00							**12.00**
Width	**1**	**2**	**3**	**4**					
	3.23	3.25	3.24	3.22					**3.24**
Thickness	**1**	**2**	**3**	**4**					
	0.84	0.85	0.84	0.85					**0.85**
Moisture Content	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
	14.1	13.8	12.8	13.0	11.8	12.7	12.4	12.6	**13%**
Weight									**0.3080**
Post-Draining Test Characteristics									**AVG**
Length	**1**	**2**							
	11.93	11.93							**11.93**
Width	**1**	**2**	**3**	**4**					
	3.30	3.30	3.31	3.33					**3.31**
Thickness	**1**	**2**	**3**	**4**					
	0.92	0.92	0.91	0.93					**0.92**
Weight									**0.3858**
Post-Test Characteristics									**AVG**
Length	**1**	**2**							
	12.00	12.00							**12.00**
Width	**1**	**2**	**3**	**4**					
	3.25	3.26	3.26	3.25					**3.26**
Thickness	**1**	**2**	**3**	**4**					
	0.88	0.88	0.86	0.87					**0.87**
Moisture Content	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
	21.1	23.3	20.7	20.4	24.2	21.7	20.7	16.0	**21.0%**
Weight									**0.3095**
Moisture content by Oven Dry Method				**Oven**	**0.288**				**7%**
Geometric Deformation									

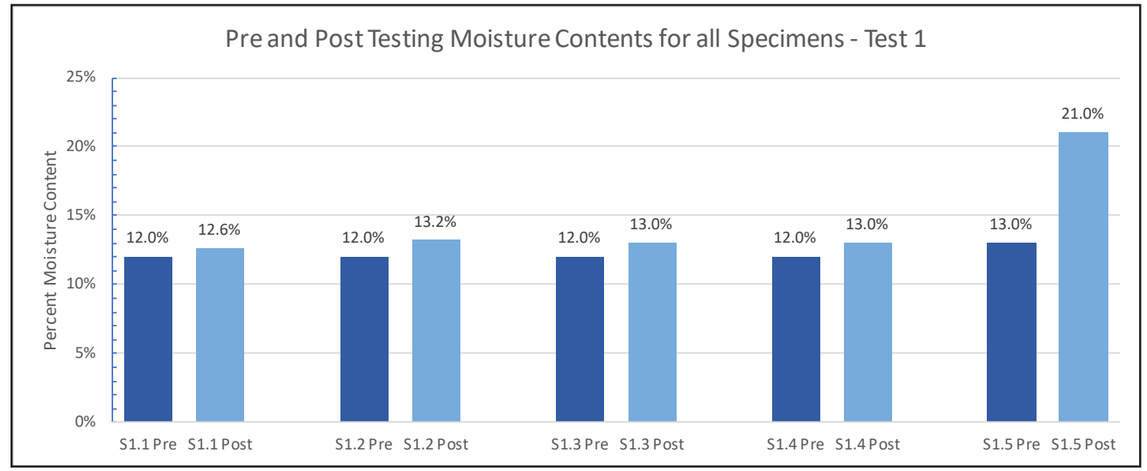
		Cupping	Crown	Buckling	Other		Notes:
Pre-Test		X	X	X	X		
Post-Test		X	X	X	X		

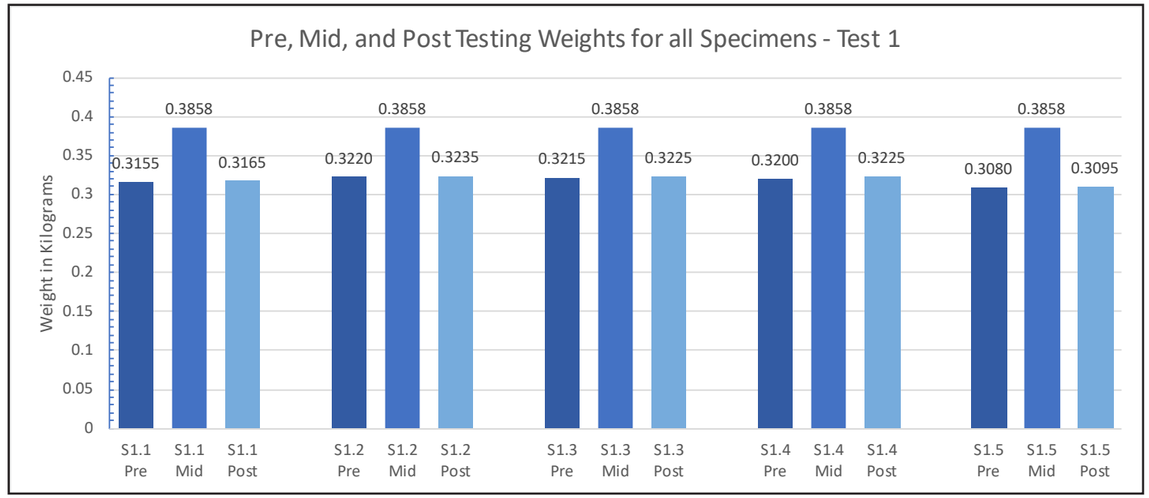
Appendix A3: Test 1 Results Graphs

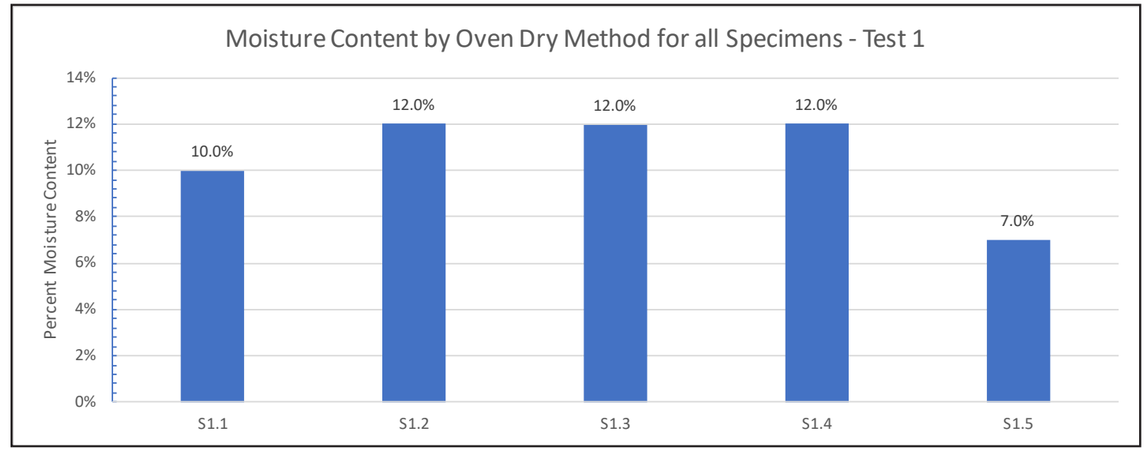


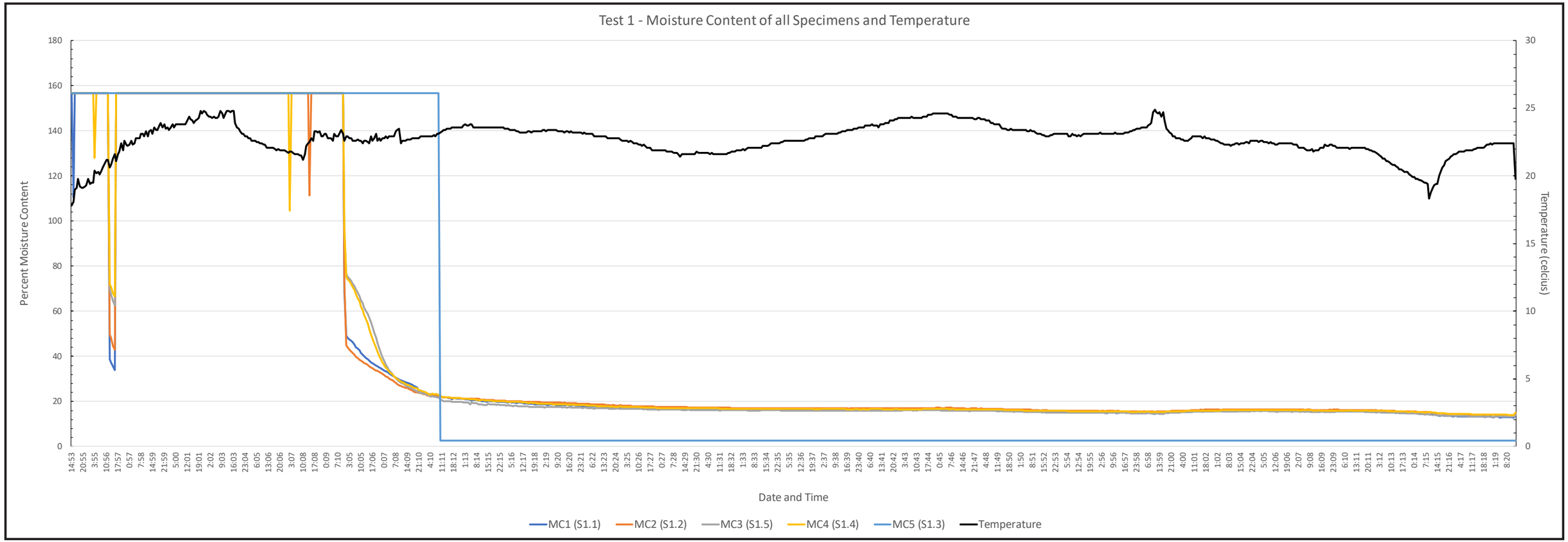










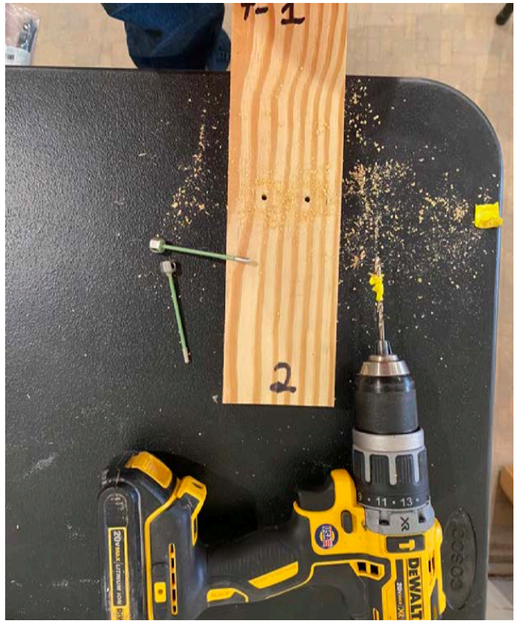

Test 1 - Moisture Content of all Specimens and Temperature
Percent Moisture Content
Temperature (celcius)
Date and Time
MC1 (S1.1)
MC2 (S1.2)
MC3 (S1.5)
MC4 (S1.4)
MC5 (S1.3)
Temperature

Appendix A4: Test 1 Photographs

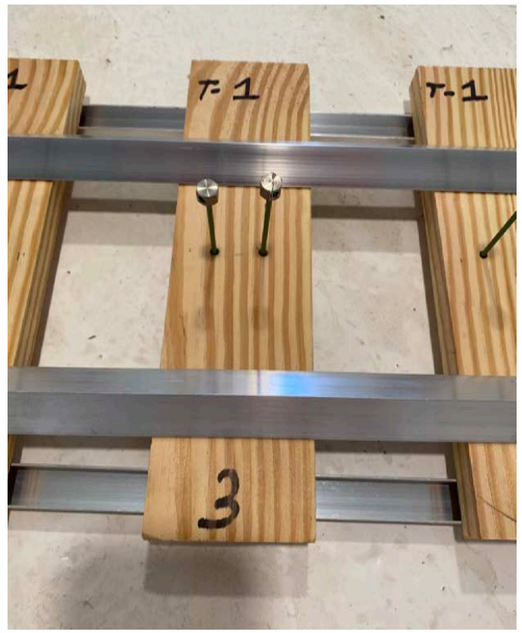
Appendix A4 Figure 1 - Example of collecting specimen width

Appendix A4 Figure 2 - Example of collecting specimen thickness

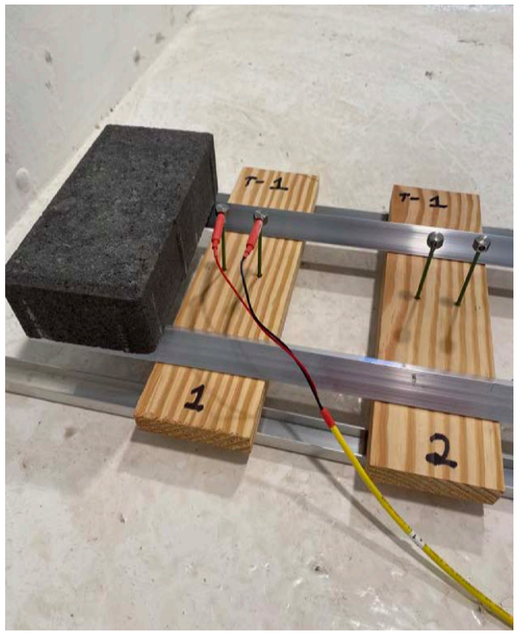
Appendix A4 Figure 3 - Example of collecting specimen weight measurements



