AN ABSTRACT OF THE THESIS OF

Byrne Tadaaki Miyamoto for the degree of Master of Science in Wood Science presented on May 8, 2017.

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Abstract approved:

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Arijit Sinha

Western juniper (*Juniperus occidentalis*) is a conifer that is native to Oregon, California, Washington, Nevada, and Idaho. Juniper is known to have highly decay resistant heartwood and is a popular choice for finished furniture. With recent forest management practices over the past 100 years have resulted in an immense population increase in western juniper stands, transforming the grasslands/sagebrush into juniper forests. Landowners have been encouraged to cutback western juniper to restore grassland habitat, but there is no major market associated with juniper. This study assessed the strength and durability properties of western juniper in order to develop design values in collaboration with the West Coast Lumber Inspection Bureau (WCLIB). The data will be presented to American Lumber Standard Committee (ALSC) for inclusion in the National Design Specification. Design values assigned to western juniper will allow contractors to use this species in structural and non-structural applications, especially for State funded projects.

Samples were harvested from three locations in eastern Oregon, one location in northeast California, and one location in southwest Idaho. Tests were performed according to procedures described in ASTM Standard D143 small-clear specimens for compression, bending, and shear. Average strength values were calculated and compared to similar wood species. Most properties were similar to those of other species, but modulus of elasticity was significantly lower. The differences between species might be attributed to cell wall structure and distribution of lignin in the cells. Design values for western juniper were calculated using the strength values following the ASTM Standard D245 procedure for establishing structural grades and related allowable properties for visually graded lumber.

Durability of western juniper was assessed using laboratory decay tests, marine tests, and ground contact exposure. The long term marine durability and ground contact tests are still on going. The laboratory decay test indicated that western juniper heartwood was highly resistant to attack by brown and white rot fungi.

Establishing Design Values for Potential Utilization of Western Juniper as a Building Material

by
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I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

Byrne Tadaaki Miyamoto, Author

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CHAPTER 1: INTRODUCTION

Western juniper is a coniferous tree species that grows to 6 to 18 m tall and a diameter of approximately 0.3 to 0.9 m (Brockman 2002). It thrives in a continental climate, with hot dry summers, cold winters, and precipitation between 230 to 355 mm/year. Western juniper is native to California, Oregon, Idaho, and parts of Nevada and Washington. Juniper cover has drastically increased in the past century as a result of the introduction of livestock grazing, increased amounts of CO_2, and the main cause, fire suppression (Miller et al. 2005). Western juniper has drastically altered the natural habitat by shading out sagebrush and consuming excessive amounts of water. Western juniper can consume up to 151 liters of ground water per day if adequate soil moisture is available (Bedell et al. 1993). Western juniper encroachment in these areas has changed the landscape by decreasing grass, forbs and shrub vegetation. Vegetation decline has caused a corresponding reduction in wildlife species in juniper forested areas (Bedell et al. 1993). Landowners have been encouraged to cut back juniper stands on their land to halt the spread of western juniper and restore the native grasses. The primary way land owners control western juniper is to bulldoze stems over or pull them down using chain. These methods produced considerable soil disturbance and result in high nutrient loss. The recommended method for western juniper removal is to chainsaw the trees and then haul them out to be processed for alternative uses. This procedure can be costly, creating little incentive for landowners. This has created a large volume of available western juniper, with few options for utilization.

There has been some investigation into creating products from western juniper like pencil stock, essential oils, and hardboard, but these markets have not developed to the extent required to encourage restoration (Leavengood 2008). There are a few niche markets where western juniper has been utilized. Wine vineyards have used juniper posts to support grape vines, since juniper is naturally durable and does not need chemical treatment for preservation. Small portable shacks provide another niche market for juniper. These shacks are generally manufactured from western red cedar, another naturally durable wood species. The natural durability of juniper makes it a good fit for this type of application. The lack of a market for western juniper is due in part to the limited knowledge and needs for data to be published on the properties of this species.

Examining markets that utilize treated or naturally durable wood species could open up avenues for western juniper utilization. Western juniper has highly fungal and insect resistant heartwood, due to the presence of extractives including cedrol (Highley 1995). Lignin levels are higher in western juniper heartwood than in most other naturally durable softwoods, such as western red cedar or redwood when placed in ground contact (Morrell et al. 1999). In 2014, the State of Oregon approved western juniper heartwood as an alternative material for areas subjected to moisture. The material must meet the definition of "naturally durable" by the Oregon Structural Specialty Code (OSSC) and the Oregon Residential Specialty Code (ORSC) (State or Oregon Building Codes Division 2014). This allows western juniper to be used for residential construction, most notably as a sill plate in a house. The "naturally durable wood" definition entails being decay and termite resistant, and was derived from prior research (Morrell et al. 1999).

Allowing western juniper as an alternative building material in applications calling for naturally durable wood has opened a larger market for this species. However, engineers and contractors need to know the material properties of the wood they are using including factored values for design or "design values". Design values are created by collecting test data for multiple mechanical properties of a material and then statistically analyzing them to generate the lower 5^{th} percentile value. Engineers can apply design values to a multitude of adjustment factors, such as load duration and wet service, to obtain a value for designing a structure.

Burke (2008) studied compression, tension, bending, shear, and hardness of western juniper, and reported the average values, but did not convert these values to design values. Raw data for the mechanical tests of each wood sample must be compiled in a specific manner. Unfortunately, the Burke data was lost before they could be properly evaluated. Therefore, there are currently no published design values for western juniper.

Design values are especially important because they are required in government-funded projects even as a non-structural material or in landscaping. These values must be listed in the National Design Specification (NDS) for Timber Construction. The absence of design values for juniper is another impediment to utilization, even for non-structural and landscaping material.

The procedures for development of design values for a wood species in the National Design Specification for Timber Construction (NDS) consists of testing samples from many different locations and going through the process of certification as laid out by the American Lumber Standards Committee (ALSC). The first step in creating design values for a species is to establish a testing and material protocol that outlines the type of testing being conducted, number of tests being conducted and the geographical origin of the material to be obtained. Once the material is procured from the listed geographical locations, the samples are prepared for testing according to relevant testing methods. The sample size needs to be sufficiently robust to obtain the lower 5^{th} percentile. After testing is complete, data are analyzed by a professional engineer affiliated with a certification agency listed in the NDS. For this study, the West Coast Lumber Inspection Bureau (WCLIB) analyzed the data and presented its report to ALSC for their approval and subsequent inclusion in the next NDS. After ALSC's review the values and the report will be handed off to American Wood Council who publishes the NDS. Mechanical and durability testing were performed on western juniper samples from different locations within the growing range. The testing was performed in the Department of Wood Science and Engineering at Oregon State University, and certified by the West Coast Lumber Inspection Bureau. Completing the process of adding western juniper to the design codes and standards will allow for the use of juniper in commercial buildings. Increased utilization will stimulate the economy of rural areas where western juniper grows.

1.1 Research Objectives

The objectives of this study were to:

1. Test multiple mechanical properties of western juniper as well as calculating the green/dry ratio for shear and compression.
2. Analyze western juniper test data to formulate design values for the standards and codes.
3. Assess the durability properties of western juniper against marine borers and fungi.

CHAPTER 2: LITERATURE REVIEW

2.1 Western Juniper

Western juniper (*Juniperus occidentalis)* is a coniferous tree species that grows to between 6 to 18 m in height and can reach 0.3 to 0.9 m in diameter (Brockman 2002). Young western juniper trees (<25 years old) have needle-like leaves, while mature trees have rectangular leaves that overlap the adjacent leaf by 1-3 mm (Miller et al. 2005). The bark of western juniper has a cinnamon brown color and is divided into large, irregular, scaly plates (Brockman 2002). The tree begins to bear seeds between 10-20 years of age, with male cones having a yellowish-brown color and the female cones ("berries") having a bluish-black color (Miller et al. 2005).

2.2 Range and Climate

Western juniper is native to the western United States and is predominantly found in Oregon, California, Washington, Idaho, and Nevada (Figure 1). Western Juniper thrives in continental climates characterized by hot dry summers, cold winters, and a precipitation range of 230 to 355 mm per year (Martin 1978). Juniper woodlands are typically found on either open savannah-like areas or rocky ridges (Miller and Rose 1995). These woodland areas are commonly found between 600 and 1800 m elevation, but western juniper does not grow above 2100 m because the foliage can be damaged by extreme winter temperatures (Gedney et al. 1999, Miller and Rose 1995). The highest concentration of western juniper woodlands is in central and eastern Oregon with approximately 2 million hectares (Miller et al. 2005). Much of these woodland areas contain other co-existing trees and shrubs, such as ponderosa pine (*Pinus ponderosa*), aspen (*Populus* spp.), and willow (*Salix* spp.), along with mountain big sagebrush (*Artemisia tridentate* spp. *vaseyana),* and basin big sagebrush (*A.tridente* spp. *tridentata*) (Miller et al. 2005).

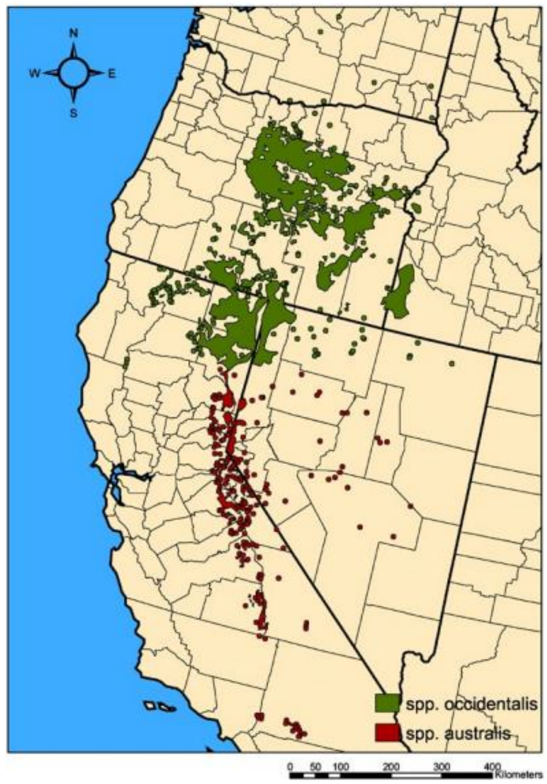

Figure 1: Native range of western juniper (Miller et al. 2005) (developed by Steve Petersen, Department of Rangeland Ecology and Management, Oregon State University, Corvallis, Oregon).

2.3 Expansion

There has been a significant increase in the area occupied by western juniper woodlands as they have aggressively sprawled over their native range. Western juniper stand area expanded by approximately 1173 hectares per year between 1650 and 1800. There was a large increase in rate of spread between 1850 and 1900 with the rate jumping to 9307 hectares per year (Gedney et al. 1999). The sudden increase in western juniper area was associated with the end of the Little Ice Age, which occurred between 1300 and 1870, and was the wettest, coolest period during the last half of the Holocene epoch (Miller et al. 2005). During this period, grass and shrub cover increased, which provided fuel that increased the potential for fires (Wigand et al. 1995). Fire is one of the main factors affecting western juniper in many regions.

The expansion of the western juniper range in last 100 years can be attributed mainly to anthropogenic factors associated with the establishment of settlements beginning approximately 130 years ago (Miller et al. 2005). Inventories taken over the past 60 years have shown a dramatic spike in the area occupied by western juniper forests from approximately 170,000 hectares (1 acre = 0.40 hectare) in 1936 to 1.3 million hectares in 1999. The area in 1936 was approximately 525,000 hectares and by 1999 increased to 2.5 million hectares when western juniper savannas were included in the inventory (Azuma et al. 2005).

There are 3 major anthropogenic factors affecting the increase in western juniper abundance – increasing atmospheric CO_2, more livestock grazing, and fewer fires. Increased CO_2 levels over the last half of the 20^{th} century may have helped increase the expansion of western juniper by accelerating tree canopy growth and establishment, as well as increasing annual sapwood growth (Johnson et al. 1993, Knapp and Soule 1996, Soule et al. 2004). Livestock grazing caused a reduction in fine fuel loads, which in turn significantly reduced the chances of fire (Miller and Rose 1999). The reduction of fire frequency is the most important factor in the establishment of western juniper. Decreased fuel loads due to livestock grazing have resulted in mean fire return intervals (MFRIs) increasing dramatically from 12-15 years to 90-130 years in some regions (Miller et al. 2005). Maintaining sagebrush grasslands free from western juniper would require MFRIs between 30 – 40 yr. Western juniper becomes more easily established when the MFRIs exceeds 50 years and produces a larger volume of seed (Burkhardt and Tisdale 1976).

Increasing areas of western juniper forest and savannah have induced many ecological changes in the affected areas. Western juniper ecosystems have lower water availability and reduced nutrient cycling due to canopy interception of rainfall and high water uptake (Bedell et al. 1993). The foliage and branches of an established western juniper canopy can intercept up to 5-8 cm of water per year, which represents a 25 to 38-percent loss of the average precipitation in these areas (Bedell et al. 1993). A western juniper tree can uptake 75 to 151 liters of water during the growing season and mid-summer if soil moisture is available (Bedell et al. 1993). Canopy interception and water uptake prevents water from reaching the understory, causing a decline in forbs, grasses, and shrubs. The decline of these native grasses, shrubs, and forbs altered the habitat for many animals. A survey conducted by the Prineville Bureau of Land Management District showed that approximately 146 species of wildlife inhabited open areas of grasses, shrubs, and forbs, but only 71 of the species were present in sites where western juniper dominated (Bedell et al. 1993). Sites with juniper lacked forbs, big sagebrush, and bitterbrush.

Landowners in these regions have been encouraged to remove western juniper to control the spread of the species and protect native grasses and animal habitats. The primary approach for removing juniper is mechanical and uses bulldozer or chaining to pull trees from the ground. These materials are then pulled and burned in slash piles. This method disturbs the soil, resulting in high nutrient losses and scalding of the soil beneath the burn pile (Bedell et al. 1993). The recommended method for removal is to hand-fell the trees, scatter the foliage around the site and use the wood for fire wood or fence posts.

2.4 Market Research

A surplus of western juniper had led to several efforts to create markets for the wood including use for pencil stock, essential oils, or hardboard. Market research suggests that there will be a considerable time lag before a product is brought to market (Leavengood 2008) (Table 1). Several very small niche markets currently use western juniper (Leavengood 2008). One niche market is for storage shacks that are manufactured from western juniper logs by Line Shack (Prineville OR). Western juniper is also used to produce grape vine posts that are used by A to Z Wineworks (Newburg OR). The lack of markets for western juniper is a function of many factors including limited knowledge of the availability and cost of western juniper lumber, lack of mechanical and physical property data and lack of data on durability attributes (Leavengood 2008). A number of studies are underway to help fill in these data gaps.

Table 1: Time line of the research on utilization of western juniper (Leavengood 2008)

Utilization	**Research conducted by and year**
Pencil Stock	Anonymous…………………………...1920
Essential Oils	Kurth and Ross……………………….1954
Hardboard	Frashour……………………………1953 Frashour and Nixon………………..1956
Drying	Kozlik ………………………..........1976 Swan and Milota…………………...1995
Lumber	Martin et al………………………...1978
Boiler Fuel	Suter, M.K…………………………2006

2.5 Physical and Mechanical Properties

Western juniper wood is richly colored, with a purplish to rose-red heartwood, and a "cedar chest" odor (Panshin and DeZeeuw 1980). The heartwood often contains bands of whitish portions of included sapwood that is a characteristic of western juniper. Western juniper wood has swirling grain patterns, numerous knots, and bark pockets, which gives it a rustic appearance (Swan 1998). Western juniper drying schedules are similar to those used for Douglas-fir and pine, and it can be successfully kiln-dried with pine with little modification to the drying schedule (Swan 1998). Myers (1998) found that western juniper contained higher amounts of lignin compared to most softwoods and hardwoods, with a lignin percentage of 35.5%. High amounts of lignin may help explain the ability to more easily dry western juniper, since lignin is known to reduce dimensional changes with moisture content fluctuations (Boyer et al. 2007, Myers et al. 1998).

Western juniper trachieds tend to be shorter than most softwoods, but longer than most hardwoods with an average length of 1.6 mm (Myers et al. 1998). The diameters of western juniper fibers were smaller than most softwoods, but were approximately the same as hardwoods with a range of 0.012 – 0.031 mm (Myers et al. 1998). The smaller diameters help account for the fine grain that is a characteristic of western juniper.

Western juniper heartwood is considered to be highly durable and insect resistant. Untreated western juniper posts have lasted over 50 years in ground contact in western Oregon (Morrell et al. 1999). The State of Oregon Building Codes Division approved western juniper heartwood as an alternative material for use in areas subjected to moisture, and meeting the definition of "naturally durable" by the Oregon Structural Specialty Code (OSSC) and the Oregon Residential Specialty Code (ORSC) (Rogers 2010). This allows this material to be used for sill plates in some construction. The durability of western juniper can be attributed to the cedrol content and the high lignin levels (Kurth and Ross 1954). Cedrol is a terpene, which is a fungicidal compound that accumulates during the transition of sapwood into heartwood (Highley 1995). Lignin can restrict fungal attack and may enhance the durability of western juniper (Boyer et al. 2007 and Myers et al. 1998). The sapwood of western juniper is not decay or insect resistant. Thus, included sapwood will still decay, causing rot pockets to form. It would be virtually impossible to economically mill western juniper to avoid these pockets.

Knowledge of mechanical properties of wood is essential for any strength-based application. The orthotropic properties of wood make it necessary to determine these properties in each direction. Four major properties that are usually analyzed are tension, compression, bending, and shear. The ASTM Standard D143 for small clear specimens and ASTM Standard D198 for lumber in structural sizes describe methods for development of all four of the major properties.

Tension can be measured parallel and perpendicular to the grain. Tension parallel occurs when a force is applied parallel to the longitudinal axis of a wood specimen. This elongates fibers causing them to slip past one another. Tension parallel to grain in wood is the highest strength property (AWC 2004), provided that there are no defects such as knots, slope of grain or checks that affect behavior. Unlike tension parallel to grain, tension perpendicular is the weakest property in wood. When a tensile force is applied in this direction, the wood fibers tend to separate along the grain (AWC 2004).

Compression in wood is assessed in two directions - parallel and perpendicular to grain. Compression parallel to grain occurs when a crushing force is applied to the end grain of a wooden member, which causes the wood fibers to compress and eventually buckle. Compression parallel to grain can be seen when a wooden member is used as a column. Compression perpendicular to grain occurs when a force is applied to a tangential or radial face of a wood member. This compresses the wood and densifies it, which slightly displaces the support members.

The other two important wood properties are bending and shear. Bending occurs when a force is applied perpendicular to a wooden beam. This force creates compression in the side of the member where the force is applied and tension on the opposite side. A shear force is formed within the beam at the natural axis when compression and tension forces act on opposite ends. Bending forces can be seen in a wooden beam such as a girder. The data from a bending test is used to calculate the stiffness of the wood or Modulus of Elasticity (MOE), and the maximum stress of the wood or Modulus of Rupture (MOR). These two properties are the most important properties for designing most structures.

Previous reports suggest that the mechanical properties of western juniper are similar to these of western redcedar, incense-cedar, and eastern redcedar (Burke 2008). Western juniper is weaker in most mechanical properties, except shear, which is similar or stronger than the other wood species. The appearance of the sawn product can be compared to ponderosa pine and Douglas-fir (Burke 2008). Burke (2008) performed shear, compression, tension, hardness, and bending tests on samples collected from California and Oregon following procedures described in ASTM Standard D-143 (Table 2). When compared to other softwood species, such as Douglas-fir, western juniper tends to be weaker in MOE, MOR, and compression parallel-to-grain, but comparable in other properties. The previous tests could be useful for development of design values for western juniper, but unfortunately the source data has been lost. As a result, any attempt to develop design values will require the generation of new data.

Table 2:Mechanical properties at 12% MC of western juniper (Burke 2008) compared to other commercially imported softwood species (USDA 2010)

Strength Property	western juniper	incense-cedar	Port-Orford-cedar	eastern redcedar	western redcedar	ponderosa pine	Douglas-fir
MOR (MPa)	64.49	55.16	87.56	60.67	51.71	64.81	86.87
MOE (MPa)	4915.96	7170.55	11721.09	6067.39	7653.18	8894.24	12617.41
Shear (MPa)	8.83	6.07	9.45	NA	6.83	7.79	8.89
Compression Parallel (MPa)	35.65	35.85	43.09	41.51	31.44	36.68	51.23
Tension Parallel (MPa)	45.99	NA	88.94	NA	51.71	65.50	121.35
Tension Perpendicular (MPa)	3.31	1.86	2.76	NA	1.52	2.90	2.00
Hardness, side grain (N)	3002.55	2090.66	2802.38	4003.40	1556.88	2046.18	2268.59
Hardness, end grain (N)	4759.60	NA	NA	NA	NA	NA	NA

2.6 Design Values

Design values for wood are based on mechanical properties developed according to the ASTM procedures for small clear wood tests. Clear, straight grained specimens are tested to obtain the strength values. Once all testing is completed, the strength values (stress) are analyzed and a 5 percent exclusion limit is calculated statistically. These values are the starting point for the reference design values (Breyer et al. 2015). The 5 percent exclusion value is calculated by finding the lower 5th percentile of the samples, which indicates that out of all the clear wood samples, 95 percent are expected to fail at or above the 5 percent exclusion value, and the remaining would be expected to fail at or below this limit (USF 1992). Small clear samples have greater strength values than full-size members with some defects. These differences are accounted for by applying a reduction factor known as a strength ratio (Breyer et al. 2015). The process of assessing data and approving standard design values falls under the purview of the American Lumber Standard Committee (ALSC). The strength ratios are factors that reduce the clear wood properties to compensate for defects such as, knots, slope of grain, pitch, and other defects (Timber Bridge Manual 1992). The final design values are found in the National Design Specifications (NDS). Additional factors are applied to design values when engineers design a structure, such as load duration, wet service, or temperature factors (NDS 2015)

One of the most recent wood species to which design values have been assigned is U.S. grown Norway spruce (*Picea abies*). The samples were harvested from Maine, Vermont, Wisconsin, and four regions of New York State. The test population consisted of 1320 boards with dimensions of 50.8 x 101.6 mm, 50.8 x 152.4mm, and 50.8 x 203.2 mm that were tested in bending (658 samples) or tension (662 samples). The results were used to establish strength values. The design values for Norway spruce were calculated using the steps provided in the section above. This process provides a blue-print for performing similar tests on western juniper.

The raw data collected by Burke (2008) were lost before proper evaluation for creating design values was completed. The available data only contains general averages for the different mechanical properties that were evaluated. When creating design values for a wood species the values are computed in accordance with clear-wood test or full-size tests following the American Society for Testing and Materials (ASTM) standards. Once testing is complete, the values are then used to calculate strength values. For example, ASTM Standard D 2555 would be used for clear wood testing (ASTM 1998). The design values are then evaluated by a certification company, such as the West Coast Lumber Inspection Bureau (WCLIB) or the Northern Softwood Lumber Bureau (NSLB). A professional engineer at the agency will review and approve the data, which will then be given to the American Lumber Standard Committee (ALSC) to be reviewed. ALSC will review the data and once approved, the data can be released to the public. The data are sent to American Wood Council (AWC), where it is published in the codes and standards. This approval process can be seen in Figure 2.

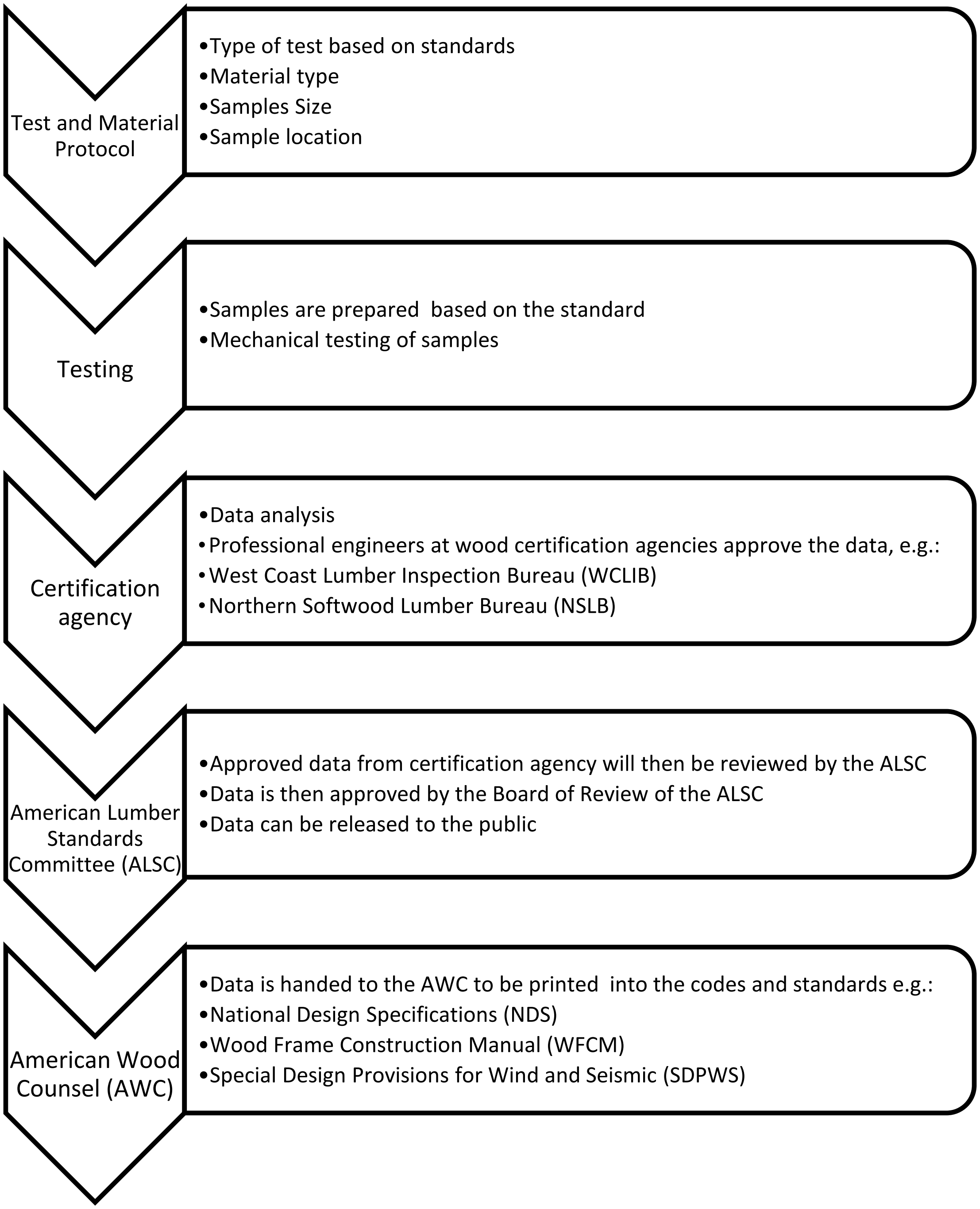

Figure 2: Flow chart of the certification process for including design values in the NDS

CHAPTER 3: MATERIAL AND METHODS

3.1 Mechanical Test Materials

Lumber samples were randomly collected from Oregon, California, and Idaho. Five different western juniper processing facies harvested and milled the juniper to size. The number of samples from each state was based on the relative volume of timber present in that state. Oregon contained the most standing western juniper with approximately 66%, followed by California with 21% and Idaho with 13% (BLM 2015). Hence, the sample size distribution between the states was based on the percentage of western juniper in each state (Table 3). Since Oregon contained the highest volume of western juniper, material was obtained from three different sites within Oregon, while samples were collected from only one site in each of the other states (Figure 3). The three locations for Oregon were based on the regions where western juniper predominated and represented three different geographical conditions. The first site was in Lake County in South Central Oregon, the second site was near Crook County, in Central Oregon, and the last site was in Harney County in Eastern Oregon. The California samples were obtained from the northeastern region of California in Modoc County. The Idaho samples were obtained from the southeast region in Owyhee County. The materials procured were either in the form of a 101.6 x 101.6 mm (4 x 4 in.) or 152.4 x 152.4 mm (6x6 in.) posts approximately 2.44 m long (8 ft.).

Table 3 : The standing timber volume and standing timber percentage of western juniper in Idaho, California, and Oregon (a)

Region	Standing Timber Volume, Ft^3	Standing Timer Volume, %
California	207,997,410	21
Idaho	129,620,751	13
Oregon	641,385,018	66
Total	979,003,179	100

(a) Source: U.S. Department of the Interior, Bureau of Land Management

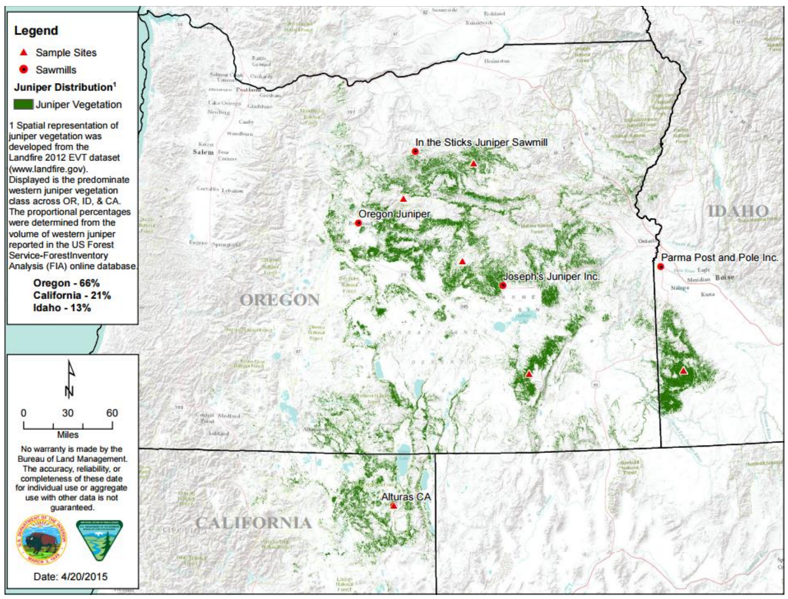

Figure 3: Location of sample sites for western juniper collection (US Forest Service - Forest Inventory Analysis (FIA))

The posts were cut into samples for evaluating bending, compression parallel or perpendicular-to-grain, or shear strength (Table 4). The number of samples for each test were derived by the WCLIB and were stipulated in their testing plan submitted to the American Lumber Standards Committee (ALSC). Samples were clear of any visible defects such as knots, decay, or wane (bark), and had straight grain. The posts were marked to define areas of clear wood before being bucked to length and then sawn to the specified sizes (Table 4). The samples were conditioned to constant weight at 20°C and 65% relative humidity to a moisture content of approximately 12%.

Table 4: Dimensions and replicates of samples used to evaluate material properties of western juniper

Region	Bending (25.4 x 25.4 x 406 mm)	Compression Para. (50.8 x 50.8 x 203 mm)	Compression Perp. (50.8 x 50.8 x 152 mm)	Shear (50.8 x 50.8 x 64 mm)
California	50	50	50	50
Idaho	31	31	31	31
Oregon	159	159	159	159

3.1.1 Dry/Green Ratio Samples

A green/dry ratio was established to understand the difference in strength properties between green and dry samples. The samples used for the dry/green ratio samples were obtained from 30 unpeeled log sections 600 – 900 mm long that had been end-sealed to retain moisture. The logs were cut in 50.8 x 50.8 mm (2 x 2 in.) squares that were either 300 or 120 mm long. These pieces were then cut in half. One half was tested in the green condition, while the other half was conditioned to a moisture content of approximately 12% before testing. The conditioned samples were tested in shear or compression. Thirty samples per mechanical test were performed with two halves, creating a total of 120 samples.

3.2 Mechanical Test Methods

3.2.1 Bending

Three-point bending tests were performed on 25.4 x 25.4 x 406.4 mm long (1 x 1 x 16 in.) juniper beams and this data were used to calculate Modulus of Elasticity (MOE) and Modulus of Rupture (MOR). The tests were conducted on an Instron 5582 universal testing machine with a 100 kN load cell and a round wooden load bearing head connected to the cross arm (Figure 4). The samples were placed in the UTM on a span of 335.6 mm (14 in.) with the tangential surface nearest to the pith facing up so that the load bearing head would come in contact during testing. The samples were loaded at a modified rate of 2 mm/min, which allowed the samples to fail between 5 – 10 min., until failure. The load/deflection curve was recorded. Each failed sample was photographed to record the failure type as described in the ASTM Standard D143. The modulus of rupture (MOR) as well as the modulus of elasticity (MOE) were calculated from the load/deflection curve using the formulas:

$$MOE = \frac{PL^3}{48ID} \tag{1}$$

Where, L is the Span (mm), P is the concentrated center load (N) below the proportional limit, D is the deflection at mid-span (mm) resulting from P, and I is the moment of inertia, a function of the beam's section (width x depth^3)/12.

$$MOR = \frac{1.5PL}{bh^2} \tag{2}$$

Where, h is depth of the beam, b is the width of the beam, P is the breaking (maximum) load (N), and L is distance between supports/span (mm).

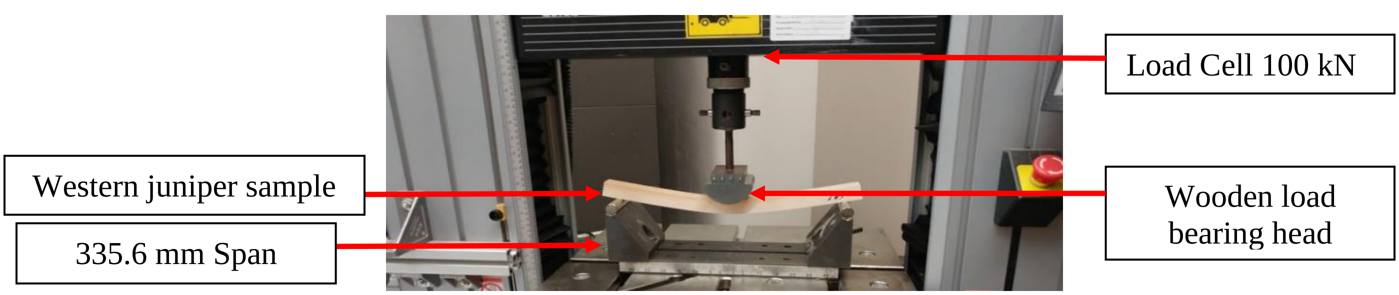

Figure 4: Three-Point Bending Test Setup

3.2.2 Compression Parallel

Compression parallel to grain tests were performed on 50.8 x 50.8 x 203.2 mm (2 x 2 x 8 in.) juniper samples on a universal testing machine (MTS) with a 178 kN load cell, using a pivoting base and flat rectangular load bearing head. A pivoting base (Figure 5) was used to ensure a uniform distribution of the load to each end of the sample. The cross-arm applied a load at a rate of 1.3 mm/min until significant failure was observed visually. The compressive failure would then be classified under six types of failure as described in ASTM Standard D143. Once the failure type was determined, the maximum load was recorded. The compressive strength of the sample using the maximum load was then calculated using the formula:

$$Compressive\ Strength = \frac{P}{w\ x\ t} \tag{3}$$

Where, *w* is width (mm), *t* is the thickness (mm), and *P* is the breaking load (N).

