Properties of the Western Juniper (*Juniperus occidentalis*) Strandboard

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This work investigated the feasibility of using western juniper (*Juniperus occidentalis*) as a material to manufacture oriented strandboard (OSB) panels. Four different material combinations of juniper sapwood, heartwood, and fibrous bark were compared with regular southern yellow pine (*Pinus* sp.) strands. The OSB panels were made at an oven-dry density of 560 kg/m^3. One pine control panel was also made at a higher density of 650 kg/m^3 with a 5% addition of phenol formaldehyde (PF) resin and a 0.5% addition of wax. The single-layer panels were formed with a hot press, and the physical and mechanical properties were tested according to the ASTM standard D1037 (2020). The testing indicated that western juniper is a potential material for manufacturing of OSB panels. The properties of the juniper panels were equivalent or slightly better than those of the southern yellow pine panels at the same density level, except for the modulus of elasticity (MOE). The lower density of the juniper OSB panels may have benefits in construction applications and can decrease transportation costs.

Keywords: Western juniper; Strandboard, OSB, Physical properties; Mechanical properties; Screw withdrawal

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INTRODUCTION

Western juniper (*Juniperus occidentalis*) is an invasive tree species that is widespread in the western United States. Western juniper woodlands are in Oregon, California, Washington, Idaho, and Nevada (Bedell *et al.* 1993; Swan 1995). These woodlands occupy approximately 3.4 million hectares, and the majority (over 2.6 million hectares) are in Oregon (Azuma *et al.* 2005; Miyamoto 2017; Eastern Oregon Agricultural Research Center 2020). The highest concentration of western juniper woodlands is in central and eastern Oregon, with approximately 2 million hectares (Miller *et al.* 2005). The standing timber volume in Oregon, California, and Idaho is 18 million m^3, 6 million m^3, and 3.7 million m^3, respectively (Miyamoto 2017). Juniper trees are quite short compared to other Pacific Northwest conifer species, and the logs are highly tapered. The wood has an average density of 497 kg/m^3 and aromatic rose-red heartwood and yellow sapwood (Panshin and de Zeeuw 1980; Swan and Connolly 1998). Juniper heartwood is highly decay-resistant, and it is typically used as fencing, decking, and landscape timbers (Highley 1995; Swan 1995; Morrell *et al.* 1999; Morrell 2011). Design values for juniper lumber have been developed (Miyamoto *et al.* 2018), and there are now 6,000 m^3 of lumber produced every year. Due to the tapered structure of the logs, lumber production generates significant volumes of residues, such as slabs, edgings, and trimmer ends. Juniper harvest operations also result in a substantial volume of non-merchantable logs. These residues are primarily used as firewood or they are discarded.

Southern yellow pine species (primarily *Pinus taeda*, *P. palustris*, *P. elliottii*, and *P. echinata*) with average density 550 kg/m^3 are commonly used to produce oriented strandboard (OSB) in the southern United States. For OSB production, it is typical to use juvenile pine logs with small diameters. In 2019, the United States produced approximately 13.5 million m^3 of OSB (Food and Agriculture Organization of the United Nations 2020). There is strong potential for manufacturing OSB from juniper based on the volume and availability of the wood. Previous research conducted on a similar species eastern redcedar (*Juniperus virginiana*) showed the possibility to use this wood for OSB manufacturing (Hiziroglu 2009, 2012).

Juniper logs, slabs, and branches are covered with very fibrous bark, and the logs often have deep bark pockets. The fibrous nature of the bark makes it difficult to remove. Furthermore, the bark can cause some challenges in the production of the strands (Swan and Connolly 1998). Due to the fibrous structure of the bark, there is an option to use it in OSB. Research by Moya *et al.* (2008) indicated that low volumes of bark did not change the final properties of OSB panels.

This study explored the uses for western juniper residuals to improve the economics of juniper harvesting and milling operations. In particular, markets were investigated for non-merchantable logs and sawmill residues. The objectives were to produce juniper OSB panels from sawmill and harvesting residues and compare the physical and mechanical properties of these boards with commercially available OSB panels produced from southern yellow pine. This research provides a comparison of OSB made from juniper sapwood, heartwood, and wood with and without bark.