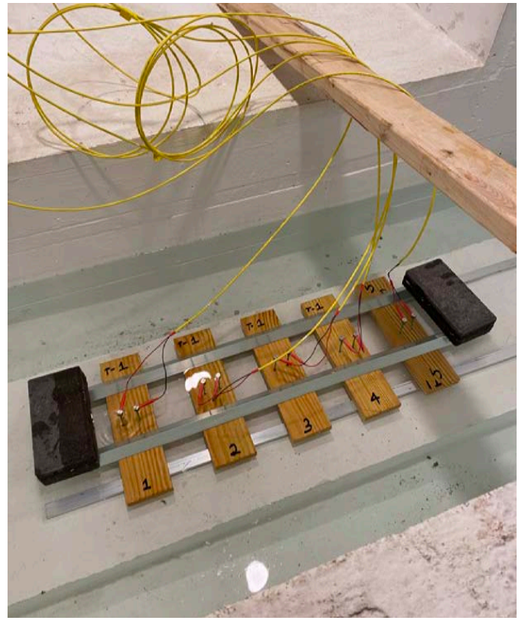
Appendix A4 Figure 4 - Example of drilling process and location of probes prior to their installation



Appendix A4 Figure 5 - Typical probe locations on specimens

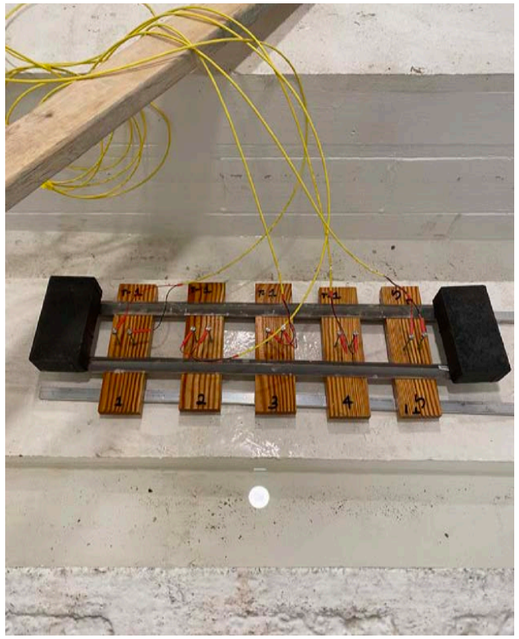


Appendix A4 Figure 6 - Typical probe locations with Lignomat moisture content data collection wires connected

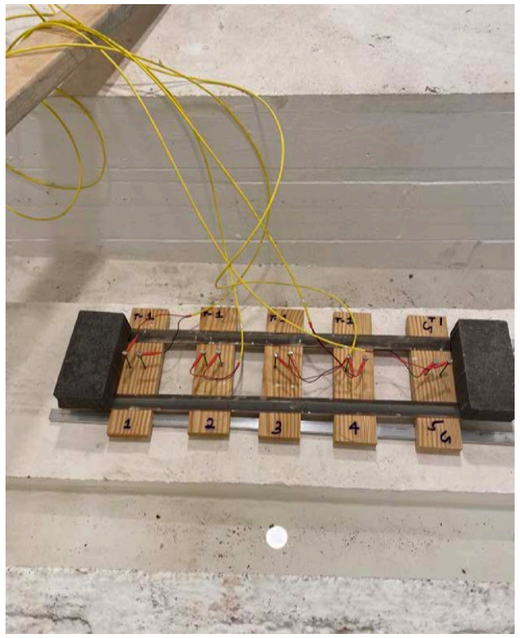


Appendix A4 Figure 7 - Test 1 specimens during flooding

Appendix A4 Figure 8 - Test 1 specimens during flooding

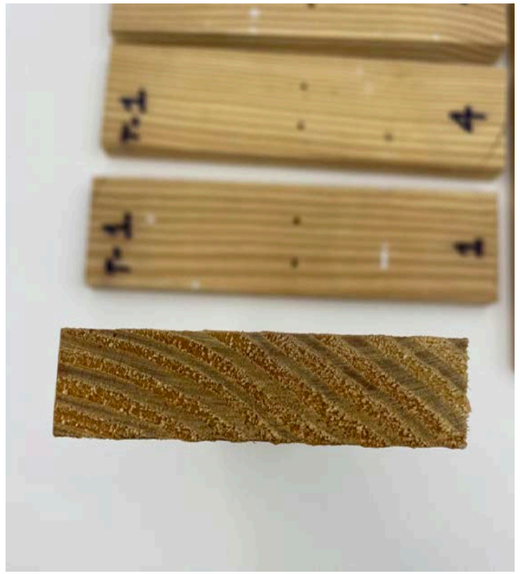


Appendix A4 Figure 9 - Test 1 specimens after draining



Appendix A4 Figure 10 - Test 1 specimens after draining and beginning to dry

Appendix A4 Figure 11 - Test 1 specimens after drying



Appendix A4 Figure 12 - Example of Test 1 grain density and thickness and assessing geometric deformations after drying

APPENDIX B: TEST 2 - OLD GROWTH SOUTHERN YELLOW PINE, RIFT SAWN

The following pages include the Testing Observations Report for Test 2, the Testing Specimens Record Sheet for each Test 2 specimen, Test 2 Results Graphs, and Test 2 photographs.

Appendix B1: Test 2 Testing Observation Report

TESTING OBSERVATIONS REPORT	
Test Protocol	Flood Test Protocol #1
Test #	Test 2
Test Duration	05/13/2022 - 05/31/2022
Starting Time Stamp	05/13/2022 - 12:54pm
Draining Time Stamp	05/16/2022 - 03:52pm
Starting Environmental Conditions • **Tempreature** • **Relative Humidity**	 71.3°F 73%
Setpoint Environmental Conditions • **Tempreature** • **Relative Humidity**	 70.0°F 70%
Water Level (above sample) • **Min** • **Max**	 3.00 in 3.25 in
Drying Duration • **Start** • **End**	 05/16/2022 - 03:52pm 05/31/2022 - 06:42pm
General Observations:	• Used wall tank as the floor tank is leaking when completely filled • Heat/cooling on set to 70 • Dehumidify/humid running set to 70 • Added 1 additional sample for testing during operation • Mid test data recorded 5/14/22 1:25pm • Dense growth Heart Pine Pinus sp. Rift cut • Drying period to 5/31/22 6:42pm

Appendix B2: Test 2 Specimen Record Sheets

Test Specimen Record Sheet									
Test Protocol #	1		**Test**	2	Date	05/13/2022			
Specimen #	1		**Type of Material**		Heart Pine		**Species**	*Pinus sp.*	
Grain Orientation	Rift			**Probe**		MC1			
Pre-Test Characteristics									**AVG**
Length	**1**	**2**							
	11.93	11.93							**11.93**
Width	**1**	**2**	**3**	**4**					
	3.25	3.24	3.23	3.25					**3.24**
Thickness	**1**	**2**	**3**	**4**					
	0.78	0.78	0.78	0.78					**0.78**
Moisture Content	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
	11.5	11.5	11.3	11.3	10.9	11.3	10.5	11.2	**11.0%**
Weight									**0.3120**
Post-Draining Test Characteristics									**AVG**
Length	**1**	**2**							
	11.93	11.93							**11.93**
Width	**1**	**2**	**3**	**4**					
	3.26	3.24	3.25	3.26					**3.25**
Thickness	**1**	**2**	**3**	**4**					
	0.85	0.83	0.82	0.81					**0.83**
Weight									**0.3300**
Post-Test Characteristics									**AVG**
Length	**1**	**2**							
	11.93	11.93							**11.93**
Width	**1**	**2**	**3**	**4**					
	3.26	3.25	3.24	3.25					**3.25**
Thickness	**1**	**2**	**3**	**4**					
	0.79	0.79	0.80	0.79					**0.79**
Moisture Content	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
	15.8	15.5	16.8	17.8	17.0	16.5	16.5	16.8	**16.6%**
Weight									**0.3215**
Moisture content by Oven Dry Method				**Oven**	**0.295**				**9.0%**
Geometric Deformation									

		Cupping	Crown	Buckling	Other		Notes:
Pre-Test		X	X	X	X		
Post-Test		X	X	X	X		

Test Specimen Record Sheet									
Test Protocol #	1		**Test**	2	Date	05/13/2022			
Specimen #	2		**Type of Material**		Heart Pine		**Species**	*Pinus sp.*	
Grain Orientation	Rift			**Probe**		MC2			
Pre-Test Characteristics									**AVG**
Length	**1**	**2**							
	12.06	12.06							**12.06**
Width	**1**	**2**	**3**	**4**					
	3.26	3.25	3.27	3.26					**3.26**
Thickness	**1**	**2**	**3**	**4**					
	0.77	0.77	0.77	0.77					**0.77**
Moisture Content	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
	11.2	11.4	11.3	11.3	11.4	10.9	11.5	11.4	**11.0%**
Weight									**0.3170**
Post-Draining Test Characteristics									**AVG**
Length	**1**	**2**							
	12.06	12.06							**12.06**
Width	**1**	**2**	**3**	**4**					
	3.26	3.25	3.27	3.26					**3.26**
Thickness	**1**	**2**	**3**	**4**					
	0.85	0.85	0.84	0.82					**0.84**
Weight									**0.3436**
Post-Test Characteristics									**AVG**
Length	**1**	**2**							
	12.06	12.06							**12.06**
Width	**1**	**2**	**3**	**4**					
	3.25	3.26	3.25	3.25					**3.25**
Thickness	**1**	**2**	**3**	**4**					
	0.78	0.78	0.78	0.78					**0.78**
Moisture Content	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
	15.5	16.4	16.1	15.6	17.3	17.0	17.2	16.8	**16.5%**
Weight									**0.3300**
Moisture content by Oven Dry Method				**Oven**	**0.295**				**12.0%**
Geometric Deformation									

		Cupping	Crown	Buckling	Other		Notes:
Pre-Test		X	X	X	X		
Post-Test		X	X	X	X		

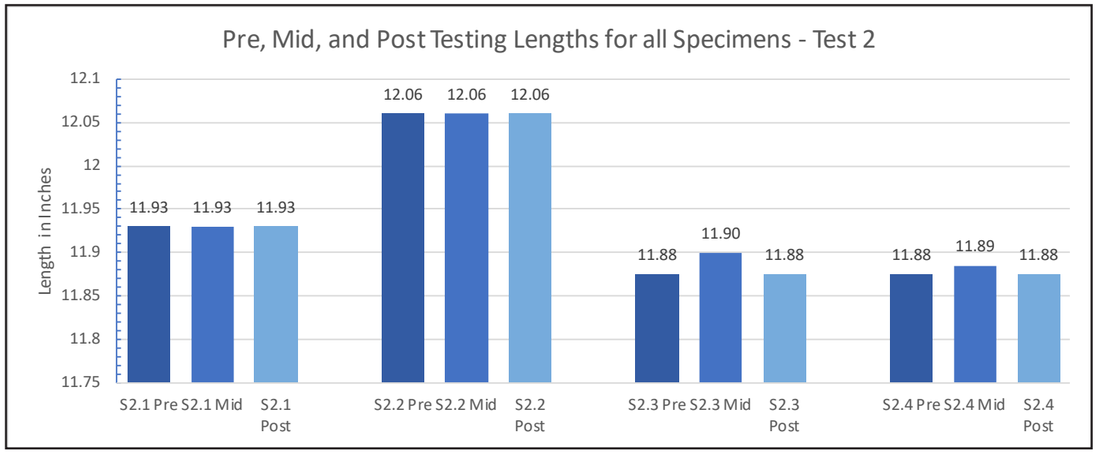
Test Specimen Record Sheet									
Test Protocol #	1		**Test**	2	**Date**	05/13/2022			
Specimen #	3		**Type of Material**		Heart Pine		**Species**	*Pinus sp.*	
Grain Orientation	Rift			**Probe**		MC3			
Pre-Test Characteristics									**AVG**
Length	**1**	**2**							
	11.88	11.88							**11.88**
Width	**1**	**2**	**3**	**4**					
	3.27	3.27	3.26	3.26					**3.27**
Thickness	**1**	**2**	**3**	**4**					
	0.77	0.77	0.77	0.77					**0.77**
Moisture Content	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
	11.2	11.0	11.1	10.9	10.9	10.2	10.8	10.2	**11.0%**
Weight									**0.3125**
Post-Draining Test Characteristics									**AVG**
Length	**1**	**2**							
	11.90	11.90							**11.90**
Width	**1**	**2**	**3**	**4**					
	3.29	3.30	3.29	3.28					**3.29**
Thickness	**1**	**2**	**3**	**4**					
	0.86	0.85	0.84	0.83					**0.85**
Weight									**0.3321**
Post-Test Characteristics									**AVG**
Length	**1**	**2**							
	11.88	11.88							**11.88**
Width	**1**	**2**	**3**	**4**					
	3.27	3.27	3.26	3.28					**3.27**
Thickness	**1**	**2**	**3**	**4**					
	0.78	0.78	0.78	0.78					**0.78**
Moisture Content	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
	16.8	15.1	16.2	14.9	16.8	16.7	16.0	16.0	**16.1%**
Weight									**0.3265**
Moisture content by Oven Dry Method				**Oven**	**0.295**				**11.0%**
Geometric Deformation									

