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

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Introduction

As previously reported[2,3,4], wood of western juniper, *Juniperus occidentalis* Hook, was collected from nine locations throughout its range in northern California, south-central and central Oregon. Trees for testing were selected, in part, by their stem form and ability to provide useable test material. Trees of unusual size and form were not, however, selected for test trees, but were bypassed in favor of those individuals that best represented the typical size and form of the potential commercially-sized trees in a particular area. The locations were chosen on the basis of the anecdotally-reported differences in stem form and perceived strength and durability from the eight geographic areas. Each general area, Alturas, California, and Klamath Falls, Sisters and Burns regions of Oregon, were chosen for the volume of standing juniper, favorable tree form and size, and presence of stands showing either relatively modest or large growth rates and stem forms.

A total of 42 trees were selected and harvested, and nine-foot bolts bucked and shipped to the mechanical properties laboratory at the University of Montana School of Forestry. Specimens were extracted and tested, according to ASTM Standard D-143-95, "Standard Methods of Testing Small Clear Specimens of Timber". Interim results have been periodically reported to enable the wood products industry in the areas where western juniper grows to gain a more complete picture of the mechanical properties of this species, as well as information on its specific gravity and shrinkage from the green condition. Data for specific properties have been distributed to users and potential users of the wood of this species for a variety of products, including house logs, structural timbers, glued panels, and composite products.

This report updates the information already disseminated, adding data from additional testing, and refining the previous data for the various locations. For this update, mechanical properties and specific gravity data are reported as means for all trees and locations. More than 3,500 tests of a projected total of over 4800 tests (green and dry condition) have been performed for seven strength and two physical properties.

Some mean values have changed, however, due to the within-sample variation, the changes generally, have not been statistically significant. In some cases, the data set was revised to include specimens from the bottom section of the tree, enabling a larger quantity of specimens to be tested for a particular tree. More precise evaluation of deflectometers used in early testing also provided changes in strain values in the static bending and compression MOE evaluations. The process of testing and data compilation is ongoing, and further additions and refinements in the data set will be forthcoming.

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[2] Mechanical Properties of Western Juniper. Interim Report #1, 4/94.

[3] Mechanical Properties of Western Juniper. Interim Report #2, 9/98.

[4] Findings in the Determination of the Mechanical Properties of the Wood of Western Juniper (*Juniperus occidentalis* Hook.) Interim Report #3, 9/01.

Comparison Species

References are made to comparison species for which western juniper might be a suitable substitute. These species are western redcedar, incense-cedar, eastern redcedar and in some cases ponderosa pine and Douglas-fir. Potential uses include both structural and non-structural applications. Generalized comparisons and suggestions for possible products and uses of western juniper are made.

Range of Strength Values

A range of values reflecting differences within the species has been thus far obtained. One explanation for this is that larger variability would be expected due to the wide range of growing conditions represented by the samples (forty trees from eight areas of California and Oregon). Western juniper grows over a large geographic area on a variety of xeric and mesic sites. The combination of adaptability and genetic heritance play complicated roles in determining wood properties. The further evaluation reported here has decreased the variability seen between the stands, but the wide range of values shows the inherent variability in physical and mechanical properties of this species as grown on a variety of sites throughout its commercial range.

Decay Resistance

It must be noted that logs stored in conditions designed to maintain a high wood moisture content for fifteen years have shown no biological deterioration. The bark is still firmly attached to the log and even the sapwood is still free from decay. The inherent decay resistance of juniper, especially the heartwood, is an advantage in applications which may require ground contact, such as some post or pole products, or outdoor structures, such as raised bed planters.

Static Bending

The results of the continuing static bending tests displayed in Table 1 show western juniper to be a very flexible wood with modest strength. Compared to other similar softwoods, such as eastern redcedar, western redcedar, northern white-cedar and incense-cedar, western juniper has lower green and dry values for Modulus of Elasticity (MOE) (Tables 6 and 7). While stiffness is desirable in most beam applications, western juniper's inherent flexibility and comparatively high bending strength may be beneficial in those structural applications where flexibility prior to breaking, such as highway signage, is desirable.

Table 6 shows that unseasoned Modulus of Rupture (MOR) values are either slightly lower than or approximately equal to the comparison species. The wood strength compares favorably though when dried to 12%. Again, high flexibility and moderate strength may allow its use in some structural applications where spans are kept small in order to moderate the beam's deflection. Western juniper could also see use as manufactured house logs, where bending stresses are generally low (wall logs above windows and doors) due to the relatively small spans and large sizes of the logs, or not a factor (wall logs stressed in side-grain compression). Recently-completed static bending tests of material from the unused bottom logs is included in the average values shown in Table 1.