EXPERIMENTAL

Manufacturing

The western juniper slabs, edgings, and low-quality/non-merchantable logs were obtained from two different locations in Oregon. All the materials contained a layer of bark that was approximately 10 mm thick. The materials were cut to 117 mm long, which is the typical average length of pine strands in OSB mills. The strands were sorted into four groups. The first group contained 100% sapwood (Sap), while the second group contained 100% heartwood (Heart). The third group contained a mixture of sapwood and heartwood without bark (Slabs). The fourth group contained a mixture of sapwood and heartwood with bark (Slabs-W). Approximately 10% of the fourth group was made up of bark.

The juniper blocks were submerged in water at a temperature of 30 °C for 72 h as a plasticization step before cutting the strands. The juniper blocks were cut to a thickness ranging from 0.6 to 0.9 mm using a veneer slicer. The strands were dried in a rotary dryer at 50 °C until they reached a moisture content (MC) of 4 ± 1%.

The pine strands were obtained from an OSB mill in Alabama. The pine strands had average dimensions of 0.6 mm × 25 mm × 117 mm (thickness × width × length). These strands were used as the control panels with a target density 560 kg/m^3 (Pine), which was the same as the juniper panels. The pine strands were used to make panels with a target density comparable to that used in commercial production (Pine-H) (650 kg/m^3).

The OSB panels were made using phenol formaldehyde (PF) resin with 49% resin solids (GP 265C08; Georgia Pacific Chemicals, Atlanta, GA, USA) with 5% resin by weight and 0.5% wax added. The resin was sprayed with a model EL-4 spinning disk atomizer (Coil Manufacturing, Surrey, BC, Canada) with a speed of 10,000 rpm. Three 12-mm thick panels and dimensions of 600 mm × 600 mm were made in each group. The target oven-dry density of the panels was 560 kg/m^3. Single layer OSB panels were formed on a wire mesh without any attempt to orient the strands. The panels were pressed at 180 °C with 30 s of closing, 240 s at position, and 80 s to vent.

Testing Procedures

The test specimens were conditioned at 20 °C and 65% relative humidity (RH) before the mechanical and physical properties were measured. All the mechanical and physical properties were tested according to the ASTM standard D1037 (2020), unless noted otherwise.

Density and density profile

The density was determined on 10 specimens from each board and the density profile was measured on three 50 mm × 50 mm × 12 mm specimens from each board. The density profile was measured at an interval of 0.01 mm through the sample thickness using an X-ray densitometer (QDP-01X; Quintek Measurement Systems, Knoxville, TN, USA) and the average density profile was calculated.

Physical properties

The MC was determined on 10 specimens with dimensions of 152 mm × 152 mm. The thickness swelling (TS) and the water absorption (WA) were measured using 10 specimens with the same dimensions.

Mechanical properties

The mechanical testing was carried out on an Instron 5582 universal testing machine with a 100 kN load cell (Norwood, MA, USA). Three-point bending tests were conducted to determine modulus of elasticity (MOE) and the modulus of rupture (MOR) on 10 specimens with dimensions 356 mm × 76 mm, with the span 305 mm. The specimens were loaded at a rate of 10 mm/min. The internal bond (IB) strength was measured on 10 specimens with dimensions 50 mm × 50 mm. The specimens were glued to the aluminum blocks and tested. The screw withdrawal resistance was tested on five specimens with 4.6 mm thread diameter type AB screws. Peak loads for the edge and face testing was recorded.

Statistical Analysis

The data was processed in Statistica 10 software (StatSoft Inc., Tulsa, OK, USA) and evaluated using a one-factor analysis of variance (ANOVA) test and Tukey's honest significance difference (HSD) test. The tests were conducted to determine if there were significant differences in the properties between the six groups, *i.e.*, the four groups of juniper materials and the two pine control groups.

RESULTS AND DISCUSSION

There were no challenges in manufacturing the OSB panels with respect to delamination (steam blows) in the press with the combination of density, resin concentration, wax, and press parameters used in this study. The juniper compression ratio for the sapwood and heartwood were 1.46 and 1.32, respectively.