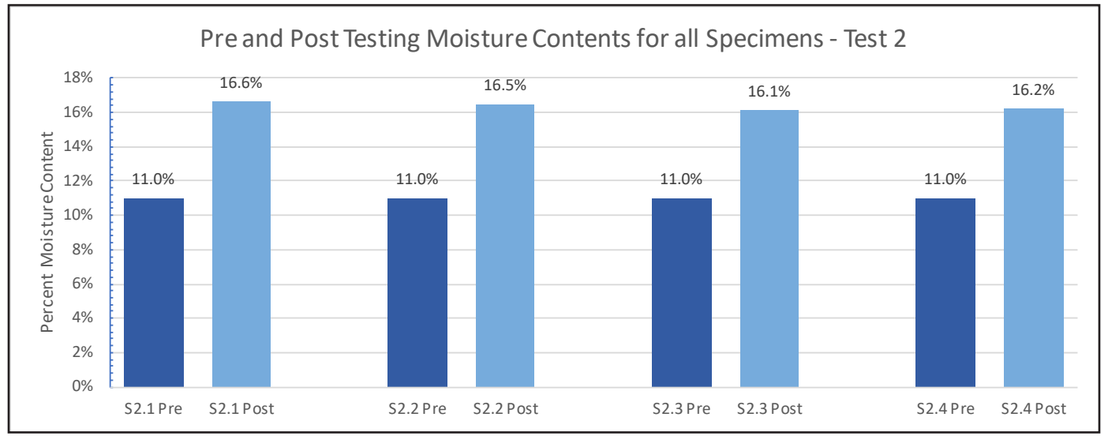
		Cupping	Crown	Buckling	Other		Notes:
Pre-Test		X	X	X	X		
Post-Test		X	X	X	X		

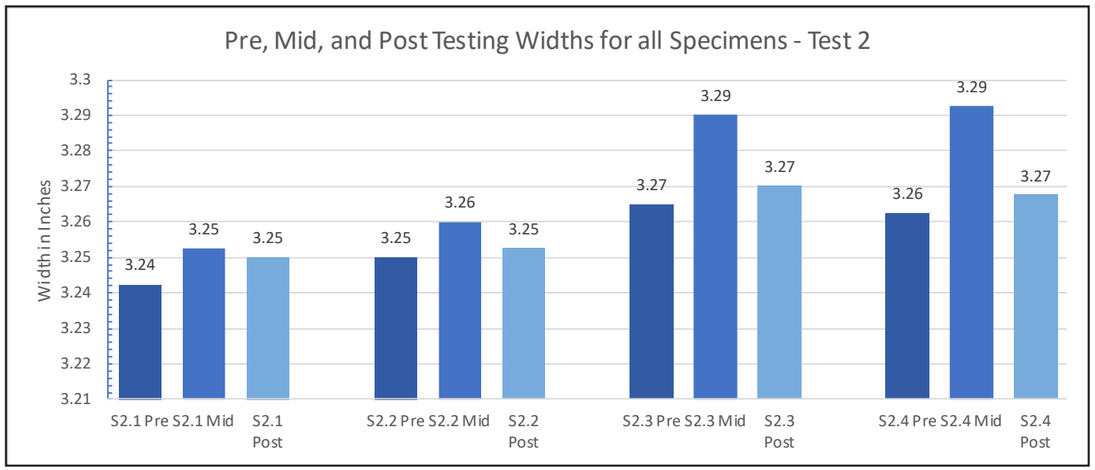
Test Specimen Record Sheet									
Test Protocol #	1		**Test**	2	**Date**	05/13/2022			
Specimen #	4		**Type of Material**		Heart Pine		**Species**	*Pinus sp.*	
Grain Orientation	Rift			**Probe**		MC4			
Pre-Test Characteristics									**AVG**
Length	**1**	**2**							
	11.88	11.88							**11.88**
Width	**1**	**2**	**3**	**4**					
	3.26	3.26	3.26	3.27					**3.26**
Thickness	**1**	**2**	**3**	**4**					
	0.77	0.77	0.77	0.77					**0.77**
Moisture Content	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
	10.4	10.3	10.9	11.2	10.9	11.0	10.9	11.1	**11.0%**
Weight									**0.3150**
Post-Draining Test Characteristics									**AVG**
Length	**1**	**2**							
	11.88	11.89							**11.89**
Width	**1**	**2**	**3**	**4**					
	3.30	3.30	3.29	3.28					**3.29**
Thickness	**1**	**2**	**3**	**4**					
	0.85	0.85	0.84	0.83					**0.84**
Weight									**0.3321**
Post-Test Characteristics									**AVG**
Length	**1**	**2**							
	11.88	11.88							**11.88**
Width	**1**	**2**	**3**	**4**					
	3.26	3.26	3.28	3.27					**3.27**
Thickness	**1**	**2**	**3**	**4**					
	0.78	0.78	0.78	0.78					**0.78**
Moisture Content	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
	16.8	15.7	16.2	15.2	17.0	16.0	16.9	16.1	**16.2%**
Weight									**0.3295**
Moisture content by Oven Dry Method				**Oven**	**0.295**				**12.0%**
Geometric Deformation									

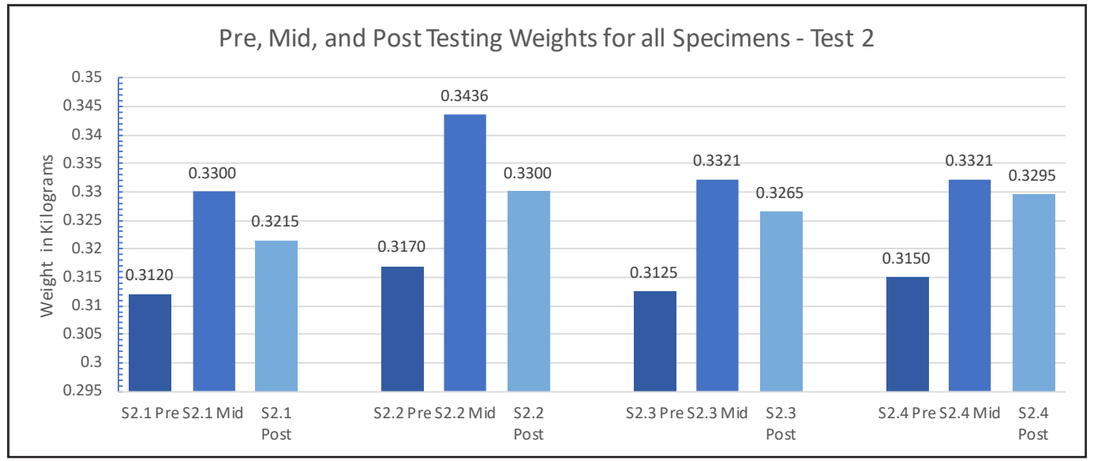
		Cupping	Crown	Buckling	Other		Notes:
Pre-Test		X	X	X	X		
Post-Test		X	X	X	X		

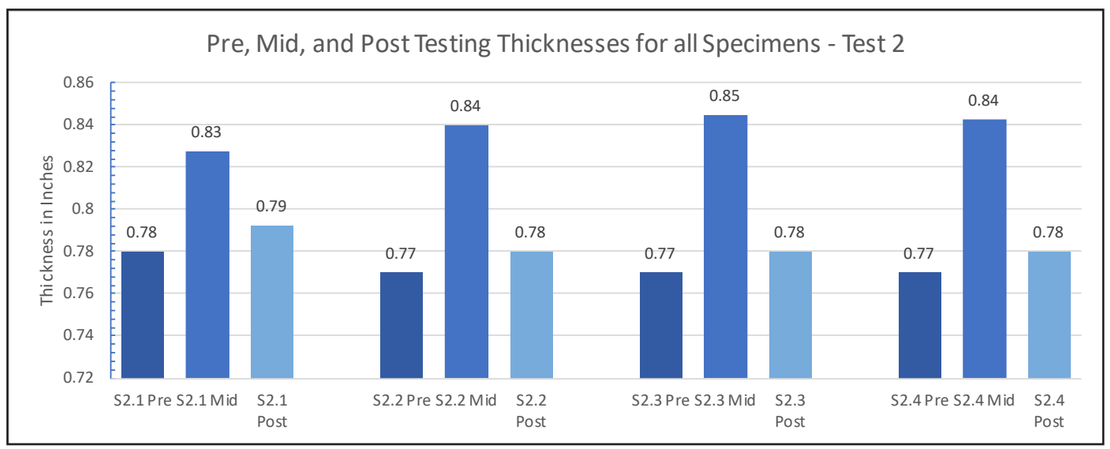
Appendix B3: Test 2 Results Graphs

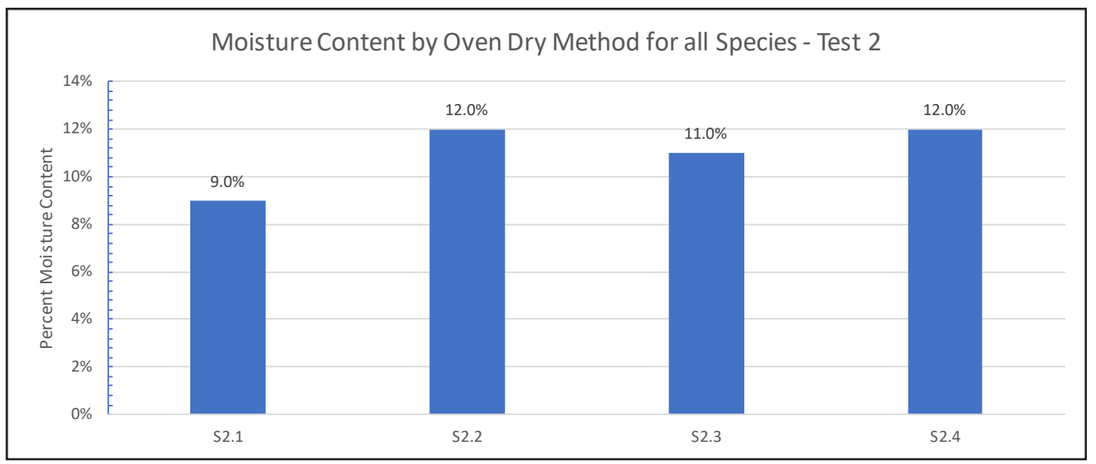


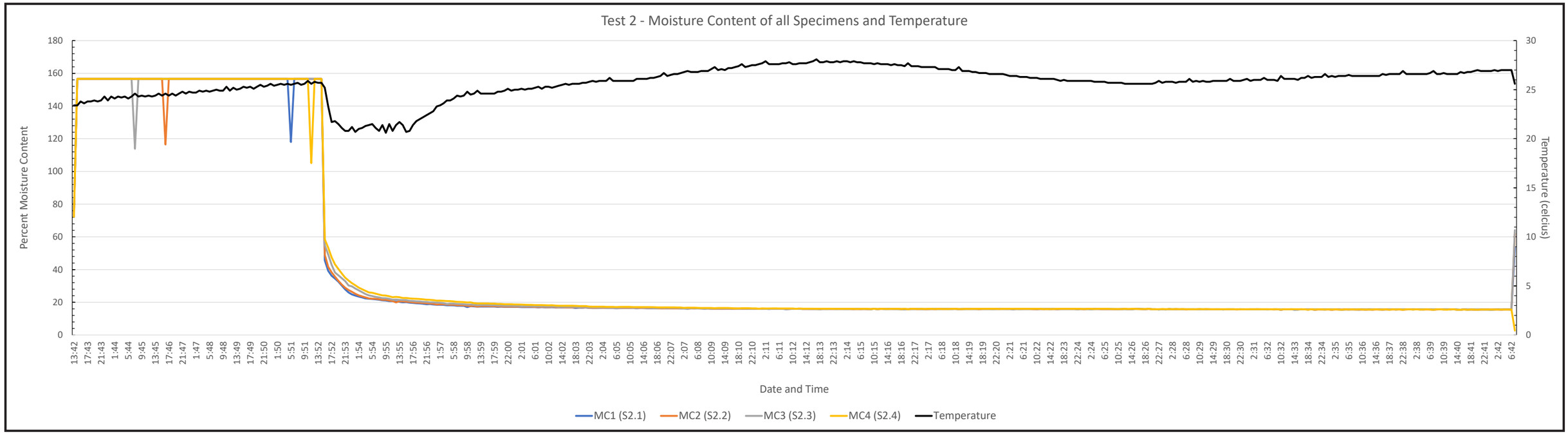








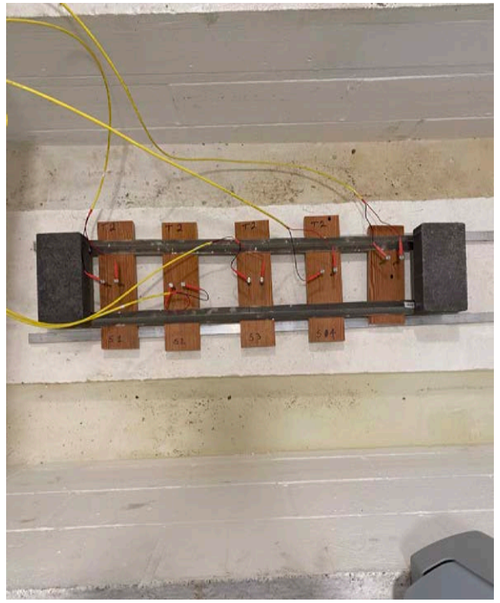



Test 2 - Moisture Content of all Specimens and Temperature
Percent Moisture Content
Temperature (celcius)
Date and Time
MC1 (S2.1)
MC2 (S2.2)
MC3 (S2.3)
MC4 (S2.4)
Temperature

Appendix B4: Test 2 Photographs

Appendix B4 Figure 1 - Typical Test 2 specimen

Appendix B4 Figure 2 - Typical Test 2 specimen



Appendix B4 Figure 3 - Test 2 specimens before flooding

APPENDIX C: TEST 3 - OLD GROWTH SOUTHERN YELLOW PINE, FLAT SAWN

The following pages include the Testing Observations Report for Test 3, the Testing Specimens Record Sheet for each Test 3 specimen, Test 3 Results Graphs, and Test 3 photographs.