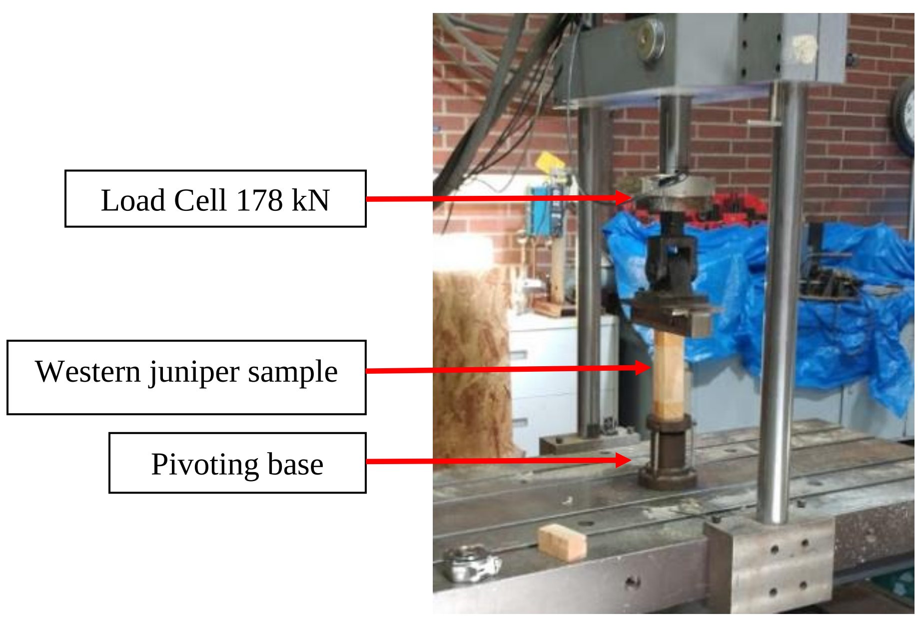

Figure 5: Compression parallel-to-grain test setup

3.2.3 Compression perpendicular

Compression perpendicular to grain tests were performed on 50.8 x 50.8 x 152.4 mm (2 x 2 x 6 in.) juniper samples on an Instron 5582 universal testing machine using a 100 kN load cell. A rectangular 50.8 mm wide load bearing plate was attached to the cross-arm. The sample was placed on a steel plate in a position so that the load bearing plate applied a load through a radial surface. The load bearing plate only compressed a 50.8 x 50.8 mm (2 x 2 in.) middle section of the sample (Figure 6). The cross-arm was then lowered at a rate of 0.305 mm/min. The test was stopped after an extension of 2.5 mm was reached. Once the test was complete, the area where the sample was compressed was marked and the maximum load was recorded. The load/deflection curve was used to obtain the compressive strength using the load at 1 mm of deflection with the formula:

$$Compressive\ Strength = \frac{P_{1mm}}{L_{sample} \times w_{load\ head}} \tag{4}$$

Where, P_{1mm} is the load at 1 mm, L_{sample} is the length of the sample (mm), and $w_{load\ head}$ is the width of load head (mm).

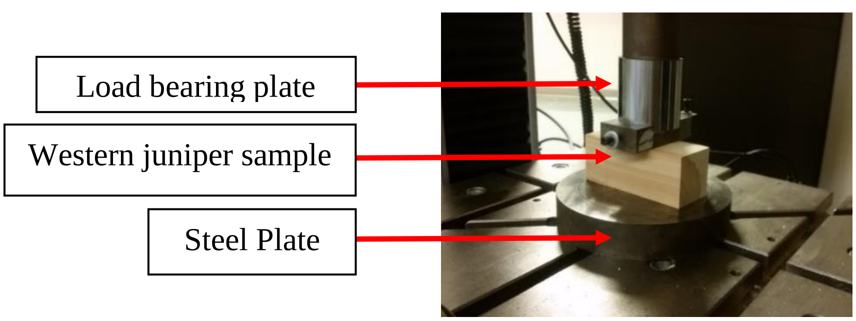

Figure 6: Compression perpendicular-to-grain test setup

3.2.4 Shear

Shear tests were performed on 50.8 x 50.8 x 63.5 mm (2 x 2 x 2.5 in.) juniper samples with a 12.7 x 19.05 mm (0.5 x 0.75 in.) notch removed to produce shear failure in the sample. The shear area was calculated by measuring the length and width of the notch. The test was performed on an Instron 5582 universal testing machine using a 100 kN load cell. The setup used a shear tool that applied a force to the area under the notch loaded at a rate of 0.6 mm/min (0.024 in./min) until failure as described in the ASTM D143 standard (Figure 7). Maximum force was recorded and shear strength was determined using the formula:

$$V = \frac{P}{w_{notch} \times l_{notch}} \tag{5}$$

Where, P is the maximum force (N), V is the shear strength (MPa), w_{notch} is the width of the block notch (mm), and L_{notch} is the length of the block notch (mm).

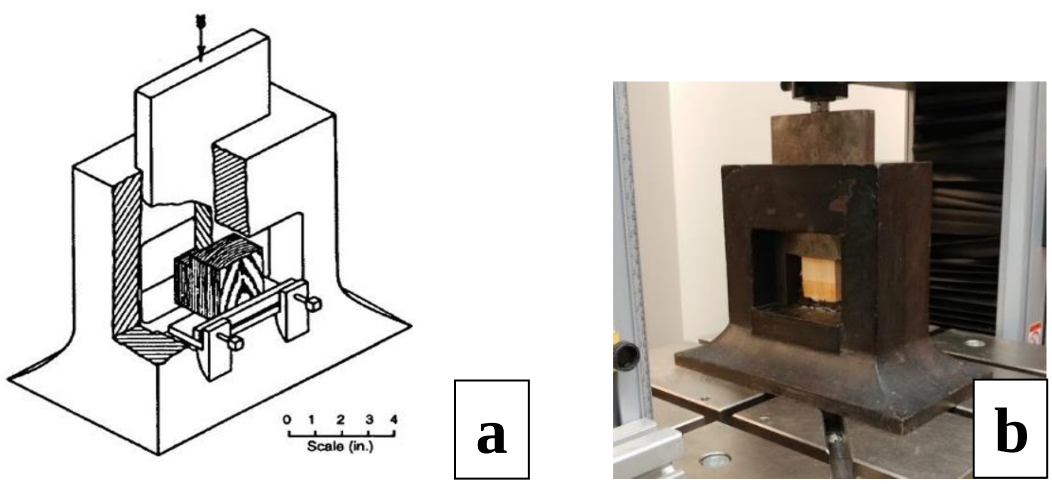

Figure 7: Shear Test Setup. (a) Shear apparatus diagram from ASTM D143. (b) Western juniper shear testing

3.2.5 Moisture Content and density

Moisture content and specific gravity were calculated following the ASTM standards D4442 Method B and D2395 Method A, respectively. Each test sample used a 25.4 x 25.4 x 50.8 mm (1 x 1 x 2 in.) section cut from the mechanical sample. For bending, a 25.4 x 25.4 x 25.4 mm (1 x 1 x 1 in.) sample was cut from the end of the beam. The samples were weighed (nearest 0.001 g) to obtain a green weight and then oven-dried at 103°C for 24 hours before being weighed again. The dimensions were measured using calipers (nearest 0.1 mm). Moisture content and density were calculated using the formulas:

$$MC\% = \frac{Mass_{Green} - Mass_{Oven\ Dry}}{Mass_{Oven\ Dry}} \times 100 \quad (6)$$

$$Density = \frac{Mass_{Oven\ Dry} \times 1000}{(width \times depth \times length)_{Oven\ Dry}} \quad (7)$$

3.2.6 Dry/Green Ratio

Once the mechanical testing was completed in shear and compression perpendicular-to-grain, their strength and MC averages were recorded. The green average (x_{green}) and the dry average (x_{dry}) for both test were divided to obtain the initial Dry/Green (DG) ratio.

$$Initial\ DG = \frac{xdry}{xgreen} \quad (8)$$

The initial DG ratio was then adjusted to12% MC using the fiber saturation point (FSP) of 27% and the average MC of both tests to create an adjustment factor.

$$12\%\ MC\ adjustmnet\ factor = \left[\frac{FSP-MC}{FSP-12}\right] \tag{9}$$

The adjustment factor was applied to the initial DG ratio to create the adjusted DG ratio (DG Ratio').

$$DG\ Ratio' = \frac{Initial\ DG\ Ratio}{(12\%\ MC\ adjustment\ factor)} \tag{10}$$

These ratios were then used in creating design values for the shear and compression perpendicular-to-grain.

3.2.7 Design Value Calculations

To calculate design values, the data for each mechanical property underwent a multistep process using equations from the ASTM standards D245 and D1990. The procedures for MOR and compression parallel-to-grain were the same, while the other three properties used different procedures. Several factors were applied to the strength properties varying from moisture content adjustments to volume adjustments. Below are the factors that were used in calculating the design values.

The seasoning factor adjusted the moisture content for each sample strength property to a 15% MC:

$$S2 = S1 + \left[\frac{S1-B1}{B2-M1}\right](M1 - M2) \tag{11}$$

Where, *M1* is the moisture content at testing (%), *M2* is the moisture content of 15% (%), *S1* is the strength property at *M1* (MPa), *S2* is the strength property at 15% MC (MPa), *B1* and *B2* are Constants: MOR (*B1*=2415, *B2*=40) and Ultimate Compressive Stress (USC) (*B1*=1400, *B2*=34).

The 5% exclusion limit was calculated by finding the 5th percentile using the formula:

$$X = \mu - Z\sigma \tag{12}$$

Where, *X* is the 5th Percentile (5% exclusion limit), μ is the average, *Z* represents 1.645, which is the corresponding value for the 5th percentile, and σ is the standard deviation.

A size factor was used to account for the testing dimensions compared to lumber dimensions, which was done using the formula:

$$F = \left(\frac{ds}{d}\right)^{1/9} \tag{13}$$

Where, *F* is a size factor, *ds* is the sample depth, and *d* is the net surface depth

A volume adjustment factor was used on the values depending on the different grade dimensions to account for different dimensions within a lumber grade, using the formula:

$$F2 = F1\,(\frac{W1}{W2})^{w}\,(\frac{L1}{L2})^{l} \tag{14}$$

Where, *F1* is the property value at volume 1, *F2* is the property value at volume 2, *W1* is the width at *F1*, *W2* is the width at *F2*, *L1* is the length at *F1*, *L2* is the length at *F2*, *w* is a constant for width: (MOR=0.29, UCS=0.13, MOE=0), and *l* is a constant for length: (MOR=0.14, UCS & MOE=0)

Strength ratio factors were observed from ASTM Standard D245, sections 4.1.6 and 4.2.3 note 2, for compression perpendicular-to-grain and shear. The strength ratio factors for the other properties were calculated by the West Coast Lumber Inspection Bureau (WCLIB) (Table 5).

Table 5: Factors from the ASTM Standard D245 and the WCLB

Strength Ratio Factors					
Grade	**Comp para***	**MOR***	**MOE***	**Comp perp**	**Shear para**
SS	0.69	0.65	1.00	1.00	0.50
No. 1	0.62	0.55	1.00	1.00	0.50
No. 2	0.52	0.45	0.90	1.00	0.50
No. 3	0.30	0.26	0.81	1.00	0.50
Stud	0.30	0.26	0.81	1.00	0.50
Construction	0.56	0.34	0.85	1.00	0.50
Standard	0.46	0.19	0.77	1.00	0.50
Utility	0.30	0.09	0.72	1.00	0.50
Other factors					
Reduction factor	1.90	2.10	0.94	1.67	2.10
Seasoning factor	Eq. 11	Eq. 11	Eq. 11	1.08	1.50

** Strength ratios calculated by the WCLB*

The reduction factors were obtained from ASTM Standard D245, section 6.2 and table 8, while the seasoning factors for compression perpendicular-to-grain and shear were obtained from ASTM Standard D245, section 7.1 and table 10 (ASTM Standard D245 2011).

The step-by-step process for calculating design values for each property can be seen in Table 6.

Table 6: Step-by-step process used to calculate design values of different wood properties

Steps to Calculate Design Values					
Steps	**Comp para**	**MOR**	**Comp perp**	**Shear para**	**MOE**
1	Seasoning Factor	Seasoning Factor	Total Average	5%EL average	Total average
2	5%EL average	5%EL average	DG ratio	DG ratio	Strength Ratio
3	Size factor	Size factor	12% DG adjustment	12% DG adjustment	Reduction factor
4	Strength Ratio	Strength Ratio	Strength ratio	Strength ratio	x
5	reduction factor	reduction factor	Seasoning factor	Seasoning factor	x
6	Volume adjustment factor	Volume adjustment factor	reduction factor	reduction factor	x

3.2.8 Statistical Analysis of Mechanical Tests

The data were analyzed in RStudio (ver. R 3.2.2) using a one-way Analysis of Variance (ANOVA) test and a Tukey-Kramer test to determine if there were differences between locations in the mechanical tests. The assumptions of these tests were verified using a Shapiro-Wilk test to evaluate normality and a Fligner-Killeen test to evaluate equal variance at $\alpha = 0.05$. These statistical tests were performed on MOR, compression parallel-to-grain, and shear tests. Due to violating the assumption for equal variance, the MOE and compression perpendicular-to-grain tests were analyzed using a Kruskal-Wallis test.

The one-way ANOVA test compared the sample means between the locations to determine if sample means are significantly different from each other. Locations were further analyzed using a Tukey-Kramer test multiple comparison procedure.

The Kruskal-Wallis test is a non-parametric test method, which is a common alternative to a one-way ANOVA when assumptions are violated. This method ranks the strength values from highest to lowest in all the locations and uses the ranks in a one-way analysis of variance to tell if there is any significant difference between the locations. The kruskalmc, which is a modified Kruskal-Wallis test, was used to identify differences between groups (Siegel and Castellan 1988).

3.3 Durability Materials and Methods

3.3.1 Marine Durability Samples

Samples for the marine durability testing were cut to dimension of 50.8 x 76.2 x 443 mm (1 x 3 x 17.5 in.) and labeled with aluminum tags. The test followed the AWPA Standard E5-15 standard field test for evaluation of wood preservatives to be used in marine applications (uc5a, uc5b, uc5c); panel and block tests. Holes were drilled into the top and bottom of each sample, and these holes were used to secure samples to plastic test racks with a weight on one end and a retrieval rope on the other. A total of 12 samples were examined. The racks were placed into a test site in Newport, OR (Figure 8). The samples were examined for evidence of marine borer damage at six month intervals. The samples were first rated visually for any surface attack using a rating system 0-10 with 10 meaning no attack and 0 meaning severe attack resulting in complete destruction.

The surfaces were probed with a sharpened awl to detect effects of softening. The cross-sectional area was examined to determine if any marine borers were present. Analysis of these samples will continue until the samples are destroyed.

Figure 8: Example of a (a) Marine borer test racks. (b) and a western juniper sample attacked by marine borers (6-month exposure).

3.3.2 Laboratory Decay Test

Cubes (19 mm cubes) (370 juniper blocks) were cut from the western juniper material to produce 74 blocks geographic source location. The blocks were oven-dried (103 C) and weighed (nearest 0.001 g). The blocks were soaked with water for 30 minutes prior to being sterilized by exposure to 2.5 mrad of ionizing radiation.

Decay chambers were prepared by half filling the 454 ml bottles with moist forest loam and placing a western hemlock feeder strip on the soil surface. The bottles were then loosely capped and autoclaved for 45 minutes at 121 C. After cooling, the bottles were inoculated with 3 mm diameter malt agar disks cut from the actively growing edges of cultures of the test fungi. The fungi evaluated in these procedures were *Gloeophyllum trabeum* (Pers.ex. Fr.) Murr. (Isolate # Madison 617) (Fries) or *Trametes versicolor* (L. ex Fr.) Pilát (Isolate # R-105). The first fungus produces brown rot while the other species causes white rot. The agar plugs were placed on the edges of the wood feeder strips, then the jars were loosely capped (to allow air exchange), and incubated until the feeder strip was thoroughly covered with fungal mycelium. The sterile test blocks were then placed on the surfaces of the feeder strips, the bottles were loosely capped and incubated at 28 C for 16 weeks (Figure 9). Blocks from each treatment group were also established in chambers without a test fungus to establish procedural mass losses with each material. Untreated southern pine sapwood blocks were similarly tested to provide a decay susceptible material to evaluate the rigor of the test procedure. At the end of the incubation period, the blocks were removed, scraped clean of adhering mycelium and weighed to determine wet weight. The blocks were then oven dried (103 C) and weighed. The difference between initial and final oven-dry weight was used as a measure of the decay resistance of each material, using the formula:

$$Mass\ Loss\ \% = \frac{(OD_{Before\ Inoculation} - OD_{After\ 16\ incubation})}{OD_{Before\ Inoculation}} \qquad (15)$$

Where, $OD_{Before\ inoculation}$ is the oven dry weight before inoculation and $OD_{After\ 16\ incubation}$ is the oven dry weight after the 16-week incubation period

Figure 9: Soil Block Test. (a) Soil block jars in incubator. (b) Soil block jar after 16-week incubation period

3.3.3 Ground Contact Test

Posts 101 x 101 x 1219 mm long (4 x 4 in.) were cut from the general sample material. The test followed the AWPA Standard E8-15 standard field test for evaluation of wood preservatives to be used in ground contact (uc4a, uc4b, uc4c); post test. Fifteen posts were cut from each of the five sites to produce a total of 75 posts. The test site (post farm) is located at Peavy Arboretum, about 11 km north of Corvallis, OR (Fig. 10) (Morrell et. al. 1991). The posts were randomly placed into 762 (2.5 ft.) mm deep holes 0.6 m (2 ft.) apart from one another (Figure 10). The post placements were recorded with the site location (Table 7). The posts will be analyzed periodically, but results will take much longer to develop. Previous studies showed that split juniper posts had an average service life of 50 years.

Figure 10: Ground Contact Samples at the Peavy test site

Table 7: Arrangement of posts at the field test site by sample location and legend

Test Site Map of Post Locations																
O	I	O	C	P	O	P	P	C	O	B	B	O	C	I	I	P
O	B	C	I	O	P	B	B	C	P	B	B	B	O	I	C	P
C	B	O	P	B	B	C	P	B	I	I	C	I	C	O	E	B
I	C	O	P	I	I	C	I	O	P	O	P	B	P	C	I	O
C	O	P	I	B	P	I	O	C	E	E	E	E	E	E	E	E

Legend of Site Map					
Klamath	Burns	Prineville	Idaho	California	Empty
O	B	P	I	C	E

CHAPTER 4: RESULTS AND DISSCUSION

Table 8 contains strength data for all the tests performed in the study.

Table 8: Mean strength properties of western juniper samples from five locations in the growing region

Mean Strength Properties (MPa)						
Means	**Burns**	**Klamath**	**Prineville**	**California**	**Idaho**	**Average**
Comp||	27.30	32.58	28.63	30.41	26.86	29.35
COV (%)	11	10	10	11	12	13
Comp⊥	5.99	5.91	6.26	5.44	4.64	5.73
COV (%)	29	25	31	29	28	30
Shear	5.96	7.27	8.00	7.70	8.24	7.35
COV (%)	17	17	14	15	19	47
MOE	3561.37	4629.80	3744.20	4603.64	2739.28	3948.48
COV (%)	29	16	18	25	17	27
MOR	57.17	60.59	61.57	57.03	53.92	58.44
COV (%)	13	15	12	15	13	14

Table 9 compares average strength properties for western juniper with similar wood species or species used in construction. The table also includes data from Burke (2008).

Table 9: Comparison between mean strength properties and specific gravity of western juniper and similar wood species.

Mean strength properties (MPa)									
	Western juniper		**Western redcedar**	**Eastern redcedar**	**incense cedar**	**P.O. cedar**	**Eastern Hemlock**	**Ponderosa pine**	**Douglas-Fir**
	Current Study	**Burke Study**							
Comp||	29.35	35.65	31.40	41.50	35.90	43.10	37.30	36.70	51.20
Comp⊥	5.73	X	3.20	6.30	4.10	5.00	4.50	4.00	5.20
Shear	7.35	8.83	3.20	6.30	4.10	5.00	7.30	7.80	8.90
MOE	3948.48	4915.96	7700.00	6067.39	7170.55	8894.24	8300.00	8900.00	12600.00
MOR	58.44	64.49	51.71	60.67	55.16	64.81	61.00	65.00	87.00
SG @ 12%	0.40	0.39	0.32	0.47	0.37	0.43	0.40	0.40	0.50

Source: Burke 2008, USDA 2010

4.1 Compression Parallel-to -Grain (||) *Test*

Compressive strength || for samples from all locations averaged 29.35 MPa (COV = 13%) (Table 8). The highest compressive strength was observed in samples procured from Klamath (32.85 MPa and COV=10%), while the lowest compressive strength was observed in samples from Idaho (26.86 MPa and COV = 12%) (Table 8). There was evidence that mean compressive strength of western juniper varied significantly with location (ANOVA, p-value < .0001). Compressive strength in samples from the Klamath and California locations were significantly greater than those from the other locations (p-values < .05). Compressive strength of samples from Prineville, Burns, and Idaho did not differ significantly (Tukey, p-values > 0.05) (Figure 11).

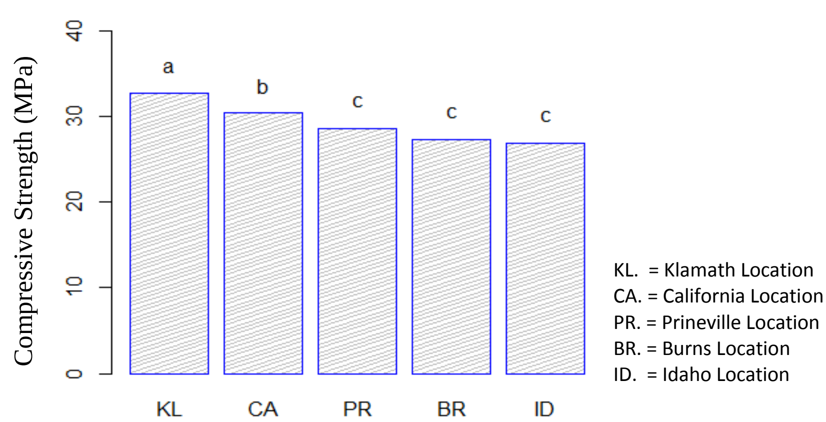

Figure 11: Compression strength parallel-to-grain of western juniper lumber obtained from five locations in the growing regions. Values followed by the same letter(s) do not differ significantly by a Tukey-Kramer Test at α=0.05

Compression || failures in western juniper were similar to those found with other wood species, with cell wall buckling under the applied stress. The common failure types can be seen in Fig.12 with a comparative illustration from ASTM Standard D143 showing failure types. Many samples developed a crushing band where buckling occurred. The majority of samples failed in shear as defined is ASTM Standard D 143 (2014). In shearing, the crushing band had an angle of 45 degrees or greater with the top of the sample (Fig. 12). Crushing and wedge split failure types were also observed.

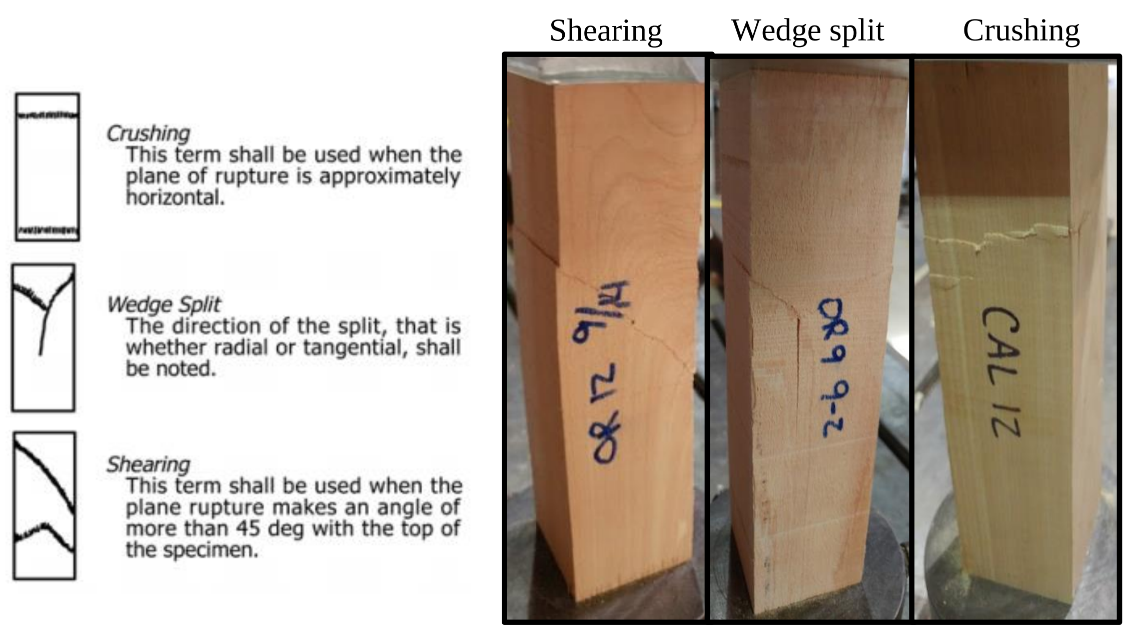

Figure 12: Examples of compression parallel-to-grain failures shown as diagrams of common failure types (ASTM Standard D143) or as actual samples from the current test (b) Shearing failure (c) Wedge split failure (d) Crushing failure

Mean compressive strength of western juniper was lower than other similar wood species such as western and eastern redcedar (Table 9) (USDA, 2010). Compression|| tends to be correlated with specific gravity (SG) of a wood species (USDA, 2010), but western juniper had lower compressive strength than species with lower SG (Table 9). Decreased compressive strength could be due to the tracheid diameters of western juniper, which are smaller than most softwoods but equivalent to the diameter of most hardwoods (Myers et al 1998). Hardwoods have been shown to have lower compressive strength in the parallel-to-grain direction than softwoods (USDA, 2010). Western juniper wood also has a fairly uniform tracheid cell wall thickness. The growth rings have only a very narrow band of denser latewood and this uniformity may have also affected load capacity (USDA, 2010).

Differences in compression strength|| could also result from the climate where the trees were grown. This could be due to more competition in the stand due to increased stand density as well as precipitation of the stand. The relationships between average rainfall, snowfall, and elevations and compressive strength were examined by county where the samples were collected. These data must be viewed with caution since microclimate can vary widely, even in a relatively close proximity (Table 10). All the samples grew in areas with similar elevations, but precipitation varied widely.

Moisture influences both quantity and quality of wood produced. Lower precipitation has obvious effects on the number of tracheids produced and lumen diameter. The pattern of precipitation may also affect wood quality (Drew et al 2012). For example, snowfall may be more conducive to steady growth because it would allow for more controlled water release into the soil.

The Idaho site received the lowest average precipitation in terms of rain and snow and materials from this area also had significantly lower compression parallel-to-grain strength than those from the Oregon sites, which all received more precipitation as either snow or rain. Samples from the California site had compressive strengths that did not differ significantly from either Oregon or Idaho samples, although the area received the highest precipitation of the five wood sources. The inconsistent relationship between precipitation and strength illustrates the difficulty in using weather data collected from a single site to characterize a broader geographic area. Precipitation can vary widely in relatively small areas and can vary widely over time. This makes it difficult to use average data for comparative purposes.

Table 10: Average rainfall, snowfall, and elevation for counties where western juniper was collected.

Annual Average Climate Data					
	Burns (Harney)	**Prineville (Crook)**	**Klamath (Lake)**	**California (Modoc)**	**Idaho (Owyhee)**
Rainfall (cm)	27.74	30.99	25.91	39.55	19.30
Snowfall (cm)	44.55	104.01	111.28	120.29	9.91
Elevation (m)	1478.58	1328.01	1563.62	1516.08	1457.25

Source of Data: National Climatic Data Center (NOAA)

4.2 Compression Perpendicular-to-Grain ($\perp$) Test

Mean compressive strength $\perp$ for all locations was approximately 5.73 MPa (COV = 30%) (Table 8). The highest compressive strength was observed in samples from Prineville (6.26 MPa; COV = 26%), while the lowest compressive strength was observed in the samples from Idaho (4.64 MPa, COV = 28%) (Table 8). There was statistical evidence that the mean compressive strength of western juniper differed significantly between locations (Kruskal-Wallis, p-value < .0001). There was no significant difference in compressive strength ⊥ in samples from Prineville, Burns, Klamath, or California locations. The compressive strength of samples from Idaho did not differ significantly from those from California, but were significantly different from the Oregon locations (Figure 13). Mean compressive strength was highest in samples from Prineville, averaging 6.26 MPa. Materials from this site also had the highest SG (0.43). The lowest mean SG (0.38) was found in samples from Burns, but these samples had the second highest mean compressive strength (5.99 MPa). Again, strength differences could vary due to the high COV%. Samples from the Idaho location were also highly variable since the COV% of SG was 14%, while COV's for samples from the other locations were between 7% and 8%.

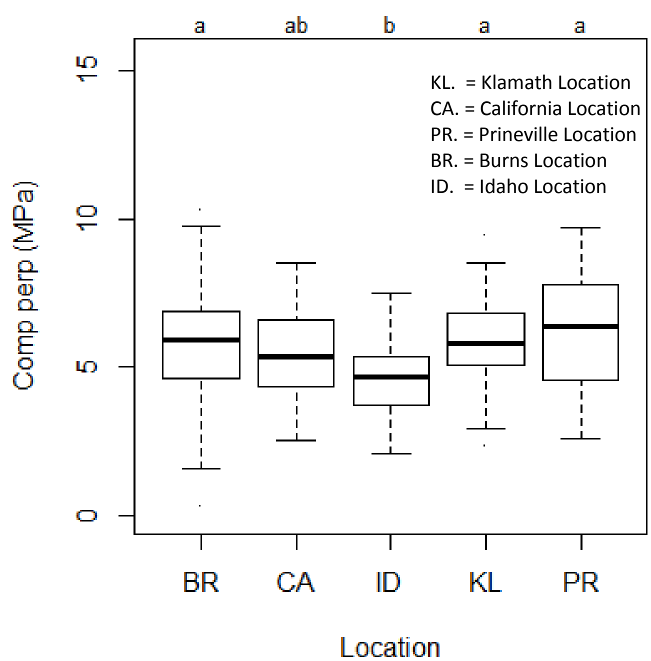

Figure 13: Compression strength perpendicular-to-grain of western juniper lumber obtained from five locations in the growing region. Values followed by the same letter(s) do not differ significantly by a Kruskalmc Test

During a compression ⊥ test, load is applied laterally to the tracheids. This load collapses the cell walls, and once this happens, the compressive stress starts to plateau. Once the tracheids are fully crushed, the load begins to increase again. This makes it difficult to obtain a maximum force (Ali et al. 2014). As a result, failure in compression ⊥ does not cause a break within the wood, but rather deformation of the loaded area. The common failure is a crushed area under the load head that varies in depth (Figure 14). For this reason, compressive strength was calculated using the force at 1 mm deflection as described in ASTM Standard D143.

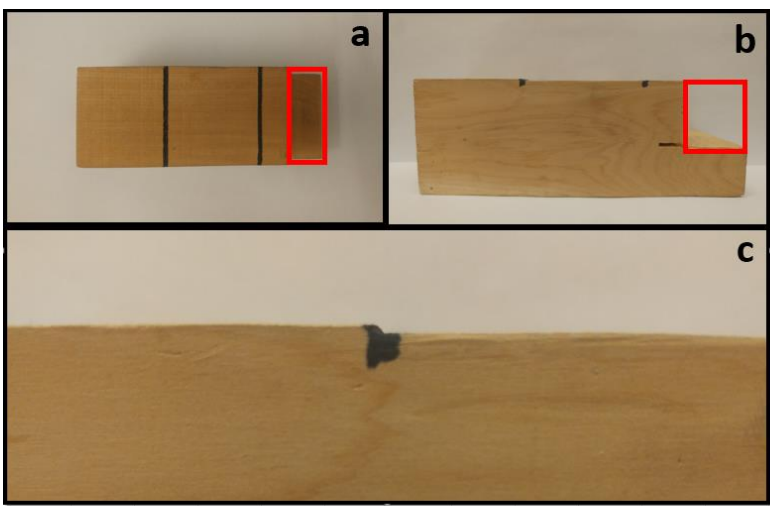

Figure 14: Compression perpendicular-to-grain failure highlighted with black sharpie. (a) Top view of sample (b) side view of sample (c) close-up of deformation at failure. *The red boxes represent sections taken for MC% and SG calculations

Compressive strength of western juniper was greater than that reported for western redcedar and incense cedar which have compressive strengths of 3.2 and 4.10 MPa, but somewhat lower than eastern redcedar which has a reported compressive strength of 6.30 MPa (Table 9). Compressive strength is generally correlated with SG (USDA 2010). However, compressive strength of western juniper was higher than Port-Orford-cedar, which has a compressive strength of 5 MPa in the perpendicular direction and a SG of 0.43. The COV for compressive strength $\perp$ was 30%. Typically, compression $\perp$ has the highest variability among all the measurable properties. Typical variability for compressive strength $\perp$ is 28% (USDA 2010). The variability observed for juniper (30%) was slightly higher than the typical values. The unique growth of western juniper made it challenging to obtain perfectly oriented samples and some tests may have been performed on samples that were not at a 90 degree angle to the load direction.