Table 1 presents the results of the density and MC testing. The MC of the specimens after they were conditioned was significantly lower ($p < 0.5$) for the boards made from juniper compared to the pine strandboard made with the same average density. The MC for the higher density pine strandboard and juniper panels were not significantly different.

Table 1. Average Values of the Density and Equilibrium MC of the Boards at 20 °C and 65% RH

OSB panel	Density (kg/m^3)	MC (%)
Pine-H	707 (36) B	7.6 (0.3) A
Pine	629 (24) A	8.3 (0.6) B
Heart	643 (31) A	7.3 (0.4) A
Sap	614 (13) A	7.4 (0.3) A
Slabs	629 (18) A	7.1 (0.3) A
Slabs-W	636 (24) A	7.3 (0.3) A
Means with the same letter in column do not differ statistically by the Tukey's test (α = 0.05). The numbers in parentheses represent standard deviation		

No attempts were made to conduct statistical analyses to compare the density profiles. The discussion here is therefore primarily qualitative in nature based on the examination of the density profile plots (Fig. 1). The density profiles for the juniper heartwood OSB panels were similar to the profiles of the pine OSB panels at comparable target densities. The juniper Sap, Slabs, and Slabs-W OSB panels had a higher density 1 mm from the surface compared to the surface density of the Pine-H OSB panels. These results show that strandboard can be made from mostly juniper sapwood with a high surface density (850 to 900 kg/m^3) and a low core density. Therefore, it may be possible to produce juniper OSB panels with comparable mechanical properties and lower densities than currently available commercial panels. This reduction in the OSB panel weight can be a significant advantage for the transportation of the panels and the feasibility of using them in building applications.

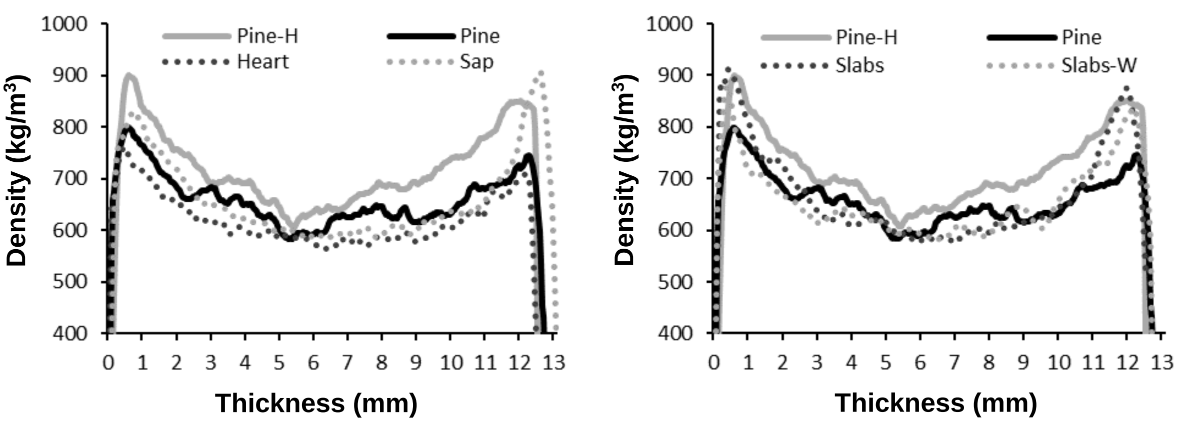

Fig. 1. Density profile of the juniper and pine strandboard at 20 °C and 65% RH

The results of the TS and WA tests are shown in Table 2. The OSB made from the pine had a higher TS and WA after 24 h. The pine OSB also had TS and WA values that were 2.5 and 2 times higher than those of the Sap OSB, respectively. The OSB made from the Sap had the lowest TS and WA values after 24 h. The TS values after 7 d of water immersion showed more consistent results for the juniper and pine OSB at the same density level. The higher density pine OSB had the greatest TS (33.3%) after 7 d. After 7 d of water immersion, the pine and juniper OSB panels had significantly different WA values. The juniper OSB WA values were approximately 15% lower than those of the pine OSB.