Appendix C1: Test 3 Testing Observation Report

TESTING OBSERVATIONS REPORT	
Test Protocol	Flood Test Protocol #1
Test #	Test 3
Test Duration	06/10/2022 - 06/21/2022
Starting Time Stamp	06/10/2022 - 03:15pm
Draining Time Stamp	06/13/2022 - 03:52pm
Starting Environmental Conditions • **Tempreature** • **Relative Humidity**	 73.0°F 74.0%
Setpoint Environmental Conditions • **Tempreature** • **Relative Humidity**	 70.0°F 70%
Water Level (above sample) • **Min** • **Max**	 3.00 in 3.25 in
Drying Duration • **Start** • **End**	 06/13/2022 - 03:52pm 06/21/2022 - 06:42pm
General Observations:	• Used wall tank as the floor tank is leaking when filled • Recycled Heart Pine, flat sawn, wider less dense than test 2 material • Installed new circulating pump for chilled water, pump • Electrical failure caused the Lignomat system to crash, not restarted • Elitech RH monitor cash lost due to power failure

Appendix C2: Test 3 Specimen Record Sheets

Test Specimen Record Sheet									
Test Protocol #	1		**Test**	3	Date	06/10/2022			
Specimen #	1		**Type of Material**		Heart Pine		**Species**	*Pinus sp.*	
Grain Orientation	Flat			**Probe**		MC1			
Pre-Test Characteristics									**AVG**
Length	**1**	**2**							
	11.94	11.94							**11.94**
Width	**1**	**2**	**3**	**4**					
	3.26	3.25	3.27	3.25					**3.26**
Thickness	**1**	**2**	**3**	**4**					
	0.77	0.77	0.77	0.77					**0.77**
Moisture Content	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
	14.3	14.7	14.4	14.7	17.1	18.4	18.7	17.0	**16.0%**
Weight									**0.4020**
Post-Draining Test Characteristics									**AVG**
Length	**1**	**2**							
	11.88	11.89							**11.89**
Width	**1**	**2**	**3**	**4**					
	3.30	3.30	3.29	3.28					**3.29**
Thickness	**1**	**2**	**3**	**4**					
	0.85	0.85	0.84	0.83					**0.84**
Weight									**0.4210**
Post-Test Characteristics									**AVG**
Length	**1**	**2**							
	11.88	11.88							**11.88**
Width	**1**	**2**	**3**	**4**					
	3.28	3.26	3.26	3.28					**3.27**
Thickness	**1**	**2**	**3**	**4**					
	0.77	0.78	0.78	0.78					**0.78**
Moisture Content	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
	15.4	15.0	14.6	15.0	15.9	16.1	16.1	16.0	**15.5%**
Weight									**0.4015**
Moisture content by Oven Dry Method				**Oven**	**0.37**				**9.0%**
Geometric Deformation									

		Cupping	Crown	Buckling	Other		Notes: Slight raised grain after test
Pre-Test		X	Slight	X	X		
Post-Test		X	X	X	X		

Test Specimen Record Sheet									
Test Protocol #	1		**Test**	3	Date	06/10/2022			
Specimen #	2		**Type of Material**		Heart Pine		**Species**	*Pinus sp.*	
Grain Orientation	Flat			**Probe**		MC2			
Pre-Test Characteristics									**AVG**
Length	**1**	**2**							
	11.94	11.94							**11.94**
Width	**1**	**2**	**3**	**4**					
	3.24	3.24	3.25	3.26					**3.25**
Thickness	**1**	**2**	**3**	**4**					
	0.77	0.77	0.78	0.78					**0.78**
Moisture Content	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
	14.8	14.7	14.7	14.3	15.3	14.8	14.9	15.3	**15.0%**
Weight									**0.4195**
Post-Draining Test Characteristics									**AVG**
Length	**1**	**2**							
	12.06	12.06							**12.06**
Width	**1**	**2**	**3**	**4**					
	3.29	3.28	3.27	3.26					**3.28**
Thickness	**1**	**2**	**3**	**4**					
	0.85	0.85	0.84	0.82					**0.84**
Weight									**0.4290**
Post-Test Characteristics									**AVG**
Length	**1**	**2**							
	11.88	11.88							**11.88**
Width	**1**	**2**	**3**	**4**					
	3.25	3.26	3.25	3.27					**3.26**
Thickness	**1**	**2**	**3**	**4**					
	0.79	0.78	0.78	0.79					**0.79**
Moisture Content	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
	15.9	14.5	15.7	15.5	18.0	17.8	17.3	18.3	**16.6%**
Weight									**0.4125**
Moisture content by Oven Dry Method				**Oven**	**0.37**				**12.0%**
Geometric Deformation									

		Cupping	Crown	Buckling	Other		Notes: Slight raised grain after test
Pre-Test		X	Slight	X	X		
Post-Test		X	X	X	X		

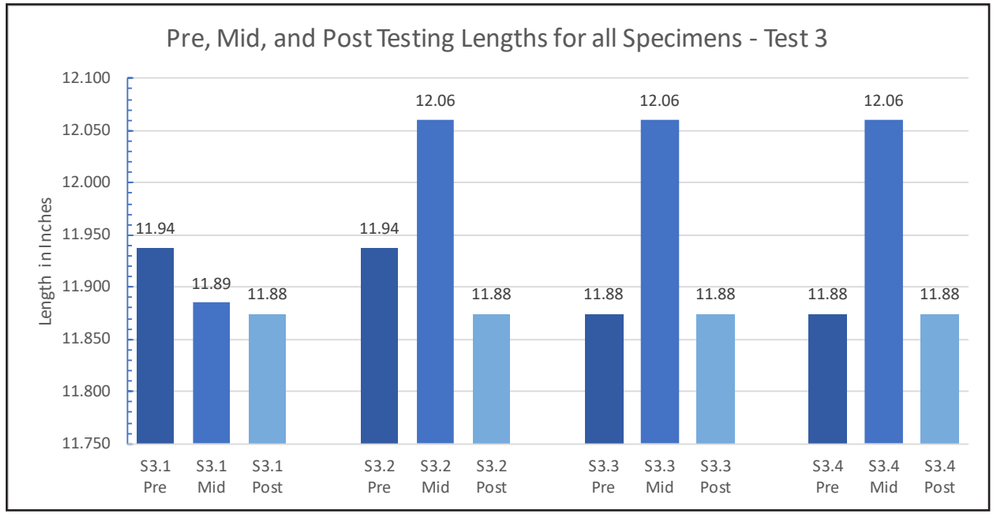
Test Specimen Record Sheet									
Test Protocol #	1		**Test**	3	**Date**	06/10/2022			
Specimen #	3		**Type of Material**		Heart Pine		**Species**	*Pinus sp.*	
Grain Orientation	Flat			**Probe**		MC3			
Pre-Test Characteristics									**AVG**
Length	**1**	**2**							
	11.88	11.88							**11.88**
Width	**1**	**2**	**3**	**4**					
	3.27	3.26	3.27	3.26					**3.27**
Thickness	**1**	**2**	**3**	**4**					
	0.77	0.77	0.77	0.77					**0.77**
Moisture Content	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
	14.0	13.7	14.6	14.1	15.6	15.0	16.1	16.0	**15.0%**
Weight									**0.4075**
Post-Draining Test Characteristics									**AVG**
Length	**1**	**2**							
	12.06	12.06							**12.06**
Width	**1**	**2**	**3**	**4**					
	3.29	3.30	3.28	3.29					**3.29**
Thickness	**1**	**2**	**3**	**4**					
	0.85	0.85	0.84	0.82					**0.84**
Weight									**0.4240**
Post-Test Characteristics									**AVG**
Length	**1**	**2**							
	11.88	11.88							**11.88**
Width	**1**	**2**	**3**	**4**					
	3.29	3.29	3.28	3.27					**3.28**
Thickness	**1**	**2**	**3**	**4**					
	0.79	0.78	0.78	0.77					**0.78**
Moisture Content	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
	14.8	14.6	14.5	14.4	15.7	16.0	16.6	15.9	**15.3%**
Weight									**0.4150**
Moisture content by Oven Dry Method				**Oven**	**0.37**				**12.0%**
Geometric Deformation									

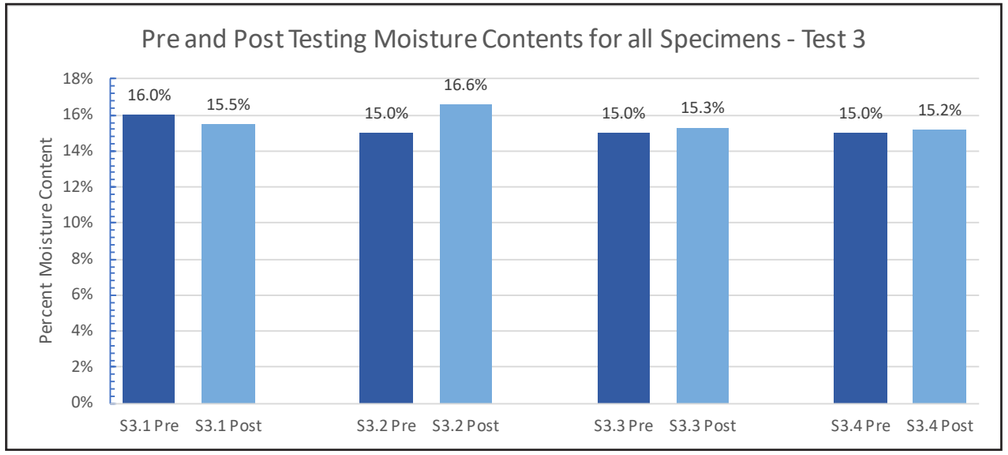
		Cupping	Crown	Buckling	Other		Notes: Slight checking and raised grain after test
Pre-Test		X	Slight	X	X		
Post-Test		X	X	X	X		

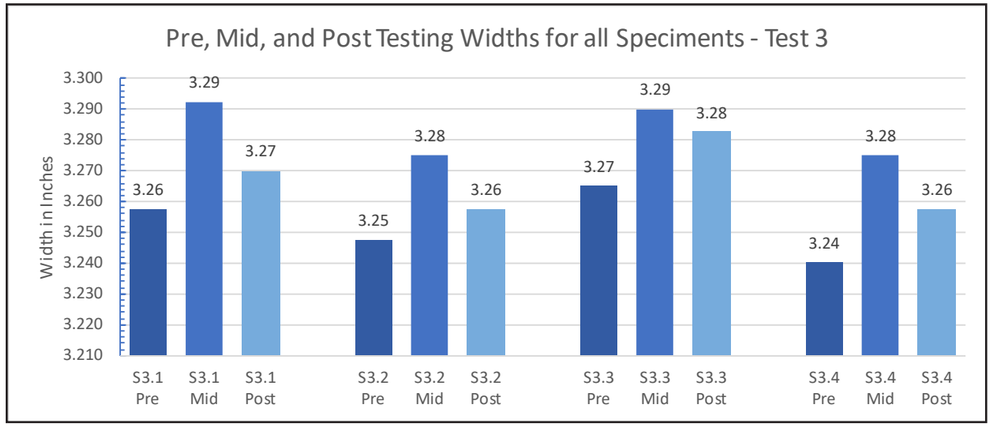
Test Specimen Record Sheet									
Test Protocol #	1		**Test**	3	**Date**	06/10/2022			
Specimen #	4		**Type of Material**		Heart Pine		**Species**	*Pinus sp.*	
Grain Orientation	Flat			**Probe**		MC4			
Pre-Test Characteristics									**AVG**
Length	**1**	**2**							
	11.88	11.88							**11.88**
Width	**1**	**2**	**3**	**4**					
	3.24	3.25	3.24	3.23					**3.24**
Thickness	**1**	**2**	**3**	**4**					
	0.77	0.77	0.77	0.77					**0.77**
Moisture Content	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
	14.6	14.2	14.4	14.2	16.9	16.1	16.0	16.2	**15.0%**
Weight									**0.4120**
Post-Draining Test Characteristics									**AVG**
Length	**1**	**2**							
	12.06	12.06							**12.06**
Width	**1**	**2**	**3**	**4**					
	3.26	3.29	3.27	3.28					**3.28**
Thickness	**1**	**2**	**3**	**4**					
	0.85	0.85	0.84	0.82					**0.84**
Weight									**0.4290**
Post-Test Characteristics									**AVG**
Length	**1**	**2**							
	11.88	11.88							**11.88**
Width	**1**	**2**	**3**	**4**					
	3.24	3.26	3.27	3.26					**3.26**
Thickness	**1**	**2**	**3**	**4**					
	0.78	0.78	0.78	0.77					**0.78**
Moisture Content	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
	14.7	14.6	15.3	15.6	14.2	15.5	16.0	15.7	**15.2%**
Weight									**0.4185**
Moisture content by Oven Dry Method				**Oven**	**0.37**				**13.0%**
Geometric Deformation									