Compression $\perp$ of western juniper was higher than that reported for many softwood species used in structural applications, such as Douglas-fir and ponderosa pine (Table 9). High compressive strength could be due to the smaller tracheid diameter in western juniper. These uncharacteristically smaller tracheid diameters are similar to the fibers found in diffuse porous hardwoods (Meyers et al. 1998). Consequently, the compressive strength $\perp$ might be similar to that found in hardwood species. Hardwoods typically have higher compressive strength in the perpendicular direction than softwoods (USDA, 2010). The second factor that could have contributed to the increase in strength is the lignin content. Western juniper contains an average of 35.5%, which is the highest lignin content of any domestic softwood or hardwood (Meyers et al. 1998). Lignin is considered the bonding agent between cellulose and hemicellulose within the cell wall. Additionally, lignin may enhance polymer interactions that increase cell rigidity

(Shmulsky and Jones 2011). These two factors may have produced a higher yield strength thereby increasing tracheids resistance to collapse. These factors could also explain the high compressive strength found in eastern redcedar, which also has smaller diameter tracheids (2.15 mm).

4.3 Shear Block Test

Mean shear strength for samples from all locations was approximately 7.35 MPa (COV=19%) (Table 8). Samples with the highest shear strength originated in Idaho with a strength of 8.24 MPa (COV=19%), while the lowest shear strength of 5.96 MPa (COV= 17%) was observed in samples from Burns, OR (Table 8). There was evidence that the mean shear strength of western juniper varied due to location (ANOVA, p-value < .0001). Samples from Idaho, Prineville, and California did not differ significantly in shear strength (Tukey, p-values > 0.05). Shear strength in samples from the Klamath and California locations did not differ significantly (Tukey, p-values = 0.35), but there was evidence that samples from Klamath differ significantly from those from Idaho and Prineville (Tukey, p-values < 0.05). The shear strength in samples from Burns were the lowest and were significantly different from all others (Tukey, p-values < 0.05) (Figure 15).

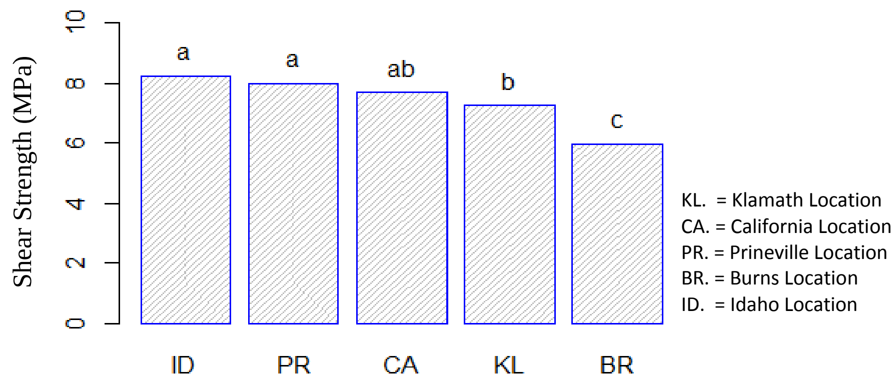

Figure 15: Shear strength of western juniper lumber obtained from five locations in the growing regions. Values followed by the same letter(s) do not differ significantly by a Tukey-Kramer Test at α=0.05

Shear failures parallel-to-grain in the radial direction tended to occur along the grain orientation in western juniper (Table 16). Failure occurred in shear when a compressive force was placed on to the shear block shelf. The section of the block that contained the shelf was not supported on the bottom causing a shear force to occur and the shelf to shear off.

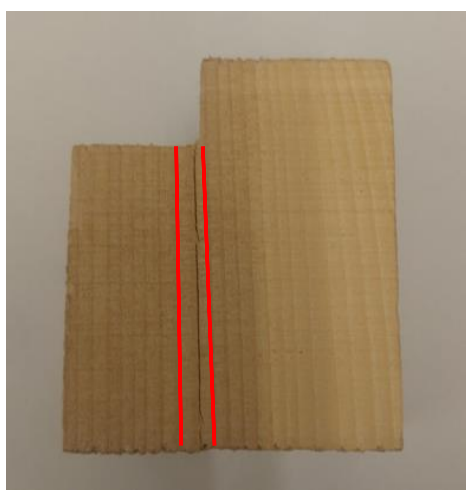

Figure 16: Example of a common shear failure in the shear blocks

Shear strength of western juniper was greater than that reported for western redcedar and incense cedar, which had shear strengths of 6.83 and 6.10 MPa, respectively, but lower than eastern redcedar which had a reported shear strength of 6.3 MPa (Table 9). Eastern redcedar had the highest SG, while those for the other species were similar or lower. Shear strength tends to be correlated with SG of the species, which can be seen when comparing juniper to the other similar species (USDA, 2010).

Mean shear strength was highest in samples from Idaho, averaging 8.24 MPa (Table 9). This was interesting because other properties in samples from the Idaho location tended to be lower. Shear strength of the samples from Idaho was similar to that for some Douglas-fir samples (coastal = 7.8 MPa and interior west =8.9 MPa) (USDA, 2010). Higher shear strength in Idaho samples could be due to the smaller tracheid diameter, results from the lower precipitation affecting the number and size of tracheids (Drew et al 2012). The smaller tracheids in the Idaho samples could be acting similarly to the fibers in diffuse porous hardwoods, which typically have higher shear strength than softwoods (USDA, 2010). Another factor that could affect properties was the position in the stem where the samples originated. Samples nearer to the pith would tend to contain higher percentages of juvenile wood which generally has lower strength properties than wood formed later (Shmulsky and Jones 2011). However, Idaho samples mainly contained sapwood suggesting that they were taken further out from the pith. Samples from the other locations contained either all heartwood or had some amount of heartwood within them. The small diameter of western juniper could increase the chance that a sample containing mainly heartwood would have some percentage of juvenile wood. The materials from most sites were cut by the cooperators making it difficult to determine the origin. Samples obtained nearer to the pith increases the likelihood of containing a larger percentage of juvenile wood. Juvenile wood is present in all wood species and becomes part of the average properties for that species.

4.4 Three-Point Bending Test

4.4.1 Modulus of Elasticity (MOE)

Mean Modulus of Elasticity (MOE) for samples from all locations was 3948.48 MPa (COV=27%) (Table 8). Samples with the highest MOE were obtained from Klamath with an MOE of 4629.30 MPa (COV=16%), while the lowest MOE was found in samples from Idaho with an MOE of 2739.28 MPa (COV=17%) (Table 8). There was evidence that mean MOEs of the western juniper varied significantly with location (ANOVA, p-value < .0001). MOEs of samples from Klamath and California were significantly greater than those from the other locations (Tukey, p-values < 0.05). MOEs of samples from Prineville and Burns were significantly different from all other locations (Tukey, p-values < 0.05). MOE’s of samples from Idaho were significantly different from all locations (Tukey, p-values < 0.05).

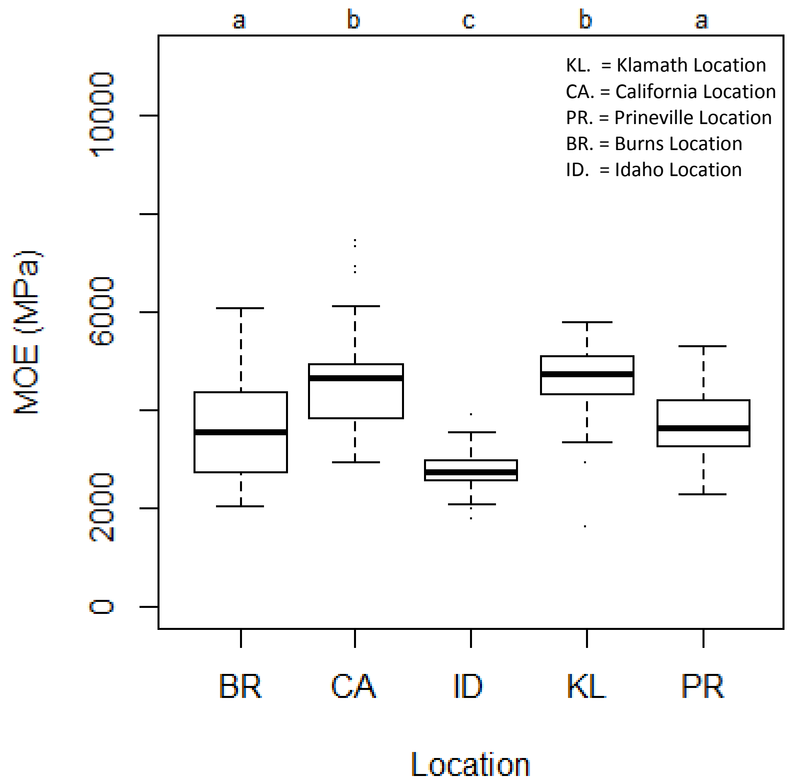

Figure 17: MOE of western juniper lumber obtained from five locations in the growing region. Values followed by the same letter(s) do not differ significantly by a Kruskalmc Test

Mean MOE of western juniper samples was significantly lower than those for all of the comparator wood species (Table 9). MOEs of other wood species similar to western juniper ranged between 7000 and 8900 MPa. As described earlier, the low mean MOE of the western juniper samples may be attributed to tracheid length and diameter, but further characterization of the anatomical differences between samples will be required.

Western juniper tracheids average 1.6 mm in length, while tracheids in most other softwoods range from 3 to 4 mm (Myers et al. 1998). Shorter tracheids in western juniper could behave similarly to juvenile wood, which has tracheids that are 3 to 4 times shorter than mature wood, and is associated with 15% to 50% decrease in mechanical properties (Shmulsky and Jones 2011). Western juniper tracheid diameters range from 0.012 to 0.031 mm which is also smaller than those for most softwoods (Myers *et al.* 1998). Tracheid length and diameter tend to be positively correlated with increased MOE (r^2 = 0.684 and r^2 = 0.678) (Kiaei et al. 2013). The lower MOEs in western juniper may be explained by cell dimensions. The decreased mean MOE of the samples from Idaho (2739.28 MPa) may be due to the effects of lower precipitation in this area on tracheid length and diameter.

Two studies should be conducted to further understand the cause for the low MOE of western juniper. The first study should examine the microfibril angles of the secondary cell wall to determine if any differences are related to strength properties. Higher microfibril angles are significantly correlated with reduced MOE's (r^2 = 0.63) (Via *et al.* 2009). The second study that should determine cellulose, hemicellulose, and lignin levels in the secondary cell wall layers. Western juniper has unusually high amounts lignin, and low cellulose and hemicellulose content compared to other softwood species. These variations may relate to the lower properties observed with this species. It is important to note that both of these studies would be costly and may not be justified for the potential applications for this species.

4.4.2 Modulus of Rupture (MOR)

Mean Modulus of Rupture (MOR) for samples from all locations was 58.44 MPa (COV=14%) (Table 8). Samples with the highest MOR originated in Prineville with a MOR of 61.57 MPa (COV=12%), while the lowest MOR was found in samples from Idaho (53.92 MPa) (Table 8). There was evidence that mean MOR of the western juniper varied significantly with location (ANOVA, p-value < .0001). MOR of samples from Prineville and Klamath did not differ significantly (Tukey, p-value = 0.95), nor did those from Klamath, Burns, or California (Tukey, p-values > 0.05). The MOR of samples from Idaho did not differ from those from Burns or California (Tukey, p-values > 0.05), but differed significantly from those from Prineville and Klamath (Tukey, p-value < 0.05).

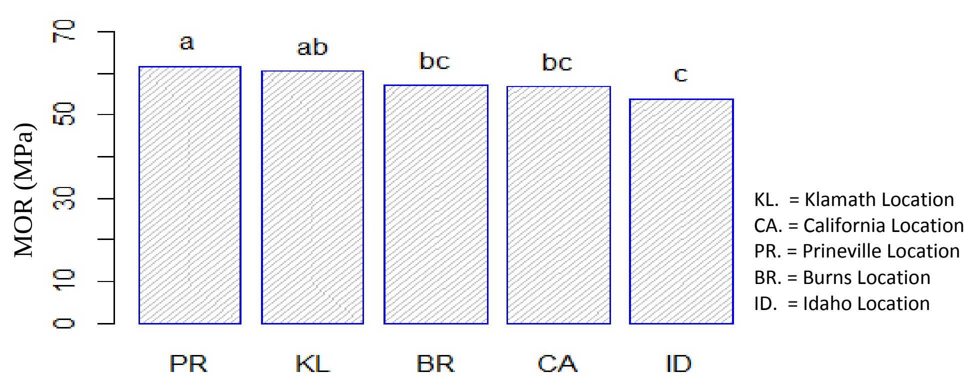

Figure 18: MOR of western juniper lumber obtained from five locations in the growing region. Values followed by the same letter(s) do not differ significantly by a Tukey-Kramer Test at α=0.05

The three-point bending test flexes a sample to failure and uses the maximum load to calculate MOR. The failure modes of the test samples were typical for bending tests with failure in tension that leads to shear (Fig. 19). These failure modes are typical of those described in ASTM Standard D143.

Figure 19: Three-point bending failures showing (a) Common failure types noted in ASTM Standard D143 (b)Simple tension failure (most common failure) (c)Cross-Grain Tension (d) Horizontal Shear (e) Catastrophic simple tension failure

Mean MOR of western juniper was similar to that found with other species such as western redcedar and incense cedar (Table 9). MOR tends to be correlated with SG, and western juniper followed this pattern (USDA 2010). Mean MOR of western juniper did not deviate from the other species as much as the MOE, and this may again, be explained by cell wall characterizations. MOR is strongly correlated with tracheid diameter (r^2=0.08), but is poorly correlated with tracheid length (r^2=0.47) (Kiaei et al. 2013). MOE is influenced by both the length and diameter of the tracheids as stated above.

4.5 Green/Dry Ratio of Compression Perpendicular-to-Grain and Shear

Green compressive strength of western juniper averaged 4.14 MPa, while dry compressive strength had a mean of 4.85 MPa. The initial dry/green ratio for the compressive strength was 1.21 and adjusting this ratio for 12% moisture content produced a value of 1.30 (Table 11).

The green shear strength of western juniper had a mean of 6.21 MPa, while dry shear strength had a mean of 7.70 MPa. The initial dry/green ratio for the shear strength was 1.24 and adjusting this ratio for 12% moisture content produced a value 1.68 (Table 11).

Table 11: The Dry/Green Ratios for Compressive and Shear Strength of western juniper samples collected from five areas within the growing range

Green/Dry Ratios of Compressive and Shear Strength (MPa)				
	Compression		**Shear**	
	Dry	***Green***	***Dry***	***Green***
Mean	4.85	4.14	7.70	6.21
StanDev	1.45	0.85	1.68	1.15
Max	8.23	6.03	12.06	8.90
Min	1.32	2.49	5.09	4.25
COV%	30%	20%	22%	18%
Ratio	1.18		1.24	
Adjusted Ratio	1.30		1.68	

Compression and shear strengths for dry western juniper were similar to the first samples tested. The results for green samples were lower than those for dry samples, for both tests, as expected due to the effect of increasing moisture content above the fiber saturation point (FSP) on wood properties. Green samples exceeded the FSP of 27% for this species. Wood above the FSP has lower stiffness and strength due to the effects of water on cellulose in the cell wall. Moisture absorbed by wood below the FSP is chemically bound to the wood via hydrogen bonding. These bonds weaken microfibril interactions, reducing wood properties (Shmulsky and Jones 2011).

4.6 Strength Values

Calculated strength values in the current study differed from those found by Burke (2008). MOE was 20% lower, while MOR was 9% lower than those found by Burke (2008). Differences between strength could have resulted from sample site selection, tree selection, or load-rate. Sample sites from the Burke (2008) work were similar to those in this study, excluding the Idaho site. Excluding the shear values, samples from Idaho had the lowest average for all other properties. These lower values reduced the overall averages. The trees in the Burke study were specifically selected for stem form, height, diameter, and crown morphology, with no defects, while this study used materials that were randomly selected from commercial products (Burke 1994). Unfortunately, Burke did not provide specific methods that could be compared with those in the current study.

4.7 Design Values

The results were used to calculate base design values for all combined locations of western juniper strength (Table 12).

Table 12: Base design values for various grades of western juniper lumber using data obtained from different areas of the growing region

Base Design Values (MPa)					
Grade	**Comp ||**	**MOE**	**MOR**	**Comp ⊥**	**Shear**
SS	6.59	3582.50	6.46	3.68	0.86
No. 1	5.92	3582.50	5.46	3.68	0.86
No. 2	4.96	3224.25	4.47	3.68	0.86
No. 3	2.86	2883.91	2.58	3.68	0.86
Stud	3.14	2883.91	3.50	3.68	0.86
Construction	6.22	3027.21	5.09	3.68	0.86
Standard	5.11	2758.52	2.84	3.68	0.86
Utility	3.33	2579.40	1.35	3.68	0.86

An example of the process for creating design values is illustrated below, for MOR and MOE:

The MOR values were first adjusted to 15% MC by applying a MC factor (Eq. 11). The MC adjusted values were averaged to calculate the 5% exclusion limit (Eq. 12) and this value was then adjusted from a 25.4 mm thickness to an 88.9 mm thickness (Eq. 13), the typical lumber dimension. A strength ratio factor was applied to determine values for each of the 8 grades (Table 5). A reduction factor was applied to account for the load duration and safety factors (Table 5). The last step developing the design values for MOR was to adjust for the volume of each grade (Eq. 14), as strength may vary by dimensions.

Average values were used for MOE design values, because design is based on strength rather than stiffness. A strength ratio factor was applied to the average based on the lumber grade (Table 8), then a reduction factor was applied to account for load duration and safety (Table9). These factors are property dependent.

4.8 Laboratory Decay Test

Southern pine sapwood samples exposed to *Trametes versicolor* experienced average weight losses of 32.15%, while those exposed to *Gloeophyllum trabeum* experienced average weight losses of 42.55% (Table 13). *T. versicolor* produced little decay over the 16-week exposure in the juniper soil block test. Average weight losses ranged from 0.30% in samples from Idaho to 1.72% in samples from Burns (Table 13) (Figure 20). Weight losses in the non-fungal inoculated controls were similar to the *T. versicolor* inoculated samples, indicating little to no attack on the inoculated samples. Western juniper inoculated with *T. versicolor* indicated high resistance compared to southern pine sapwood, which averaged 32.15% weight loss (Table 13)

Table 13: Mass loss of western juniper heartwood samples from locations in the growing area as determined by exposure to decay fungi – an AWPA E10 soil block test (a)

Mean Weight Loss Percent (%)				
Species	**Wood Source**	**Rot Fungi**		
		T. versicolor	***G. trabeum***	***Controls***
W. juniper	***Burns***	1.63 (0.5)	1.51 (1.7)	2.30 (0.7)
W. juniper	***California***	1.04 (0.7)	11.06 (19.4)	0.96 (1.1)
W. juniper	***Idaho***	0.30 (0.9)	7.95 (8.3)	0.89 (0.3)
W. juniper	***Klamath***	1.72 (1.5)	2.85 (1.8)	1.48 (0.1)
W. juniper	***Prineville***	1.50 (0.8)	4.09 (4.7)	1.49 (0.3)
S. Pine	-	32.15 (9.4)	42.55 (25.2)	-0.32 (0.2)

(a) Values represent means of samples sites and values in (parentheses) are SD.

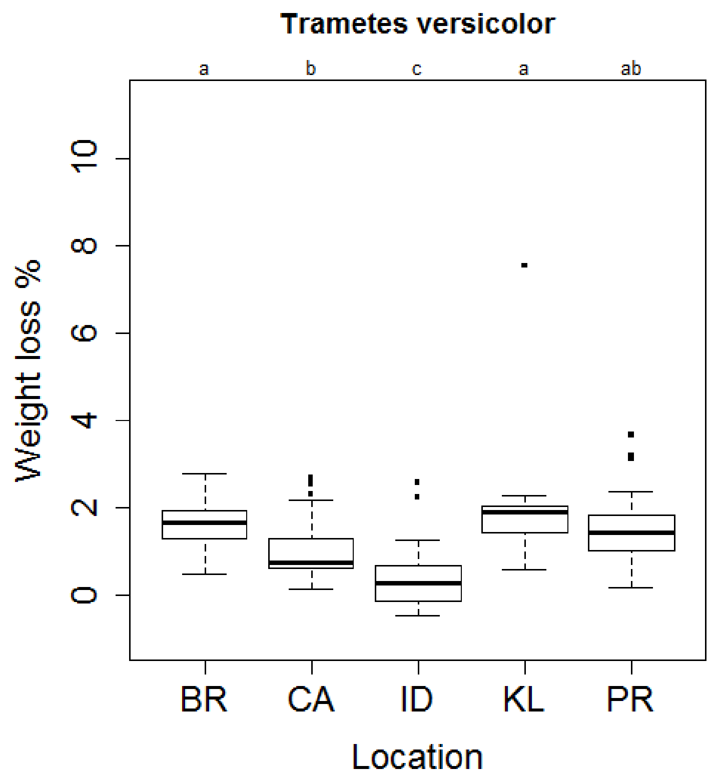

Figure 20: Percent weight losses of western juniper lumber obtained from four locations in the growing regions and exposed to *T. versicolor* in an AWPA E10 soil block tests. Values followed by the same letter(s) do not differ significantly by a Kruskalmc Test

T. versicolor is a white-rot fungus that can decay all wood components uniformly (Zabel and Morrell 1992). Western juniper's heartwood was highly resistant to attack. The most abundant extractive in western juniper heartwood is cedrol, which is a sesquiterpenoid (Myers et al. 1998). High cedrol levels in western juniper contribute to its antifungal properties and this compound is effective against white-rot fungi, including *T. versicolor* (Tumen *et al*. 2013).

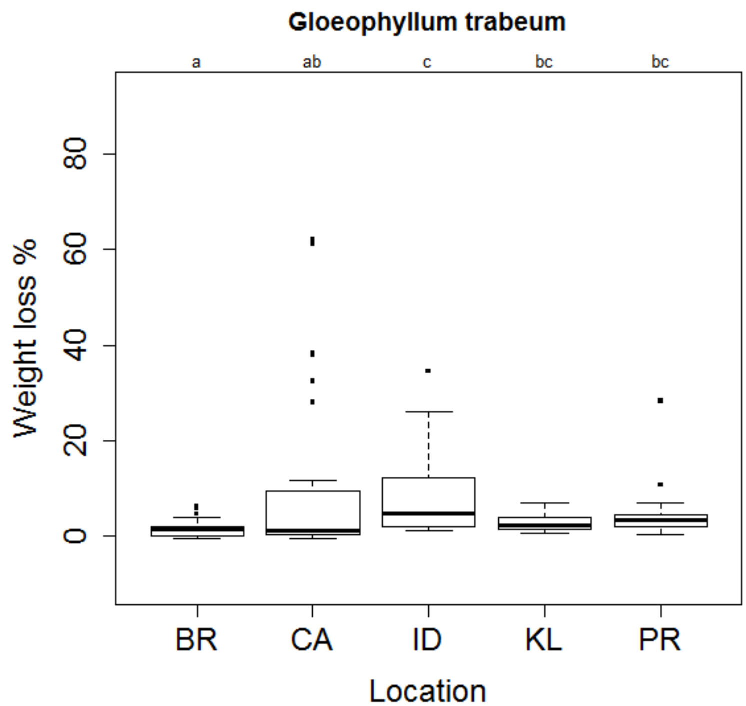

Figure 21: Percent weight losses of western juniper lumber obtained from four locations in the growing regions and exposed to *G. trabeum*, in an AWPA E10 soil block tests. Values followed by the same letter(s) do not differ significantly by a Kruskalmc Test

G. trabeum, produced some decay over the 16-week exposure in the soil block test. Average weight losses ranged from 2% in samples from Burns to11% in samples from California (Table 13) (Figure 21). Weight loss in the non-fungal inoculated controls were lower than some of *G. trabeum* inoculated samples, indicating some attack on the inoculated sample, but weight losses were still in the highly decay resistant range. Western juniper inoculated with *G. trabeum* indicated high resistance compared to southern pine sapwood, which averaged 42.55% weight loss (Table 13)

G.trabeum is a brown-rot fungus that decomposes the cell-wall carbohydrates and leaves a modified lignin. Western juniper heartwood was more sensitive to *G. trabeum* compared to *T. versicolor*. The soil block samples exposed to *G.trabeum* had a total mean weight loss of 6%. Cedrol has been shown to be less effective against brown-rot fungi (Tumen *et al*. 2013).

There were a number of outliers in the blocks from the California and Idaho locations exposed to *G. trabeum*, with weight losses between 30% and 65%. These outliers also contained fruiting bodies on the surface of the western juniper blocks (Figure 22). High weight losses with *G. trabeum* could be attributed to the presence of included sapwood. Included sapwood or white ring, is less resistant to decay and termite attack, than the heartwood that surrounds it (Taylor 2003). Variability between and within heartwood also affects the decay resistance (Freitag and Morrell 2001; Ajuong *et al.* 2014). The variability could be a contributor, since the outliers in the California location all came from the same post and section of the tree.

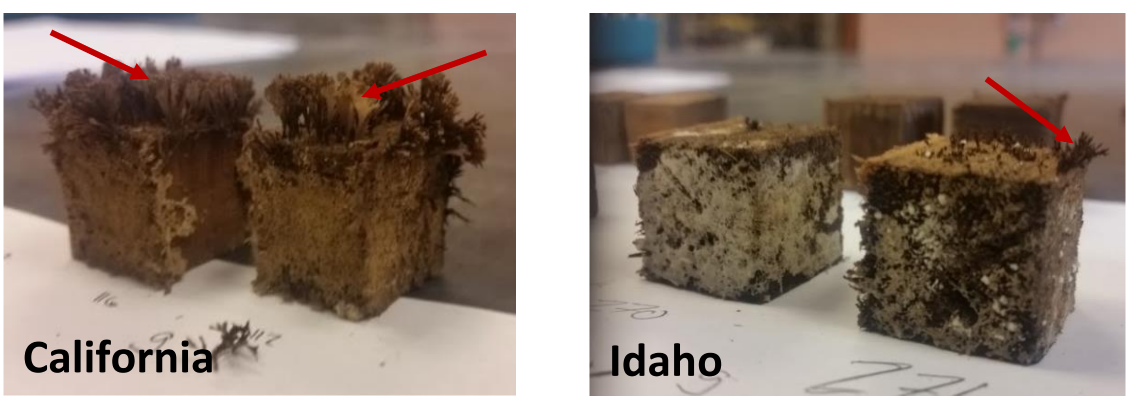

Figure 22: Outliers from the California and Idaho locations that were exposed to *Gloephyllum trabeum* in an AWPA E10 soil block test. Blocks contain fruiting bodies on the surface (arrows)

The American Society for Testing and Materials Standard D-2017 uses weight loss in a soil block test as a measure of durability and lists the criteria for various decay resistance classes as follows:

0-10 %	Highly resistant
11-24	Resistant
25-44 %	Moderately resistant
>45 %	Slightly or non-resistant

The *T. versicolor* and *G. trabeum* samples for western juniper had averages of 1% and 6% weight loss, which falls under the category of highly resistant to both brown and white-rot fungi.

CHAPTER 5: SUMMARY

5.1 Summary

This study conducted tests on western juniper to assess its mechanical property and durability attributes. Four mechanical tests were performed on western juniper samples, compression parallel-to-grain, compression perpendicular-to-grain, shear parallel-to-grain, and bending. Sub-samples were cut in compression perpendicular-to-grain and shear parallel-to-grain tests to obtain green/dry ratios for western juniper. Three durability tests were conducted on western juniper, which included a marine borer test, laboratory decay test, and ground contact test. The marine borer and ground contact tests were long term studies and are still on going.

Mechanical properties of juniper showed some variability within location from where the samples were procured. The compression $\perp$, shear, and MOR properties appeared to be similar or higher when compared to other similar softwood species. The compression || and MOE properties were significantly lower than those of similar species. The cause behind the variability in strength could be attributed to the anatomy and chemical makeup of western juniper. The short tracheids could cause the low MOE values, while small diameter of tracheids could have affected the other strength properties. The chemical compounds and the fact that juniper has a very high lignin content, may have caused the tracheids to become more rigid giving it higher compressive strength in the perpendicular-to-grain direction.

The samples from Idaho tend to have significantly different properties than the other locations and this could be due to the climatic conditions around the site with very low precipitation as compared to the other four locations. It has been shown that drought like conditions have an effect on the anatomy of softwoods, which could explain the Idaho location values. The Klamath and Prineville locations consistently had the highest strength values out of the other locations and both had similar climatic conditions.

The laboratory decay test showed western juniper was both brown and white-rot resistant. The soil blocks that were used in the decay test had an average range of 0% to 6% weight loss, and the ASTM Standard D 2017 states any wood species having an average weight loss below 10% is considered highly decay resistant. The high decay resistant properties can be attributed to the high amounts of chemical compounds. The high amounts of cedrol deterred the white-rot fungi, while the combination of cedrol and lignin deterred the brown-rot fungi. The observations on the marine borer and ground contact tests had shown no signs of attack within the evaluations done thus far after one year of exposure.

5.2 Conclusion

After evaluation of strength and durability attributes of western juniper, this species has shown to have some beneficial properties that could be utilized. High decay resistance of the heartwood of western juniper could allow this species to be used as a substitute for some treated wood applications. With the inclusion of western juniper in the NDS, it would give the option for it to be used in government funded construction projects. The adaptation of western juniper in the NDS could provide engineer with another option when deciding material for the project. In conclusion, western juniper would be considered as a prominent naturally durable wood substitute for non-structural applications. It could be implicated into certain structural applications, but special consideration should be taken in to account for the lower strength values. The base design values have taken into account for many wood defects and low strength, which have dropped the average strength significantly. The applications for western juniper can be evaluated once it has been approved by the ALSC, and the values have been published in codes and standards. The design values may limit western juniper in its use due to the low strength and the amount needed to compensate for these values.

5.3 Limitation and Future Work Recommendations

This study had some limitations that should be considered in future work in the area of juniper processing and anatomy. When processing western juniper for this study, there was a substantial amount of rejected material due to hidden defects in the wood or rot in the sapwood. For large amounts of western juniper lumber processing, more efficient ways of sorting would need to be developed to detect defect and rot pockets within the wood.

As previously mentioned, in the MOE discussion, a study should be conducted on both the MFA and chemical concentration within the cell-wall to understand if these factors could also be contributing to the low values. Measuring lumen space in the tracheids could help calculate the cell-wall thickness. The anatomical features can also be compared to different stand locations that may have different climate conditions. By understanding the correlation between anatomical features and growth climate of western juniper it could help predict strength values based on stand locations. By knowing how the climate effects the strength, certain locations can be considered for different applications, which then different grades could be assigned.

BIBLIOGRAPHY

Ajuong E., Freitag C., Morrell J. J., (2014). *Decay resistance and extractive content of second-growth port orford cedar (chamaecyparis lawsoniana) wood*, Wood and Fiber Science, 2014 Oct, Vol.46(4), pp.502-509

Ali, K. H., Hussain, T., and Kamali, A., (2014). *Compression perpendicular to grain in timber – Bearing strength for a sill plate*, Master Thesis, Civil Engineering, Department of Building Technology, University Linnsuniversitetet

American Wood Council (AWC). (2004). *Wood Structural Design Data.* American Forest and paper Association Inc. Washington, DC. 20036

ASTM D143. (2014). *ASTM D143-14 Standard Test Methods for Small Clear Specimens of Timber*. West Conshohocken, PA: ASTM International

ASTM D198. (2015). *ASTM D198-15 Standard Test Methods of Static Tests of Lumber in Structural Sizes*. West Conshohocken, PA: ASTM International

ASTM D2395. (2014). *ASTM D2395-14e1 Standard Test Methods for Density and Specific Gravity of Wood and Wood-Based Materials*. West Conshohocken, PA: ASTM International

ASTM D2555. (2016). *ASTM D2555-16 Standard Practices for Establishing Clear Wood Strength Values*. West Conshohocken, PA: ASTM International

ASTM D4442. (2016). *ASTM D4442-16 Standard Test Methods for Direct Moisture Content Measurement of Wood and Wood-based Materials*. West Conshohocken, PA: ASTM International

American Wood Protection Association (AWPA) (2016*). Standard Field Test for Evaluation of Wood Preservatives to be Used in Marine Applications (uc5a, uc5b, uc5c); Panel and Block Tests. AWPA E5-15 In.* AWPA Annual Book Standards. AWPA, Birmingham, Alabama.

American Wood Protection Association (AWPA) (2016). *Standard Field Test for Evaluation of Wood Preservatives to be Used in Ground Contact (uc4a, uc4b, uc4c); Post Test. AWPA E8-15 In.* AWPA Annual Book Standards. AWPA, Birmingham, Alabama.

Azuma, D. L., Hiserote, B. A., Dunham, P.A. (2005). *The western juniper resource of eastern Oregon, 1999*. Resour. Bull. PNW-RB-249. Portland, OR: U.S.

Department of Agriculture, Forest Service, Pacific Northwest Research Station. 18 p.

Bedell, T.E., L.E. Eddlemann, T. Deboodt, AND C. Jacks. (1993). Western juniper—Its impact and management in Oregon rangelands. EC 1417, Oregon State University Extension Service, Corvallis, OR.

Bowyer, J.L., Shmulsky, R., Hagreen, J.G. 2007. Forest products and wood science – an introduction. 131-134. Blackwell Publishing, Ames, Iowa, USA.

Burke, E.J. (2008). *Interim Report: Updated Findings in the Determination of the Mechanical Properties of the Wood of Western Juniper (Juniperus occidentalis Hook.)*. Report of 3, September 2008. Unpublished report. 10 p.

Drew, D.M., Allen K., Downes, G. M., Evans, R., Battaglia, M., Baker, P., (2012) *Wood properties in a long-lived conifer reveal strong climate signals where ring-width series do not*, Tree Physiol 2013; 33 (1): 37-47.

Freitag, C., Morrell J. J., (2001) *Durability of a changing western redcedar resource,* Wood and Fiber Science, 2001 Jan, Vol.33(1), pp.69-75 Taylor 2003

Gedney, D.R., Azuma, D.L., Bolsinger, C.L., and McKay N. (1999). *Western juniper in eastern Oregon*. USDA Forest Service Pacific Northwest Research Station General Technical Report PNW-GTR-464. 64 pp

Highley, T.L., (1995) *Comparative durability of untreated wood in use above ground* Int. Biodeter Biodegr., 35 (1995), pp. 409–419

Johnson, H.B., Polley, H.W., and Mayeux, H.S. (1993). *Increasing CO2 and plant-plant interactions: effects on natural vegetation*. Vegetatio 104/105:157–170.

Kiaei, M., Sadegh, A. N., and Moya, R., (2013). *Site variation of tracheid features and static bending properties in pinus eldarica wood,* Cellulose Chem. Technol., 47 (1-2), 49-59 (2013)

Knapp, P.A., and Soulé, P.T. (1996). *Vegetation change and the role of atmospheric CO2 enrichment on a relict site in central Oregon*: 1960–1994. Annals of the Association of American Geographers 86:387–411.