The OSB panels that were made from the eastern redcedar (*J. virginiana*) with PF resin from strands that included bark, had TS values of 15.2% after 24 h of water immersion (Hiziroglu 2009). This is comparable to the TS values of the OSB panels that were made in this research, especially for the Slabs-W panels.

Table 2. The TS and WA Values after 24 h and 7 d of Water Immersion

	24 h		7 d	
OSB Panel	TS (%)	WA (%)	TS (%)	WA (%)
Pine-H	29.7 (2.4) D	67.8 (8.5) C	33.3 (4.6) B	88.1 (6.9) B, C
Pine	20.2 (2.5) C	70.8 (8.1) C	21.5 (2.7) A	95.0 (6.4) C
Heart	15.3 (3.1) B	43.2 (6.1) B	19.4 (3.7) A	72.4 (7.6) A
Sap	11.8 (2.5) A	33.6 (4.5) A	21.5 (3.6) A	75.1 (9.2) A
Slabs	14.4 (1.8) A, B	36.6 (1.6) A, B	22.2 (2.8) A	76.6 (2.8) A
Slabs-W	15.1 (2.2) A, B	39.0 (4.8) A, B	24.1 (2.3) A	81.4 (9.3) A, B
Means with the same letter in column do not differ statistically by the Tukey's test (α = 0.05). The numbers in parentheses represent the standard deviation				

Figure 2 presents the results of the static bending tests. The OSB made from the juniper sapwood had MOE values that were comparable to the Pine-H OSB. According to Haataja and Laks (1995), northern white-cedar (*Thuja occidentalis*) OSB bonded with polymeric diphenyl methane diisocyanate (pMDI) resin had MOE values of 4,275 MPa. The MOE of the panels made from eastern redcedar (Hiziroglu 2009) was 2,845 MPa, which is at the low end of the results from the research presented in this paper.

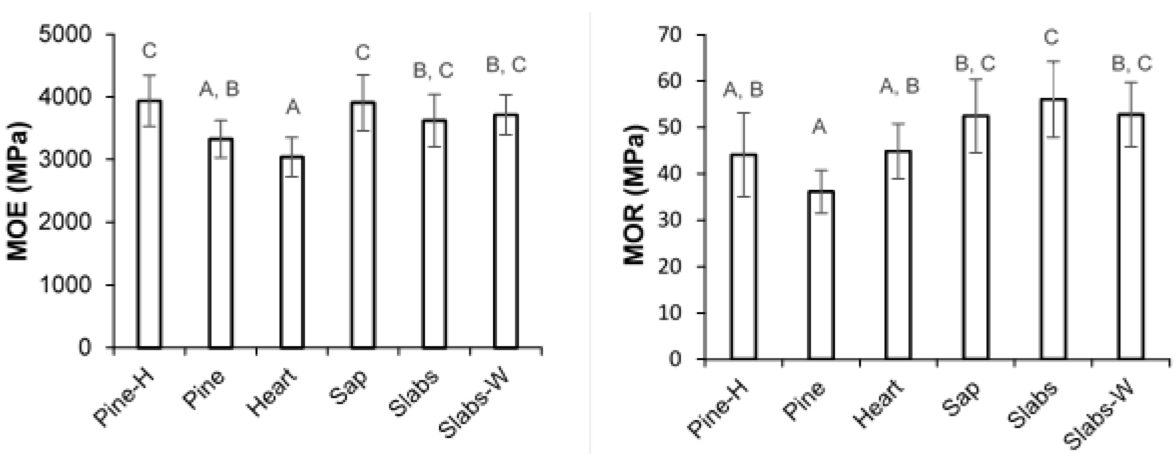

Fig. 2. The average values of the bending properties of the juniper and pine OSB panels at 20 °C and 65% RH

The OSB panels made from Slabs had the highest average MOR of 56 MPa, which is approximately 12 and 20 MPa higher than the MOR values of the Pine-H and Pine boards, respectively. Haataja and Laks (1995) found that the MOR of northern white-cedar panels made with pMDI resin was 39 MPa, which is lower than the results in this research. Hiziroglu (2009) found that the MOR for eastern redcedar OSB, with a density of 650 kg/m^3, was 17.5 MPa (Hiziroglu 2009).