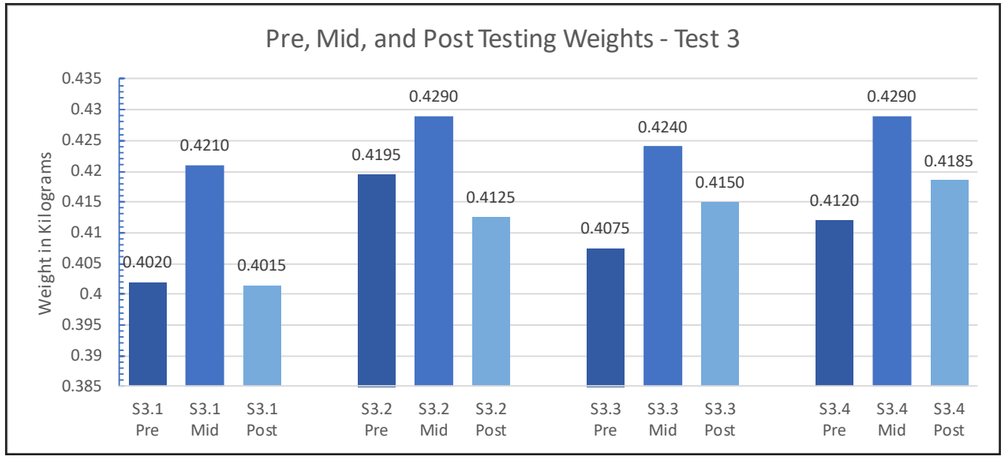
		Cupping	Crown	Buckling	Other		Notes: Slight checking and raised grain after test
Pre-Test		X	Slight	X	X		
Post-Test		X	X	X	X		

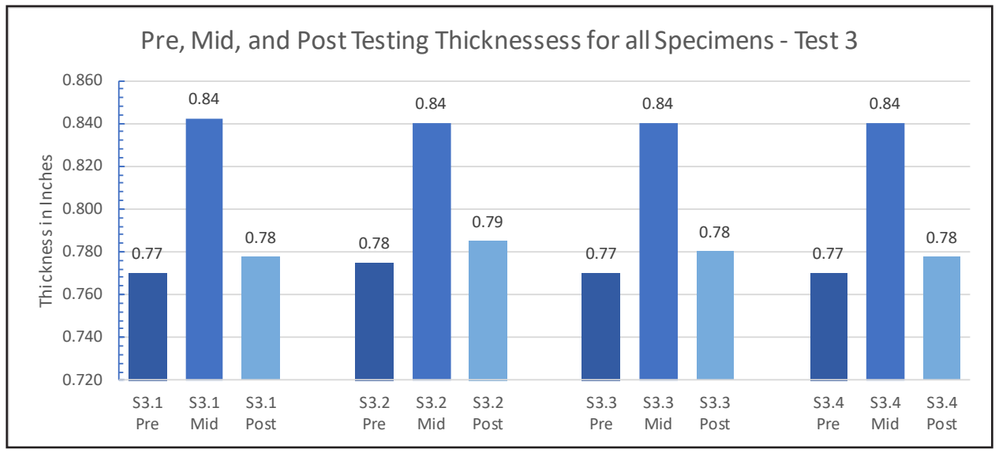
Appendix C3: Test 3 Results Graphs

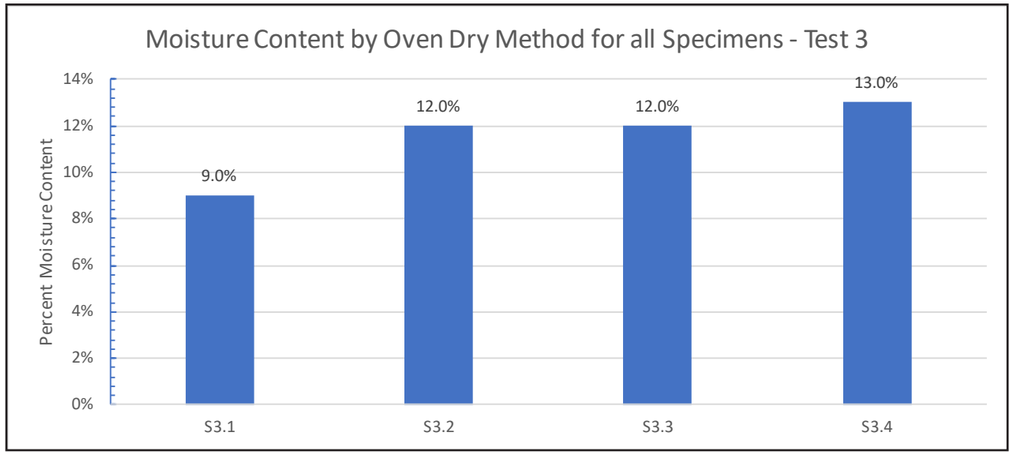


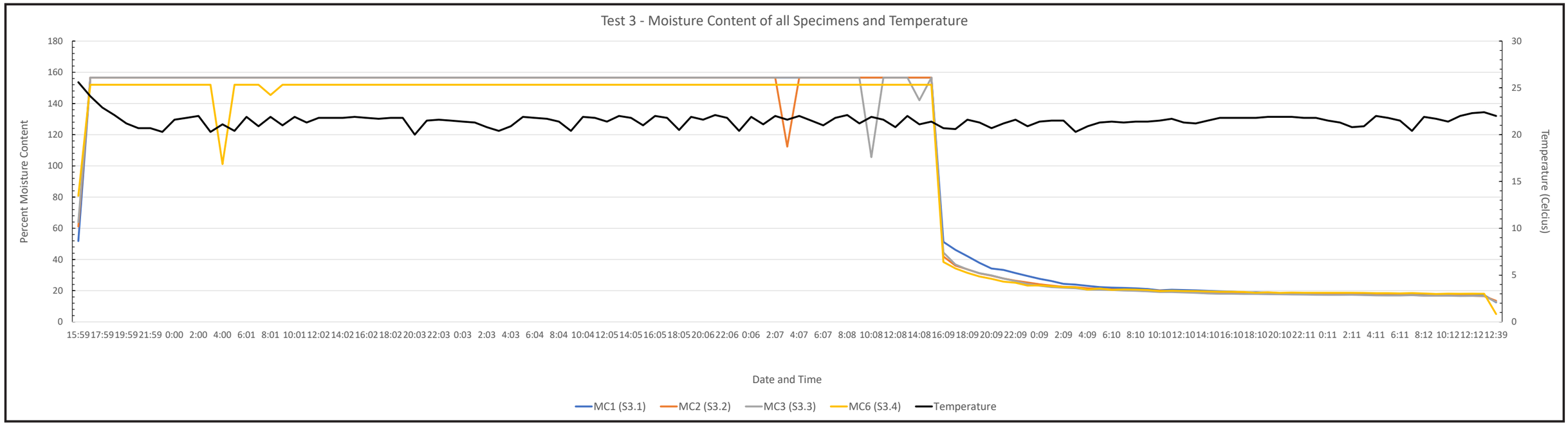










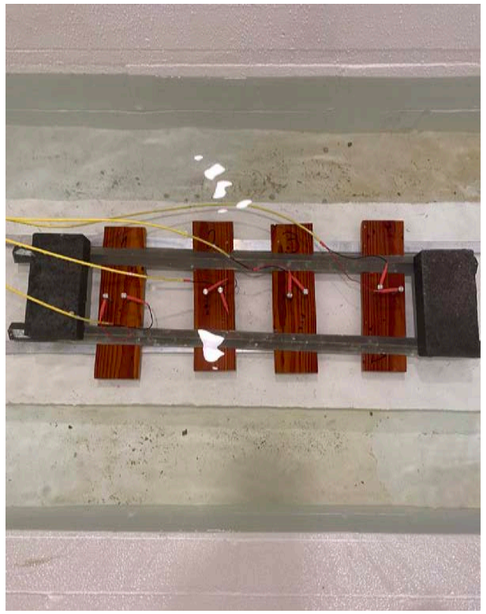

Test 3 - Moisture Content of all Specimens and Temperature
Percent Moisture Content
Temperature (Celcius)
180
160
140
120
100
80
60
40
20
0
30
25
20
15
10
5
0
15:59 17:59 19:59 21:59 0:00 2:00 4:00 6:01 8:01 10:01 12:02 14:02 16:02 18:02 20:03 22:03 0:03 2:03 4:03 6:04 8:04 10:04 12:05 14:05 16:05 18:05 20:06 22:06 0:06 2:07 4:07 6:07 8:08 10:08 12:08 14:08 16:09 18:09 20:09 22:09 0:09 2:09 4:09 6:10 8:10 10:10 12:10 14:10 16:10 18:10 20:10 22:11 0:11 2:11 4:11 6:11 8:12 10:12 12:12 12:39
Date and Time
MC1 (S3.1)
MC2 (S3.2)
MC3 (S3.3)
MC6 (S3.4)
Temperature

Appendix C4: Test 3 Photographs

Appendix C4 Figure 1 - Test 3 specimens before testing

Appendix C4 Figure 2 - Typical Test 3 specimen before testing

Appendix C4 Figure 3 - Test 3, specimens 4 and 2 before testing



Appendix C4 Figure 3 - Test 3 specimens during flooding

APPENDIX D: TEST 4 - MODERN WHITE OAK & MODERN SOUTHERN YELLOW PINE

The following pages include the Testing Observations Report for Test 4, the Testing Specimens Record Sheet for each Test 4 specimen, Test 4 Results Graphs, and Test 3 photographs.

Appendix D1: Test 4 Testing Observation Report

TESTING OBSERVATIONS REPORT	
Test Protocol	Flood Test Protocol #1
Test #	Test 4
Test Duration	06/21/2022 - 06/29/2022
Starting Time Stamp	06/21/2022 - 12:40pm
Draining Time Stamp	06/24/2022 - 03:55pm
Starting Environmental Conditions • **Tempreature** • **Relative Humidity**	 69.5°F 80%
Setpoint Environmental Conditions • **Tempreature** • **Relative Humidity**	 70.0°F 70%
Water Level (above sample) • **Min** • **Max**	 3.00 in 3.25 in
Drying Duration • **Start** • **End**	 06/24/2022 - 03:55pm 06/29/2022 - 01:00pm
General Observations:	• Used wall tank as the floor tank is leaking when completely filled • Testing open growth modern SYP and White Oak flooring together • Started test data collection Test 4 • Data collection normal • Elitech RH/T collection “BRS 4” • Tank water brown in color from tannins in Oak

Appendix D2: Test 4 Specimen Record Sheets

Test Specimen Record Sheet									
Test Protocol #	1		**Test**	4	**Date**	06/21/2022			
Specimen #	1		**Type of Material**		W. Oak T&G		**Species**	*Quercus sp.*	
Grain Orientation	Rift			**Probe**		MC1			
Pre-Test Characteristics									**AVG**
Length	**1**	**2**							
	11.94	11.94							**11.94**
Width	**1**	**2**	**3**	**4**					
	3.47	3.47	3.47	3.47					**3.47**
Thickness	**1**	**2**	**3**	**4**					
	0.75	0.75	0.74	0.74					**0.75**
Moisture Content	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
	12.8	14.3	12.0	12.4	8.9	9.3	8.2	9.6	**11.0%**
Weight									**0.3925**
Post-Draining Test Characteristics									**AVG**
Length	**1**	**2**							
	12.00	12.00							**12.00**
Width	**1**	**2**	**3**	**4**					
	3.26	3.25	3.27	3.26					**3.26**
Thickness	**1**	**2**	**3**	**4**					
	0.85	0.85	0.84	0.82					**0.84**
Weight									**0.4210**
Post-Test Characteristics									**AVG**
Length	**1**	**2**							
	11.94	11.94							**11.94**
Width	**1**	**2**	**3**	**4**					
	3.50	3.50	3.50	3.50					**3.50**
Thickness	**1**	**2**	**3**	**4**					
	0.77	0.75	0.76	0.78					**0.77**
Moisture Content	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
	17.6	18.0	18.8	18.2	14.5	13.8	15.5	14.3	**16.3%**
Weight									**0.4015**
Moisture content by Oven Dry Method				**Oven**	**0.3825**				**5.0%**
Geometric Deformation									