Kurth, E.F. and Ross J.D. (1954). Volatile Oil from Western Juniper. Report No. C-3, Oregon Forest Products, Oregon State University, Corvallis, OR.

Leavengood, S. (2008). *Developing Markets for Lesser-Known Species: The Case of Western Juniper in Oregon.* Proceedings of the 51st International Convention of Society of Wood Science and Technology November 10-12, 2008 Concepción, CHILE

Martin, R.E., J.E. Dealy, and D.L. Caraher. (1978). *Proceedings of the western juniper ecology and management workshop.* PNW-GTR-074. USDA Forest Service Pacific Northwest Research Station, Portland, OR. 176 pp.

Miller, R.F., Bates, J.D., Svejcar, T.J., Pierson, F.B., and Eddleman L.E. (2005*). Biology, ecology, and management of western juniper (Juniperus occidentalis)*. Oregon State University Agricultural Experiment Station Technical Bulletin 152, 82 pp.

Miller, R.F. and Rose, J.A. (1995) Historic Expansion of Juniperus occidentalis (western juniper) in southeast Oregon. Great Basin Nat. 55:37-45

Morrell, JJ, DJ Miller, and PF Schneider. (1999*). Service Life of Treated and Untreated Fence Posts: 1996 Post Farm Report*. Research Contribution 26, Forest Research Laboratory, Oregon State University. 24 p.

Myers, C. G., Weidenhoeft, W. M., and Davis, W. M., (1998). *Basic fiber and chemical properties of western juniper*, Prepared by the U.S. Forest Products Laboratory, Madison, WI. Unpublished report. 3

Panshin, A. and C de Zeeuw. (1980). *Text of wood Technology: Structure, Identification, Properties, and Uses of the Commercial Woods of the United states and Canada.* McGraw-Hill, New York. p705.

Shmulsky, R., and David P. J. (2011). *Forest Products and Wood Science: An Introduction*, Hoboken, NJ: Wiley-Blackwell, 2011. Print

Soulé, P.T., Knapp, P.A., and Grissino-Mayer, H.D. (2004). *Human agency, environmental drivers, and western juniper establishment during the late Holocene*. Ecological Applications 14:96–112.

Swan, L., and Connolly, M. (1998). *Processing and finishing western juniper*. Note prepared for the Wood Technology Clinic and Show, Portland, OR.

Taylor, A. M., (2003). *'Included sapwood' in redcedar,* Forest Products Extension, College of Agriculture Scieces and Natural Resources, University of Tennessee. Website Database: http://web.utk.edu/~mtaylo29/pages/Included%20sapwood%20in%20cedar.html

Tumen, I., Eller, F. J., Clausen, C. A., and Teel, J. A. (2013). *Antifungal activity of heartwood extracts from three Juniperus species*. BioResources.com 8(1):12-20

USDA. (2010). *Wood handbook—Wood as an engineering material*. General Technical Report FPL-GTR-190. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 508 p.

Via, B.K., So, C.L., Shupe, T.F., Groom, L.H., and Wikaira, J., (2009). *Mechanical response of longleaf pine to variation in microfibril angle, chemistry associated wavelengths, density, and radial position*, Composites: Part A. 40: 60-66.

Wigand, P.E., Hemphill, M.L., Sharpe, S., and Patra, S. (1995). *Great Basin semi-arid woodland dynamics during the late Quaternary*. Pages 51–70. In W.J. Waugh (editor). Proceedings: climate change in the four corners and adjacent regions: implications for environmental restoration and land-use planning. Mesa State College, Grand Junction CO. U.S. Department of Energy.

Zabel, A.R. and Morrell, J.J., (1992). *Wood Microbiology: Decay and Its Prevention*, San Diego, CA: Academic Press Inc., 1992. Print

APPENDICES

A.1 Compression || Data Tables

Appendix 1: Compression || Burns

Specimen lable	width mm	Thickness mm	GR #	Max Load (N)	Comp. Strength (MPa)	Width mm	Thickness mm	Length mm	Wet mass g	Dry Mass g	MC %	G
1	49.94	50.46	17	67565.12	26.81	25.19	25.17	48.09	12.89	11.38	13%	0.37
2	50.69	49.21	7	69526.69	27.87	25.62	25.50	49.54	13.58	11.92	14%	0.37
3	50.79	51.85	9	62903.62	23.89	25.31	25.60	51.72	13.27	11.67	14%	0.35
4	50.63	50.50	13	69244.80	27.08	25.38	25.35	50.12	14.96	13.08	14%	0.41
5	50.31	50.80	15	68975.14	26.99	24.87	25.09	50.44	15.89	13.91	14%	0.44
6	48.36	50.01	10	66493.15	27.49	25.25	25.35	48.92	14.74	12.88	14%	0.41
7	50.30	51.54	22	84787.78	32.71	25.43	25.23	51.34	16.07	14.03	15%	0.43
8	50.92	50.44	12	70958.94	27.63	25.37	24.76	50.42	14.10	12.32	14%	0.39
9	51.32	50.64	9	78653.98	30.26	25.36	25.11	50.98	15.34	13.43	14%	0.41
10	52.18	51.41	20	77377.41	28.84	25.35	25.07	50.28	13.51	12.00	13%	0.38
11	49.35	50.06	14	63010.37	25.51	25.42	25.31	49.34	13.67	11.94	14%	0.38
12	51.08	51.87	14	66986.88	25.28	25.24	24.74	51.90	14.90	13.21	13%	0.41
13	50.78	49.78	9	63944.45	25.30	24.95	25.58	50.09	14.05	12.24	15%	0.38
14	50.32	50.09	13	61671.52	24.47	25.36	24.38	49.29	13.49	11.82	14%	0.39
15	47.50	49.35	19	59162.85	25.24	25.22	25.23	52.30	12.25	10.97	12%	0.33
16	46.68	47.08	13	53633.98	24.40	25.59	25.05	46.32	11.92	10.43	14%	0.35
17	47.30	42.57	8	50364.70	25.01	25.30	25.33	47.56	11.72	10.27	14%	0.34
18	50.40	50.36	11	72355.62	28.51	24.90	25.16	49.80	14.55	12.77	14%	0.41

19	49.96	50.29	16	64696.16	25.75	25.24	25.22	49.84	13.84	12.14	14%	0.38
20	48.84	50.56	7	56796.51	23.00	25.25	25.42	48.99	14.19	12.43	14%	0.40
21	50.02	49.91	10	66973.54	26.83	25.14	24.89	49.72	13.84	12.31	12%	0.40
22	50.86	50.08	5	84049.41	33.00	25.38	25.11	50.04	18.61	16.19	15%	0.51
23	49.77	49.20	14	65345.57	26.69	25.46	25.58	48.92	13.99	12.26	14%	0.38
24	48.39	45.32	11	66164.00	30.17	25.65	25.52	44.97	12.78	11.23	14%	0.38
25	47.99	49.36	11	48652.22	20.54	25.74	25.41	49.03	11.74	10.27	14%	0.32
26	51.08	49.44	16	60012.42	23.76	25.83	25.42	53.92	18.04	15.82	14%	0.45
27	49.43	50.24	16	81647.49	32.88	25.38	25.41	49.43	15.96	13.83	15%	0.43
28	49.45	50.57	13	59950.14	23.97	25.26	25.22	50.77	14.00	12.27	14%	0.38
29	49.17	49.74	12	60937.60	24.92	25.13	24.99	49.10	12.14	10.65	14%	0.35
30	50.70	49.86	11	68103.33	26.94	25.05	25.08	50.60	12.74	11.18	14%	0.35
31	45.05	50.70	10	64064.54	28.05	25.38	24.93	50.58	13.64	11.94	14%	0.37
32	52.19	52.40	15	68766.08	25.15	25.64	25.04	52.31	13.94	12.21	14%	0.36
33	52.63	51.21	19	73805.66	27.38	25.06	24.94	50.79	15.01	12.93	16%	0.41
34	49.82	49.62	22	62814.66	25.41	25.32	25.12	49.46	13.20	11.54	14%	0.37
35	50.10	51.93	8	81834.30	31.45	25.30	25.30	50.18	15.75	13.52	16%	0.42
36	52.08	51.86	8	74321.63	27.52	25.63	25.32	51.87	14.49	12.66	14%	0.38
37	52.18	50.96	17	83382.21	31.36	25.26	25.29	50.53	16.23	14.20	14%	0.44
38	52.31	50.84	10	70229.47	26.41	25.37	25.29	50.96	15.47	13.60	14%	0.42
39	51.34	51.50	12	71501.60	27.04	25.30	25.18	50.48	13.17	11.61	13%	0.36
40	50.76	51.50	11	69553.38	26.61	24.77	24.69	51.64	13.83	12.26	13%	0.39
41	51.95	52.13	10	74957.70	27.68	24.18	25.07	51.69	12.76	11.33	13%	0.36
42	50.75	50.17	12	78178.05	30.70	25.13	25.00	50.34	14.53	12.69	14%	0.40
43	50.34	50.37	12	81745.34	32.24	25.26	24.98	50.04	14.83	13.17	13%	0.42

44	51.56	52.13	9	64464.86	23.98	25.98	25.23	51.61	12.67	11.30	12%	0.33
45	50.83	51.08	17	66279.65	25.53	25.21	25.43	51.04	15.73	14.04	12%	0.43
46	51.70	52.18	12	63997.82	23.72	25.42	25.69	52.03	17.18	14.95	15%	0.44
47	50.08	50.53	11	56649.73	22.39	25.24	24.77	49.18	13.07	11.59	13%	0.38
48	50.09	50.38	18	65487.90	25.95	25.35	25.04	49.71	12.74	11.30	13%	0.36
49	50.33	49.84	7	71906.37	28.67	25.36	25.11	50.42	14.63	12.99	13%	0.40
50	48.02	47.80	13	75211.23	32.77	25.29	25.33	47.73	14.40	12.68	14%	0.41
51	50.67	49.73	5	74779.78	29.68	25.37	25.24	49.75	14.57	12.71	15%	0.40
52	51.24	51.76	21	69802.46	26.32	25.27	25.39	51.45	13.99	12.35	13%	0.37
53	50.82	50.08	10	85926.46	33.76	25.22	25.25	50.29	17.71	15.57	14%	0.49
54	50.39	49.76	14	74664.13	29.78	25.19	25.26	50.59	13.67	12.23	12%	0.38
55	50.75	50.22	9	77159.456	30.27	25.51	24.9	50.95	15.35	13.62	13%	0.42
Average	50.23	50.24	12.53	68953.27	27.30	25.30	25.18	50.17	14.28	12.54	14%	0.39
Standard	1.48	1.63	4.13	8557.78	3.01	0.27	0.25	1.49	1.53	1.31	1%	0.04
min	45.05	42.57	5.00	48652.22	20.54	24.18	24.38	44.97	11.72	10.27	12%	0.32
max	52.63	52.40	22.00	85926.46	33.76	25.98	25.69	53.92	18.61	16.19	16%	0.51
cov	3%	3%	33%	12%	11%	1%	1%	3%	11%	10%	7%	9%

Appendix 2: Compression || California

Specimen label	width mm	Thickness mm	GR #	Max Load (N)	Comp. Strength (MPa)	Width mm	Thickness mm	Length mm	Wet mass g	Dry Mass g	MC %	G
1	55.79	57.15	12	90943.81	28.52	24.92	25.04	55.23	15.37	13.75	12%	0.40
2	51.62	51.82	17	78524.99	29.36	25.32	25.24	52.38	13.99	12.21	15%	0.36

3	51.27	52.20	19	88323.94	33.00	25.24	24.74	51.90	14.90	13.21	13%	0.41
4	52.28	52.34	14	105190.75	38.44	25.61	25.15	51.63	15.78	13.84	14%	0.42
5	51.75	51.68	10	86113.28	32.20	25.73	25.33	51.47	15.96	14.15	13%	0.42
6	50.64	51.32	14	62961.44	24.23	25.42	25.46	51.27	12.54	11.03	14%	0.33
7	51.14	49.85	21	85214.78	33.43	25.29	25.49	51.26	15.14	13.41	13%	0.41
8	51.55	50.85	10	89533.79	34.16	25.39	25.29	50.82	14.08	12.37	14%	0.38
9	55.66	56.71	7	94475.52	29.93	25.04	25.46	55.30	14.19	12.67	12%	0.36
11	53.34	53.13	11	86402.40	30.49	24.58	25.29	51.95	15.34	13.63	13%	0.42
12	55.68	55.61	16	86504.70	27.94	25.04	25.58	56.12	14.36	12.79	12%	0.36
13	52.00	51.70	21	88270.56	32.83	25.30	25.24	51.48	14.11	12.51	13%	0.38
14	53.18	52.51	7	70211.68	25.14	25.42	24.82	52.72	12.90	11.46	13%	0.34
15	52.76	53.50	9	75825.06	26.86	25.63	25.27	52.10	13.26	11.76	13%	0.35
16	52.80	53.32	11	84925.66	30.17	25.34	25.04	53.56	14.77	13.13	12%	0.39
17	52.40	52.72	11	73191.84	26.49	25.10	25.25	52.08	13.30	11.8	13%	0.36
18	52.64	53.89	19	86927.26	30.64	25.04	25.24	52.43	14.85	13.2	13%	0.40
19	52.58	53.37	7	97784.83	34.85	25.09	25.10	51.61	15.86	14.02	13%	0.43
20	53.29	55.48	15	94906.98	32.10	25.39	25.27	54.92	15.86	14.15	12%	0.40
21	53.72	52.30	10	100760.54	35.86	25.20	24.77	52.46	16.21	14.23	14%	0.43
22	52.72	52.69	18	96272.51	34.66	25.31	25.33	51.50	14.89	13.25	12%	0.40
23	53.50	53.53	15	92304.90	32.23	25.46	25.12	54.73	14.46	12.69	14%	0.36
24	53.74	53.66	12	98180.70	34.05	25.38	25.24	53.58	17.48	15.24	15%	0.44
25	55.57	53.56	16	98514.30	33.10	24.64	24.33	53.14	16.73	14.56	15%	0.46
27	51.65	51.90	16	73289.70	27.34	25.67	25.26	51.50	13.82	12.18	13%	0.36
28	53.14	52.37	10	81433.98	29.26	25.23	25.39	53.25	16.01	14.1	14%	0.41
29	51.71	51.87	10	76060.80	28.36	25.54	25.39	51.72	14.13	12.58	12%	0.38

30	51.04	50.97	8	76928.16	29.57	25.19	24.87	50.75	13.02	11.49	13%	0.36
31	52.36	52.34	13	84409.70	30.80	24.96	24.78	52.29	14.28	12.54	14%	0.39
32	50.42	50.20	12	68837.25	27.20	25.12	25.16	49.92	14.38	12.59	14%	0.40
33	51.69	52.23	13	86566.98	32.06	24.77	25.60	51.59	15.31	13.47	14%	0.41
34	52.17	51.58	12	86268.96	32.06	25.29	25.02	51.06	14.58	12.94	13%	0.40
35	53.79	51.04	12	72093.18	26.26	25.26	25.22	52.90	14.86	13.17	13%	0.39
36	52.40	51.96	8	88586.37	32.54	25.04	24.74	51.90	15.23	13.46	13%	0.42
37	54.47	54.23	15	88564.13	29.98	25.12	25.48	54.61	15.10	13.47	12%	0.39
38	50.85	52.56	16	77893.38	29.14	25.23	25.13	52.33	14.74	12.99	13%	0.39
39	50.47	50.50	7	80958.05	31.76	25.34	24.99	50.32	15.04	13.39	12%	0.42
40	50.62	50.74	7	84138.37	32.76	25.21	25.37	50.92	15.80	13.88	14%	0.43
41	52.13	52.71	6	70638.69	25.71	25.36	24.67	51.63	14.41	12.57	15%	0.39
42	50.58	50.74	22	72702.56	28.33	25.50	25.16	50.23	14.01	12.32	14%	0.38
43	52.62	53.00	8	86006.53	30.84	25.63	25.20	52.61	15.35	13.67	12%	0.40
44	51.32	51.10	6	70087.14	26.73	24.91	25.24	50.59	14.24	12.35	15%	0.39
45	53.09	51.83	21	78805.22	28.64	25.28	25.29	51.66	14.03	12.26	14%	0.37
46	52.08	53.43	15	88902.18	31.95	25.30	25.18	53.90	16.62	14.78	12%	0.43
47	49.20	48.40	10	61386.85	25.78	24.63	25.33	47.43	11.95	10.68	12%	0.36
48	53.14	52.91	10	84681.02	30.12	25.33	25.15	53.11	15.55	13.91	12%	0.41
49	51.20	52.34	8	64304.74	24.00	25.36	24.92	51.75	14.06	12.33	14%	0.38
50	51.62	52.79	10	77635.39	28.49	25.28	25.20	52.39	14.50	12.65	15%	0.38
51	52.18	51.44	10	86375.71	32.18	24.99	24.87	50.91	14.58	12.92	13%	0.41
52	50.86	51.54	13	82950.75	31.64	25.18	25.27	50.68	14.63	12.83	14%	0.40
53	50.63	53.65	28	99274.912	36.55	25.41	25.37	53.1	16.47	14.67	12%	0.43
Average	52.33	52.46	12.71	83569.55	30.41	25.24	25.16	52.17	14.77	13.04	0.13	0.39

Standard	1.45	1.60	4.80	10199.55	3.22	0.26	0.25	1.55	1.09	0.96	0.01	0.03
min	49.20	48.40	6.00	61386.85	24.00	24.58	24.33	47.43	11.95	10.68	0.12	0.33
max	55.79	57.15	28.00	105190.75	38.44	25.73	25.60	56.12	17.48	15.24	0.15	0.46
cov	3%	3%	38%	12%	11%	1%	1%	3%	7%	7%	7%	7%

Appendix 3: Compression || Prineville

Specimen Label	width mm	Thickness mm	GR #	Max Load (N)	Comp. Strength (MPa)	Width mm	Thickness mm	Length mm	Wet mass g	Dry Mass g	MC %	G
1	49.85	50.11	16	73067.296	29.25	25.18	25.39	50.8	17.16	14.89	15%	0.46
2	50.22	49.35	11	73414.24	29.62	25.38	25.53	50.43	16.47	14.37	15%	0.44
3	50.43	51.71	8	69072.992	26.49	25.49	25.29	50.65	13.9	12.1	15%	0.37
4	50.04	49.21	6	65634.688	26.65	24.81	25.25	49.1	12.7	11.33	12%	0.37
5	53.24	54.35	15	89484.864	30.93	25.46	25.56	54.34	17.36	15.08	15%	0.43
6	51.53	50.93	12	76803.616	29.26	25.45	25.2	50.87	15.68	13.56	16%	0.42
7	50.78	50.29	21	81216.032	31.80	25.24	25.3	50.08	14.78	12.93	14%	0.40
8	50.41	50.14	16	62921.408	24.89	25.14	25.08	50.36	17.14	14.54	18%	0.46
9	49.95	48.86	11	83177.6	34.08	25.35	25.37	49.4	16.86	14.97	13%	0.47
10	49.92	50.61	14	62734.592	24.83	25.05	25.38	50.29	15.99	13.84	16%	0.43
11	51.58	50.85	10	64046.752	24.42	25.55	24.93	52.11	15.86	13.8	15%	0.42
12	50.04	49.75	11	70269.504	28.23	24.5	25.24	49.39	15.27	13.28	15%	0.43
13	51.92	51.13	9	78676.224	29.64	25.25	25.04	51.47	15.7	13.74	14%	0.42
14	51.62	51.36	13	79561.376	30.01	25.65	25.29	51.05	15.67	13.89	13%	0.42

15	49.45	50.18	10	68276.8	27.52	25.48	25.22	49.98	14.95	13.05	15%	0.41
16	51	50.96	17	78578.368	30.23	25.36	25.3	50.53	15.1	13.19	14%	0.41
17	50.05	50.22	10	70514.144	28.05	25.04	25.07	50.09	15.58	13.62	14%	0.43
18	50.21	48.58	12	69135.264	28.34	25.16	25.12	48.06	15.52	13.49	15%	0.44
19	49.5	49.64	4	52935.648	21.54	25.08	25.34	50.49	14.21	12.29	16%	0.38
20	50.8	49.54	13	90850.4	36.10	25.11	25.27	50.07	17.78	15.3	16%	0.48
21	49.01	49.67	9	68023.264	27.94	25.41	25.4	50.18	15.42	13.4	15%	0.41
22	53.51	52.7	17	80935.808	28.70	25.63	25.17	51.97	16.06	14.01	15%	0.42
23	51.31	49.7	19	71337.024	27.97	25.44	24.71	49.56	14.9	12.96	15%	0.42
24	52.33	52.7	10	80700.064	29.26	26.14	25.73	51.75	16.59	14.5	14%	0.42
25	51.17	50.12	14	75358.016	29.38	25.42	25.69	52.03	17.18	14.95	15%	0.44
26	52.37	51.18	17	67627.392	25.23	25.24	24.86	52.64	16.47	14.12	17%	0.43
27	53.91	52.55	15	86664.832	30.59	25.73	25.38	54.08	16.72	14.55	15%	0.41
28	49.7	49.85	22	69077.44	27.88	24.89	24.99	49.3	16.48	14.16	16%	0.46
29	51.47	51.2	11	72996.128	27.70	25.07	24.83	51.44	14.19	12.44	14%	0.39
30	51.27	51.49	11	64624.992	24.48	24.85	24.62	51.88	14.22	12.29	16%	0.39
31	51.12	51.53	21	65914.912	25.02	25.13	25.36	51.22	14.62	12.71	15%	0.39
32	51.13	50.48	19	66564.32	25.79	25.33	24.82	50.89	14.72	12.76	15%	0.40
33	50.14	50.6	13	80188.544	31.61	25.65	25.33	50.56	15.52	13.67	14%	0.42
34	49.08	49.47	10	63521.888	26.16	25.44	25.32	49.41	15.41	13.33	16%	0.42
35	49.75	50.4	9	78538.336	31.32	25.46	25.24	50.05	16.77	14.4	16%	0.45
36	48.48	49.23	18	61453.568	25.75	25.71	25.46	50.13	16.71	14.33	17%	0.44
37	49.56	49.79	9	69424.384	28.13	25.61	25.23	50.71	16.67	14.44	15%	0.44
38	50.71	50.02	20	81162.656	32.00	25.25	24.85	51.78	15.35	13.54	13%	0.42
39	50.76	50.88	18	90552.384	35.06	25.31	25.17	50.69	16.41	14.41	14%	0.45

40	49.87	50.1	8	69993.728	28.01	25.44	25.37	49.49	14.17	12.47	14%	0.39
41	49.59	49.82	10	70158.304	28.40	25.31	25.21	49.49	16.01	13.84	16%	0.44
42	49.52	49.4	8	59425.28	24.29	25.38	25.23	50.1	13.88	12.1	15%	0.38
43	50.12	50.38	13	78449.376	31.07	25.16	24.97	49.71	14.66	12.8	15%	0.41
44	51.32	50.64	10	71132.416	27.37	25.1	25.21	50.41	14.08	12.2	15%	0.38
45	48.86	49.89	14	63659.776	26.12	25.22	25.07	48.5	15.08	12.97	16%	0.42
46	49.91	49.81	7	70665.376	28.43	25.09	24.57	49.8	14.84	12.95	15%	0.42
47	49.8	49.98	14	71617.248	28.77	25.67	24.85	49.44	16.25	14.28	14%	0.45
48	50.58	50.15	16	73974.688	29.16	25.21	25.47	50.32	16.07	13.91	16%	0.43
49	50.97	49.09	15	88573.024	35.40	25.03	24.67	49.37	16.2	14.01	16%	0.46
50	49.4	49.73	8	70798.816	28.82	25.31	25.25	49.77	16.18	14.04	15%	0.44
51	50.12	50.19	17	81834.304	32.53	25.18	24.89	49.35	16.29	14.11	15%	0.46
52	50.38	50.04	19	75233.472	29.84	24.87	24.87	50.53	14.22	12.55	13%	0.40
53	51.12	51.84	12	72609.152	27.40	25.38	25.15	51.14	14.02	12.21	15%	0.37
Average	50.58	50.42	13.06	73078.54	28.63	25.30	25.17	50.51	15.59	13.56	0.15	0.42
Standard	1.14	1.07	4.25	8313.80	2.95	0.28	0.26	1.20	1.10	0.91	0.01	0.03
min	48.48	48.58	4.00	52935.65	21.54	24.50	24.57	48.06	12.70	11.33	0.12	0.37
max	53.91	54.35	22.00	90850.40	36.10	26.14	25.73	54.34	17.78	15.30	0.18	0.48
cov	2%	2%	33%	11%	10%	1%	1%	2%	7%	7%	7%	6%

Appendix 4: Compression || Klamath

Specimen	width	Thickness	GR	Max Load	Comp. Strength	Width	Thickness	Length	Wet mass	Dry Mass	MC	G

Label	mm	mm	#	(N)	(MPa)	mm	mm	mm	g	g	%	
1	49.03	50.28	6	78160.26	31.71	25.44	25.24	49.21	13.45	11.90	13%	0.38
2	52.11	51.67	16	97678.08	36.28	25.26	25.23	52.18	14.82	13.18	12%	0.40
3	52.77	54.07	12	94942.56	33.27	25.56	25.14	54.04	14.97	13.35	12%	0.38
4	53.19	52.01	9	94929.22	34.31	25.04	25.06	52.39	15.10	13.41	13%	0.41
5	51.32	51.84	15	80886.88	30.40	25.44	25.20	52.30	16.04	14.14	13%	0.42
6	50.23	50.11	15	90418.94	35.92	25.25	25.21	50.25	15.35	13.51	14%	0.42
7	51.66	51.44	11	81064.80	30.51	25.16	25.15	51.92	13.36	11.69	14%	0.36
8	50.46	50.16	8	93875.04	37.09	24.69	25.33	49.49	16.73	14.67	14%	0.47
9	51.68	51.83	15	95520.80	35.66	25.09	25.08	51.57	14.02	12.44	13%	0.38
10	50.75	50.62	14	89449.28	34.82	25.10	25.30	50.63	15.42	13.65	13%	0.42
11	49.84	51.25	8	85352.67	33.42	25.32	25.19	50.51	15.56	13.79	13%	0.43
12	51.4	51.32	6	92651.84	35.12	25.21	25.16	51.26	15.06	13.11	15%	0.40
13	52.58	52.04	14	93545.89	34.19	25.15	25.43	52.28	15.55	13.68	14%	0.41
14	50.45	51.48	10	98007.23	37.74	24.83	25.33	50.43	16.72	14.82	13%	0.47
15	51.42	51.33	8	84129.47	31.87	25.48	25.26	51.46	14.27	12.50	14%	0.38
16	50.21	50.85	24	88657.54	34.72	25.32	25.49	51.15	16.73	14.72	14%	0.45
17	52.48	52.25	10	85023.52	31.01	24.96	24.83	52.20	14.53	12.81	13%	0.40
18	51.72	52.13	12	95756.54	35.52	25.56	25.36	52.13	16.31	14.33	14%	0.42
19	52.85	52.37	23	88937.76	32.13	25.41	25.29	52.45	15.71	13.72	15%	0.41
20	50.88	51.42	14	89969.70	34.39	25.42	25.40	52.15	16.41	14.64	12%	0.43
21	51.87	51.74	25	104914.98	39.09	25.53	25.18	50.92	14.52	12.90	13%	0.39
22	52.49	52.89	14	84325.18	30.37	25.24	25.21	52.29	15.18	13.37	14%	0.40
23	50.74	51.18	7	83279.90	32.07	25.37	25.59	51.06	15.60	13.64	14%	0.41
24	52.08	51.69	12	88435.14	32.85	25.32	24.76	52.19	14.20	12.57	13%	0.38

25	51.08	50.25	9	98318.59	38.30	25.43	25.23	49.98	16.14	14.32	13%	0.45
26	50.97	51.59	5	84467.52	32.12	25.52	25.34	51.38	16.59	14.58	14%	0.44
27	50.57	49.36	11	82385.86	33.01	25.46	25.10	50.70	13.25	11.81	12%	0.36
28	52.34	52.31	21	100204.54	36.60	25.18	25.05	51.99	16.80	14.91	13%	0.45
29	52.28	51.75	10	84547.58	31.25	25.48	25.21	52.11	14.59	12.71	15%	0.38
30	51.25	51.81	18	88742.05	33.42	25.68	25.28	51.09	14.13	12.52	13%	0.38
31	49.88	50.64	5	72475.71	28.69	25.53	25.22	50.00	16.14	14.28	13%	0.44
32	52.39	51.72	9	89253.57	32.94	25.38	25.49	52.18	15.72	13.64	15%	0.40
33	51.82	51.62	9	83907.07	31.37	25.45	25.33	51.95	15.16	13.30	14%	0.40
34	51.54	50.76	11	83551.23	31.94	25.43	25.30	51.12	13.94	12.50	12%	0.38
35	52.27	51.91	8	86531.39	31.89	25.44	25.29	52.59	15.50	13.54	14%	0.40
36	51.75	51.63	16	92531.74	34.63	25.16	25.12	51.52	15.36	13.57	13%	0.42
37	50.33	51.4	9	83426.69	32.25	25.46	25.25	50.30	12.98	11.58	12%	0.36
38	51.86	51.87	15	85890.88	31.93	25.44	25.33	52.72	16.12	14.12	14%	0.42
40	50.37	50.53	14	78062.40	30.67	25.45	25.16	50.70	13.66	12.13	13%	0.37
42	52.87	53.8	11	96832.96	34.04	25.26	24.82	52.67	15.97	13.96	14%	0.42
43	50.75	51.47	10	89258.02	34.17	25.23	25.21	50.72	16.10	14.18	14%	0.44
44	51.56	49.71	9	78952.00	30.80	25.45	25.39	49.94	13.35	11.95	12%	0.37
45	51.54	52.82	7	57961.89	21.29	25.20	25.14	51.98	16.61	14.48	15%	0.44
46	52.25	52.27	10	87505.50	32.04	24.93	25.32	51.91	14.96	13.11	14%	0.40
47	50.2	49.92	9	82621.60	32.97	25.35	25.29	49.60	13.06	11.63	12%	0.37
48	52.9	52.49	12	88412.90	31.84	25.39	25.32	52.76	15.43	13.48	14%	0.40
50	51.7	51.74	13	76136.42	28.46	25.31	25.22	51.95	15.35	13.46	14%	0.41
51	51.42	51.29	11	67418.34	25.56	25.22	25.03	51.44	13.31	11.76	13%	0.36
52	50.36	50.49	17	88341.73	34.74	25.14	24.92	51.49	14.44	12.77	13%	0.40

53	51.92	51.69	19	76954.85	28.67	25.81	25.43	51.54	14.67	12.86	14%	0.38
54	51.8	52.58	13	73000.58	26.80	25.27	23.98	52.05	13.51	11.88	14%	0.38
55	51.02	50.9	13	86429.09	33.28	25.24	25.23	50.49	13.81	12.27	13%	0.38
56	50.75	51.17	23	68548.13	26.40	25.59	25.11	51.26	15.11	13.37	13%	0.41
Average	51.43	51.50	12.36	86275.17	32.58	25.32	25.20	51.45	15.04	13.27	0.13	0.40
Standard	0.93	0.92	4.81	8793.34	3.25	0.21	0.23	0.98	1.10	0.94	0.01	0.03
min	49.03	49.36	5.00	57961.89	21.29	24.69	23.98	49.21	12.98	11.58	0.12	0.36
max	53.19	54.07	25.00	104914.98	39.09	25.81	25.59	54.04	16.80	14.91	0.15	0.47
cov	2%	2%	39%	10%	10%	1%	1%	2%	7%	7%	7%	7%

Appendix 5: Compression || Idaho

Specimen Label	Width mm	Thickness mm	GR #	Max N	Comp strength MPa	Width mm	Thickness mm	Length mm	Wet mass g	Dry Mass g	MC %	g
1	56.5	56.49	14	91904.58	28.80	24.93	25.21	55.97	16.67	14.73	13%	0.42
2	55.75	55.52	3	83319.94	26.92	25.17	25.32	55.24	17.53	15.44	14%	0.44
3	58.26	56.95	6	79877.18	24.07	24.94	25.39	53.30	19.21	16.92	14%	0.50
4	55.73	60.9	16	119344.29	35.16	24.99	24.82	54.60	19.53	17.22	13%	0.51
5	56.25	55.63	8	87336.48	27.91	25.24	25.04	55.89	16.92	14.96	13%	0.42
6	56.78	57.78	6	84507.55	25.76	25.36	25.30	56.00	14.82	13.15	13%	0.37
7	53.83	51.55	5	73996.93	26.67	25.46	25.41	51.28	14.16	12.57	13%	0.38

8	57.72	58.11	13	90454.53	26.97	25.68	25.29	58.44	17.31	15.26	13%	0.40
9	55.91	58.81	9	104341.18	31.73	25.13	25.59	55.89	18.46	16.28	13%	0.45
10	54.75	53.57	6	89707.26	30.59	25.34	25.54	55.30	22.04	19.31	14%	0.54
11	56.65	54.56	4	89324.74	28.90	25.26	24.95	54.37	20.15	17.67	14%	0.52
12	55.65	55.54	17	92745.25	30.01	25.08	25.24	55.64	16.69	14.78	13%	0.42
13	56.66	56.86	12	84743.30	26.30	26.04	24.64	56.50	17.55	15.61	12%	0.43
14	45.77	53.57	7	61093.28	24.92	25.10	25.45	52.65	12.89	11.36	13%	0.34
15	56.01	56.05	5	82688.32	26.34	24.87	25.34	56.42	18.42	16.17	14%	0.45
16	55.91	53.75	4	68850.59	22.91	25.16	25.38	55.04	15.70	13.88	13%	0.39
17	51	52.95	5	86006.53	31.85	24.73	25.23	50.49	18.13	16.05	13%	0.51
18	59.75	56.66	6	95654.24	28.25	25.12	25.34	52.48	20.35	17.81	14%	0.53
19	54.17	53.77	11	90881.54	31.20	24.01	25.15	50.93	17.62	15.44	14%	0.50
20	55.26	54.42	6	89084.54	29.62	25.21	24.93	54.94	15.72	13.82	14%	0.40
21	54.87	57.19	4	79094.34	25.21	25.19	25.08	53.91	14.56	12.93	13%	0.38
22	49.56	51.46	7	63043.98	24.72	25.30	25.18	50.48	13.17	11.61	13%	0.36
23	50.31	50.77	12	67384.35	26.38	25.67	25.29	50.63	15.11	13.33	13%	0.41
24	50.03	51.19	10	63229.20	24.69	25.49	25.26	51.13	15.06	13.32	13%	0.40
25	49.66	50.58	13	53121.94	21.15	24.93	25.29	49.77	13.92	12.23	14%	0.39
26	48.75	51.59	10	62140.47	24.71	25.63	25.20	49.79	14.53	12.77	14%	0.40
27	48.76	50.86	7	53764.92	21.68	25.52	25.30	50.64	14.40	12.71	13%	0.39
28	51.25	49.82	10	63230.99	24.76	25.50	25.42	50.16	13.41	11.82	13%	0.36
29	50.11	51.68	9	62961.89	24.31	25.54	25.15	50.51	13.66	12.06	13%	0.37
30	50.6	51.67	6	65513.43	25.06	25.29	25.45	51.52	15.47	13.64	13%	0.41
31	50.89	49.15	10	63070.28	25.22	25.77	25.29	50.00	15.40	13.49	14%	0.41
Average	53.65	54.17	8.42	78787.68	26.86	25.25	25.24	53.22	16.41	14.46	13%	0.43