Table 1: Static Bending (all locations)[5]

Location	MOE_{gn} (psi)	$MOE_{12\%}$ (psi)	MORgn (psi)	$MOR_{12\%}$ (psi)
California #1 (Alturas)	509,000 +2.6%	735,000 -8.6%	5,821 +6.7%	9,423 +7.6%
California #2 (Modoc)	519,000 +3.6%	749,000 -7.6%	5,948 +5.8%	9,104 +13.3%
Klamath #1	496,000 +1%	711,000 -13%	6,037 +4.7%	9,202 +8.5%
Klamath #2	499,000 -1%	681,000 -6.5%	5,850 -3.4%	9,425 +7.7%
Sisters #1	540,000 +2.0%	744,000 -7.9%	6,080 +3.2%	9,603 +8.3%
Sisters #2	502,000 +2.7%	681,000 -13.9%	5,540 +3.6%	9,259 +15.9%
Burns #1	529,000 +3.5%	713,000 -10.9%	5,878 +4.5%	9,754 +9.5%
Burns #2	520,000 +4%	687,000 -12.4%	5,489 +5.7%	9,062 +9.6%
Location Means	514,000 +2.0%	713,000 -9.9%	5,831 +3.8%	9,354 +10%

Shear

Western juniper typically displays shear values that are approximately equal-to or greater-than the comparison species. Noted, however, was a low value for shear in the radial plane. Relatively low radial shear strength may account for western juniper's propensity to split very cleanly in the radial direction and develop numerous, small seasoning checks when subjected to rapid initial drying. Its relatively high tangential shear strength, however, offsets these values, and the composite shear strength, tabulated below, shows it to be approximately equal to the composite shear strength of the comparison species (see Tables 6 and 7). Recently-completed tests of material from the unused bottom logs is being compiled and will not likely change the values a structurally-significant amount.

Table 2: Shear Parallel-to-the-Grain (all locations) [6]

[5] Data include additional tests for all locations conducted since previous report. Some test data for poor quality specimens were replaced with values for high quality specimens coming from additional trees and test sticks.
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Location	Radial Shear gn (psi)	Radial Shear 12% (10^6 psi)	Tangential Shear gn (psi)	Tangential Shear 12% (psi)
California #1 (Alturas)	790	1165	1005	1485
California #2 (Modoc)	805	1105	1040	1460
Klamath #1	770	1060	1020	1525
Klamath #2	785	1020	995	1390
Sisters #1	820	1095	1190	1615
Sisters #2	735	985	985	1470
Burns #1	795	1140	1180	1495
Burns #2	810	1085	1100	1390
Mean of Location Means	790	1080	1065	1480

Compression

Maximum crushing strength indicates the maximum allowable loading parallel-to-grain, and is often used to evaluate wood to be used with large bearing loads, such as poles, piles and posts. The values for western juniper are approximately equal to the comparison species, with the exception of eastern redcedar (*Juniperus virginiana*), which possesses higher values for both green and dry conditions (see Tables 6 and 7). Recently-completed tests of material from the unused bottom logs is being compiled and will not likely change the values a structurally-significant amount.

Table 3: Compression Parallel-to-Grain—Maximum Crushing Strength (all locations) [7]

Location	Compression Parallel $_{gn}$ (psi)	Compression Parallel $_{12\%}$ (psi)
California #1 (Alturas)	2440	5020
California #2 (Modoc)	3115	5175
Klamath #1	2760	4985
Klamath #2	2555	5545
Sisters #1	2520	4995
Sisters #2	2810	5035
Burns #1	3065	5660
Burns #2	2405	4935
Mean of Location Means	2710	5170

[7] Data include additional tests for all locations conducted since previous report. Some test data for poor quality specimens were replaced with values for high quality specimens coming from additional trees and test sticks.

Tension

Tension parallel-to-grain is a strength property that is important in bending members as well as pure tension members, such as truss members. While the values for bending strength, MOE and MOR, are generally used for most applications, the tension value obtained in this test is necessary to provide a valuable database for future work. Data for pure tension strength are reported for only a few species, including four comparison species. Results to date indicate that western juniper has tension strength values lower than the comparison species (Tables 6 and 7). It is noted that the green strength values are being reevaluated and additional dry specimens have been prepared for additional testing. Modifications have been made to the standard specimen in the form of a failure zone of larger area in order to to include at least 5 growth rings. Several of the previously-tested specimens contained only one growth ring due to the small cross section, and, hence, had especially low values compared to the specimens that contained 3 or more rings. The specimens tested at 12% moisture content were prepared to have at least 3-5 growth rings included in the fracture area of the specimen, and offer a more realistic estimate of this property. Since the supply of logs in the never-dried condition is exhausted, these new specimens will be tested after resaturation by light vacuum immersion. While the use of resaturated test specimens is not found in ASTM Standard D-143, this exercise will help present a clearer picture of the pure tension strength than that offered by previous tests that included a minimum number of rings.