		Cupping	Crown	Buckling	Other		Notes: Sample has one open knot
Pre-Test		X	X	X	X		
Post-Test		X	X	X	X		

Test Specimen Record Sheet									
Test Protocol #	1		**Test**	4	**Date**	06/21/2022			
Specimen #	2		**Type of Material**		W. Oak T&G		**Species**	*Quercus sp.*	
Grain Orientation	Rift			**Probe**		MC2			
Pre-Test Characteristics									**AVG**
Length	**1**	**2**							
	11.94	11.94							**11.94**
Width	**1**	**2**	**3**	**4**					
	3.39	3.40	3.39	3.40					**3.40**
Thickness	**1**	**2**	**3**	**4**					
	0.75	0.75	0.76	0.76					**0.76**
Moisture Content	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
	11.8	11.4	11.4	11.4	10.6	17.7	18.6	17.4	**14.0%**
Weight									**0.3435**
Post-Draining Test Characteristics									**AVG**
Length	**1**	**2**							
	12.06	12.06							**12.06**
Width	**1**	**2**	**3**	**4**					
	3.45	3.49	3.44	3.49					**3.47**
Thickness	**1**	**2**	**3**	**4**					
	0.85	0.85	0.86	0.82					**0.85**
Weight									**0.3612**
Post-Test Characteristics									**AVG**
Length	**1**	**2**							
	11.94	11.94							**11.94**
Width	**1**	**2**	**3**	**4**					
	3.42	3.42	3.41	3.41					**3.42**
Thickness	**1**	**2**	**3**	**4**					
	0.75	0.75	0.77	0.77					**0.76**
Moisture Content	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
	7.4	7.5	7.6	6.9	10.6	17.7	18.6	17.4	**11.7%**
Weight									**0.3495**
Moisture content by Oven Dry Method				**Oven**	**0.3321**				**5.0%**
Geometric Deformation									

		Cupping	Crown	Buckling	Other		Notes:
Pre-Test		X	X	X	X		
Post-Test		X	X	X	X		

Test Specimen Record Sheet									
Test Protocol #	1		**Test**	4	Date	06/21/2022			
Specimen #	3		**Type of Material**		W. Oak T&G		**Species**	*Quercus sp.*	
Grain Orientation	Rift			**Probe**		MC3			
Pre-Test Characteristics									**AVG**
Length	**1**	**2**							
	12.00	12.00							**12.00**
Width	**1**	**2**	**3**	**4**					
	3.44	3.44	3.44	3.44					**3.44**
Thickness	**1**	**2**	**3**	**4**					
	0.76	0.75	0.75	0.75					**0.75**
Moisture Content	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
	11.8	11.4	11.4	11.4	10.6	17.7	18.6	17.4	**14.0%**
Weight									**0.3435**
Post-Draining Test Characteristics									**AVG**
Length	**1**	**2**							
	12.06	12.00							**12.03**
Width	**1**	**2**	**3**	**4**					
	3.48	3.49	3.50	3.49					**3.49**
Thickness	**1**	**2**	**3**	**4**					
	0.85	0.85	0.86	0.82					**0.85**
Weight									**0.3980**
Post-Test Characteristics									**AVG**
Length	**1**	**2**							
	12.00	12.00							**12.00**
Width	**1**	**2**	**3**	**4**					
	3.45	3.45	3.46	3.46					**3.46**
Thickness	**1**	**2**	**3**	**4**					
	0.76	0.77	0.77	0.77					**0.77**
Moisture Content	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
	18.5	20.1	19.0	17.5	12.4	13.3	13.6	13.8	**16.0%**
Weight									**0.4015**
Moisture content by Oven Dry Method				**Oven**	**0.3695**				**9.0%**
Geometric Deformation									

		Cupping	Crown	Buckling	Other		Notes: Sample has 1 open knot
Pre-Test		X	X	X	X		
Post-Test		X	X	X	X		

Test Specimen Record Sheet									
Test Protocol #	1		**Test**	4	Date	06/21/2022			
Specimen #	4		**Type of Material**		Pine S4S		**Species**	*Pinus sp.*	
Grain Orientation	Rift			**Probe**		MC4			
Pre-Test Characteristics									**AVG**
Length	**1**	**2**							
	11.94	11.94							**11.94**
Width	**1**	**2**	**3**	**4**					
	3.50	3.50	3.50	3.50					**3.50**
Thickness	**1**	**2**	**3**	**4**					
	0.74	0.75	0.74	0.74					**0.74**
Moisture Content	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
	8.7	8.8	9.4	9.2	9.5	9.0	10.2	10.0	**9.0%**
Weight									**0.2130**
Post-Draining Test Characteristics									**AVG**
Length	**1**	**2**							
	12.06	12.06							**12.06**
Width	**1**	**2**	**3**	**4**					
	3.87	3.67	3.70	3.69					**3.73**
Thickness	**1**	**2**	**3**	**4**					
	0.85	0.85	0.86	0.82					**0.85**
Weight									**0.2780**
Post-Test Characteristics									**AVG**
Length	**1**	**2**							
	12.06	12.10							**12.08**
Width	**1**	**2**	**3**	**4**					
	3.59	3.62	3.60	3.55					**3.59**
Thickness	**1**	**2**	**3**	**4**					
	0.75	0.75	0.76	0.75					**0.75**
Moisture Content	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
	11.0	11.5	11.5	11.2	11.8	12.3	12.1	11.7	**11.6%**
Weight									**0.2200**
Moisture content by Oven Dry Method				**Oven**	**0.2065**				**7.0%**
Geometric Deformation									

		Cupping	Crown	Buckling	Other		Notes:
Pre-Test		X	X	X	X		
Post-Test		X	X	X	X		

Test Specimen Record Sheet									
Test Protocol #	1		**Test**	4	Date	06/21/2022			
Specimen #	5		**Type of Material**		Pine S4S		**Species**	*Pinus sp.*	
Grain Orientation	Rift			**Probe**		MC5			
Pre-Test Characteristics									**AVG**
Length	**1**	**2**							
	11.94	11.94							**11.94**
Width	**1**	**2**	**3**	**4**					
	3.50	3.50	3.50	3.50					**3.50**
Thickness	**1**	**2**	**3**	**4**					
	0.75	0.75	0.74	0.74					**0.75**
Moisture Content	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
	9.8	10.5	9.8	9.5	10.6	9.8	9.8	9.8	**10.0%**
Weight									**0.2200**
Post-Draining Test Characteristics									**AVG**
Length	**1**	**2**							
	12.06	12.06							**12.06**
Width	**1**	**2**	**3**	**4**					
	3.78	3.79	3.80	3.77					**3.79**
Thickness	**1**	**2**	**3**	**4**					
	0.85	0.85	0.86	0.82					**0.85**
Weight									**0.2670**
Post-Test Characteristics									**AVG**
Length	**1**	**2**							
	11.94	11.94							**11.94**
Width	**1**	**2**	**3**	**4**					
	3.59	3.65	3.60	3.61					**3.61**
Thickness	**1**	**2**	**3**	**4**					
	0.75	0.76	0.77	0.75					**0.76**
Moisture Content	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
	11.6	12.0	12.5	12.3	11.7	11.9	11.7	11.4	**11.9%**
Weight									**0.2265**
Moisture content by Oven Dry Method				**Oven**	**0.2065**				**10.0%**
Geometric Deformation									

		Cupping	Crown	Buckling	Other		Notes:
Pre-Test		X	X	X	X		
Post-Test		X	X	X	X		

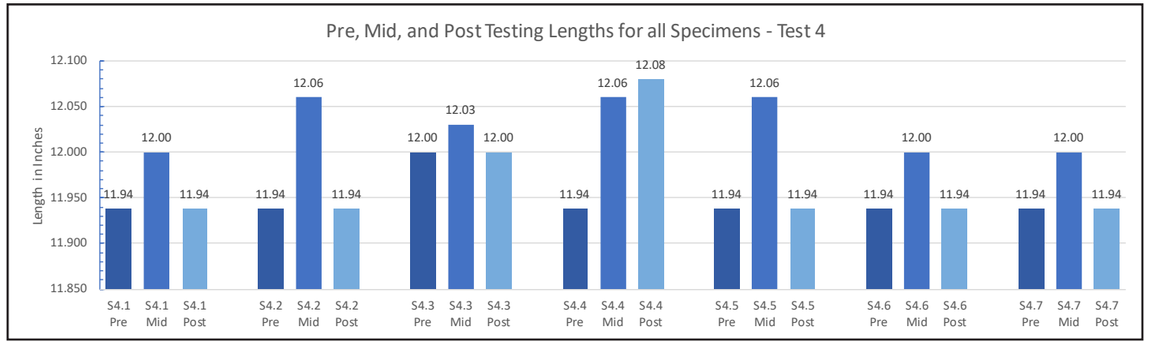
Test Specimen Record Sheet									
Test Protocol #	1		**Test**	4	Date	06/21/2022			
Specimen #	6		**Type of Material**		Pine S4S		**Species**	*Pinus sp.*	
Grain Orientation	Rift			**Probe**		MC4			
Pre-Test Characteristics									**AVG**
Length	**1**	**2**							
	11.94	11.94							**11.94**
Width	**1**	**2**	**3**	**4**					
	3.50	3.49	3.49	3.50					**3.50**
Thickness	**1**	**2**	**3**	**4**					
	0.75	0.75	0.74	0.74					**0.75**
Moisture Content	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
	10.4	10.1	10.2	10.1	10.0	9.6	10.0	9.9	**10.0%**
Weight									**0.2170**
Post-Draining Test Characteristics									**AVG**
Length	**1**	**2**							
	12.00	12.00							**12.00**
Width	**1**	**2**	**3**	**4**					
	3.76	3.70	3.71	3.69					**3.69**
Thickness	**1**	**2**	**3**	**4**					
	0.85	0.85	0.85	0.82					**0.84**
Weight									**0.2650**
Post-Test Characteristics									**AVG**
Length	**1**	**2**							
	11.94	11.94							**11.94**
Width	**1**	**2**	**3**	**4**					
	3.60	3.59	3.58	3.60					**3.60**
Thickness	**1**	**2**	**3**	**4**					
	0.75	0.75	0.78	0.78					**0.77**
Moisture Content	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
	12.3	12.3	12.6	12.2	12.2	11.9	11.4	11.8	**12.1%**
Weight									**0.2240**
Moisture content by Oven Dry Method				**Oven**	**0.2065**				**8.0%**
Geometric Deformation									

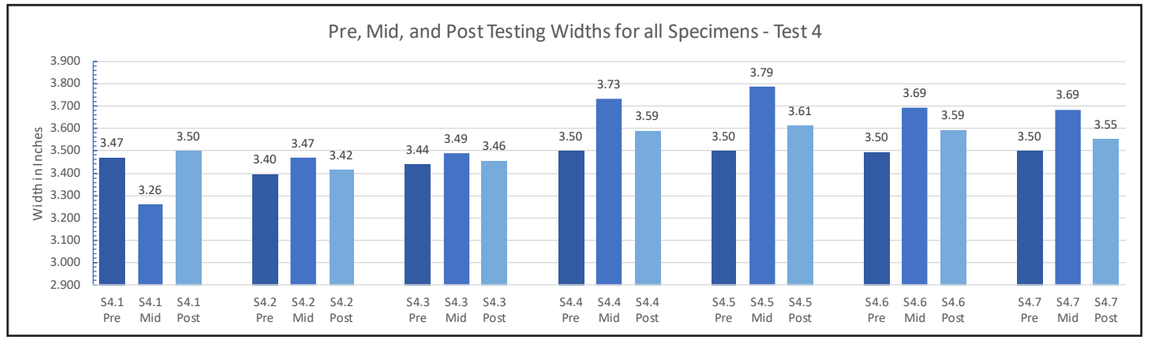
		Cupping	Crown	Buckling	Other		Notes:
Pre-Test		X	X	X	X		
Post-Test		X	X	X	X		