Standard	3.47	2.97	3.70	15631.93	3.17	0.37	0.20	2.57	2.35	2.05	0%	0.06
min	45.77	49.15	3.00	53121.94	21.15	24.01	24.64	49.77	12.89	11.36	12%	0.34
max	59.75	60.90	17.00	119344.29	35.16	26.04	25.59	58.44	22.04	19.31	14%	0.54
cov	6%	5%	44%	20%	12%	1%	1%	5%	14%	14%	4%	13%

A.2 Compression⊥ Data Table

Appendix 6: Compression ⊥ Burns

Specimen Label	width mm	Thickness mm	GR #	Load at 1 mm (N)	Comp. Strength (MPa)	Width mm	Thickness mm	Length mm	Wet mass g	Dry Mass g	MC %	G
1	50.16	49.02	21	16869.36	6.86	25.19	25.23	48.83	14.06	12.19	15%	0.39
2	48.71	50.43	14	7254.33	2.95	25.33	24.55	49.19	11.95	10.45	14%	0.34
3	50.33	49.95	11	15668.70	6.23	25.38	25.19	50.00	13.97	12.24	14%	0.38
4	52.77	50.85	16	14459.09	5.39	25.66	24.79	50.75	12.72	11.06	15%	0.34
5	48.99	52.1	14	12734.14	4.99	25.43	24.84	51.15	13.04	11.35	15%	0.35
6	49.48	50.39	14	16387.33	6.57	25.13	25.12	49.72	13.77	12.01	15%	0.38
7	50.05	49.85	18	15016.32	6.02	25.07	25.05	49.57	12.22	10.68	14%	0.34
8	48.44	47.58	24	10245.09	4.45	25.64	24.97	48.34	12.07	10.72	13%	0.35
9	52.67	51.24	17	10172.14	3.77	25.27	25.19	51.03	14.13	12.27	15%	0.38
10	51.58	50.21	9	10699.40	4.13	25.33	25.69	51.34	15.51	13.54	15%	0.41
11	49.54	49.04	17	12943.20	5.33	25.26	25.32	49.68	13.74	11.98	15%	0.38
12	49.45	49.82	11	12293.81	4.99	25.22	24.92	49.61	12.74	11.09	15%	0.36
13	47.46	46.74	19	9219.52	4.16	25.57	25.14	46.68	10.87	9.51	14%	0.32
14	49.87	49.19	13	13199.05	5.38	25.41	24.48	50.14	13.96	12.81	9%	0.41
15	49.6	49.02	12	9763.69	4.02	25.38	25.35	50.15	12.40	10.84	14%	0.34
16	50.18	50.19	23	9812.80	3.90	24.28	24.97	50.49	13.25	11.43	16%	0.37
17	49.49	49.41	20	11296.01	4.62	25.41	25.51	48.17	11.32	9.94	14%	0.32

18	51.74	51.82	25	18399.56	6.86	25.14	25.24	51.20	13.16	11.51	14%	0.35
19	49.67	51.6	10	9948.71	3.88	25.28	25.10	51.08	13.38	11.62	15%	0.36
20	48.99	49.76	14	14368.77	5.89	25.36	25.44	49.28	15.54	13.92	12%	0.44
21	48.55	49.38	11	14780.09	6.17	25.10	24.45	48.67	13.91	12.19	14%	0.41
22	48.72	49.26	17	16483.28	6.87	25.42	25.33	48.53	14.73	12.86	15%	0.41
23	50.09	50.76	11	13400.54	5.27	25.32	25.31	49.48	13.16	11.44	15%	0.36
24	48.56	50.73	10	11611.41	4.71	25.53	24.91	50.35	13.44	11.67	15%	0.36
25	48.43	48.53	9	10723.76	4.56	25.45	25.01	49.81	14.01	12.24	14%	0.39
26	50.39	48.85	11	11084.53	4.50	25.00	25.24	50.22	12.90	11.25	15%	0.36
27	52.84	54.9	23	15252.01	5.26	25.31	25.04	55.05	15.14	13.45	13%	0.39
28	50.13	50.36	11	16917.52	6.70	25.44	25.17	50.19	14.39	12.59	14%	0.39
29	50.43	50.49	9	9576.56	3.76	25.24	25.48	50.80	13.90	12.48	11%	0.38
30	53	52.5	12	27105.83	9.74	25.29	24.74	52.71	16.19	14.46	12%	0.44
31	52.29	52.15	15	8489.94	3.11	25.47	25.51	52.21	15.05	13.54	11%	0.40
32	50.39	50.25	19	10661.81	4.21	24.99	25.27	49.53	14.73	13.04	13%	0.42
33	49.94	49.8	11	21637.19	8.70	25.49	24.71	49.61	14.29	12.69	13%	0.41
34	50.22	49.49	17	20371.89	8.20	25.29	25.24	49.50	13.41	11.93	12%	0.38
35	48.31	50.63	15	12746.90	5.21	25.20	24.88	47.93	12.16	10.87	12%	0.36
36	50.36	48.94	10	25375.64	10.30	25.07	25.36	48.53	13.39	11.94	12%	0.39
37	51.84	49.22	13	14066.63	5.51	25.21	25.52	51.04	12.66	11.61	9%	0.35
38	51.1	51.35	16	21286.38	8.11	25.37	25.13	51.30	15.28	13.53	13%	0.41
39	49.64	50.85	25	24300.88	9.63	25.28	25.26	48.77	14.41	13.24	9%	0.43
40	50.76	50.87	15	20818.45	8.06	25.40	25.41	50.81	12.45	11.06	13%	0.34
41	50.37	50.01	14	18701.76	7.42	25.28	24.87	49.69	13.39	11.86	13%	0.38
42	49.92	55.94	14	20979.85	7.51	23.56	25.19	55.14	15.00	13.44	12%	0.41

43	48.75	48.82	11	19173.01	8.06	25.48	25.40	48.73	15.76	13.94	13%	0.44
44	52.44	51.43	14	19685.18	7.30	25.85	25.36	52.68	15.00	13.34	12%	0.39
45	50.21	50.04	10	15618.72	6.22	25.35	25.21	49.44	12.05	10.91	10%	0.35
46	51.76	51.65	12	15465.41	5.78	25.49	25.23	51.49	13.60	12.34	10%	0.37
47	52.13	51.61	15	22590.91	8.40	25.44	24.99	52.19	13.77	12.44	11%	0.37
48	55.36	54.26	15	19105.75	6.36	25.11	25.20	54.82	15.59	14.04	11%	0.40
49	51.02	50.15	14	17277.56	6.75	25.52	25.16	49.67	14.92	13.21	13%	0.41
50	53.57	51.23	9	17542.80	6.39	26.07	25.58	53.47	14.80	13.10	13%	0.37
51	52.16	52.34	21	18612.39	6.82	25.65	25.04	52.71	14.24	13.06	9%	0.39
52	49.86	50.46	25	16301.00	6.48	25.50	25.35	49.95	13.53	11.94	13%	0.37
53	51.25	49.87	12	12910.94	5.05	25.59	25.41	49.60	13.10	11.54	14%	0.36
Average	50.45	50.48	14.87	15309.58	5.99	25.31	25.15	50.40	13.74	12.16	13%	0.38
Standard	1.56	1.62	4.57	4633.11	1.72	0.35	0.27	1.75	1.19	1.11	2%	0.03
min	47.46	46.74	9.00	7254.33	2.95	23.56	24.45	46.68	10.87	9.51	9%	0.32
max	55.36	55.94	25.00	27105.83	10.30	26.07	25.69	55.14	16.19	14.46	16%	0.44
cov	3%	3%	31%	30%	29%	1%	1%	3%	9%	9%	14%	8%

Appendix 7: Compression ⊥ California

Specimen Label	width mm	Thickness mm	GR #	Load at 1 mm (N)	Comp. Strength (MPa)	Width mm	Thickness mm	Length mm	Wet mass g	Dry Mass g	MC %	G
1	52.75	52.94	8	14226.37	5.09	25.43	25.99	25.37	7.54	6.74	12%	0.40
2	51.38	51.55	9	13568.68	5.12	25.34	25.56	25.42	7.27	6.51	12%	0.40
3	51.2	51.33	11	21388.14	8.14	25.04	25.4	25.58	6.78	6.06	12%	0.37

4	51.35	51.42	12	13532.23	5.13	25.32	25.34	25.61	6.62	5.89	12%	0.36
5	52.61	50.65	11	17611.77	6.61	25.31	25.49	24.87	7.49	6.56	14%	0.41
6	51.6	53.4	17	13587.13	4.93	25.53	25.55	24.6	7.4	6.58	12%	0.41
7	52.45	49.49	10	15847.07	6.11	25.3	25.42	25.4	7.5	6.71	12%	0.41
8	51.05	52.71	15	9491.97	3.53	25.48	25.2	25.22	6.98	6.19	13%	0.38
9	53.69	53.73	12	15810.93	5.48	25.58	26.06	25.61	7.95	7.09	12%	0.42
10	52.56	51.02	11	14204.86	5.30	25.17	25.26	52.56	15.75	13.99	13%	0.42
11	53.62	52.78	19	21683.02	7.66	25.22	25.34	25.64	7.53	6.88	9%	0.42
12	56.32	55.14	14	14595.01	4.70	25.3	25.41	25.45	7.16	6.50	10%	0.40
13	50.93	51.15	8	22145.48	8.50	25.48	25.44	25.45	8.06	7.01	15%	0.42
14	55.52	55.39	10	11341.31	3.69	25.19	25.55	25.51	7.06	6.33	12%	0.39
15	54.87	54.21	12	9531.70	3.20	25.51	25.14	25.57	6.82	6.08	12%	0.37
16	52.17	51.7	9	17840.08	6.61	25.59	25.68	25.53	7.82	6.92	13%	0.41
17	51.39	50.83	11	11184.97	4.28	25.68	25.45	25.39	6.81	6.03	13%	0.36
18	52.36	52.82	6	21914.86	7.92	25.18	25.7	25.1	8.3	7.31	14%	0.45
19	51.42	52.23	9	13561.47	5.05	24.81	25.59	25.16	6.77	6.00	13%	0.38
20	53.06	54.05	10	12189.82	4.25	24.96	25.65	25.49	6.44	5.73	12%	0.35
21	55.81	56.08	15	10942.65	3.50	25.39	25.24	25.56	7.3	6.51	12%	0.40
22	53.94	53.91	8	15965.05	5.49	25.01	25.09	54.02	14.36	12.61	14%	0.37
23	50.89	52.04	12	6961.42	2.63	24.69	23.8	50.17	13.07	11.55	13%	0.39
24	55.32	55.04	10	9598.97	3.15	24.83	25.38	54.34	13	11.53	13%	0.34
25	52.33	52.91	12	10808.20	3.90	24.94	25.27	52.69	14.18	12.60	13%	0.38
26	51.75	51.9	13	17008.94	6.33	24.75	24.91	51.48	13.4	11.92	12%	0.38
27	53.49	53.09	10	23356.28	8.22	24.66	24.96	53.41	17.07	15.00	14%	0.46
28	55.48	55.56	17	10220.44	3.32	25.45	25.54	55.3	15.86	14.10	12%	0.39

29	50.86	51.67	14	18520.82	7.05	25	24.93	50.98	14.6	12.80	14%	0.40
30	52.09	49.71	22	19656.13	7.59	24.84	24.95	52.17	13.71	12.01	14%	0.37
31	56.55	55.68	10	15423.21	4.90	25.19	24.95	56.13	17.19	15.12	14%	0.43
32	52.44	52.97	13	7936.31	2.86	24.98	25.19	52.69	14.4	12.89	12%	0.39
33	51.06	50.6	18	12324.32	4.77	25.25	25.18	51.11	12.25	10.84	13%	0.33
34	52.07	51.91	12	17852.31	6.60	25.42	25.02	51.59	14.55	12.78	14%	0.39
35	50.99	52.09	18	14647.52	5.51	24.88	24.98	21.35	14.11	12.43	14%	0.94
36	53.77	53.51	9	11944.16	4.15	24.99	24.65	53.3	15.14	13.39	13%	0.41
37	53.12	52.96	22	22251.31	7.91	24.67	25.62	25.59	7.7	6.86	12%	0.42
38	55.4	56.08	13	7887.21	2.54	24.67	25.04	54.4	15.87	14.02	13%	0.42
39	52.82	53	12	18054.84	6.45	24.98	24.79	52.52	14.1	12.43	13%	0.38
40	52.33	52.58	17	18430.93	6.70	24.9	25.14	51.94	16.42	14.55	13%	0.45
41	52.57	52.93	27	19096.35	6.86	24.76	24.94	52.88	14.44	12.76	13%	0.39
42	52.11	52.18	13	17225.28	6.33	24.68	25	52.39	14.99	13.6	10%	0.42
43	55.15	56.39	8	16628.10	5.35	25.34	24.92	56.43	17.43	15.44	13%	0.43
44	53.04	52.77	11	16757.67	5.99	24.73	24.95	53.44	13.66	12.07	13%	0.37
45	50.92	51.65	9	12183.30	4.63	24.78	24.9	51.8	14.11	12.43	14%	0.39
46	59.66	54.03	18	17400.44	5.40	25.11	24.99	54.32	14.43	12.75	13%	0.37
47	52.41	51.33	21	11908.55	4.43	24.8	24.39	52.63	14.6	12.92	13%	0.41
48	55.25	54.5	28	16532.38	5.49	28.21	25.2	55.42	16.87	14.9	13%	0.38
49	50.36	50.85	5	18333.92	7.16	26.19	25.67	49.77	13.76	12.11	14%	0.36
50	52.99	49.58	18	16125.04	6.14	25.7	25.83	52.74	17.39	15.46	12%	0.44
51	50.25	57.54	22	13171.12	4.56	26	26.05	49.27	13.15	11.64	13%	0.35
Average	52.93	52.85	13.35	15106.08	5.44	25.22	25.25	40.91	11.71	10.38	13%	0.41
Standard	1.91	1.84	5.08	4082.21	1.57	0.56	0.41	13.89	3.89	3.42	1%	0.08

min	50.25	49.49	5.00	6961.42	2.54	24.66	23.80	21.35	6.44	5.73	9%	0.33
max	59.66	57.54	28.00	23356.28	8.50	28.21	26.06	56.43	17.43	15.46	15%	0.94
cov	4%	3%	38%	27%	29%	2%	2%	34%	33%	33%	8%	20%

Appendix 8: Compression ⊥ Prineville

Specimen Label	width mm	Thickness mm	GR #	Load at 1 mm (N)	Comp. Strength (MPa)	Width mm	Thickness mm	Length mm	Wet mass g	Dry Mass g	MC %	G
1	50.02	49.84	14	19222.55	7.71	24.53	25.4	49.09	14.48	12.47	16%	0.41
2	48.57	50.28	6	19251.80	7.88	25.57	25.36	49.46	15.49	13.16	18%	0.41
3	57.05	48.89	10	15973.55	5.73	25.57	25.32	50.61	13.1	11.68	12%	0.36
4	49.85	49.76	19	12117.63	4.89	25.13	24.9	50.17	15.24	13.23	15%	0.42
5	50.69	50.83	14	26945.97	10.46	25.08	25.84	50.9	15.29	13.38	14%	0.41
6	50.96	50.27	15	21528.94	8.40	25.26	25.51	49.86	14.81	12.93	15%	0.40
7	52.46	52.59	19	25073.33	9.09	25.26	25.27	51.57	15.66	13.8	13%	0.42
8	49.82	49.16	8	14604.12	5.96	25.13	26.11	49.29	16.61	13.24	25%	0.41
9	49.62	49.47	21	21002.68	8.56	25.36	25.51	49.91	15.21	13.15	16%	0.41
10	50.18	50.22	11	24149.25	9.58	25.23	25.55	49.69	14.8	13.06	13%	0.41
11	50.3	50.96	13	25990.43	10.14	24.77	25.84	51.07	16.72	14.54	15%	0.44
12	50.54	50.78	11	28284.43	11.02	25.47	25.22	50.49	16.83	14.9	13%	0.46
13	49.04	50.2	18	21591.46	8.77	25.47	24.95	49.4	15.03	12.8	17%	0.41
14	49.85	48.86	30	20540.55	8.43	24.81	24.73	48.78	15.13	12.71	19%	0.42

15	50.02	49.76	17	26612.31	10.69	24.33	25.52	49.64	14.9	12.99	15%	0.42
16	51.13	51.22	14	19390.27	7.40	24.88	25.27	51.1	14.19	12.23	16%	0.38
17	50.54	50.66	16	18928.55	7.39	25.58	25.02	50.07	15.09	13.21	14%	0.41
18	51.1	50.61	10	21715.18	8.40	25.12	25.08	49.98	16.51	14.38	15%	0.46
19	50.17	50.31	24	19828.64	7.86	25.05	25.22	49.79	15.48	13.43	15%	0.43
20	50.83	50.4	21	27525.35	10.74	24.99	25.62	50.48	15.87	14.14	12%	0.44
21	49.63	48.95	28	18998.37	7.82	25.31	25.51	47.89	16.36	14.22	15%	0.46
22	50.55	50.25	15	21143.87	8.32	25.68	25.52	50.92	15.76	13.83	14%	0.41
23	51.33	51.45	11	18613.86	7.05	25.46	25.4	51.04	15.87	13.85	15%	0.42
24	50.69	50.83	15	27852.21	10.81	26.13	25.48	50.84	16.43	14.81	11%	0.44
25	48.96	49.97	9	13308.27	5.44	24.52	25.47	49.09	12.6	10.77	17%	0.35
26	49.93	49.85	12	11549.81	4.64	25.1	25.2	49.37	15.55	13.56	15%	0.43
27	50.61	50.17	15	23678.71	9.33	25.47	25.45	50.2	16.61	14.32	16%	0.44
28	48.19	50.09	8	12262.47	5.08	25.81	25.77	48.37	15.2	13.25	15%	0.41
29	49.08	51.44	20	33448.25	13.25	25.87	25.9	49.32	19.48	17.17	13%	0.52
30	51.57	52.59	12	22845.28	8.42	26.17	25.97	51.8	18.06	15.69	15%	0.45
31	49.92	50.09	13	20695.80	8.28	25.8	25.57	49.79	19.02	16.62	14%	0.51
32	50.42	49.84	10	15005.06	5.97	25.25	25.29	49.35	13.97	12.15	15%	0.39
33	51.15	51.98	17	21880.07	8.23	26.04	25.75	51.15	15.29	13.46	14%	0.39
34	49.89	50.68	19	27978.06	11.07	25.75	26.12	49.69	18.25	16.02	14%	0.48
35	51.5	51.22	20	17640.44	6.69	25.96	25.88	51.52	16.11	14.18	14%	0.41
36	50.58	50.58	8	25525.48	9.98	25.74	25.71	50.51	17.58	15.21	16%	0.46
37	49.85	49.42	18	18928.62	7.68	25.67	25.16	50.53	17.52	15.34	14%	0.47
38	52.21	51.57	12	13403.52	4.98	25.82	25.08	52.64	15.34	13.39	15%	0.39
39	49.28	50.41	12	19229.85	7.74	26.01	25.39	50.63	16.52	14.44	14%	0.43

40	51.32	50.17	15	10193.64	3.96	25.85	26.2	51.53	16.11	14.04	15%	0.40
41	49.06	49.11	14	22641.06	9.40	25.91	25.55	49.05	15.53	13.59	14%	0.42
42	49.85	50.46	19	28897.15	11.49	25.96	25.99	49.99	17.65	15.56	13%	0.46
43	49.82	49.56	9	24162.60	9.79	26.28	25.9	50.3	17.63	15.58	13%	0.46
44	50.83	50.46	6	22093.08	8.61	26.07	26	50.52	17.85	15.69	14%	0.46
45	49.98	41.16	10	16215.58	7.88	25.93	25.56	51.03	17.03	14.78	15%	0.44
46	52.32	52.33	21	18118.47	6.62	25.94	25.83	52.38	18.53	16.18	15%	0.46
47	50.31	50.27	47	17635.04	6.97	26.06	25.66	50.76	16.43	14.49	13%	0.43
48	51.59	50.81	14	18185.47	6.94	26.12	25.76	51.73	14.8	12.9	15%	0.37
49	51.39	51.31	16	12129.89	4.60	26.11	25.96	51.56	16.18	14.06	15%	0.40
50	49.9	49.37	13	12486.65	5.07	25.81	26.04	49.97	17.55	15.36	14%	0.46
51	49.98	50.61	12	27589.50	10.91	25.49	25.6	50.37	19.48	16.96	15%	0.52
52	49.81	49.44	4	20128.29	8.17	25.66	25.72	50.3	15.01	13.26	13%	0.40
53	49.01	50.15	16	16096.62	6.55	26.33	26.14	48.81	15.15	13.48	12%	0.40
Average	50.44	50.22	15.11	20393.17	8.05	25.54	25.56	50.27	16.09	14.03	0.15	0.43
Standard	1.31	1.54	6.88	5276.14	2.06	0.48	0.35	0.99	1.47	1.33	0.02	0.04
min	48.19	41.16	4.00	10193.64	3.96	24.33	24.73	47.89	12.60	10.77	0.11	0.35
max	57.05	52.59	47.00	33448.25	13.25	26.33	26.20	52.64	19.48	17.17	0.25	0.52
cov	3%	3%	46%	26%	26%	2%	1%	2%	9%	9%	14%	8%

Appendix 9: Compression ⊥ Klamath

Specimen Label	width mm	Thickness mm	GR #	Load at 1 mm (N)	Comp. Strength (MPa)	Width mm	Thickness mm	Length mm	Wet mass g	Dry Mass g	MC %	G

1	51.44	52.26	12	14240.02	5.30	25.09	25.14	50.95	15.4	13.61	13%	0.42
2	51.98	52.16	8	13927.16	5.14	25.23	25.02	51.68	14.41	12.61	14%	0.39
3	52.38	52.19	17	15914.18	5.82	25.21	25.21	51.93	15.69	13.73	14%	0.42
4	52.12	50.51	7	13907.25	5.28	25.29	25.18	52.07	13.97	12.2	15%	0.37
5	51.61	52.22	8	17160.81	6.37	25.61	25.5	49.51	14.54	12.97	12%	0.40
6	51.94	51.19	17	21241.47	7.99	24.84	25.25	51.84	15.81	13.95	13%	0.43
7	51.71	51.43	20	25028.18	9.41	25.29	25.4	51.74	17.67	15.43	15%	0.46
8	50.87	50.96	14	14744.36	5.69	25.09	25.31	50.97	15.91	13.76	16%	0.43
9	50.85	51.05	15	19855.69	7.65	25.58	25.25	51.1	16.49	14.5	14%	0.44
10	53.12	53.74	8	18441.87	6.46	25.11	25.29	52.98	15.39	13.46	14%	0.40
11	51.88	49.56	14	9342.07	3.63	25.16	24.82	52.48	15.75	13.97	13%	0.43
12	52.25	52.68	34	16112.22	5.85	25.43	24.9	52.73	15.88	13.94	14%	0.42
13	51.97	51.01	7	17893.89	6.75	25.15	25.08	52.17	17.63	15.38	15%	0.47
14	52.50	53.11	19	15687.83	5.63	24.98	24.89	52.9	14.36	12.59	14%	0.38
15	51.59	51.72	21	21674.97	8.12	24.96	25.04	52.11	15.51	13.65	14%	0.42
16	52.05	52.03	18	19524.70	7.21	26.44	25.77	51.17	14.52	12.96	12%	0.37
17	52.46	52.58	8	18965.90	6.88	24.92	24.94	52.83	14.19	12.56	13%	0.38
18	51.87	51.94	17	14368.91	5.33	25.22	25.02	52.07	15.51	13.54	15%	0.41
19	52.18	52.11	13	17356.50	6.38	24.92	25.21	52.28	14.53	12.7	14%	0.39
20	51.31	50.15	10	21685.26	8.43	24.81	25.32	52.01	16.92	14.94	13%	0.46
21	51.57	51.76	15	22035.59	8.26	25.02	25.34	52.78	15.7	13.74	14%	0.41
22	51.63	52.8	12	18656.56	6.84	24.64	24.9	51.82	16.6	14.61	14%	0.46
23	51.25	51.36	25	20450.36	7.77	24.78	25.26	51.75	16.13	14.2	14%	0.44
24	51.44	52.36	12	16943.72	6.29	25.07	25.9	51.96	15.28	13.28	15%	0.39
25	51.27	51.87	15	14075.86	5.29	24.72	24.87	51.93	14.12	12.28	15%	0.38

26	52.10	52.12	13	14350.66	5.28	24.93	24.83	52.09	14.53	12.7	14%	0.39
27	50.36	51.62	7	12843.65	4.94	25.6	24.35	51.44	15.79	13.71	15%	0.43
28	50.86	50.77	14	17420.49	6.75	24.52	25.21	50.88	16.22	14.16	15%	0.45
29	50.74	51.52	16	19661.38	7.52	25.04	24.84	51.31	15.09	13.2	14%	0.41
30	53.27	52.73	13	8210.26	2.92	26.44	24.85	53.19	17.01	14.78	15%	0.42
31	51.4	51.11	22	19466.28	7.41	24.97	25	51.25	16.28	14.6	12%	0.46
32	51.05	49.32	10	14386.55	5.71	25.62	25.33	50.33	17.18	15.43	11%	0.47
33	50.08	51.77	16	17996.72	6.94	25.5	25.59	51.02	15.95	14.23	12%	0.43
34	50.10	48.68	7	14189.78	5.82	25.2	25.17	49.54	14.03	12.45	13%	0.40
35	49.40	50.38	6	10075.70	4.05	25.53	25.55	48.86	15.21	13.52	13%	0.42
36	51.72	51.71	11	15365.12	5.75	25.31	25.37	51.14	15.64	13.96	12%	0.43
37	51.30	50.75	8	14880.93	5.72	24.96	25.13	50.76	16.58	14.54	14%	0.46
38	51.20	49.42	7	14726.34	5.82	25.52	25.6	48.89	15.27	13.73	11%	0.43
39	51.34	50	14	12470.84	4.86	24.9	25.05	50.42	13.61	12.11	12%	0.39
40	50.59	50.51	14	12158.82	4.76	25.01	25.15	50.43	14.11	12.53	13%	0.40
41	50.01	51.37	9	6035.69	2.35	25.71	25.49	50.97	13.99	12.96	8%	0.39
42	50.63	50.49	9	11555.26	4.52	25.23	25.13	49.98	13.76	12.33	12%	0.39
43	54.15	52.8	12	14330.72	5.01	25.23	25.68	52.19	13.87	12.49	11%	0.37
44	50.94	50.52	16	13180.84	5.12	25.21	25.21	51.01	14.47	12.74	14%	0.39
45	50.64	51.43	8	13654.39	5.24	25.1	25.34	50.59	15.39	13.68	13%	0.43
46	51.10	52.09	10	9319.77	3.50	24.51	25.2	51.03	13.26	11.78	13%	0.37
47	50.19	50.63	12	15404.13	6.06	25.57	25.7	50.33	16.6	15.03	10%	0.45
48	52.04	50.84	14	12737.44	4.81	26.64	25.41	51.83	15.53	13.86	12%	0.40
49	50.45	49.88	12	11190.58	4.45	25.28	25.53	49.94	13.7	12.15	13%	0.38
50	50.38	50.5	11	16180.39	6.36	24.95	25.06	51.52	15.91	13.85	15%	0.43

51	50.11	50.76	9	21682.39	8.52	25.18	24.89	50.65	16.24	14.45	12%	0.46
52	50.73	50.43	14	9575.03	3.74	25.15	25.11	50.49	14.74	13.05	13%	0.41
53	51.57	50.93	9	12282.51	4.68	25.27	25.09	51.32	15.98	14.04	14%	0.43
54	51.45	51.4	22	16081.72	6.08	24.89	25.33	51.14	14.23	12.64	13%	0.39
55	52.67	52.56	10	17508.09	6.32	25.36	25.44	25.89	15.84	14.25	11%	0.85
Average	51.41	51.34	13.11	15602.87	5.91	25.22	25.21	50.88	15.34	13.55	0.13	0.42
Standard	0.90	1.04	5.28	3901.54	1.45	0.42	0.28	3.57	1.08	0.93	0.01	0.07
min	49.40	48.68	6.00	6035.69	2.35	24.51	24.35	25.89	13.26	11.78	0.08	0.37
max	54.15	53.74	34.00	25028.18	9.41	26.64	25.90	53.19	17.67	15.43	0.16	0.85
cov	2%	2%	40%	25%	25%	2%	1%	7%	7%	7%	11%	15%

Appendix 10: Compression ⊥ Idaho

Specimen Label	Width (mm)	Thickness (mm)	GR #	Load at 1 mm (N)	Comp. Strength (MPa)	Width mm	Thickness mm	Length mm	Wet mass g	Dry Mass g	MC %	G
1	56.42	54.11	17	21016.86	6.88	25.41	24.45	56.25	16.32	14.30	14%	0.41
2	55.89	54.91	14	14114.05	4.60	24.61	25.38	56.06	15.88	13.89	14%	0.40
3	55.99	55.31	11	15573.63	5.03	25.42	24.70	56.92	13.29	11.65	14%	0.33
4	50.38	48.07	13	6944.03	2.87	25.11	22.37	51.87	15.79	13.70	15%	0.47
5	55.89	59.08	8	16471.73	4.99	25.29	24.72	56.48	15.15	13.30	14%	0.38
6	57.28	55.88	10	12112.71	3.78	24.00	25.38	54.73	15.24	13.56	12%	0.41
7	57.11	58.24	5	6886.33	2.07	24.33	25.15	56.87	21.15	18.39	15%	0.53

8	52.17	56.23	9	15735.16	5.36	24.19	26.90	56.46	14.76	12.92	14%	0.35
9	55.28	59.39	14	16277.92	4.96	24.73	25.08	55.07	13.35	11.71	14%	0.34
10	53.19	55.61	25	15261.97	5.16	25.63	25.66	53.56	17.22	15.06	14%	0.43
11	56.55	54.96	15	13639.27	4.39	23.77	24.93	54.20	13.15	11.48	15%	0.36
12	57.77	55.56	8	14753.31	4.60	25.23	24.86	55.42	13.40	11.74	14%	0.34
13	55.69	55.85	19	23047.44	7.41	25.40	25.18	54.93	16.32	14.30	14%	0.41
14	55.98	56.12	9	14667.62	4.67	25.21	25.52	56.16	14.02	12.25	14%	0.34
15	56.77	57.4	17	14248.82	4.37	24.16	28.60	55.99	14.55	12.80	14%	0.33
16	56.8	53.7	32	22909.88	7.51	25.63	25.25	53.68	17.46	15.33	14%	0.44
17	56.04	54.41	15	16336.18	5.36	25.15	25.39	54.55	15.22	13.27	15%	0.38
18	60.49	56.83	24	19529.36	5.68	24.19	23.53	60.58	22.62	19.71	15%	0.57
19	54.88	55.35	13	8137.41	2.68	25.23	25.35	55.10	15.09	13.22	14%	0.38
20	54.64	55.66	9	14110.82	4.64	25.59	24.97	56.54	21.86	19.04	15%	0.53
21	55.37	55.99	17	12856.78	4.15	24.97	25.43	55.07	16.43	14.41	14%	0.41
22	54.05	54.26	12	15821.35	5.39	24.59	25.30	53.22	15.83	13.95	13%	0.42
23	50.53	52.08	9	14781.89	5.62	25.33	25.17	50.47	14.08	12.26	15%	0.38
24	52.86	52.79	13	9334.80	3.35	25.33	25.42	52.91	14.89	12.98	15%	0.38
25	52.28	51.77	10	9724.58	3.59	25.53	25.37	51.58	14.09	12.25	15%	0.37
26	51.03	51.98	6	9294.72	3.50	24.80	24.01	51.09	12.52	10.96	14%	0.36
27	50.48	49.88	7	7943.35	3.15	25.50	25.23	50.18	14.71	12.68	16%	0.39
28	49.81	49.85	8	12442.98	5.01	25.53	25.37	50.23	16.12	13.84	16%	0.43
29	49.33	50.19	5	9523.14	3.85	25.48	25.57	50.28	14.97	13.07	15%	0.40
30	50.39	50.13	14	14586.62	5.77	25.31	25.52	49.79	15.10	13.02	16%	0.40
31	50.5	50.42	10	8788.73	3.45	25.40	25.35	50.32	14.37	12.48	15%	0.39
Average	54.25	54.26	12.84	13770.11	4.64	25.03	25.20	54.08	15.64	13.66	0.14	0.40

Standard	2.88	2.89	6.07	4308.41	1.29	0.54	0.98	2.65	2.39	2.07	0.01	0.06
min	49.33	48.07	5.00	6886.33	2.07	23.77	22.37	49.79	12.52	10.96	0.12	0.33
max	60.49	59.39	32.00	23047.44	7.51	25.63	28.60	60.58	22.62	19.71	0.16	0.57
cov	5%	5%	47%	31%	28%	2%	4%	5%	15%	15%	5%	14%

