# Interim Report

# New Findings in the Determination of the Mechanical Properties of the Wood of Western Juniper (*Juniperus occidentalis* Hook.)

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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 based on 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.

Forty-two trees were selected and harvested, and 77 nine-foot bolts bucked and shipped to the University of Montana Wood Science Laboratory, an International Accreditation Service accredited test facility located at the University of Montana College of Forestry (IAS Testing Lab #291). 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 averages for all trees and locations. More than 4,000 tests and measurements of a projected total of over 4800 procedures (green and dry condition) have been performed for seven strength and two physical properties.

Some mean values have changed, however, due to the significant within-sample variation, the changes generally, have not been statistically significant. In some cases, the data set was revised to separate data from samples containing small defects such as tiny knots, suspected compression wood, isolated areas of incipient decay, and cross-grain in excess of 1:20. Testing notes were used to determine if data came from questionable material (not all broken specimens are still available for reinspection). The process of testing 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] Mechanical Properties of Western Juniper. 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. In addition, when evaluated with the comparison species, this natural range of strength values shows up as a comparatively large standard deviation. When the remaining twenty percent of the tests are completed, this large variability will most likely equalize all but individual extreme values.

## Static Bending

The results of the static bending tests displayed in Table 1 show western juniper to be a very flexible wood with modest bending 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 may be beneficial in those structural applications where flexibility prior to breaking, such as posts for highway signage, is desirable. Additionally, the inherent decay resistance of juniper, especially the heartwood, is an advantage in applications that may require ground contact, such as some post or pole products, or outdoor structures, such as raised-bed planters.

Table 6 shows that unseasoned Modulus of Rupture (MOR) values are either moderately lower than or nearly equal to the comparison species. The wood strength continues these relationships when dried to 12%. Again, high flexibility and only 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 short spans above windows and doors and large sizes of the logs, or not a factor (wall logs stressed in side-grain compression).

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

| Location | $MOE_{gn}$ (psi) | $MOE_{12\%}$ (psi) | MORgn (psi) | $MOR_{12\%}$ (psi) |
|---|---|---|---|---|
| California #1 (Alturas) | 496,000 | 817,000 | 5,455 | 8,870 |
| California #2 (Modoc) | 501,000 | 814,000 | 5,620 | 8,064 |
| Klamath #1 | 486,000 | 802,000 | 5,765 | 8,480 |
| Klamath #2 | 504,000 | 728,000 | 6,065 | 8,750 |
| Sisters #1 | 529,000 | 808,000 | 5,890 | 8,865 |
| Sisters #2 | 489,000 | 791,000 | 5,350 | 7,990 |
| Burns #1 | 511,000 | 803,000 | 5,625 | 8,980 |
| Burns #2 | 502,000 | 789,000 | 5,215 | 8,350 |
| Average of Location Averages | 502,000 | 794,000 | 5,620 | 8,540 |

[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.**

## Shear

Western juniper typically displays combination radial and tangential shear values that are comparable to the comparison species. Noted during this and other testing regimes, however, was a low value for shear in the radial plane. This comparatively 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).

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

| Location | Radial Shear $_{gn}$ (psi) | Radial Shear $_{12\%}$ ($10^6$ psi) | Tangential Shear $_{gn}$ (psi) | Tangential Shear $_{12\%}$ (psi) |
|---|---|---|---|---|
| California #1 (Alturas) | 790 | 1,165 | 1,005 | 1,485 |
| California #2 (Modoc) | 805 | 1,105 | 1,040 | 1,460 |
| Klamath #1 | 770 | 1,060 | 1,020 | 1,565 |
| Klamath #2 | 785 | 1,020 | 995 | 1,390 |
| Sisters #1 | 820 | 1,095 | 1,190 | 1,615 |
| Sisters #2 | 735 | 985 | 985 | 1,470 |
| Burns #1 | 795 | 1,140 | 1,180 | 1,495 |
| Burns #2 | 810 | 1,085 | 1,100 | 1,440 |
| Average of Location Averages | 790 | 1,080 | 1,065 | 1,490 |

**[6] 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.**

## Compression

Maximum crushing strength is the indicator of the maximum allowable loading parallel-to-grain, and is often used to evaluate wood to be used with large parallel-to-grain 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) during compression parallel to the grain.