Tension perpendicular-to-grain is a measure of the resistance of wood to forces acting across the grain that tend to split or pull apart a member. Values presented in Table 4 are averages of radial and tangential tests. Tables 6 and 7 show that western juniper has green and dry tension perpendicular-to-grain values approximately equal to those of the comparison species. Results of additional tests from auxilliary sticks from the lower sections of the trees are being compiled and will complete the test matrix. Determination of the final coefficient of variation will likely show these values to change, but to a relatively minor extent.

Table 4: Tension Parallel and Perpendicular-to-the-Grain (all locations)[8]

Location	Tension Parallel $_{gn}$ (psi)	Tension Parallel $_{12\%}$ (psi)	Tension Perpendicular $_{gn}$ (psi)	Tension Perpendicular $_{12\%}$ (psi)
California #1 (Alturas)	4325	6680	285	510
California #2 (Modoc)	4540	6940	265	505
Klamath #1	4160	6460	270	470
Klamath #2	4425	6820	260	455
Sisters #1	4365	6550	250	420
Sisters #2	4060	6275	260	460
Burns #1	4560	7060	290	510
Burns #2	4510	6580	275	505
Mean of Location Means	4370	6670	270	480

[8] Data include additional tests for all locations conducted since previous report. Some test data for poor quality specimens were replaced with values for high quality specimens coming from additional trees and test sticks.

Hardness

Hardness tests measure the resistance of wood to denting and wear. The test involves measuring the force needed to embed a 0.44"-diameter ball 0.22" in the radial, tangential and transverse (end grain) surfaces of a test prism. Table 5 presents the average of the radial and tangential values as "side grain", as well the transverse grain for both the green and dry conditions. Results in Tables 5,6 and 7 show that western juniper has side hardness values equal to or greater than the comparison species, with the exception of eastern redcedar. Table 6 also shows that western juniper has side hardness values that compare favorably with strong western and eastern softwoods, including Douglas-fir and southern yellow pine.

Table 5: Side and End-Grain Hardness (all locations) [9] [10]

Location	Side Grain $_{gn}$ (lbs.)	Side Grain $_{12\%}$ (lbs.)	Transverse Grain $_{gn}$ (lbs.)	Transverse Grain $_{12\%}$ (lbs.)
California #1 (Alturas)	505	670	825	1020
California #2 (Modoc)	495	655	845	1115
Klamath #1	550	685	810	1055
Klamath #2	525	690	855	1080
Sisters #1	490	660	795	1100
Sisters #2	520	645	815	1030
Burns #1	550	680	840	1050
Burns #2	530	700	800	1120
Mean of Location Means	520	675	825	1070

[9] Side grain values are averages of radial and tangential

[10] Data include additional tests for all locations conducted since previous report. Some test data for poor quality specimens were replaced with values for high quality specimens coming from additional trees and test sticks.

Table 6. Strength Values for Western Juniper and Comparison Species in the Green Condition.

Strength Property	western juniper	incense-cedar	Port Orford-cedar	eastern redcedar	western redcedar	ponderosa pine	Douglas-fir (interior west)
MOR (psi)	5,831	6,200	6,600	7,000	5,200	5,100	7,700
MOE (10^6 psi)	0.514	0.840	1.300	0.650	0.940	1.000	1.500
Shear (psi)	928	830	840	1,010	770	700	940
Compression Parallel (psi)	2,710	3,150	3,140	3,570	2,770	2,450	3,870
Tension Parallel (psi)	4,370	NA	11,400	NA	6,600	8,400	15,600[11]
Tension Perpendicular (psi)	270	280	180	330	230	310	290
Hardness, side grain (lbs.)	520	390	380	650	260	320	510
Hardness, end grain (lbs.)	825	NA	NA	NA	NA	NA	NA

[11] This value is for Interior North Douglas-fir

Table 7. Strength Values for Western Juniper and Comparison Species at 12% Moisture Content.

Strength Property	western juniper	incense-cedar	Port Orford-cedar	eastern redcedar	western redcedar	ponderosa pine	Douglas-fir[12]
MOR (psi)	9,354	8,000	12,700	8,800	7,500	9,400	12,600
MOE (10^6 psi)	0.713	1.040	1.700	0.880	1.110	1.290	1.830
Shear (psi)	1,280	880	1,370	NA	990	1,130	1,290
Compression Parallel (psi)	5,170	5,200	6,250	6,020	4,560	5,320	7,430
Tension[13] Parallel (psi)	6,670	NA	12,900	NA	7,500	9,500	17,600
Tension Perpendicular (psi)	480	270	400	NA	220	420	290
Hardness, side grain[14] (lbs.)	675	470	630	900	350	460	510
Hardness, end grain (lbs.)	1,070	NA	NA	NA	NA	NA	NA

[12] Values for Douglas-fir are for Interior North Douglas-fir.
[13] Values for 12% moisture content are estimated to be 13% higher than those for the green condition in accordance with the Wood Handbook, Ag. Handbook #72.
[14] Values for side hardness are the averages of values for the radial and tangential faces.