A.3 Shear Data Tables

Appendix 11: Shear Block Burns

Specimen	Width (mm)	Length (mm)	GR (#)	Max load (N)	Width mm	Thickness mm	Length mm	Wet mass g	Dry Mass g	MC %	G
1	50.88	47.76	21	12491.60	24.83	24.77	50.72	16.92	14.82	14%	0.48
2	48.46	47.25	12	14633.31	25.39	24.98	51.90	15.92	13.64	17%	0.41
3	50.62	50.30	15	13195.43	24.81	24.65	49.31	12.44	10.79	15%	0.36
4	51.69	52.18	14	17753.37	24.57	24.37	49.06	12.59	11.01	14%	0.37
5	50.33	47.62	18	14644.44	24.81	24.92	50.07	12.28	10.72	15%	0.35
6	50.95	49.83	13	13876.18	24.94	24.73	50.55	15.73	13.62	15%	0.44
7	49.93	49.92	28	10479.33	25.07	25.68	48.40	15.40	13.52	14%	0.43
8	52.17	48.71	12	19812.83	24.41	24.97	50.75	15.54	13.67	14%	0.44
9	48.61	47.15	13	16052.03	24.55	24.59	49.76	11.97	10.46	14%	0.35
10	52.71	47.87	13	13811.78	24.73	24.80	50.65	14.78	12.94	14%	0.42
11	50.49	47.47	16	14816.19	24.45	24.65	50.24	14.54	12.71	14%	0.42
12	49.50	48.97	14	9724.32	24.82	25.04	48.39	13.01	11.30	15%	0.38
13	50.65	53.16	11	15951.30	24.85	25.04	49.32	15.58	13.47	16%	0.44
14	51.57	48.67	18	13059.37	24.48	24.55	49.79	15.07	13.13	15%	0.44
15	49.47	48.84	13	13241.75	25.12	24.93	49.21	13.32	11.69	14%	0.38
16	49.50	50.72	10	13072.10	24.98	24.37	50.28	13.61	11.83	15%	0.39
17	50.76	51.18	15	12827.91	24.97	24.95	51.68	13.43	11.88	13%	0.37

18	49.24	48.17	16	12370.27	24.95	24.37	49.04	11.58	10.10	15%	0.34
19	49.32	47.88	13	14342.33	24.46	24.91	48.32	13.19	11.55	14%	0.39
20	49.89	48.61	6	10893.86	24.57	24.81	49.48	13.65	11.96	14%	0.40
21	52.21	50.38	9	14985.82	24.88	24.58	51.33	13.39	11.69	15%	0.37
22	49.58	47.87	10	15565.69	24.69	24.89	49.31	13.78	11.79	17%	0.39
23	48.77	46.98	11	14487.44	24.78	24.53	47.48	11.49	9.98	15%	0.35
24	50.57	48.79	15	11715.25	24.62	24.68	49.79	12.98	11.34	14%	0.37
25	50.90	53.64	14	11322.11	25.40	24.98	50.98	13.90	12.27	13%	0.38
26	48.98	51.68	14	18380.41	25.20	24.85	48.90	12.99	11.45	13%	0.37
27	50.69	49.41	17	15141.68	24.78	24.41	49.22	15.27	13.37	14%	0.45
28	51.59	50.75	12	18492.53	24.93	24.96	52.03	14.52	12.75	14%	0.39
29	50.47	50.12	8	14751.32	24.86	24.91	49.31	13.25	11.59	14%	0.38
30	51.06	52.27	7	19679.73	24.70	25.00	50.39	13.42	11.68	15%	0.38
31	50.40	49.22	17	17524.05	25.12	24.97	48.23	13.08	11.45	14%	0.38
32	49.88	49.19	15	16553.25	24.93	25.01	49.22	12.81	11.35	13%	0.37
33	51.33	50.86	14	19893.94	24.88	24.83	51.33	13.48	11.85	14%	0.37
34	49.54	54.13	10	18258.08	25.28	25.11	48.89	14.68	12.76	15%	0.41
35	49.59	50.73	17	13342.14	25.22	24.74	49.46	13.12	11.56	13%	0.37
36	49.51	48.03	12	16595.65	25.05	24.76	48.81	12.60	11.05	14%	0.37
37	51.75	46.01	13	19010.32	24.76	24.93	50.95	13.27	11.52	15%	0.37
38	49.85	50.41	21	14608.65	24.81	25.13	50.01	14.25	12.63	13%	0.41
39	49.67	48.27	11	13563.54	24.84	24.92	48.53	12.05	10.51	15%	0.35
40	50.17	50.58	15	12919.53	24.83	24.47	49.77	13.23	11.54	15%	0.38
41	53.01	49.88	13	19400.71	25.01	24.93	48.60	13.03	11.43	14%	0.38
42	52.12	48.80	11	14225.00	25.06	24.85	51.26	13.42	11.63	15%	0.36

43	49.73	49.15	12	18287.48	24.75	24.21	50.06	13.04	11.42	14%	0.38
44	49.09	49.66	15	14574.50	25.26	25.05	49.45	11.67	10.22	14%	0.33
45	48.51	48.63	18	16643.43	25.59	24.86	47.14	13.12	11.37	15%	0.38
46	49.48	48.77	12	10901.96	25.03	25.09	49.67	14.88	13.20	13%	0.42
47	50.41	51.24	15	13867.56	24.87	24.92	51.09	12.67	11.03	15%	0.35
48	50.80	48.59	6	11188.84	24.84	24.98	50.79	15.72	13.53	16%	0.43
49	50.23	51.69	17	13294.93	24.52	24.19	49.87	12.81	11.20	14%	0.38
50	50.03	51.66	13	13110.58	24.55	24.59	48.92	12.00	10.46	15%	0.35
51	50.06	51.72	6	19374.76	25.00	24.58	49.68	13.37	11.76	14%	0.39
52	49.38	52.54	7	16714.06	24.77	24.69	49.61	13.40	11.66	15%	0.38
53	47.73	51.58	14	14493.06	24.83	25.19	49.42	13.28	11.85	12%	0.38
Average	50.26	49.73	13.43	14904.11	24.88	24.81	49.74	13.59	11.88	0.14	0.39
Standard	1.12	1.82	4.03	2665.31	0.26	0.27	1.07	1.23	1.06	0.01	0.03
min	47.73	46.01	6.00	9724.32	24.41	24.19	47.14	11.49	9.98	0.12	0.33
max	53.01	54.13	28.00	19893.94	25.59	25.68	52.03	16.92	14.82	0.17	0.48
cov	2%	4%	30%	18%	1%	1%	2%	9%	9%	6%	8%

Appendix 12: Shear Block California

Specimen	Width (mm)	Length (mm)	GR (#)	Max load (N)	Width mm	Thickness mm	Length mm	Wet mass g	Dry Mass g	MC %	G
1	49.36	50.16	15	22266.41	24.93	25.21	49.57	14.43	12.84	12%	0.41
2	53.20	50.27	14	19281.35	25.03	25.19	53.23	15.05	13.46	12%	0.40
3	51.54	50.21	16	22237.72	25.06	25.04	51.45	12.42	11.08	12%	0.34

4	52.70	50.07	16	14167.61	25.35	25.01	53.26	13.35	11.90	12%	0.35
5	51.50	49.94	9	20569.16	25.09	25.16	51.40	14.90	13.36	12%	0.41
6	52.12	50.32	8	24188.67	25.21	25.14	52.05	15.14	13.46	12%	0.41
7	49.99	50.15	7	18547.55	25.14	25.07	49.94	14.52	13.00	12%	0.41
8	50.87	51.73	15	19959.30	25.00	24.97	50.89	14.81	13.09	13%	0.41
9	51.72	50.09	12	20232.17	25.19	25.18	51.45	13.74	12.34	11%	0.38
10	55.85	50.70	12	22642.56	25.32	25.22	55.86	14.22	12.68	12%	0.36
11	55.24	50.05	9	18456.75	25.01	25.17	55.49	13.09	11.67	12%	0.33
12	49.23	50.06	14	15965.93	25.15	25.22	49.40	14.33	12.81	12%	0.41
13	51.55	50.00	16	20665.73	25.07	25.19	51.73	13.86	12.40	12%	0.38
14	49.49	50.06	8	17698.74	25.20	25.15	48.59	12.98	11.62	12%	0.38
15	53.21	50.44	16	15257.04	25.20	25.11	52.93	15.40	13.75	12%	0.41
16	55.29	49.72	16	24256.37	25.31	24.92	55.18	16.92	15.12	12%	0.43
17	51.80	50.39	10	21995.03	25.04	25.17	52.00	16.71	14.87	12%	0.45
18	53.12	50.27	11	24124.22	24.94	25.15	53.18	16.62	14.86	12%	0.45
19	53.28	49.51	7	16973.62	25.08	25.00	52.72	13.50	12.07	12%	0.37
20	52.77	50.45	26	23533.70	25.17	25.25	52.81	15.01	13.35	12%	0.40
21	53.37	50.37	9	20237.34	25.22	25.14	53.40	13.47	12.00	12%	0.35
22	52.00	50.23	10	21517.91	25.00	25.07	51.67	12.41	11.02	13%	0.34
23	52.44	50.01	7	22126.06	25.05	25.11	52.19	14.86	13.25	12%	0.40
24	51.31	50.42	11	21385.88	25.08	25.11	51.45	13.37	11.96	12%	0.37
25	52.71	50.87	15	19147.96	25.05	25.05	53.03	16.32	14.56	12%	0.44
26	52.65	50.35	10	22371.53	25.03	25.17	52.51	15.34	13.71	12%	0.41
27	53.24	50.54	15	17374.19	25.10	25.12	53.30	13.97	12.45	12%	0.37
28	51.03	51.81	10	22460.30	25.18	24.95	50.49	15.57	13.84	13%	0.44

29	54.73	48.90	7	25920.92	25.22	25.04	54.90	14.89	13.26	12%	0.38
30	51.75	48.50	9	17104.29	25.02	25.25	51.84	12.74	11.34	12%	0.35
31	51.51	48.84	6	21871.94	25.32	25.32	51.76	14.70	12.94	14%	0.39
32	54.22	49.68	7	18560.55	25.36	25.14	53.76	14.05	12.45	13%	0.36
33	55.65	48.44	10	24497.30	25.21	25.02	56.18	16.19	14.36	13%	0.41
34	51.94	48.55	7	19662.32	25.04	25.15	51.91	12.26	10.89	13%	0.33
35	50.44	48.58	8	21762.57	24.82	25.31	51.57	15.59	13.65	14%	0.42
36	53.49	48.44	9	20986.92	25.17	25.15	53.36	13.17	11.72	12%	0.35
37	52.12	48.22	11	19236.32	25.15	25.25	52.32	13.87	12.25	13%	0.37
38	51.61	49.09	8	21982.83	25.35	25.39	51.72	13.08	11.67	12%	0.35
39	52.20	48.52	20	20608.37	25.27	25.14	52.28	16.48	14.66	12%	0.44
40	53.63	48.17	10	17648.29	25.15	24.97	53.81	13.46	11.87	13%	0.35
41	51.99	48.51	7	14393.97	25.34	24.82	52.10	13.68	12.05	14%	0.37
42	50.48	49.27	17	19571.12	25.22	25.21	50.55	13.42	11.97	12%	0.37
43	49.74	48.39	13	16695.63	25.29	25.36	49.87	13.82	12.16	14%	0.38
44	54.85	48.68	11	24231.51	25.27	25.25	54.84	14.68	13.00	13%	0.37
45	57.01	49.81	18	16843.98	25.19	25.23	57.12	15.09	13.60	11%	0.37
46	51.61	48.62	8	24791.50	25.96	25.83	51.67	16.03	14.30	12%	0.41
47	52.01	48.30	11	20612.67	25.25	25.27	52.33	15.43	13.68	13%	0.41
48	51.28	48.70	14	16556.28	24.98	25.14	51.21	12.73	11.40	12%	0.35
49	55.58	48.42	15	14950.53	25.31	24.98	55.48	13.87	12.30	13%	0.35
50	51.40	48.54	14	16463.68	25.31	25.08	51.41	14.17	12.49	13%	0.38
51	56.43	48.51	11	16783.36	25.26	25.07	56.34	15.78	13.93	13%	0.39
Average	52.51	49.59	11.67	20027.01	25.17	25.15	52.54	14.42	12.83	0.12	0.39
Standard	1.84	0.95	4.06	2983.93	0.17	0.15	1.87	1.22	1.09	0.01	0.03

min	49.23	48.17	6.00	14167.61	24.82	24.82	48.59	12.26	10.89	0.11	0.33
max	57.01	51.81	26.00	25920.92	25.96	25.83	57.12	16.92	15.12	0.14	0.45
cov	4%	2%	35%	15%	1%	1%	4%	8%	8%	5%	8%

Appendix 13: Shear Block Prineville

Specimen	Width (mm)	Length (mm)	GR (#)	Max load (N)	Width mm	Thickness mm	Length mm	Wet mass g	Dry Mass g	MC %	G
1	50.15	49.29	15	17582.85	26.09	26.06	49.41	16.58	14.39	15%	0.43
2	51.06	49.64	10	21884.14	24.59	25.05	51.22	17.11	14.86	15%	0.47
3	52.50	49.11	14	16346.43	25.21	25.27	52.51	16.38	14.27	15%	0.43
4	50.18	49.54	10	16448.31	25.18	25.41	49.88	14.14	12.31	15%	0.39
5	52.47	49.55	10	22901.52	25.29	25.16	52.26	15.47	13.48	15%	0.41
6	49.50	48.76	9	19590.49	24.87	25.38	49.26	15.33	13.32	15%	0.43
7	52.65	49.59	10	21177.26	25.20	25.16	52.82	17.48	15.33	14%	0.46
8	50.73	49.05	9	24517.85	25.29	25.05	50.32	16.01	13.86	16%	0.43
9	50.45	49.53	15	18316.26	25.67	25.99	50.09	15.10	13.11	15%	0.39
10	50.37	49.52	13	20603.13	25.19	25.18	50.14	14.79	12.79	16%	0.40
11	52.83	49.05	16	17226.72	25.23	25.35	52.63	15.50	13.54	14%	0.40
12	50.36	49.21	14	20717.20	25.18	25.03	49.95	14.30	12.47	15%	0.40
13	50.87	49.28	14	22375.28	25.16	25.33	51.00	13.93	12.34	13%	0.38
14	57.18	49.86	14	20774.56	25.34	25.15	51.10	15.21	13.41	13%	0.41

15	50.00	48.90	13	17536.84	26.02	25.67	50.11	15.98	13.80	16%	0.41
16	50.46	48.90	13	19922.33	25.24	25.31	50.17	15.36	13.36	15%	0.42
17	49.20	49.48	17	13043.92	25.31	25.50	49.37	14.96	12.98	15%	0.41
18	51.18	49.28	10	21569.19	24.68	25.01	51.78	16.03	13.96	15%	0.44
19	51.74	45.62	19	23632.63	25.30	24.99	51.02	16.17	14.10	15%	0.44
20	50.69	49.52	16	20929.65	25.21	25.28	49.48	16.63	14.36	16%	0.46
21	49.84	49.82	11	20103.37	25.29	25.00	49.89	16.66	14.39	16%	0.46
22	52.50	49.07	15	16584.33	26.08	26.05	52.63	16.27	14.23	14%	0.40
23	50.18	49.05	7	21521.99	26.18	25.97	50.47	16.16	14.26	13%	0.42
24	50.24	49.36	11	23102.59	25.76	26.04	50.20	15.75	13.81	14%	0.41
25	49.74	49.28	7	18631.21	25.22	25.20	49.46	13.38	11.95	12%	0.38
26	49.36	49.14	12	25289.14	25.38	25.13	49.32	15.36	13.55	13%	0.43
27	50.86	49.53	11	19221.79	25.30	25.38	50.23	15.66	13.63	15%	0.42
28	57.20	48.03	14	21952.35	25.94	25.76	51.47	17.55	15.26	15%	0.44
29	49.55	49.25	11	20508.38	24.80	25.13	49.94	16.03	13.92	15%	0.45
30	50.01	49.52	13	20943.29	25.31	25.40	50.52	15.26	13.43	14%	0.41
31	50.55	49.33	15	21072.34	25.41	25.18	50.08	15.08	13.14	15%	0.41
32	50.22	49.90	8	16726.86	25.10	25.82	50.67	13.38	11.66	15%	0.36
33	50.76	49.62	16	23522.80	25.92	25.82	50.58	16.76	14.42	16%	0.43
34	50.48	49.00	8	22378.86	25.24	25.26	50.18	15.70	13.69	15%	0.43
35	51.18	49.20	14	17087.19	25.08	25.12	51.37	16.49	14.40	15%	0.44
36	50.15	48.97	17	21182.09	25.15	25.19	50.11	18.08	15.68	15%	0.49
37	51.69	49.13	14	16781.63	25.12	24.98	51.80	13.81	12.02	15%	0.37
38	49.94	49.04	8	22135.76	24.95	25.12	48.20	13.83	12.11	14%	0.40
39	50.12	49.10	13	16285.54	25.25	25.00	49.52	13.25	11.72	13%	0.37

40	50.54	49.38	24	19219.20	25.08	25.25	50.26	13.58	12.06	13%	0.38
41	50.24	49.10	11	21135.62	25.12	25.29	49.99	14.96	13.19	13%	0.42
42	49.54	49.05	27	15555.27	25.23	25.17	49.03	14.16	12.25	16%	0.39
43	50.27	49.78	7	20265.77	25.20	25.09	50.14	17.05	14.98	14%	0.47
44	50.57	49.44	9	23220.60	25.23	24.77	50.59	16.78	14.80	13%	0.47
45	49.01	49.83	5	23772.88	26.07	26.13	49.21	13.98	12.41	13%	0.37
46	51.71	49.67	15	21063.20	25.30	24.94	51.77	14.89	12.94	15%	0.40
47	49.54	49.58	16	18838.65	25.98	25.95	49.56	15.68	13.69	15%	0.41
48	51.43	49.08	14	17345.68	25.09	25.23	51.72	15.05	13.06	15%	0.40
49	49.61	49.30	19	22489.59	25.81	24.95	49.86	18.37	16.04	15%	0.50
50	49.13	49.36	17	21117.88	26.01	26.61	48.75	19.56	17.02	15%	0.50
51	50.37	49.07	11	18608.18	25.29	24.85	49.72	15.82	13.76	15%	0.44
52	50.28	49.70	8	17142.16	25.23	25.17	50.01	12.84	11.24	14%	0.35
53	48.07	49.63	21	16144.94	26.16	26.65	47.06	16.59	14.34	16%	0.44
Average	50.74	49.25	13.02	19963.16	25.37	25.38	50.36	15.59	13.61	15%	0.42
Standard	1.61	0.61	4.29	2667.94	0.39	0.43	1.14	1.38	1.17	1%	0.03
min	48.07	45.62	5.00	13043.92	24.59	24.77	47.06	12.84	11.24	12%	0.35
max	57.20	49.90	27.00	25289.14	26.18	26.65	52.82	19.56	17.02	16%	0.50
cov	3%	1%	33%	13%	2%	2%	2%	9%	9%	6%	8%

Appendix 14: Shear Block Klamath

Specimen	Width (mm)	Length (mm)	GR (#)	Max load (N)	Width mm	Thickness mm	Length mm	Wet mass g	Dry Mass g	MC %	G

1	50.82	50.82	11	18456.92	25.12	25.03	51.57	14.74	12.95	14%	0.40
2	51.92	49.61	9	17600.06	25.29	25.36	51.29	13.54	11.99	13%	0.36
3	49.97	51.03	6	19145.59	25.27	25.10	49.98	12.78	11.42	12%	0.36
4	50.68	50.85	14	17718.34	25.26	25.21	51.71	16.05	14.15	13%	0.43
5	51.45	50.62	9	18646.64	25.16	25.07	51.06	15.41	13.55	14%	0.42
6	50.72	51.13	10	17464.16	25.89	25.13	50.43	12.97	11.48	13%	0.35
7	51.48	50.86	9	18849.70	25.27	25.21	50.97	14.85	13.10	13%	0.40
8	50.31	51.32	14	18867.80	25.08	25.25	50.26	13.58	12.06	13%	0.38
9	50.37	52.24	9	14054.39	24.99	25.03	51.50	12.88	11.52	12%	0.36
10	51.56	49.35	8	23327.54	25.01	25.25	49.72	13.34	11.89	12%	0.38
11	50.29	51.05	6	18806.49	25.13	25.20	50.32	15.32	13.61	13%	0.43
12	52.08	50.03	16	16629.66	25.06	25.30	51.22	15.94	13.94	14%	0.43
13	50.75	50.62	7	20652.90	25.26	24.70	50.55	15.42	13.68	13%	0.43
14	49.74	50.82	10	15147.02	25.02	25.06	49.55	13.14	11.63	13%	0.37
15	51.49	50.81	11	17209.82	25.07	25.31	51.88	13.98	12.21	14%	0.37
16	50.65	51.11	12	21136.48	24.82	25.00	50.74	16.31	14.45	13%	0.46
17	49.20	51.11	5	21583.19	24.72	25.13	51.35	12.95	11.41	13%	0.36
18	50.83	51.32	9	23590.67	25.12	25.12	51.70	14.05	12.34	14%	0.38
19	52.49	49.34	17	22441.18	25.09	25.00	52.12	14.93	13.09	14%	0.40
20	51.69	49.89	11	19427.65	25.07	25.29	51.43	14.53	12.79	14%	0.39
21	51.81	50.81	16	10976.22	25.25	25.09	51.83	13.38	11.85	13%	0.36
22	51.00	51.34	20	17021.74	24.85	25.04	50.87	13.84	12.27	13%	0.39
23	51.15	49.71	23	11014.90	25.17	25.12	50.33	15.11	13.46	12%	0.42
24	51.65	51.09	8	18170.22	25.00	24.94	51.40	13.14	11.67	13%	0.36
25	51.38	49.61	29	16857.44	25.38	25.09	51.85	15.10	13.33	13%	0.40

26	51.07	49.81	7	19274.91	25.08	25.24	51.71	15.52	13.64	14%	0.42
27	52.32	49.63	10	20302.16	25.23	25.26	51.58	15.90	13.84	15%	0.42
28	51.92	49.81	7	22488.20	25.25	25.06	51.79	14.70	12.89	14%	0.39
29	50.55	50.65	9	18318.88	25.32	25.04	50.44	12.66	11.24	13%	0.35
30	50.82	49.54	15	17890.05	24.97	24.83	51.05	15.67	13.65	15%	0.43
31	52.43	49.69	7	22931.44	25.12	25.29	52.34	15.12	13.27	14%	0.40
32	51.81	49.75	11	24858.36	25.01	25.15	51.76	14.78	13.05	13%	0.40
33	49.72	50.93	1	17709.77	25.00	25.18	49.62	13.74	12.16	13%	0.39
34	51.76	49.65	14	19315.50	25.20	25.29	50.91	14.79	12.92	14%	0.40
35	51.25	49.00	5	18679.27	25.29	25.03	51.34	13.95	12.35	13%	0.38
36	51.33	49.77	13	20834.04	24.90	25.01	51.97	14.97	13.06	15%	0.40
37	52.30	49.29	10	18401.13	25.44	25.04	52.16	14.89	13.09	14%	0.39
38	51.83	49.38	8	18208.25	25.21	24.98	51.19	15.95	14.04	14%	0.44
39	52.94	49.46	10	22312.17	25.05	25.06	52.73	15.06	13.27	13%	0.40
40	51.19	49.59	24	21165.00	24.78	24.87	51.06	15.12	13.28	14%	0.42
41	52.00	49.46	13	17663.39	25.17	25.17	51.80	15.28	13.45	14%	0.41
42	51.58	51.00	7	17904.39	25.11	24.92	50.87	15.45	13.57	14%	0.43
43	51.52	48.84	11	17105.20	25.39	25.22	51.55	14.62	12.88	14%	0.39
44	50.74	49.73	7	19054.11	25.09	25.14	51.86	15.27	13.39	14%	0.41
45	53.08	49.50	10	21151.88	25.22	25.17	53.01	14.01	12.22	15%	0.36
46	51.71	49.89	12	24522.00	25.23	25.07	50.96	16.63	14.71	13%	0.46
47	51.22	49.16	5	8751.60	24.93	25.29	50.98	15.28	13.42	14%	0.42
48	52.06	48.87	13	14591.63	25.09	25.10	51.90	13.82	12.27	13%	0.38
49	51.43	49.61	7	20505.21	25.24	25.25	50.26	12.91	11.45	13%	0.36
50	48.09	49.16	15	16738.34	25.16	25.15	51.51	13.34	11.82	13%	0.36

51	51.18	48.62	22	17169.60	25.12	24.97	51.01	15.31	13.43	14%	0.42
52	52.30	49.08	10	17293.33	25.05	25.00	51.98	15.70	13.76	14%	0.42
53	52.11	49.47	21	19580.25	25.26	24.78	52.24	15.91	14.10	13%	0.43
Average	51.28	50.09	11.38	18670.13	25.14	25.11	51.27	14.60	12.87	13%	0.40
Standard	0.92	0.84	5.40	3160.47	0.18	0.14	0.76	1.06	0.90	1%	0.03
min	48.09	48.62	1.00	8751.60	24.72	24.70	49.55	12.66	11.24	12%	0.35
max	53.08	52.24	29.00	24858.36	25.89	25.36	53.01	16.63	14.71	15%	0.46
cov	2%	2%	47%	17%	1%	1%	1%	7%	7%	6%	7%

Appendix 15: Shear Block Idaho

Specimen	Width (mm)	Length (mm)	GR (#)	Max load (N)	Width mm	Thickness mm	Length mm	Wet mass g	Dry Mass g	MC %	G
1	51.19	47.20	14	12801.48	24.99	25.28	50.70	14.52	12.83	13%	0.40
2	51.54	42.23	9	12863.54	24.87	25.20	51.56	14.66	12.93	13%	0.40
3	51.30	47.94	15	23431.38	25.18	25.01	51.24	15.39	13.71	12%	0.42
4	49.17	41.90	6	18178.10	24.85	25.07	49.06	13.96	12.49	12%	0.38
5	51.84	47.07	13	24697.60	24.46	25.08	52.25	15.03	13.26	13%	0.41
6	51.81	43.11	9	15081.10	25.12	25.12	51.02	15.96	14.07	13%	0.44
7	49.95	42.23	12	18752.69	24.86	25.13	49.67	14.19	12.50	14%	0.40
8	50.94	48.66	4	21043.12	25.16	25.35	50.94	13.71	12.18	13%	0.37
9	52.84	42.62	9	12587.85	24.54	25.02	52.49	12.16	10.79	13%	0.33

10	50.94	42.82	11	13629.14	25.04	25.17	50.71	15.01	13.24	13%	0.41
11	51.33	47.87	10	15265.88	25.17	24.97	51.43	16.29	14.34	14%	0.44
12	51.28	45.52	18	23597.90	24.83	25.09	51.12	15.29	13.53	13%	0.42
13	51.09	42.27	19	20488.38	24.51	25.18	51.25	14.47	12.86	13%	0.41
14	51.55	42.02	7	16914.61	25.07	24.87	50.63	14.29	12.62	13%	0.40
15	50.97	47.21	20	21335.11	24.86	24.55	50.97	15.13	13.46	12%	0.43
16	50.61	46.03	12	20566.29	25.14	24.93	50.45	12.27	10.82	13%	0.34
17	49.84	44.47	17	16830.28	25.02	24.82	49.80	12.09	10.70	13%	0.35
18	52.30	42.23	8	20582.82	25.10	25.04	52.35	15.43	13.62	13%	0.41
19	50.55	45.47	7	16996.75	25.14	25.10	50.31	16.81	14.80	14%	0.47
20	52.47	41.57	12	14249.00	24.91	24.17	52.45	14.12	12.50	13%	0.40
21	51.13	42.50	9	19807.77	25.04	25.13	51.18	14.82	13.08	13%	0.41
22	51.19	42.26	5	20503.78	25.07	25.05	51.78	13.95	12.36	13%	0.38
23	51.63	41.51	6	19168.52	25.16	25.21	51.51	13.47	11.92	13%	0.36
24	50.61	43.25	12	15063.63	25.25	25.04	50.65	15.30	13.51	13%	0.42
25	51.57	41.92	20	17738.04	24.97	24.89	51.37	14.37	12.69	13%	0.40
26	51.37	41.82	8	15602.41	24.95	25.09	50.00	13.32	11.75	13%	0.38
27	51.74	43.40	23	24495.70	24.82	25.00	51.92	14.69	12.91	14%	0.40
28	49.81	42.28	9	23053.76	25.05	24.90	48.80	14.63	13.02	12%	0.43
29	51.84	40.85	6	17385.42	24.88	25.07	52.29	15.57	13.68	14%	0.42
30	52.48	42.69	9	21319.71	24.97	25.06	51.81	14.28	12.67	13%	0.39
31	52.36	48.69	14	18030.05	25.01	25.16	52.21	15.36	13.68	12%	0.42
Average	51.27	43.92	11.39	18467.72	24.97	25.02	51.09	14.53	12.86	13%	0.40
Standard	0.83	2.32	4.98	3617.29	0.20	0.22	0.96	1.12	0.97	0%	0.03
min	49.17	40.85	4.00	12587.85	24.46	24.17	48.80	12.09	10.70	12%	0.33

max	52.84	48.66	23.00	24697.60	25.25	25.35	52.49	16.81	14.80	14%	0.47
cov	2%	5%	44%	20%	1%	1%	2%	8%	8%	4%	8%

A.4 Bending Data Tables

Appendix 16: Bending Burns

Specimen	Width mm	Thickness mm	GR #	Max Load N	MOE Mpa	MOR MPa	Width mm	Thickness mm	Length mm	Wet mass g	Dry Mass g	MC %	G
1	25.33	24.39	24.00	1386.89	2621.23	49.09	25.41	25.52	24.20	6.43	5.66	14%	0.36
2	25.49	25.50	33.00	1747.17	3841.45	56.23	25.46	25.48	25.78	7.16	6.35	13%	0.38
3	25.35	25.52	21.00	1768.97	2925.30	57.15	25.33	25.53	26.03	7.65	6.76	13%	0.40
4	26.01	25.68	28.00	2078.55	4555.61	64.64	26.14	25.65	25.69	7.48	6.60	13%	0.38
5	25.35	23.40	33.00	1525.22	3038.14	58.61	25.19	23.21	25.36	6.44	5.62	15%	0.38
6	24.59	23.86	15.00	1268.57	2366.20	48.34	24.41	24.03	24.56	6.18	5.63	10%	0.39
7	25.23	25.29	16.00	1946.44	5829.22	64.34	25.67	25.20	25.35	7.61	6.67	14%	0.41
8	27.53	25.46	22.00	1386.44	2926.17	41.44	25.51	25.06	25.72	6.04	5.30	14%	0.32
9	27.38	25.91	21.00	1983.36	2941.31	57.56	24.55	26.19	26.52	9.92	8.53	16%	0.50
10	25.24	25.31	25.00	1925.54	4424.12	63.52	25.62	25.72	25.12	7.39	6.51	14%	0.39
11	25.73	25.66	18.00	1782.31	3520.62	56.12	25.64	25.32	25.67	7.82	7.12	10%	0.43
12	25.16	25.54	19.00	1386.44	2854.77	45.06	25.62	25.59	25.50	6.23	5.49	13%	0.33
13	25.90	25.67	19.00	1805.44	4255.78	56.43	25.23	25.76	24.30	7.25	6.58	10%	0.42
14	22.83	24.96	29.00	1634.64	2547.69	61.30	24.64	23.64	25.28	7.87	7.11	11%	0.48
15	25.24	24.36	14.00	1313.49	2170.81	46.78	25.15	24.44	24.39	5.74	5.07	13%	0.34
16	26.38	27.67	16.00	2224.89	6074.39	58.76	25.52	27.49	25.45	8.96	7.88	14%	0.44
17	25.46	25.60	24.00	1780.98	3504.91	56.93	25.45	25.18	25.52	7.05	6.23	13%	0.38

18	23.99	23.75	14.00	1309.05	2959.95	51.60	23.94	25.37	23.48	5.77	5.18	11%	0.36
19	25.39	25.47	16.00	2030.96	3783.37	65.77	25.30	25.46	25.60	8.50	7.36	15%	0.45
20	27.29	27.11	17.00	2074.10	5132.77	55.16	25.33	27.33	25.49	8.52	7.49	14%	0.42
21	23.66	23.00	14.00	1179.16	2317.68	50.25	25.62	23.27	23.82	5.44	4.88	11%	0.34
22	25.80	25.59	15.00	1888.18	5508.99	59.61	25.56	25.45	25.60	8.56	7.60	13%	0.46
23	24.53	23.49	16.00	1409.13	2023.47	55.53	25.69	24.35	24.62	8.23	7.22	14%	0.47
24	25.58	25.57	22.00	1872.16	3589.26	59.71	25.55	25.59	25.02	7.00	6.24	12%	0.38
25	25.08	22.32	23.00	1561.69	2189.97	66.67	23.04	24.91	25.41	7.04	6.00	17%	0.41
26	25.96	26.23	13.00	1747.62	3818.03	52.19	25.44	25.22	25.21	6.71	5.97	12%	0.37
27	25.17	25.15	15.00	1964.24	4395.29	65.81	25.41	26.09	26.47	6.83	6.37	7%	0.36
28	25.38	24.91	13.00	1478.52	4236.12	50.08	25.66	25.10	25.30	7.07	6.28	13%	0.39
29	24.73	24.21	17.00	1483.41	3258.46	54.59	25.94	23.66	25.47	6.79	6.13	11%	0.39
30	25.47	25.74	8.00	1925.54	4010.53	60.86	25.48	26.07	25.74	7.13	6.41	11%	0.37
31	22.25	24.80	9.00	1305.49	2293.09	50.89	25.51	24.52	24.52	6.75	6.12	10%	0.40
32	24.96	24.05	13.00	1349.08	2172.22	49.84	23.95	25.17	25.29	7.91	7.12	11%	0.47
33	25.79	25.58	27.00	1831.69	3372.40	57.90	25.64	25.52	25.32	6.98	6.29	11%	0.38
34	26.05	25.68	10.00	1653.77	4356.13	51.35	25.51	26.15	25.90	7.67	7.01	9%	0.41
35	25.13	25.56	25.00	1844.59	3616.78	59.93	25.35	25.31	25.48	6.44	5.74	12%	0.35
36	26.73	24.11	19.00	2171.96	4271.38	74.56	26.03	26.98	25.31	9.29	8.35	11%	0.47
37	25.16	25.57	16.00	1453.61	3354.42	47.13	25.60	25.80	25.51	7.19	6.37	13%	0.38
38	25.38	25.23	13.00	1975.36	4455.96	65.22	25.30	25.70	25.14	7.39	6.60	12%	0.40
39	25.37	24.47	8.00	1631.53	2728.93	57.29	25.35	25.50	24.77	6.60	5.87	12%	0.37
40	26.00	26.10	23.00	2292.94	5133.51	69.05	25.41	26.35	26.06	7.34	6.67	10%	0.38
41	24.84	25.18	10.00	1551.91	3519.52	52.56	25.32	25.18	29.10	7.97	7.09	12%	0.38
42	25.93	25.47	19.00	2355.66	4448.40	74.70	25.55	27.76	16.61	5.36	4.78	12%	0.41