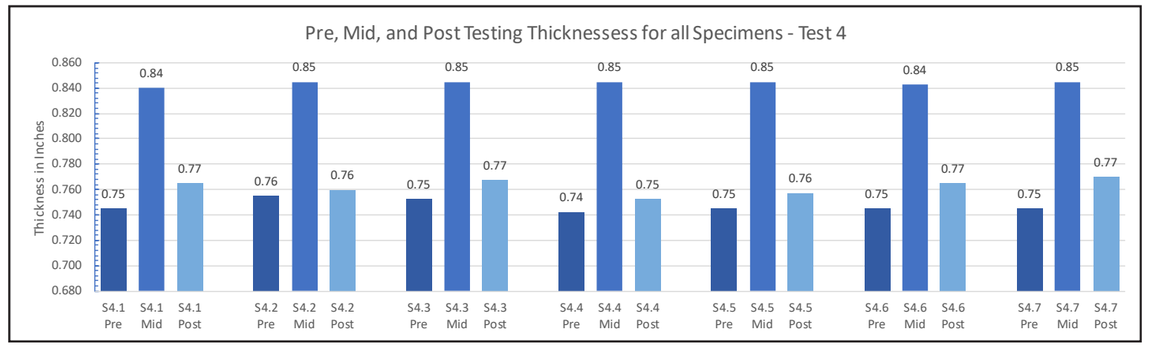
Test Specimen Record Sheet									
Test Protocol #	1		**Test**	4	**Date**	06/21/2022			
Specimen #	7		**Type of Material**		Pine S4S		**Species**	*Pinus sp.*	
Grain Orientation	Rift			**Probe**		MC7			
Pre-Test Characteristics									**AVG**
Length	**1**	**2**							
	11.94	11.94							**11.94**
Width	**1**	**2**	**3**	**4**					
	3.50	3.50	3.50	3.50					**3.50**
Thickness	**1**	**2**	**3**	**4**					
	0.75	0.75	0.74	0.74					**0.75**
Moisture Content	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
	11.7	10.7	11.2	10.9	11.0	11.9	10.1	10.4	**11.0%**
Weight									**0.2260**
Post-Draining Test Characteristics									**AVG**
Length	**1**	**2**							
	12.00	12.00							**12.00**
Width	**1**	**2**	**3**	**4**					
	3.70	3.69	3.65	3.70					**3.69**
Thickness	**1**	**2**	**3**	**4**					
	0.85	0.85	0.86	0.82					**0.85**
Weight									**0.2720**
Post-Test Characteristics									**AVG**
Length	**1**	**2**							
	11.94	11.94							**11.94**
Width	**1**	**2**	**3**	**4**					
	3.52	3.60	3.57	3.52					**3.55**
Thickness	**1**	**2**	**3**	**4**					
	0.75	0.77	0.78	0.78					**0.77**
Moisture Content	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
	13.5	12.9	13.3	13.1	12.4	12.8	12.3	12.8	**12.9%**
Weight									**0.2330**
Moisture content by Oven Dry Method				**Oven**	**0.2065**				**13.0%**
Geometric Deformation									

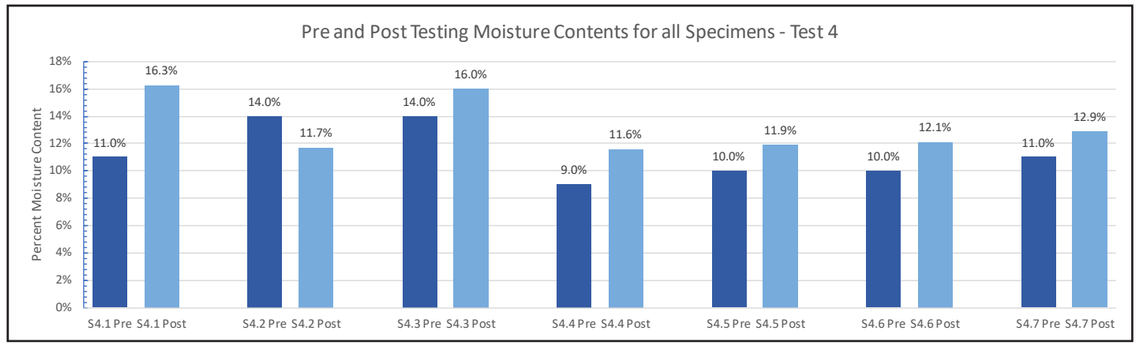
		Cupping	Crown	Buckling	Other		Notes:
Pre-Test		X	X	X	X		
Post-Test		X	X	X	X		

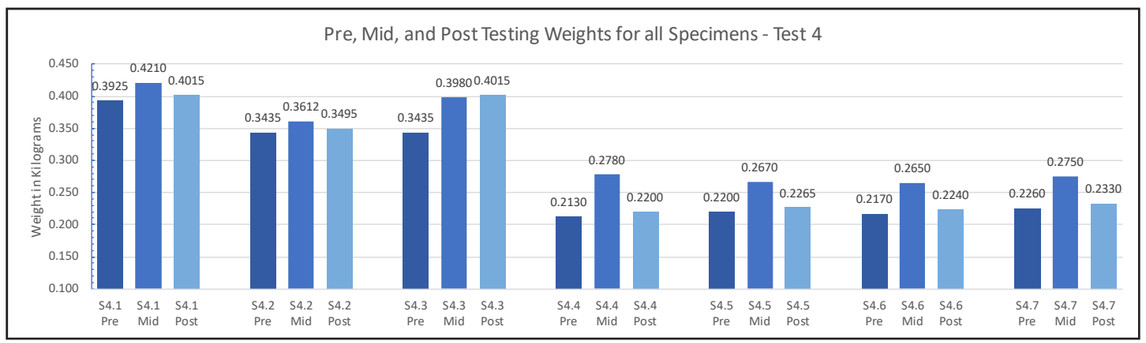
Appendix D3: Test 4 Results Graphs

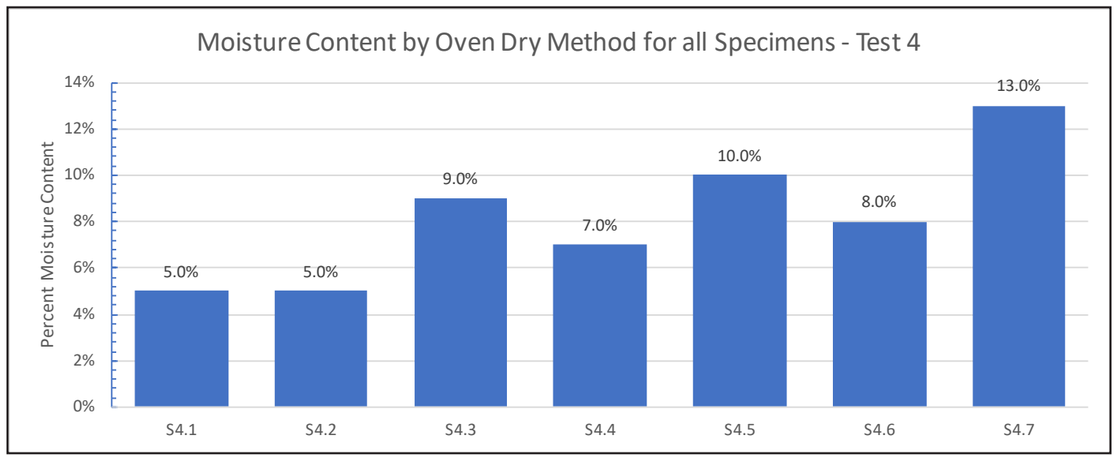












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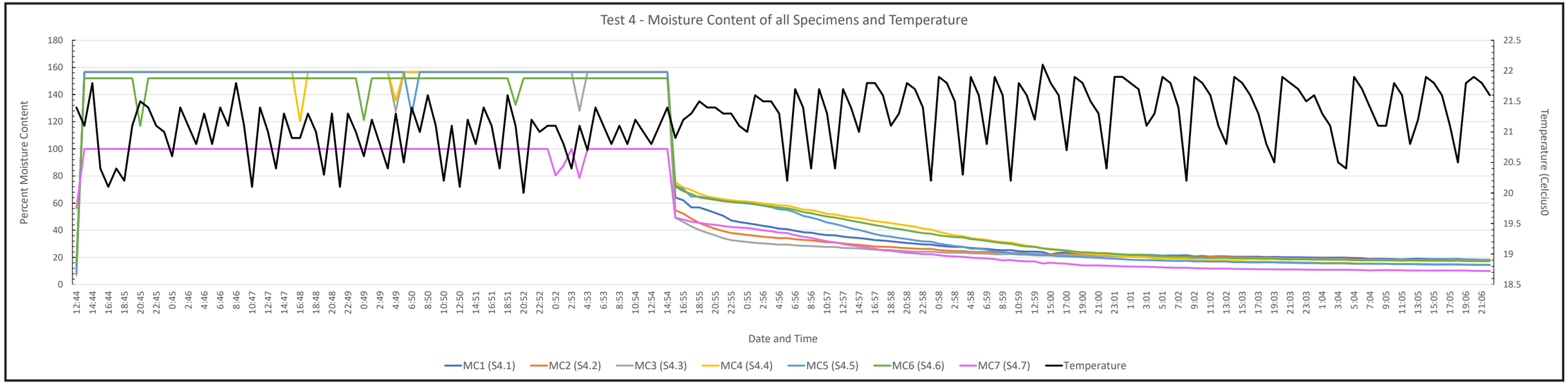
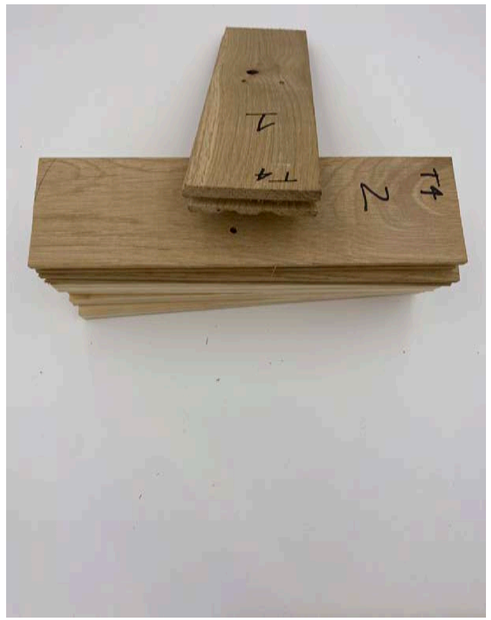
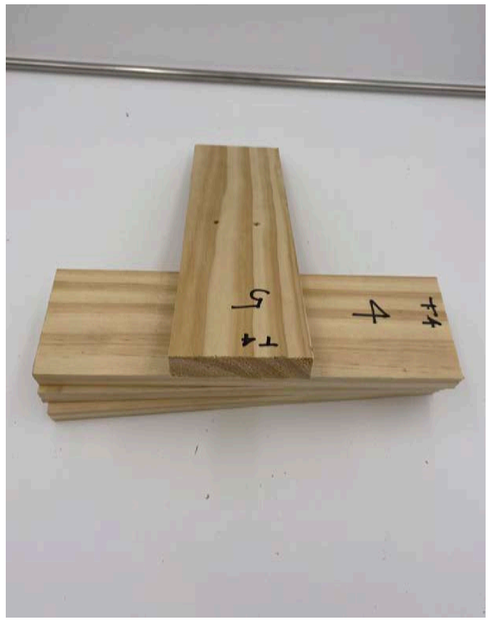

Test 4 - Moisture Content of all Specimens and Temperature
Percent Moisture Content
Temperature (Celcius)
Date and Time
MC1 (S4.1)
MC2 (S4.2)
MC3 (S4.3)
MC4 (S4.4)
MC5 (S4.5)
MC6 (S4.6)
MC7 (S4.7)
Temperature

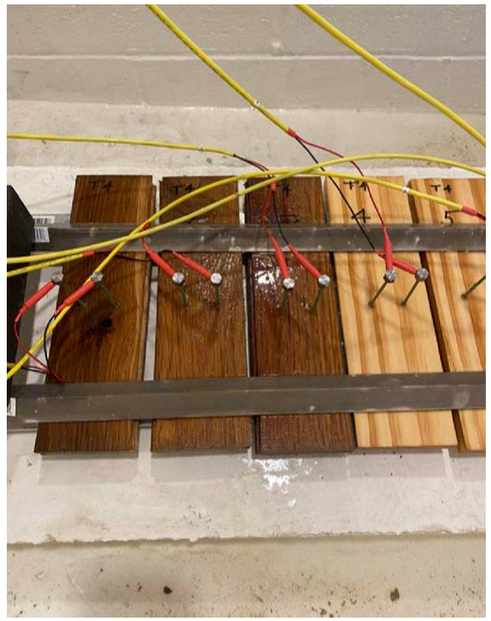
Appendix D4: Test 4 Photographs



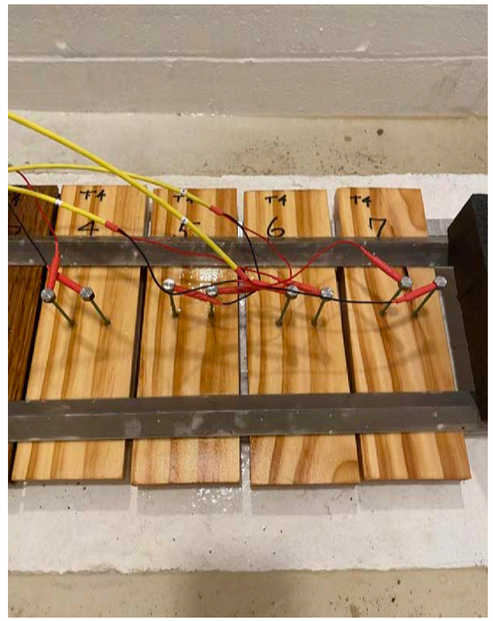
Appendix D4 Figure 1 - Test 4, specimens 1 and 2 before testing