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

| Location | Compression Parallel $_{gn}$ (psi) | Compression Parallel $_{12\%}$ (psi) |
|---|---|---|
| California #1 (Alturas) | 2,440 | 5,090 |
| California #2 (Modoc) | 3,115 | 5,140 |
| Klamath #1 | 2,760 | 4,985 |
| Klamath #2 | 2,555 | 5,545 |
| Sisters #1 | 2,520 | 4,995 |
| Sisters #2 | 2,810 | 5,035 |
| Burns #1 | 3,065 | 5,530 |
| Burns #2 | 2,405 | 5,015 |
| Average of Location Averages | 2,710 | 5,115 |

## 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 strength properties related to 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 in the Wood Handbook[8] for only a few species, including four comparison species. Test results to date for western juniper show tension strength values generally lower than the comparison species (Tables 6 and 7). It is noted that the dry strength values are being reevaluated due to the possible effects of small defects, and

[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.**

[8] Wood Handbook: Wood as an Engineering Material. Forest Products Society, Madison Wisconsin. 2001.

additional specimens prepared for additional testing. Modifications to the standard specimen are planned in order to enlarge the tested area to include at least 5 growth rings. Several of the specimens contained only one growth ring due to the small cross section, and, hence, had especially low values compared to the specimens that contained three 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.

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. Determination of the final coefficient of variation will likely show these values to not be significantly different.

**Table 4: Tension Parallel and Perpendicular-to-the-Grain (all locations)[9]**

| Location | Tension Parallel $_{gn}$ (psi) | Tension Parallel $_{12\%}$ (psi) | Tension Perpendicular $_{gn}$ (psi) | Tension Perpendicular $_{12\%}$ (psi) |
|---|---|---|---|---|
| California #1 (Alturas) | 4,325 | 6,760 | 285 | 510 |
| California #2 (Modoc) | 4,540 | 6,860 | 265 | 505 |
| Klamath #1 | 4,160 | 6,460 | 270 | 480 |
| Klamath #2 | 4,425 | 6,820 | 260 | 455 |
| Sisters #1 | 4,365 | 6,550 | 250 | 400 |
| Sisters #2 | 4,060 | 6,275 | 260 | 445 |
| Burns #1 | 4,560 | 6,940 | 290 | 525 |
| Burns #2 | 4,510 | 6,050 | 275 | 480 |
| Average of Location Averages | 4,370 | 6,670 | 270 | 475 |

[9] **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) [10] [11]**

| Location | Side Grain $_{gn}$ (lbs.) | Side Grain $_{12\%}$ (lbs.) | Transverse Grain $_{gn}$ (lbs.) | Transverse Grain $_{12\%}$ (lbs.) |
|---|---|---|---|---|
| California #1 (Alturas) | 505 | 645 | 825 | 995 |
| California #2 (Modoc) | 495 | 665 | 845 | 1,135 |
| Klamath #1 | 550 | 685 | 810 | 1,055 |
| Klamath #2 | 525 | 690 | 855 | 1,080 |
| Sisters #1 | 490 | 660 | 795 | 1,100 |
| Sisters #2 | 520 | 645 | 815 | 1,030 |
| Burns #1 | 550 | 655 | 840 | 1,005 |
| Burns #2 | 530 | 680 | 800 | 1,095 |
| Average of Location Averages | 520 | 665 | 825 | 1,060 |

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

[11] 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) | 5,620 | 6,200 | 6,600 | 7,000 | 5,200 | 5,100 | 7,700 |
| MOE ($10^6$ psi) | 0.502 | 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[12] |
| 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 |

[12] 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[13] |
|---|---|---|---|---|---|---|---|
| MOR (psi) | 8,540 | 8,000 | 12,700 | 8,800 | 7,500 | 9,400 | 12,600 |
| MOE ($10^6$ psi) | 0.794 | 1.040 | 1.700 | 0.880 | 1.110 | 1.290 | 1.830 |
| Shear (psi) | 1,285 | 880 | 1,370 | NA | 990 | 1,130 | 1,290 |
| Compression Parallel (psi) | 5,115 | 5,200 | 6,250 | 6,020 | 4,560 | 5,320 | 7,430 |
| Tension[14] Parallel (psi) | 6,670 | NA | 12,900 | NA | 7,500 | 9,500 | 17,600 |
| Tension Perpendicular (psi) | 475 | 270 | 400 | NA | 220 | 420 | 290 |
| Hardness, side grain[15] (lbs.) | 665 | 470 | 630 | 900 | 350 | 460 | 510 |
| Hardness, end grain (lbs.) | 1,060 | NA | NA | NA | NA | NA | NA |

[13] Values for Douglas-fir are for Interior North Douglas-fir.
[14] 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.
[15] Values for side hardness are the average of values for the radial and tangential faces.