43	23.59	24.39	9.00	1445.16	2600.87	54.93	24.78	25.15	30.59	8.28	7.36	13%	0.39
44	24.82	24.70	4.00	1289.03	2320.56	45.41	25.20	24.41	28.79	7.33	6.46	13%	0.36
45	25.56	25.82	17.00	1807.67	4067.90	56.58	24.32	25.61	28.66	7.69	6.84	12%	0.38
46	25.01	23.37	5.00	1300.15	2484.35	50.77	24.90	23.91	28.96	7.86	6.93	13%	0.40
47	25.93	25.70	11.00	1605.28	3155.81	50.00	26.05	25.15	27.60	8.26	7.31	13%	0.40
48	24.10	24.67	7.00	1426.47	2410.85	51.88	24.11	22.75	29.44	7.91	6.76	17%	0.42
49	25.88	25.86	21.00	2119.03	4892.94	65.31	25.93	26.09	29.74	9.44	8.31	14%	0.41
50	25.77	25.83	9.00	1867.27	2725.38	57.93	25.87	25.84	29.25	9.74	8.51	14%	0.44
51	25.00	25.28	27.00	2028.73	4708.11	67.73	24.74	24.97	29.59	8.22	7.33	12%	0.40
52	24.07	24.21	14.00	1616.40	3524.00	61.11	24.41	24.80	30.13	7.66	6.66	15%	0.37
53	24.14	23.75	13.00	1728.94	4517.39	67.73	24.47	24.09	30.03	9.14	7.94	15%	0.45
Average	24.90	25.05	17.15	1707.94	3561.37	57.17	25.24	25.28	26.03	7.46	6.62	13%	0.40
Standard	2.93	1.00	6.83	299.37	1024.24	7.46	0.61	1.01	2.26	1.05	0.90	2%	0.04
min	5.16	22.32	4.00	1179.16	2023.47	41.44	23.04	22.75	16.61	5.36	4.78	7%	0.32
max	27.53	27.67	33.00	2355.66	6074.39	74.70	26.14	27.76	30.59	9.92	8.53	17%	0.50
cov	12%	4%	40%	18%	29%	13%	2%	4%	9%	14%	14%	15%	10%

Appendix 17: Bending California

Specimen	Width mm	Thickness mm	GR #	Max Load N	MOE Mpa	MOR MPa	Width mm	Thickness mm	Length mm	Wet mass g	Dry Mass g	MC %	G
1	27.18	26.97	7	1990.93	4690.10	53.72	27.37	27.29	29.62	9.60	8.49	13%	0.38
2	26.95	27.45	7	2235.24	4060.70	58.71	30.07	27.28	29.94	11.31	9.97	13%	0.41

3	24.65	23.94	16	1690.11	3163.42	63.81	24.74	24.95	29.28	7.93	7.06	12%	0.39
4	25.69	25.50	12	2080.38	4646.27	66.42	25.65	26.95	25.38	8.78	7.84	12%	0.45
5	27.50	26.62	14	2304.66	6062.58	63.08	30.11	26.69	27.88	9.19	8.13	13%	0.36
6	27.55	25.62	18	2081.71	4946.90	61.40	29.48	25.42	25.92	8.56	7.58	13%	0.39
7	25.84	25.15	13	2111.53	3989.89	68.91	25.77	29.64	24.70	8.77	7.81	12%	0.41
8	27.83	27.37	22	1962.01	6103.58	50.20	26.91	28.66	27.73	9.04	8.01	13%	0.37
9	26.05	25.78	18	2083.05	4849.66	64.18	30.69	26.31	25.83	9.44	8.34	13%	0.40
10	26.20	27.34	27	2380.75	6924.18	64.84	29.74	26.94	27.70	9.18	8.13	13%	0.37
11	25.60	26.76	23	1855.21	4416.43	53.98	26.51	30.68	26.87	9.14	8.09	13%	0.37
12	26.42	26.43	20	2091.50	5356.95	60.45	30.23	26.27	26.49	9.68	8.50	14%	0.40
13	25.92	25.90	13	1812.04	3877.83	55.59	31.01	26.15	26.02	10.77	9.52	13%	0.45
14	27.50	27.20	12	1826.73	3202.62	47.89	27.43	32.95	26.87	11.12	9.60	16%	0.40
15	25.64	25.70	17	2253.04	4841.50	70.96	27.47	25.96	25.82	9.03	7.98	13%	0.43
16	24.75	24.96	19	1309.64	3390.29	45.30	30.20	25.26	24.86	8.01	7.06	13%	0.37
17	27.32	27.71	32	2420.80	6900.77	61.55	28.09	31.81	27.74	10.20	9.04	13%	0.36
18	25.64	25.10	17	1760.42	3671.61	58.13	26.07	29.43	25.46	8.91	7.93	12%	0.41
19	27.21	27.69	20	2265.50	6130.66	57.92	26.91	26.95	32.07	10.38	9.23	12%	0.40
20	27.38	27.51	14	1696.34	4677.15	43.67	31.20	27.59	27.61	13.38	11.70	14%	0.49
21	25.78	25.89	21	1966.90	4689.24	60.71	26.07	26.25	29.70	8.52	7.59	12%	0.37
22	26.27	26.14	23	1924.18	4739.95	57.18	26.23	26.64	26.36	8.58	7.63	12%	0.41
23	25.84	25.31	10	1430.68	3040.15	46.10	29.29	25.72	29.27	7.76	6.93	12%	0.31
24	25.32	24.96	18	1960.67	4459.75	66.30	25.97	30.21	25.87	9.43	8.40	12%	0.41
25	27.69	28.04	16	2116.42	6774.22	51.85	27.70	29.08	27.80	10.83	9.59	13%	0.43
26	25.78	25.93	12	2108.41	4715.58	64.88	29.71	26.10	26.02	8.42	7.43	13%	0.37
27	26.64	26.84	20	2059.46	5092.02	57.24	26.90	26.80	28.98	10.37	9.16	13%	0.44

28	24.89	25.23	7	847.73	3850.67	28.54	25.22	29.62	24.91	7.85	6.95	13%	0.37
29	27.62	27.52	15	1858.32	3964.66	47.39	30.74	27.77	27.68	8.49	7.54	13%	0.32
30	27.09	27.89	26	2331.80	7309.35	59.03	29.03	26.92	28.27	9.26	8.16	13%	0.37
31	25.57	25.54	20	1557.06	4178.12	49.79	29.48	25.73	25.61	9.04	8.01	13%	0.41
32	27.41	27.34	25	2123.54	5665.03	55.29	27.15	27.25	36.17	11.91	10.54	13%	0.39
33	27.05	27.72	18	2537.39	7449.20	65.12	29.81	27.35	27.75	9.36	8.27	13%	0.37
34	25.67	25.88	17	2087.05	4769.40	64.75	25.34	25.86	25.87	7.38	6.57	12%	0.39
35	26.05	25.99	7	1834.74	3174.14	55.62	24.95	26.23	26.02	7.04	6.15	14%	0.36
36	25.42	25.86	25	1405.76	3425.35	44.11	27.06	26.23	24.96	6.60	5.80	14%	0.33
37	25.16	25.45	8	1539.26	2933.42	50.38	24.81	25.31	25.02	6.52	5.71	14%	0.36
38	24.98	25.11	7	1699.46	4926.97	57.55	24.27	25.62	25.41	6.69	5.88	14%	0.37
39	25.87	25.92	18	1923.74	3780.28	59.04	25.28	26.01	26.57	7.18	6.34	13%	0.36
40	25.71	26.00	9	2026.53	3054.23	62.20	25.25	25.90	25.86	7.64	6.77	13%	0.40
41	25.60	25.95	8	1854.76	4143.11	57.39	25.14	25.31	25.82	6.58	5.82	13%	0.35
42	25.76	25.71	5	1878.79	3815.90	58.85	24.18	25.73	25.71	6.57	5.75	14%	0.36
43	25.07	25.75	10	1266.92	3220.69	40.65	24.60	25.52	25.83	6.06	5.29	15%	0.33
44	26.11	26.28	9	1920.18	4108.33	56.80	25.26	26.19	26.25	8.23	7.19	14%	0.41
45	25.72	25.70	12	1563.29	3174.93	49.09	23.66	26.09	25.86	6.43	5.59	15%	0.35
46	26.05	25.82	28	2044.33	4046.07	62.79	25.41	26.07	26.38	7.96	7.15	11%	0.41
47	26.33	26.16	17	2147.13	4358.84	63.56	25.40	26.38	26.50	8.07	7.22	12%	0.41
48	26.18	26.06	19	2080.82	4939.32	62.43	26.09	25.66	26.20	7.21	6.43	12%	0.37
49	26.20	26.39	20	1728.83	4869.54	50.54	26.34	25.74	26.06	7.61	6.83	11%	0.39
50	25.18	25.32	17	2056.79	5460.11	67.96	25.19	25.26	25.44	6.66	5.98	11%	0.37
51	25.40	25.33	12	1970.02	4754.11	64.48	25.62	25.24	25.47	6.63	6.08	9%	0.37
Average	26.16	26.19	16.08	1922.79	4603.64	57.03	27.11	26.92	26.93	8.61	7.62	13%	0.39

Standard	0.86	0.93	6.32	317.69	1155.24	8.30	2.15	1.77	2.05	1.57	1.38	1%	0.03
min	24.65	23.94	5.00	847.73	2933.42	28.54	23.66	24.95	24.70	6.06	5.29	9%	0.31
max	27.83	28.04	32.00	2537.39	7449.20	70.96	31.20	32.95	36.17	13.38	11.70	16%	0.49
cov	3%	4%	39%	17%	25%	15%	8%	7%	8%	18%	18%	8%	9%

Appendix 18: Bending Prineville

Specimen	Width mm	Thickness mm	GR #	Max Load N	MOE Mpa	MOR MPa	Width mm	Thickness mm	Length mm	Wet mass g	Dry Mass g	MC %	G
1	25.57	25.65	20	1853.48	2996.79	58.77	25.59	25.56	25.66	7.56	6.88	10%	0.41
2	25.25	25.62	14	1525.22	2638.79	49.09	25.56	25.41	25.48	7.63	6.96	10%	0.42
3	25.07	25.12	31	1760.52	3643.46	59.36	25.07	24.91	25.61	7.35	6.61	11%	0.41
4	25.11	25.02	30	1718.26	3947.51	58.31	27.78	24.38	25.38	7.52	6.75	11%	0.39
5	24.95	25.14	39	2119.92	3371.53	71.71	25.09	24.72	24.27	7.99	7.31	9%	0.49
6	25.86	25.95	34	2414.37	4392.10	73.95	25.97	25.84	26.14	10.34	9.46	9%	0.54
7	25.31	25.45	17	1889.51	3735.62	61.48	25.25	25.21	24.60	7.78	7.09	10%	0.45
8	25.63	25.36	13	2043.86	3489.65	66.14	25.23	25.47	24.32	9.07	8.23	10%	0.53
9	25.74	25.58	21	2496.22	4696.41	79.05	25.65	25.31	24.41	8.69	7.90	10%	0.50
10	25.00	25.85	39	1730.27	4645.82	55.25	25.26	25.22	24.49	7.55	6.79	11%	0.44
11	26.06	25.85	29	1861.49	4007.09	57.02	23.69	24.89	25.03	6.71	6.03	11%	0.41
12	25.30	25.47	35	2083.89	3135.14	67.72	24.97	25.21	24.62	8.35	7.58	10%	0.49
13	25.61	25.43	15	1945.11	3454.84	62.65	25.58	25.18	24.79	7.81	7.12	10%	0.45
14	25.48	25.14	20	1784.54	2799.40	59.11	24.65	25.34	25.16	7.98	7.28	10%	0.46

15	25.72	25.60	33	1764.52	3985.48	55.84	25.58	25.15	25.88	7.43	6.72	11%	0.40
16	25.48	25.49	17	1929.54	4289.78	62.17	25.30	25.34	24.31	7.60	6.90	10%	0.44
17	25.05	24.95	24	1752.51	3378.49	59.95	25.35	24.85	25.04	8.03	7.34	9%	0.47
18	25.67	25.70	26	2301.84	5087.32	72.42	25.64	25.25	25.41	8.86	8.03	10%	0.49
19	25.44	25.83	18	1547.46	3585.00	48.63	25.37	25.18	26.44	6.70	6.03	11%	0.36
20	24.34	24.84	18	1699.14	4212.18	60.35	24.68	24.15	25.54	7.47	6.81	10%	0.45
21	24.54	25.11	31	2094.12	4263.00	72.19	25.16	25.18	26.76	9.75	8.85	10%	0.52
22	25.57	25.38	42	1963.79	3790.51	63.60	25.70	25.20	25.04	8.20	7.48	10%	0.46
23	25.70	26.04	25	1811.67	2851.70	55.45	25.68	25.71	25.41	6.71	6.03	11%	0.36
24	25.12	25.08	26	1522.55	3712.25	51.40	25.09	24.99	25.75	6.37	5.82	9%	0.36
25	25.35	25.05	21	1753.85	3608.87	58.81	24.75	25.26	25.48	6.89	6.24	10%	0.39
26	25.61	25.57	19	1822.79	3181.18	58.07	25.69	26.43	17.06	4.64	4.21	10%	0.36
27	25.63	25.60	25	2006.49	3512.61	63.72	25.45	25.70	24.07	6.92	6.23	11%	0.40
28	25.41	25.26	33	1921.09	3144.26	63.20	25.42	25.68	25.41	9.16	8.32	10%	0.50
29	25.71	25.75	15	1724.49	2621.31	53.96	25.64	25.45	24.78	7.31	6.63	10%	0.41
30	25.68	25.59	16	1681.34	3850.63	53.33	24.92	25.87	25.27	6.35	5.70	11%	0.35
31	25.49	25.44	28	1788.10	3618.43	57.81	25.44	25.45	24.59	6.53	5.90	11%	0.37
32	25.05	25.11	15	1707.14	3206.77	57.65	24.48	25.94	25.25	7.66	6.93	11%	0.43
33	25.86	25.88	21	2196.42	4774.84	67.64	25.81	25.68	25.98	8.13	7.35	11%	0.43
34	25.83	25.75	32	1991.37	4183.53	62.02	25.67	25.73	25.06	7.13	6.43	11%	0.39
35	25.43	25.43	22	1884.17	4203.93	61.11	25.39	25.25	24.86	7.97	7.22	10%	0.45
36	24.75	25.21	26	2114.58	4682.87	71.71	24.72	25.08	25.62	7.34	6.64	11%	0.42
37	25.42	25.64	28	1932.66	3548.60	61.69	25.47	25.46	24.61	7.21	6.46	12%	0.40
38	25.47	25.29	46	1699.14	3278.53	55.64	24.93	25.03	25.33	7.19	6.48	11%	0.41
39	25.69	25.67	21	1605.73	3763.89	50.60	25.74	25.75	24.83	8.21	7.36	12%	0.45

40	25.62	25.52	20	1740.95	3391.21	55.65	25.45	25.43	24.99	7.66	6.96	10%	0.43
41	25.47	25.53	27	2065.65	3193.13	66.37	24.91	25.73	25.98	8.45	7.65	10%	0.46
42	25.79	25.98	18	2184.86	4203.62	66.95	26.06	26.03	25.07	7.17	6.45	11%	0.38
43	25.13	26.51	17	1950.00	2991.99	58.89	25.35	25.65	25.00	7.76	6.94	12%	0.43
44	25.29	25.38	22	1901.52	3437.16	62.26	25.16	25.42	25.41	7.08	6.44	10%	0.40
45	25.06	25.10	15	1711.15	2945.34	57.81	24.97	24.90	25.45	7.58	6.87	10%	0.43
46	25.58	25.64	16	2139.49	5307.16	67.86	25.58	25.64	25.95	7.94	7.15	11%	0.42
47	25.64	25.57	11	2277.38	4825.82	72.46	25.64	25.57	25.27	7.45	6.69	11%	0.40
48	25.38	25.89	23	2214.66	4319.64	69.44	25.38	25.89	25.99	8.29	7.44	11%	0.44
49	25.48	24.90	19	2260.92	4629.04	76.34	25.48	24.90	24.77	7.31	6.50	12%	0.41
50	24.41	25.58	32	2009.61	3723.57	67.11	24.41	25.58	24.52	7.85	7.06	11%	0.46
51	25.41	24.90	12	1400.68	2254.96	47.42	25.41	24.90	25.54	6.82	6.09	12%	0.38
52	25.73	25.21	9	1790.76	3280.10	58.41	25.73	25.21	25.25	6.94	6.27	11%	0.38
53	25.20	25.36	13	1757.74	4649.78	57.85	25.03	24.63	25.16	6.37	5.78	10%	0.37
Average	25.40	25.47	23.38	1902.80	3744.20	61.57	25.34	25.34	25.06	7.60	6.88	11%	0.43
Standard	0.36	0.34	8.43	234.32	680.01	7.24	0.55	0.42	1.26	0.91	0.84	1%	0.05
min	24.34	24.84	9.00	1400.68	2254.96	47.42	23.69	24.15	17.06	4.64	4.21	9%	0.35
max	26.06	26.51	46.00	2496.22	5307.16	79.05	27.78	26.43	26.76	10.34	9.46	12%	0.54
cov	1%	1%	36%	12%	18%	12%	2%	2%	5%	12%	12%	7%	11%

Appendix 19: Bending Klamath

Specimen	width mm	Thickness mm	GR #	Max Load N	MOE Mpa	MOR MPa	Width mm	Thickness mm	Length mm	Wet mass g	Dry Mass g	MC %	G

1	25.45	25.65	13	2132.44	5175.84	67.93	28.77	25.76	25.89	9.25	8.13	14%	0.42
2	25.78	24.96	17	1918.40	5106.22	63.71	29.43	25.52	25.75	8.52	7.47	14%	0.39
3	24.70	24.74	11	1633.60	4324.17	57.64	33.75	25.21	24.99	9.62	8.14	18%	0.38
4	26.07	25.98	17	2260.60	4739.70	68.53	31.12	26.04	25.46	9.96	8.77	14%	0.43
5	25.80	25.50	27	2147.57	5459.54	68.28	30.82	25.12	25.88	8.91	7.87	13%	0.39
6	24.67	25.08	23	1759.09	4683.01	60.47	25.83	30.65	25.64	10.27	9.08	13%	0.45
7	25.22	25.67	18	1997.16	4041.82	64.10	30.07	26.06	25.36	8.98	7.88	14%	0.40
8	25.83	25.88	20	2095.51	5302.48	64.61	28.59	25.42	26.48	9.00	7.93	13%	0.41
9	25.34	24.66	15	2156.47	4248.76	74.65	27.89	25.35	24.80	9.17	8.15	13%	0.46
10	25.61	25.11	11	1955.78	4868.82	64.61	24.78	30.79	25.60	8.35	7.45	12%	0.38
11	25.18	25.17	16	1912.61	3851.50	63.95	29.65	25.44	24.29	8.78	7.79	13%	0.43
12	25.92	26.78	15	2248.59	5400.66	64.52	29.54	25.83	24.71	8.68	7.62	14%	0.40
13	26.22	25.97	12	1917.51	5138.94	57.84	30.77	25.77	25.78	8.51	7.53	13%	0.37
14	25.05	24.91	14	1670.53	2916.02	57.33	29.70	25.22	25.20	8.83	7.81	13%	0.41
15	25.87	26.36	38	1755.08	4865.35	52.08	28.74	25.50	25.91	8.93	7.91	13%	0.42
16	23.92	25.66	11	1645.61	4387.63	55.73	28.47	25.12	25.25	8.27	7.24	14%	0.40
17	25.19	24.13	18	2011.40	4873.62	73.15	30.37	25.22	24.77	9.77	8.71	12%	0.46
18	25.09	25.36	28	2148.46	5078.58	71.02	25.75	27.69	24.29	8.21	7.24	13%	0.42
19	25.03	25.14	8	1589.54	3919.90	53.60	29.96	25.48	25.57	8.89	7.79	14%	0.40
20	25.55	25.44	18	2226.34	5314.01	71.82	29.66	26.22	25.47	9.32	8.20	14%	0.41
21	25.04	24.66	16	1742.18	4365.52	61.03	29.81	24.95	24.87	7.75	6.90	12%	0.37
22	25.05	25.63	12	2042.11	4963.58	66.20	29.71	24.79	25.67	8.01	7.09	13%	0.38
23	26.12	26.18	13	2013.63	4845.10	60.00	26.13	26.88	26.27	10.44	9.20	13%	0.50
24	24.66	24.05	13	1003.92	1602.36	37.54	29.03	24.31	25.25	9.05	7.99	13%	0.45
25	25.53	25.36	28	1860.55	4798.71	60.44	28.73	24.59	25.33	9.27	8.48	9%	0.47

26	26.11	26.03	15	2067.03	5073.43	62.32	25.09	29.52	25.64	7.93	6.98	14%	0.37
27	26.28	25.87	20	1120.51	3320.65	33.98	30.11	25.72	26.23	9.24	8.10	14%	0.40
28	26.70	25.87	22	1995.83	4445.34	59.58	28.89	24.07	26.61	7.95	6.98	14%	0.38
29	26.78	26.95	7	2141.79	3992.57	58.74	30.76	27.34	27.20	11.87	10.45	14%	0.46
30	25.62	25.80	15	1886.80	4296.29	59.01	25.29	25.60	24.20	8.16	7.08	15%	0.45
31	25.15	25.17	15	1659.41	4054.84	55.55	24.55	25.05	25.73	7.05	6.21	14%	0.39
32	25.77	25.83	14	1579.75	4219.60	49.01	25.13	24.59	26.92	6.66	5.85	14%	0.35
33	25.20	25.19	7	1850.76	5123.84	61.74	25.50	25.17	24.87	6.54	5.70	15%	0.36
34	24.52	25.84	15	2289.97	4604.29	74.61	26.17	25.88	24.28	7.61	6.66	14%	0.41
35	25.56	25.12	9	1711.03	4745.02	56.59	24.81	25.35	25.20	6.63	5.85	13%	0.37
36	25.87	25.60	15	1727.05	4488.49	54.34	25.79	25.92	25.91	7.67	6.77	13%	0.39
37	25.91	24.86	6	1867.67	5067.97	62.21	25.63	25.66	24.78	7.68	6.72	14%	0.41
38	25.50	24.74	7	1462.72	4346.77	49.99	25.59	24.50	25.43	6.47	5.70	14%	0.36
39	25.85	25.95	14	2047.89	5795.87	62.75	25.19	24.43	25.47	7.48	6.59	14%	0.42
40	25.81	24.87	25	1856.54	4282.59	62.03	25.78	25.65	24.42	6.91	6.06	14%	0.38
41	25.64	25.66	11	1865.89	5447.46	58.95	24.92	25.65	25.46	6.70	5.89	14%	0.36
42	26.14	25.81	7	2209.43	5404.17	67.68	25.32	25.64	24.81	8.42	7.40	14%	0.46
43	25.89	25.18	11	1675.43	4405.87	54.44	26.04	25.56	24.29	6.79	6.00	13%	0.37
44	25.52	25.22	10	1725.27	5063.79	56.69	24.31	25.78	25.33	6.70	5.91	13%	0.37
45	25.46	26.02	8	1715.92	4106.59	53.10	24.98	25.95	25.81	7.00	6.08	15%	0.36
46	25.64	24.33	7	1932.19	4731.62	67.90	25.89	24.76	25.14	7.61	6.63	15%	0.41
47	25.63	25.53	11	1125.41	5567.25	35.93	25.47	25.63	25.53	7.21	6.33	14%	0.38
48	25.78	25.73	12	1994.49	5439.34	62.33	24.34	25.62	25.63	6.79	5.99	13%	0.37
49	25.88	25.59	14	2400.78	5671.08	75.56	25.38	24.80	25.43	8.18	7.14	15%	0.45
50	25.61	24.72	17	2290.42	4328.20	78.07	24.61	25.57	20.69	6.98	6.16	13%	0.47

51	25.26	25.40	19	1804.92	4235.82	59.08	25.99	25.44	24.76	7.43	6.50	14%	0.40
52	25.91	25.49	16	1912.17	4320.68	60.59	25.42	24.94	26.60	7.30	6.37	15%	0.38
53	25.86	25.96	9	1888.14	4528.36	57.79	25.01	24.51	25.50	6.68	5.86	14%	0.37
Average	25.56	25.44	14.91	1880.18	4629.80	60.59	27.34	25.72	25.33	8.20	7.21	14%	0.40
Standard	0.53	0.59	6.30	289.77	723.77	8.99	2.39	1.33	0.94	1.18	1.05	1%	0.04
min	23.92	24.05	6.00	1003.92	1602.36	33.98	24.31	24.07	20.69	6.47	5.70	9%	0.35
max	26.78	26.95	38.00	2400.78	5795.87	78.07	33.75	30.79	27.20	11.87	10.45	18%	0.50
cov	2%	2%	42%	15%	16%	15%	9%	5%	4%	14%	15%	8%	9%

Appendix 20: Bending Idaho

Specimen	Width mm	Thickness mm	GR #	Max Load N	MOE Mpa	MOR MPa	Width mm	Thickness mm	Length mm	Wet mass g	Dry Mass g	MC %	G
1	24.67	24.06	14	1556.80	2872.94	58.15	24.05	24.47	24.66	7.31	6.45	13%	0.44
2	25.08	24.87	16	1941.55	3553.20	66.76	24.61	25.64	25.31	8.29	7.35	13%	0.46
3	25.01	21.45	16	1159.59	2296.82	53.75	21.62	25.67	24.96	6.00	5.30	13%	0.38
4	25.23	23.54	19	1707.14	2722.43	65.13	22.47	25.67	25.44	8.44	7.43	14%	0.51
5	25.67	23.14	34	1260.56	1961.43	48.92	25.58	25.43	23.02	6.96	6.15	13%	0.41
6	24.76	24.88	7	1263.23	3121.35	43.96	23.96	25.65	24.89	6.88	5.99	15%	0.39
7	25.00	22.85	15	1248.55	1742.25	51.02	24.82	25.56	25.43	8.52	7.38	15%	0.46
8	25.47	24.17	15	1373.99	2161.44	49.26	25.35	25.71	24.15	8.56	7.41	16%	0.47
9	24.65	22.91	19	1308.60	2632.65	53.95	23.79	25.57	24.82	6.65	5.88	13%	0.39
10	24.15	23.53	21	1261.01	2703.54	50.30	23.77	25.86	29.57	6.63	5.81	14%	0.32

11	25.00	23.77	18	1375.77	2877.05	51.95	24.06	25.62	24.99	7.14	6.22	15%	0.40
12	24.87	24.19	9	1324.17	2706.84	48.53	24.16	25.28	24.98	6.84	6.07	13%	0.40
13	25.23	24.43	15	1493.19	2139.91	52.89	24.56	25.43	25.28	8.29	7.29	14%	0.46
14	25.44	24.25	18	1713.81	3052.83	61.10	24.84	25.32	25.36	9.12	7.93	15%	0.50
15	25.34	23.35	12	1408.68	2085.03	54.39	24.90	25.33	25.26	8.32	7.29	14%	0.46
16	24.40	24.05	13	1432.26	3166.21	54.13	24.58	25.40	24.56	6.65	5.82	14%	0.38
17	24.64	24.52	12	1400.68	2816.92	50.43	24.50	25.26	24.82	6.54	5.72	14%	0.37
18	24.51	24.27	7	1338.85	2738.62	49.47	24.55	25.54	24.58	6.41	5.68	13%	0.37
19	24.33	23.78	14	1422.92	3165.07	55.17	24.26	25.45	25.31	6.71	5.88	14%	0.38
20	24.74	24.56	7	1369.09	2895.17	48.94	24.82	25.29	24.49	6.74	5.97	13%	0.39
21	24.80	23.58	10	1295.26	2539.22	50.10	24.25	24.65	29.00	7.48	6.66	12%	0.38
22	25.01	24.96	11	2220.89	3897.26	76.03	24.63	24.34	24.23	8.06	7.16	13%	0.49
23	25.05	24.00	13	1647.54	2708.20	60.91	23.64	25.36	33.61	9.89	8.70	14%	0.43
24	25.47	24.50	13	1361.53	2343.40	47.50	23.01	25.36	25.63	7.01	6.18	13%	0.41
25	24.86	24.40	9	1268.57	2582.23	45.72	22.38	24.62	23.64	5.56	4.95	12%	0.38
26	25.10	25.04	8	1374.43	2882.90	46.58	24.95	24.00	26.34	6.90	6.11	13%	0.39
27	24.85	24.90	9	1734.28	3023.93	60.04	25.00	26.39	25.13	9.61	8.45	14%	0.51
28	24.38	23.62	24	1428.25	3161.25	56.01	24.28	27.97	24.09	7.25	6.30	15%	0.39
29	25.26	22.78	13	1288.14	2856.00	52.42	24.10	25.03	26.53	7.02	6.13	15%	0.38
30	25.18	24.73	13	1490.08	2691.41	51.61	24.84	24.93	24.04	8.10	7.06	15%	0.47
31	25.20	23.57	19	1478.07	2820.31	56.32	26.08	25.25	25.13	6.73	5.90	14%	0.36
Average	24.95	23.96	14.29	1449.92	2739.28	53.92	24.27	25.39	25.46	7.44	6.54	14%	0.42
Standard	0.37	0.79	5.66	224.11	452.15	6.81	0.93	0.68	2.00	1.04	0.90	1%	0.05
min	24.15	21.45	7.00	1159.59	1742.25	43.96	21.62	24.00	23.02	5.56	4.95	12%	0.32
max	25.67	25.04	34.00	2220.89	3897.26	76.03	26.08	27.97	33.61	9.89	8.70	16%	0.51

cov	1%	3%	40%	15%	17%	13%	4%	3%	8%	14%	14%	7%	12%

A.5 Green/Dry Ratio Data Tables

A.5.1 Shear

Appendix 21: Green Shear Block Samples

Specimen	length (mm)	Width (mm)	Max Load (N)	Width (mm)	Thickness (mm)	Length (mm)	Weight G (g)	Weight D (g)	MC %
1	51.05	52.16	18180.61	24.83	18.58	50.78	24.58	8.09	204%
2	49.23	49.95	15971.24	24.79	25.05	50.14	25.18	13.48	87%
3	48.72	50.73	20656.93	25.17	24.94	50.69	27.64	15.39	80%
4	50.75	49.53	19421.03	24.90	25.32	50.04	21.88	12.63	73%
5	48.33	51.91	16102.77	25.05	25.06	54.11	35.81	13.64	163%
6	49.67	50.63	15781.00	24.73	24.98	50.56	27.07	12.19	122%
7	50.28	54.13	16690.69	23.83	24.98	54.17	24.26	14.88	63%
8	51.49	51.05	21518.50	24.84	24.65	51.01	24.23	13.59	78%
9	52.38	53.46	24917.33	24.90	24.08	53.72	19.05	13.81	38%
10	50.24	55.53	20616.53	25.00	24.75	55.76	29.44	12.57	134%
11	50.58	54.02	16374.11	24.71	24.83	54.60	24.71	13.12	88%
12	50.52	50.93	16095.46	25.03	24.92	51.04	33.27	12.12	175%
13	50.94	50.81	16863.91	24.56	24.61	50.43	32.67	11.11	194%
14	51.03	51.28	17178.25	25.00	21.02	51.22	28.80	9.86	192%
15	49.93	54.63	16618.60	24.92	24.96	55.03	37.47	12.79	193%
16	47.52	50.50	10533.61	25.08	25.00	51.40	23.20	10.65	118%
17	50.91	49.88	10785.18	24.81	24.72	50.22	23.37	11.37	106%

18	50.14	49.18	17524.89	24.92	24.79	49.12	25.96	15.06	72%
19	49.71	50.17	14656.88	24.82	24.62	50.00	32.19	13.95	131%
20	50.60	50.73	15970.67	24.72	24.70	50.88	37.04	11.42	224%
21	53.00	50.41	18439.26	25.11	24.77	50.37	25.26	11.77	115%
22	50.76	50.52	12156.66	24.87	25.06	50.54	30.71	12.34	149%
23	52.21	50.67	14612.24	25.10	24.93	50.74	27.77	12.74	118%
24	51.05	51.53	14655.49	24.91	25.06	51.78	25.83	12.40	108%
25	50.08	50.43	12842.81	25.03	24.80	49.91	31.11	10.70	191%
26	50.48	48.84	13451.96	24.74	24.91	49.14	29.79	10.74	177%
27	47.96	50.22	13539.53	25.00	24.70	50.46	15.55	10.90	43%
28	48.44	50.33	12134.48	24.68	24.91	50.25	26.93	11.33	138%
29	50.51	49.77	14166.40	25.02	24.77	50.04	18.65	12.13	54%
30	48.44	49.94	11418.05	24.98	24.96	50.33	28.18	11.17	152%
Mean	50.23	51.13	15995.84	24.87	24.51	51.28	27.25	12.26	126%
Stan Dev	1.29	1.65	3322.37	0.24	1.34	1.79	5.21	1.60	52%
Min	47.52	48.84	10533.61	23.83	18.58	49.12	15.55	8.09	38%
Max	53.00	55.53	24917.33	25.17	25.32	55.76	37.47	15.39	224%
COV	3%	3%	21%	1%	5%	3%	19%	13%	41%

Appendix 22: Dry Shear Block Samples

Specimen	length (mm)	Width (mm)	Max Load (N)	Width (mm)	Thickness (mm)	Length (mm)	Weight G (g)	Weight D (g)	MC %
1	50.11	50.36	22766.69	24.91	25.12	50.87	14.65	12.67	16%
2	49.42	49.38	14355.11	25.01	24.67	49.41	15.72	13.66	15%