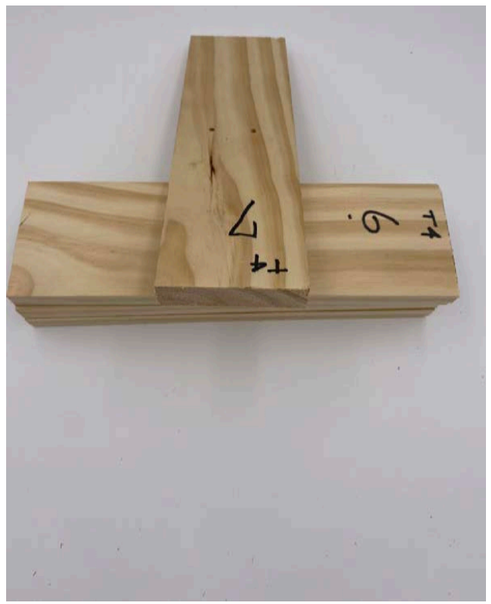
Appendix D4 Figure 2 - Test 4, specimens 4 and 5 before testing



Appendix D4 Figure 5 - Test 4, specimens 1-5 after draining



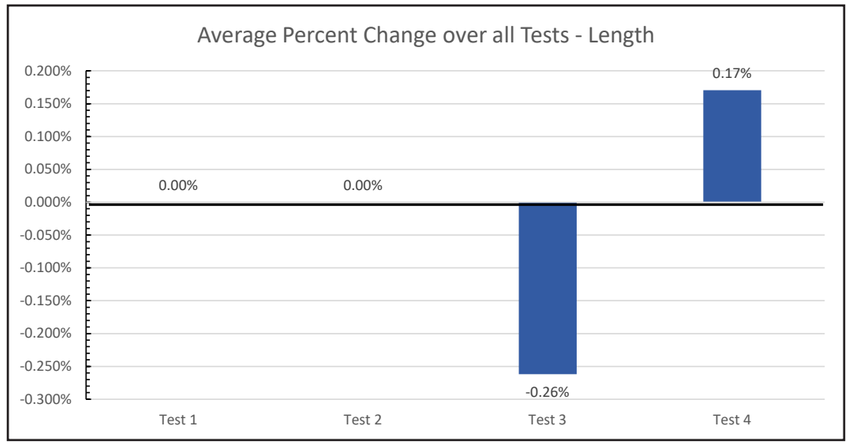
Appendix D4 Figure 5 - Test 4, specimens 4-7 after draining

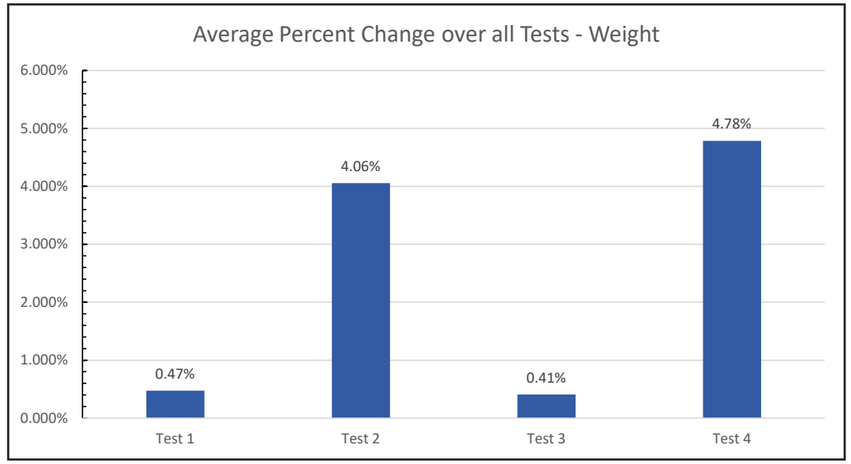


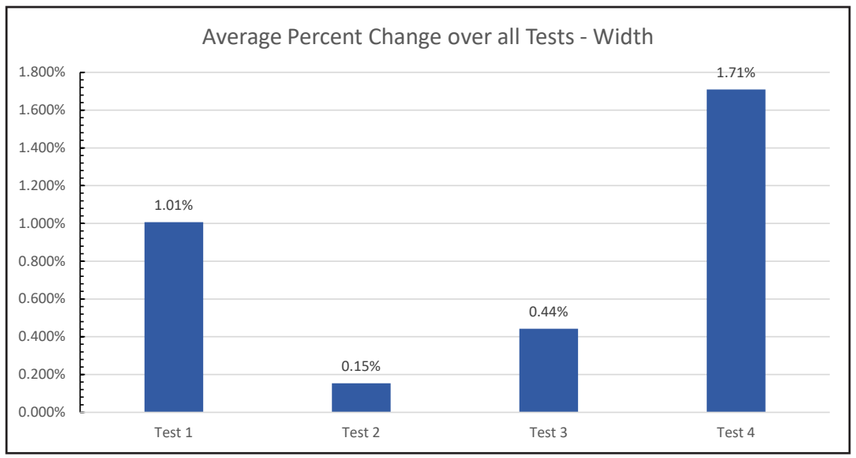
Appendix D4 Figure 3 - Test 4, specimens 6 and 7 before testing

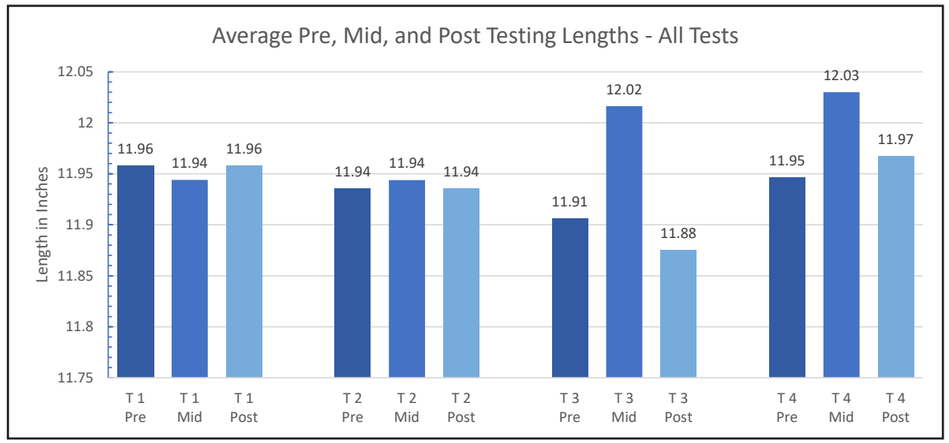
Appendix D4 Figure 4 - Test 4 specimens after draining

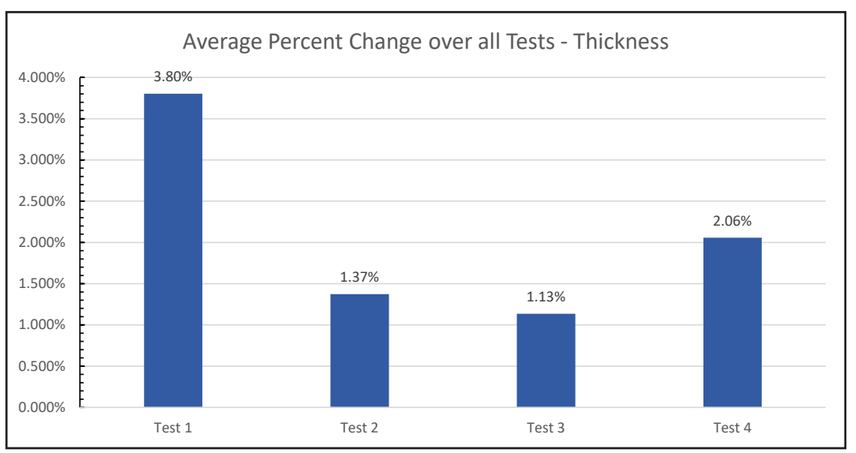
APPENDIX E: COMPARATIVE RESULTS ACROSS TESTS 1-4

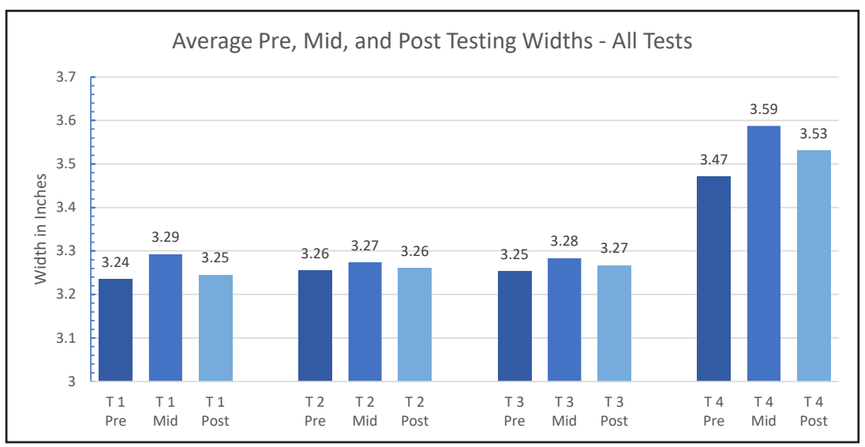


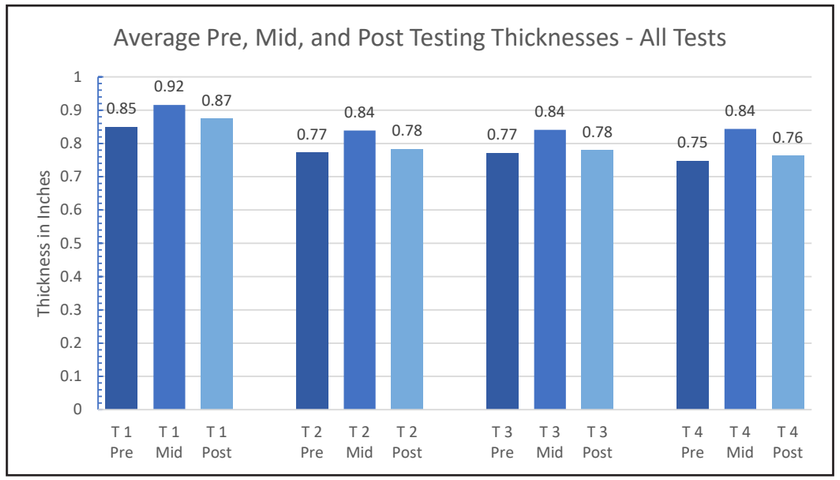


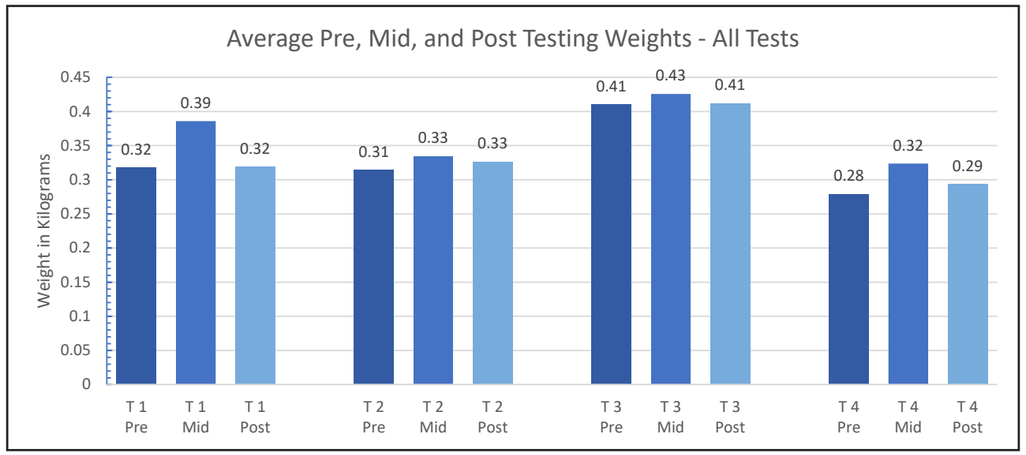


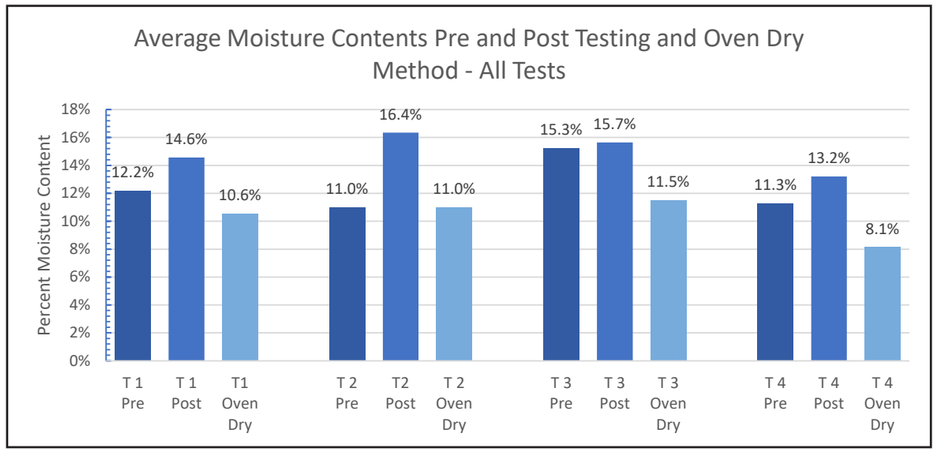












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