3	50.32	49.81	15923.49	24.90	34.89	49.99	17.69	15.15	17%
4	50.49	48.48	21694.17	24.73	24.91	48.83	15.71	13.64	15%
5	47.90	51.74	21021.47	25.01	23.62	51.90	15.46	13.49	15%
6	51.32	50.03	18210.84	24.67	24.98	49.87	14.19	12.20	16%
7	50.36	53.20	25116.15	24.86	24.86	53.01	18.31	15.82	16%
8	51.34	50.31	31140.60	24.53	24.78	50.40	16.55	14.32	16%
9	50.24	53.14	21374.92	24.78	24.62	52.56	16.44	14.46	14%
10	50.63	54.79	26216.16	24.80	24.85	55.39	15.64	13.64	15%
11	50.44	52.76	18113.78	24.80	24.81	53.23	14.32	12.35	16%
12	50.95	50.23	17608.79	24.62	24.88	50.52	15.32	13.04	17%
13	51.16	49.43	17356.96	24.32	24.77	48.20	13.60	11.50	18%
14	50.54	50.31	24102.50	24.67	24.09	50.41	14.87	12.85	16%
15	50.87	49.82	19893.34	24.81	24.89	49.58	14.43	12.09	19%
16	50.80	50.38	23666.62	24.75	24.76	50.23	12.00	10.63	13%
17	50.77	47.13	25028.32	24.63	24.96	47.68	13.28	11.45	16%
18	49.49	47.64	11995.16	24.71	24.80	47.83	16.12	13.91	16%
19	50.89	48.76	19252.69	24.81	24.78	48.62	16.70	14.26	17%
20	49.97	50.27	20853.82	24.92	24.84	50.42	13.98	12.07	16%
21	47.87	49.49	18842.69	24.75	24.82	49.23	14.55	12.42	17%
22	50.11	49.34	20242.96	24.55	24.70	49.03	13.86	12.05	15%
23	50.16	49.64	21320.21	24.85	23.73	50.02	14.50	12.63	15%
24	50.63	50.68	20893.06	24.94	25.01	50.72	15.12	12.88	17%
25	51.53	49.43	13520.08	24.81	24.96	49.85	13.28	11.64	14%
26	49.33	48.57	15469.40	24.81	24.81	48.69	13.90	12.20	14%
27	52.08	49.21	16070.38	24.68	24.71	49.02	12.76	11.06	15%

28	48.82	50.47	12552.06	24.84	24.50	50.41	13.52	11.37	19%
29	52.38	48.82	16535.20	24.88	25.06	48.92	14.86	12.50	19%
30	49.03	49.35	12794.00	24.65	25.00	49.42	13.67	12.03	14%
Mean	50.33	50.10	19464.39	24.77	25.07	50.14	14.83	12.80	16%
Stan Dev	1.05	1.65	4487.38	0.15	1.89	1.69	1.43	1.23	2%
Min	47.87	47.13	11995.16	24.32	23.62	47.68	12.00	10.63	13%
Max	52.38	54.79	31140.60	25.01	34.89	55.39	18.31	15.82	19%
COV	2%	3%	23%	1%	8%	3%	10%	10%	10%

A.5.2 Compression ⊥

Appendix 23: Green Compression ⊥ Samples

Specimen	length (mm)	Width (mm)	Load @ 1 mm (N)	Width (mm)	Thickness (mm)	Length (mm)	Wieght G (g)	Weight D (g)	MC %
1	52.77	52.47	9958.76	25.31	24.79	52.74	35.84	12.52	186%
2	50.73	50.03	10473.09	24.90	25.07	50.54	24.38	13.23	84%
3	51.57	50.67	10047.32	24.23	24.76	51.28	28.49	12.98	119%
4	53.09	53.82	15112.94	24.75	25.23	52.84	33.32	14.04	137%
5	53.98	53.00	12016.48	25.17	24.63	53.79	37.07	14.25	160%
6	50.85	48.64	12030.70	24.45	25.24	49.60	30.69	11.17	175%
7	52.63	52.97	14947.98	24.42	24.92	53.23	28.59	15.12	89%
8	50.58	50.67	12087.05	24.94	24.66	50.67	25.25	13.30	90%
9	58.63	56.57	12200.15	24.35	25.04	57.59	34.19	13.24	158%
10	52.23	53.18	10210.53	24.84	25.00	52.38	25.42	11.38	123%
11	50.71	50.45	11366.77	25.12	24.88	50.79	22.45	11.54	95%
12	52.72	53.18	13173.83	25.03	24.87	53.06	31.89	12.90	147%
13	49.36	49.62	11647.15	24.89	24.37	48.75	31.71	11.11	185%
14	52.62	53.14	12363.81	24.94	24.54	52.56	33.91	12.28	176%
15	49.60	54.31	11596.10	25.02	24.92	50.97	29.93	12.26	144%
16	48.87	50.73	9000.10	25.18	24.91	48.77	26.89	10.68	152%
17	49.42	50.00	6155.32	24.18	24.86	50.36	25.95	11.14	133%
18	50.15	51.79	8759.64	24.96	24.51	50.33	34.58	14.89	132%

19	49.85	48.67	14641.74	24.97	24.84	50.53	32.01	13.85	131%
20	50.15	50.46	7044.65	25.25	24.90	50.11	32.72	10.65	207%
21	48.57	49.29	7419.20	24.77	24.71	49.29	32.04	11.45	180%
22	50.13	50.16	8715.42	24.94	25.09	50.70	29.52	17.95	64%
23	51.64	50.09	9324.20	24.46	24.35	51.24	26.98	14.30	89%
24	51.20	50.53	11444.80	24.95	25.20	50.84	30.46	11.53	164%
25	46.80	47.27	7485.80	24.76	24.90	47.26	26.26	10.21	157%
26	50.37	49.93	9827.23	24.62	24.35	50.31	22.03	12.39	78%
27	50.00	49.57	8930.90	24.78	24.75	49.78	20.29	13.26	53%
28	50.02	50.29	8964.28	24.51	24.94	50.35	21.12	11.50	84%
29	53.83	54.19	15197.64	24.91	25.00	54.08	26.76	15.76	70%
30	50.58	49.58	14067.29	24.60	25.04	50.61	26.53	11.28	135%
Mean	51.12	51.18	10873.70	24.81	24.84	51.18	28.91	12.74	130%
Stan Dev	2.15	2.07	2482.71	0.30	0.24	1.98	4.48	1.75	42%
Min	46.80	47.27	6155.32	24.18	24.35	47.26	20.29	10.21	53%
Max	58.63	56.57	15197.64	25.31	25.24	57.59	37.07	17.95	207%
COV	4%	4%	23%	1%	1%	4%	15%	14%	32%

Appendix 24: Dry Compression ⊥ Samples

Specimen	length (mm)	Width (mm)	Load @ 1 mm (N)	Width (mm)	Thickness (mm)	Length (mm)	Wieght G (g)	Weight D (g)	MC %
1	51.85	51.89	10668.45	24.63	24.56	51.57	14.85	12.97	14%

2	50.17	49.84	10995.72	24.36	25.07	49.29	15.32	13.63	12%
3	50.69	50.77	7073.86	24.25	24.44	50.53	13.87	12.49	11%
4	52.50	53.16	18680.60	24.60	24.41	52.98	15.47	14.08	10%
5	52.28	51.42	9462.12	24.87	24.88	51.82	16.95	14.68	15%
6	50.23	49.59	3292.19	23.60	24.76	48.52	12.29	11.17	10%
7	51.91	52.36	19152.31	24.69	24.97	52.14	16.98	15.31	11%
8	49.79	49.61	14703.58	24.17	24.82	49.36	15.38	13.71	12%
9	56.76	56.67	18202.47	23.32	24.43	56.80	14.11	12.82	10%
10	52.41	52.16	12600.00	24.59	24.95	52.27	13.63	12.33	11%
11	49.93	49.81	12429.49	24.46	24.81	49.98	12.59	11.34	11%
12	52.31	52.16	15372.62	24.72	24.62	51.96	14.63	13.27	10%
13	48.18	50.08	8843.95	24.95	24.78	48.80	14.05	11.47	22%
14	51.19	52.42	8175.42	24.89	24.62	52.03	14.07	12.59	12%
15	54.26	50.12	11699.60	24.53	24.97	54.24	17.24	13.84	25%
16	48.59	50.52	12292.35	24.38	24.87	50.46	13.65	12.02	14%
17	48.85	49.07	13768.41	24.90	24.82	49.03	13.32	11.88	12%
18	49.35	50.29	9263.96	24.89	24.72	51.49	18.06	15.00	20%
19	49.56	49.16	20048.78	24.79	24.70	49.27	16.93	14.65	16%
20	47.29	50.57	8504.22	24.38	24.70	50.72	15.96	14.25	12%
21	49.10	50.25	12123.19	24.85	24.80	49.32	14.15	11.34	25%
22	48.84	50.11	9148.55	24.63	24.72	48.11	13.51	12.01	12%
23	50.66	49.21	15036.94	24.49	24.47	48.66	14.20	13.01	9%
24	51.13	50.51	15655.97	25.00	24.27	49.47	14.70	12.99	13%
25	46.29	46.74	13190.52	24.17	24.93	46.27	11.91	10.74	11%
26	48.72	49.46	14589.11	24.11	24.62	49.17	13.88	12.37	12%

27	48.71	48.60	8167.20	24.49	24.05	48.44	13.94	12.16	15%
28	49.26	49.68	13797.30	24.99	24.58	49.90	14.04	12.78	10%
29	53.78	52.96	15233.59	24.91	24.69	53.85	18.30	15.22	20%
30	49.51	49.16	10367.59	24.84	25.03	49.79	13.34	11.74	14%
Mean	50.47	50.61	12418.00	24.55	24.70	50.54	14.71	12.93	14%
Stan Dev	2.19	1.82	3894.45	0.40	0.23	2.16	1.65	1.28	4%
Min	46.29	46.74	3292.19	23.32	24.05	46.27	11.91	10.74	9%
Max	56.76	56.67	20048.78	25.00	25.07	56.80	18.30	15.31	25%
COV	4%	4%	31%	2%	1%	4%	11%	10%	32%

A.6 Laboratory Decay Test

Appendix 25: Laboratory Decay Test Data

Last week of March					After 16 weeks				
Samaple # #	Location	Fungi	Sample Piece	OD Weight g	GR Weight g	OD Weight g	Δ Mass g	MC% %	Mass loss% %
1	Klamath	w	OR 2	2.754	3.358	2.715	0.039	24%	1%
2	Klamath	w	OR 2	2.721	3.450	2.677	0.044	29%	2%
3	Klamath	w	OR 2	2.808	3.567	2.772	0.036	29%	1%
4	Klamath	w	OR 2	2.612	3.203	2.573	0.039	24%	1%
5	Klamath	w	OR 2	2.651	3.304	2.603	0.048	27%	2%
6	Klamath	w	OR 2	2.634	3.493	2.619	0.015	33%	1%
7	Klamath	w	OR 2	2.789	3.648	2.739	0.050	33%	2%
8	Klamath	w	OR 15	3.281	4.158	3.217	0.064	29%	2%
9	Klamath	w	OR 15	3.032	3.655	2.97	0.062	23%	2%
10	Klamath	w	OR 15	3.214	3.997	3.147	0.067	27%	2%
11	Klamath	w	OR 15	3.209	3.899	3.148	0.061	24%	2%
12	Klamath	w	OR 15	3.333	4.529	3.467	-0.134	31%	-4%
13	Klamath	w	OR 15	3.272	3.974	3.203	0.069	24%	2%
14	Klamath	w	OR 15	3.442	4.354	3.381	0.061	29%	2%
15	Klamath	w	OR 1	3.432	4.254	3.359	0.073	27%	2%
16	Klamath	w	OR 1	3.402	4.209	3.336	0.066	26%	2%
17	Klamath	w	OR 1	3.377	4.255	3.312	0.065	28%	2%
18	Klamath	w	OR 1	3.382	4.333	3.321	0.061	30%	2%

19	Klamath	w	OR 1	3.610	4.528	3.54	0.070	28%	2%
20	Klamath	w	OR 1	3.368	4.298	3.3	0.068	30%	2%
21	Klamath	w	OR 1	3.541	4.125	3.274	0.267	26%	8%
22	Klamath	w	OR 3	3.075	3.972	3.035	0.040	31%	1%
23	Klamath	w	OR3	3.055	3.990	3.021	0.034	32%	1%
24	Klamath	w	OR 3	3.032	3.950	2.992	0.040	32%	1%
25	Klamath	w	OR 3	3.040	3.962	2.998	0.042	32%	1%
26	Klamath	w	OR 3	2.984	3.897	2.941	0.043	33%	1%
27	Klamath	w	OR 3	2.964	3.907	2.924	0.040	34%	1%
28	Klamath	w	OR 3	2.892	3.769	2.861	0.031	32%	1%
29	Klamath	w	OR5	3.286	3.927	3.22	0.066	22%	2%
30	Klamath	w	OR5	3.284	3.934	3.21	0.074	23%	2%
31	Klamath	w	OR5	3.282	4.042	3.215	0.067	26%	2%
32	Klamath	w	OR5	3.258	4.069	3.197	0.061	27%	2%
33	Klamath	w	OR5	3.220	3.926	3.15	0.070	25%	2%
34	Klamath	w	OR5	3.148	3.829	3.08	0.068	24%	2%
35	Klamath	g	OR5	3.119	5.635	3.074	0.045	83%	1%
36	Klamath	g	OR 21	2.835	6.345	2.749	0.086	131%	3%
37	Klamath	g	OR 21	2.797	6.955	2.598	0.199	168%	7%
38	Klamath	g	OR 21	2.835	6.618	2.678	0.157	147%	6%
39	Klamath	g	OR 21	2.950	5.984	2.882	0.068	108%	2%
40	Klamath	g	OR 21	3.604	7.007	3.487	0.117	101%	3%
41	Klamath	g	OR 21	3.035	7.033	2.893	0.142	143%	5%
42	Klamath	g	OR 21	3.021	6.529	2.984	0.037	119%	1%
43	Klamath	g	OR 18	3.661	6.918	3.579	0.082	93%	2%

44	Klamath	g	OR 18	3.310	5.583	3.241	0.069	72%	2%
45	Klamath	g	OR 18	3.170	6.557	2.976	0.194	120%	6%
46	Klamath	g	OR 18	3.087	6.364	2.9	0.187	119%	6%
47	Klamath	g	OR 18	3.031	5.967	2.915	0.116	105%	4%
48	Klamath	g	OR 18	2.987	6.792	2.818	0.169	141%	6%
49	Klamath	g	OR 10	3.041	6.160	2.916	0.125	111%	4%
50	Klamath	g	OR 10	3.191	5.994	3.144	0.047	91%	1%
51	Klamath	g	OR 10	3.197	6.057	3.179	0.018	91%	1%
52	Klamath	g	OR 10	3.185	5.981	3.162	0.023	89%	1%
53	Klamath	g	OR 10	3.195	6.271	3.145	0.050	99%	2%
54	Klamath	g	OR 10	3.179	6.676	3.14	0.039	113%	1%
55	Klamath	g	OR 10	3.163	8.209	3.135	0.028	162%	1%
56	Klamath	g	OR 10	3.166	7.938	3.136	0.030	153%	1%
57	Klamath	g	OR 11	3.408	6.653	3.338	0.070	99%	2%
58	Klamath	g	OR 11	3.427	6.595	3.327	0.100	98%	3%
59	Klamath	g	OR 11	3.436	7.698	3.374	0.062	128%	2%
60	Klamath	g	OR 11	3.405	6.738	3.385	0.020	99%	1%
61	Klamath	g	OR 11	3.352	7.455	3.282	0.070	127%	2%
62	Klamath	g	OR 11	3.356	6.713	3.311	0.045	103%	1%
63	Klamath	g	OR 11	3.324	6.882	3.253	0.071	112%	2%
64	Klamath	g	OR 8	3.255	7.654	3.175	0.080	141%	2%
65	Klamath	g	OR 8	3.242	7.981	3.121	0.121	156%	4%
66	Klamath	g	OR 8	3.225	8.255	3.082	0.143	168%	4%
67	Klamath	g	OR 8	3.234	7.241	3.098	0.136	134%	4%
68	Klamath	g	OR 8	3.239	7.284	3.135	0.104	132%	3%

69	Klamath	b	OR 8	3.185	5.666	3.146	0.039	80%	1%
70	Klamath	b	OR 8	3.215	4.286	3.167	0.048	35%	1%
71	Klamath	b	OR 13	2.990	5.256	2.946	0.044	78%	1%
72	Klamath	b	OR 13	3.027	5.604	2.979	0.048	88%	2%
73	Klamath	b	OR 13	2.934	4.878	2.886	0.048	69%	2%
74	Klamath	b	OR 13	2.888	5.174	2.845	0.043	82%	1%
76	Cal	w	CA 29	2.912	3.886	2.877	0.035	35%	1%
77	Cal	w	CA 29	2.826	3.870	2.792	0.034	39%	1%
78	Cal	w	CA 29	2.850	3.660	2.83	0.020	29%	1%
79	Cal	w	CA 29	2.809	3.646	2.793	0.016	31%	1%
80	Cal	w	CA 29	2.914	5.049	2.891	0.023	75%	1%
81	Cal	w	CA 29	2.907	4.230	2.865	0.042	48%	1%
82	Cal	w	CA 29	2.965	3.933	2.918	0.047	35%	2%
83	Cal	w	CA 21	2.909	4.370	2.872	0.037	52%	1%
84	Cal	w	CA 21	3.433	4.164	3.345	0.088	24%	3%
85	Cal	w	CA 21	2.909	3.554	2.835	0.074	25%	3%
86	Cal	w	CA 21	3.334	4.251	3.247	0.087	31%	3%
87	Cal	w	CA 21	3.304	4.250	3.228	0.076	32%	2%
88	Cal	w	CA 21	2.878	3.666	2.816	0.062	30%	2%
89	Cal	w	CA 21	3.112	4.039	3.029	0.083	33%	3%
90	Cal	w	CA 7	3.066	4.090	3.046	0.020	34%	1%
91	Cal	w	CA 7	3.061	4.060	3.041	0.020	34%	1%
92	Cal	w	CA 7	3.032	4.118	3.011	0.021	37%	1%
93	Cal	w	CA 7	3.055	4.299	3.038	0.017	42%	1%
94	Cal	w	CA 7	3.190	4.195	3.174	0.016	32%	1%

95	Cal	w	CA 7	3.138	4.468	3.134	0.004	43%	0%
96	Cal	w	CA 7	3.052	3.969	3.04	0.012	31%	0%
97	Cal	w	CA 9	3.261	4.240	3.234	0.027	31%	1%
98	Cal	w	CA 9	3.163	4.016	3.135	0.028	28%	1%
99	Cal	w	CA 9	3.174	4.034	3.155	0.019	28%	1%
100	Cal	w	CA 9	3.184	3.906	3.164	0.020	23%	1%
101	Cal	w	CA 9	3.227	4.993	3.203	0.024	56%	1%
102	Cal	w	CA 9	3.205	4.003	3.185	0.020	26%	1%
103	Cal	w	CA 9	3.180	3.987	3.162	0.018	26%	1%
104	Cal	w	CA 20	3.570	4.798	3.556	0.014	35%	0%
105	Cal	w	CA 20	3.645	4.819	3.622	0.023	33%	1%
106	Cal	w	CA 20	3.707	4.717	3.702	0.005	27%	0%
107	Cal	w	CA 20	3.620	4.513	3.596	0.024	26%	1%
108	Cal	w	CA 20	3.627	5.038	3.597	0.030	40%	1%
109	Cal	w	CA 20	3.635	5.348	3.607	0.028	48%	1%
110	Cal	g	CA 20	3.799	7.972	3.738	0.061	113%	2%
111	Cal	g	CA 16	2.798	2.362	1.068	1.730	121%	62%
112	Cal	g	CA 16	2.760	5.499	1.71	1.050	222%	38%
113	Cal	g	CA 16	2.795	6.275	2.011	0.784	212%	28%
114	Cal	g	CA 16	2.747	5.129	1.694	1.053	203%	38%
115	Cal	g	CA 16	2.762	5.555	1.868	0.894	197%	32%
116	Cal	g	CA 16	2.767	2.039	1.075	1.692	90%	61%
117	Cal	g	CA 16	2.759	2.053	1.05	1.709	96%	62%
118	Cal	g	CA 27	2.966	5.841	2.963	0.003	97%	0%
119	Cal	g	CA 27	2.947	6.176	2.903	0.044	113%	1%

120	Cal	g	CA 27	2.939	5.778	2.91	0.029	99%	1%
121	Cal	g	CA 27	2.912	5.997	2.923	-0.011	105%	0%
122	Cal	g	CA 27	2.914	7.166	2.89	0.024	148%	1%
123	Cal	g	CA 27	3.029	7.186	2.999	0.030	140%	1%
124	Cal	g	CA 27	2.955	6.369	2.927	0.028	118%	1%
125	Cal	g	CA 25	3.058	6.781	3.02	0.038	125%	1%
126	Cal	g	CA 25	2.945	6.147	2.947	-0.002	109%	0%
127	Cal	g	CA 25	3.140	6.493	3.129	0.011	108%	0%
128	Cal	g	CA 25	3.323	7.116	3.31	0.013	115%	0%
129	Cal	g	CA 25	3.325	6.345	3.326	-0.001	91%	0%
130	Cal	g	CA 25	3.328	6.816	3.328	0.000	105%	0%
131	Cal	g	CA 25	3.518	7.472	3.514	0.004	113%	0%
132	Cal	g	CA 18	3.244	6.295	3.202	0.042	97%	1%
133	Cal	g	CA 18	3.233	7.526	3.199	0.034	135%	1%
134	Cal	g	CA 18	3.211	6.913	3.161	0.050	119%	2%
135	Cal	g	CA 18	3.199	6.404	3.16	0.039	103%	1%
136	Cal	g	CA 18	3.182	6.470	3.147	0.035	106%	1%
137	Cal	g	CA 18	3.202	6.389	3.152	0.050	103%	2%
138	Cal	g	CA 18	3.197	6.160	3.156	0.041	95%	1%
139	Cal	g	CA 28	2.814	7.150	2.48	0.334	188%	12%
140	Cal	g	CA 28	2.824	7.319	2.555	0.269	186%	10%
141	Cal	g	CA 28	2.842	6.681	2.638	0.204	153%	7%
142	Cal	g	CA 28	2.889	7.047	2.653	0.236	166%	8%
143	Cal	g	CA 28	2.916	4.750	2.921	-0.005	63%	0%
144	Cal	b	CA 28	2.890	4.732	2.892	-0.002	64%	0%

145	Cal	b	CA 28	2.913	6.454	2.82	0.093	129%	3%
146	Cal	b	CA 27	2.844	3.695	2.824	0.020	31%	1%
147	Cal	b	CA 27	2.902	3.874	2.885	0.017	34%	1%
148	Cal	b	CA 27	2.953	4.906	2.938	0.015	67%	1%
149	Cal	b	CA 27	2.899	3.882	2.874	0.025	35%	1%
151	Burns	g	ORB	3.077	4.259	3.033	0.044	40%	1%
152	Burns	g	ORB	3.121	4.525	3.076	0.045	47%	1%
153	Burns	g	ORB	3.127	3.896	3.066	0.061	27%	2%
154	Burns	g	ORB	3.182	3.946	3.124	0.058	26%	2%
155	Burns	g	ORB	3.223	7.071	3.173	0.050	123%	2%
156	Burns	g	ORB	3.517	6.663	3.464	0.053	92%	2%
158	Burns	g	ORB	3.195	7.757	3.152	0.043	146%	1%
159	Burns	g	ORB	3.180	6.852	3.101	0.079	121%	2%
160	Burns	g	ORB	3.200	7.383	3.18	0.020	132%	1%
161	Burns	g	ORB	3.261	7.966	3.245	0.016	145%	0%
162	Burns	g	ORB	3.614	6.589	3.555	0.059	85%	2%
163	Burns	g	ORB	3.247	6.285	3.218	0.029	95%	1%
164	Burns	g	ORB	3.415	6.832	3.388	0.027	102%	1%
165	Burns	g	ORB	3.340	6.548	3.234	0.106	102%	3%
166	Burns	g	ORB	3.363	6.023	3.361	0.002	79%	0%
167	Burns	g	ORB	3.318	6.295	3.32	-0.002	90%	0%
168	Burns	g	ORB	3.321	6.565	3.334	-0.013	97%	0%
169	Burns	g	ORB	3.335	6.513	3.357	-0.022	94%	-1%
170	Burns	g	ORB	3.380	7.472	3.38	0.000	121%	0%
171	Burns	g	ORB	3.483	8.363	3.384	0.099	147%	3%

172	Burns	g	ORB	2.929	7.103	2.854	0.075	149%	3%
173	Burns	g	ORB	2.981	6.687	2.976	0.005	125%	0%
174	Burns	g	ORB	2.924	6.021	2.926	-0.002	106%	0%
175	Burns	g	ORB	3.036	7.766	2.844	0.192	173%	6%
176	Burns	g	ORB	2.870	7.496	2.735	0.135	174%	5%
177	Burns	g	ORB	2.897	7.550	2.781	0.116	171%	4%
178	Burns	g	ORB	2.878	7.017	2.705	0.173	159%	6%
179	Burns	g	ORB	3.002	6.500	2.951	0.051	120%	2%
180	Burns	g	ORB	3.065	5.702	3.059	0.006	86%	0%
181	Burns	g	ORB	3.082	5.579	3.072	0.010	82%	0%
182	Burns	g	ORB	3.187	6.404	3.18	0.007	101%	0%
183	Burns	g	ORB	3.200	6.397	3.143	0.057	104%	2%
184	Burns	g	ORB	3.125	5.753	3.132	-0.007	84%	0%
185	Burns	g	ORB	3.207	6.271	3.187	0.020	97%	1%
186	Burns	w	ORB	4.271	5.397	4.218	0.053	28%	1%
187	Burns	w	ORB	3.470	4.297	3.411	0.059	26%	2%
188	Burns	w	ORB	3.620	4.410	3.567	0.053	24%	1%
189	Burns	w	ORB	3.512	4.504	3.466	0.046	30%	1%
190	Burns	w	ORB	3.578	4.385	3.536	0.042	24%	1%
191	Burns	w	ORB	3.576	4.522	3.525	0.051	28%	1%
192	Burns	w	ORB	3.708	5.169	3.651	0.057	42%	2%
193	Burns	w	ORB	2.963	3.992	2.919	0.044	37%	1%
194	Burns	w	ORB	2.998	4.141	2.955	0.043	40%	1%
195	Burns	w	ORB	2.993	3.970	2.958	0.035	34%	1%
196	Burns	w	ORB	2.976	3.769	2.94	0.036	28%	1%

197	Burns	w	ORB	2.938	3.731	2.888	0.050	29%	2%
198	Burns	w	ORB	2.956	3.740	2.898	0.058	29%	2%
199	Burns	w	ORB	2.988	3.711	2.934	0.054	26%	2%
200	Burns	w	ORB	2.432	3.298	2.421	0.011	36%	0%
201	Burns	w	ORB	2.436	3.243	2.425	0.011	34%	0%
202	Burns	w	ORB	2.538	3.089	2.495	0.043	24%	2%
203	Burns	w	ORB	2.576	3.149	2.529	0.047	25%	2%
204	Burns	w	ORB	2.421	2.913	2.39	0.031	22%	1%
205	Burns	w	ORB	2.363	2.933	2.344	0.019	25%	1%
206	Burns	w	ORB	2.457	3.144	2.428	0.029	29%	1%
207	Burns	w	ORB	3.063	3.872	2.982	0.081	30%	3%
208	Burns	w	ORB	3.132	3.765	3.045	0.087	24%	3%
209	Burns	w	ORB	3.018	3.696	2.955	0.063	25%	2%
210	Burns	w	ORB	3.045	3.739	2.988	0.057	25%	2%
211	Burns	w	ORB	3.089	3.767	3.021	0.068	25%	2%
212	Burns	w	ORB	3.030	3.758	2.96	0.070	27%	2%
213	Burns	w	ORB	2.989	3.716	2.91	0.079	28%	3%
214	Burns	w	ORB	2.919	3.611	2.873	0.046	26%	2%
215	Burns	w	ORB	3.125	3.827	3.069	0.056	25%	2%
216	Burns	w	ORB	3.142	3.809	3.082	0.060	24%	2%
217	Burns	w	ORB	2.968	3.645	2.921	0.047	25%	2%
218	Burns	w	ORB	2.880	3.526	2.823	0.057	25%	2%
219	Burns	w	ORB	2.869	3.539	2.817	0.052	26%	2%
220	Burns	b	ORB	3.124	4.338	3.064	0.060	42%	2%
221	Burns	b	ORB	3.863	5.402	3.782	0.081	43%	2%

222	Burns	b	ORB	3.776	4.733	3.706	0.070	28%	2%
223	Burns	b	ORB	2.458	3.528	2.42	0.038	46%	2%
224	Burns	b	ORB	3.007	2.821	2.914	0.093	-3%	3%
225	Burns	b	ORB	3.354	4.253	3.243	0.111	31%	3%
226	Idaho	b	ID	3.108	4.996	3.082	0.026	62%	1%
227	Idaho	b	ID	3.250	5.630	3.226	0.024	75%	1%
228	Idaho	b	ID	3.260	4.139	3.224	0.036	28%	1%
229	Idaho	b	ID	3.175	3.977	3.16	0.015	26%	0%
230	Idaho	b	ID	3.155	4.031	3.118	0.037	29%	1%
231	Idaho	b	ID	3.125	4.213	3.093	0.032	36%	1%
232	Idaho	w	ID	3.244	5.788	3.257	-0.013	78%	0%
233	Idaho	w	ID	3.371	5.725	3.373	-0.002	70%	0%
234	Idaho	w	ID	3.396	4.290	3.412	-0.016	26%	0%
235	Idaho	w	ID	3.423	4.354	3.428	-0.005	27%	0%
236	Idaho	w	ID	3.287	4.227	3.279	0.008	29%	0%
237	Idaho	w	ID	3.321	4.259	3.334	-0.013	28%	0%
238	Idaho	w	ID	3.442	4.663	3.435	0.007	36%	0%
239	Idaho	w	ID	3.449	4.539	3.441	0.008	32%	0%
240	Idaho	w	ID	2.928	3.781	2.91	0.018	30%	1%
241	Idaho	w	ID	2.997	3.755	2.967	0.030	27%	1%
242	Idaho	w	ID	2.892	3.534	2.877	0.015	23%	1%
243	Idaho	w	ID	2.924	3.554	2.902	0.022	22%	1%
244	Idaho	w	ID	2.845	3.605	2.829	0.016	27%	1%
245	Idaho	w	ID	2.901	3.653	2.867	0.034	27%	1%
246	Idaho	w	ID	2.851	3.531	2.832	0.019	25%	1%

247	Idaho	w	ID	3.416	4.290	3.42	-0.004	25%	0%
248	Idaho	w	ID	4.045	4.978	3.995	0.050	25%	1%
249	Idaho	w	ID	3.440	4.277	3.425	0.015	25%	0%
250	Idaho	w	ID	4.074	5.183	3.983	0.091	30%	2%
251	Idaho	w	ID	3.461	4.619	3.426	0.035	35%	1%
252	Idaho	w	ID	4.172	5.329	4.065	0.107	31%	3%
253	Idaho	w	ID	3.440	4.284	3.423	0.017	25%	0%
254	Idaho	w	ID	3.256	4.007	3.246	0.010	23%	0%
255	Idaho	w	ID	3.148	3.837	3.14	0.008	22%	0%
256	Idaho	w	ID	3.157	3.969	3.166	-0.009	25%	0%
257	Idaho	w	ID	3.185	3.946	3.181	0.004	24%	0%
258	Idaho	w	ID	3.184	3.890	3.18	0.004	22%	0%
259	Idaho	w	ID	3.173	4.032	3.169	0.004	27%	0%
260	Idaho	w	ID	3.193	5.082	3.277	-0.084	55%	-3%
261	Idaho	w	ID	3.300	4.214	3.311	-0.011	27%	0%
262	Idaho	w	ID	3.370	4.363	3.376	-0.006	29%	0%
263	Idaho	w	ID	3.235	4.320	3.246	-0.011	33%	0%
264	Idaho	w	ID	3.323	4.254	3.333	-0.010	28%	0%
265	Idaho	w	ID	3.382	4.370	3.35	0.032	30%	1%
266	Idaho	g	ID	3.471	6.049	3.394	0.077	78%	2%
267	Idaho	g	ID	3.458	5.847	3.409	0.049	72%	1%
268	Idaho	g	ID	2.992	5.981	1.959	1.033	205%	35%
269	Idaho	g	ID	3.010	6.872	2.317	0.693	197%	23%
270	Idaho	g	ID	3.123	7.384	2.53	0.593	192%	19%
271	Idaho	g	ID	3.182	7.561	2.612	0.570	189%	18%

272	Idaho	g	ID	3.225	7.953	2.819	0.406	182%	13%
273	Idaho	g	ID	3.201	8.234	2.876	0.325	186%	10%
274	Idaho	g	ID	3.183	7.679	2.706	0.477	184%	15%
275	Idaho	g	ID	3.197	5.911	3.121	0.076	89%	2%
276	Idaho	g	ID	3.341	6.767	2.465	0.876	175%	26%
277	Idaho	g	ID	3.209	5.896	2.955	0.254	100%	8%
278	Idaho	g	ID	3.293	7.098	3.199	0.094	122%	3%
279	Idaho	g	ID	3.233	6.756	3.178	0.055	113%	2%
280	Idaho	g	ID	2.872	4.591	2.818	0.054	63%	2%
281	Idaho	g	ID	4.205	8.318	3.968	0.237	110%	6%
282	Idaho	g	ID	3.430	7.144	3.005	0.425	138%	12%
283	Idaho	g	ID	4.553	7.695	4.164	0.389	85%	9%
284	Idaho	g	ID	3.185	5.800	3.15	0.035	84%	1%
285	Idaho	g	ID	2.800	5.051	2.73	0.070	85%	2%
286	Idaho	g	ID	3.263	6.833	3.208	0.055	113%	2%
287	Idaho	g	ID	3.521	6.826	3.448	0.073	98%	2%
288	Idaho	g	ID	3.442	7.900	2.869	0.573	175%	17%
289	Idaho	g	ID	3.277	7.501	3.211	0.066	134%	2%
290	Idaho	g	ID	3.566	6.155	3.499	0.067	76%	2%
291	Idaho	g	ID	3.358	6.537	3.195	0.163	105%	5%
292	Idaho	g	ID	3.279	6.397	3.093	0.186	107%	6%
293	Idaho	g	ID	3.206	6.556	3.029	0.177	116%	6%
294	Idaho	g	ID	3.320	6.805	3.226	0.094	111%	3%
295	Idaho	g	ID	2.841	5.750	2.703	0.138	113%	5%
296	Idaho	g	ID	3.436	7.173	3.374	0.062	113%	2%

297	Idaho	g	ID	3.638	7.643	3.586	0.052	113%	1%
298	Idaho	g	ID	3.590	7.232	3.397	0.193	113%	5%
299	Idaho	g	ID	3.465	6.497	3.307	0.158	96%	5%

A.7 Related Documents: Proposal

Proposal.pdf