The IB values of the OSB panels are shown in Table 3. The juniper samples had an average value of 0.85 MPa, which is significantly higher (1.7 times), than the average value of the pine samples. Research on the utilization of northern white-cedar bonded with pMDI resin reported IB values of 0.72 MPa, which are comparable with the OSB panels made from slabs with bark (Slabs-W) in this research (Haataja and Laks 1995). Hiziroglu (2009) reported IB values of 0.77 MPa for OSB panels made from eastern redcedar with bark, which is comparable with the Slabs-W panels made in this research. The utilization of low-density species increases the number of strands used, resulting in a higher total wood surface area of the strands and a lower area covered by the adhesive (Barbuta *et al.* 2011).

Table 3. Average IB Values of the Juniper and Pine OSB Panels at 20 °C and 65% RH

OSB Panel	IB (MPa)
Pine-H	0.47 (0.13) A
Pine	0.53 (0.09) A
Heart	0.85 (0.14) B
Sap	0.90 (0.12) B
Slabs	0.91 (0.08) B
Slabs-W	0.74 (0.20) B
Means with the same letter in column do not differ statistically by the Tukey´s test (α = 0.05). The numbers in parentheses represent the standard deviation	

The results of the screw withdrawal resistance tests are presented in Table 3. The juniper OSB panels showed comparable or higher results for the screw withdrawal resistance, especially for the Sap and Slabs-W panels, which had significantly higher peak loads for the edge screw withdrawal resistance. The screw withdrawal with pilot hole 2.4mm and torque level 1.5 Nm for southern yellow pine OSB in the research of Tor *et al.* (2016) was 1859N, 1477N, and 2469N for edge-grain, end-grain, and face-grain respectively.

Table 4. Average Values of the Screw Withdrawal Resistance of the Juniper and Pine OSB Panels at 20 °C and 65% RH

	Peak Load: Edge (N)	Peak Load: Surface (N)
Pine-H	1119 (340) A	1455 (491) A
Pine	1185 (250) A	1254 (136) A
Heart	1568 (144) A, B	1417 (364) A
Sap	2127 (29) B	1752 (420) A
Slabs	1651 (235) A, B	1551 (361) A
Slabs-W	2010 (574) B	1598 (365) A
Means with the same letter in column do not differ statistically by the Tukey´s test (α = 0.05). Numbers in parentheses represent standard deviation		

CONCLUSIONS

1. The testing in this study indicated that heartwood and sapwood western juniper residues can be used to successfully produce OSB panels, even at lower densities and a small amount (approximately 10%) of bark in the strands.
2. There were no indications that the lower density of the western juniper (compared to southern yellow pine) require a higher amount of resin. This is beneficial for the utilization of juniper to manufacture OSB panels.
3. All the physical and mechanical properties presented in this work support the potential for manufacturing juniper OSB panels. The properties of the juniper panels were equivalent or slightly better than higher density panels made from southern yellow pine, apart from the MOE. Specifically, higher density pine panels had higher MOE values than the pure heartwood juniper panels. However, the MOE values were equivalent for the other juniper materials tested in this study.
4. The lower density of the juniper OSB panels may be beneficial in construction applications and can reduce transportation costs.

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REFERENCES CITED

Azuma, D. L., Hiserote, B. A., and Dunham, P. A. (2005). *The Western Juniper Resource of Eastern Oregon, 1999* (Report No. PNW-RB-249). U. S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Corvallis, OR. DOI: 10.2737/PNW-RB-249

ASTM D1037-12 (2020). "Standard test methods for evaluating properties of wood-base fiber and particle panel materials," American Society for Testing and Materials, West Conshohocken, PA.

Barbuta, C., Cloutier, A., Blanchet, P., Yadama, V., and Lowell, E. (2011). "Tailor made OSB for special application," *European Journal of Wood and Wood Products* 69(4), 511-519. DOI: 10.1007/s00107-010-0477-z

Bedell, T. E., Eddleman, L. E., Deboodt, T., and Jacks, C. (1993). *Western Juniper: Its Impact and Management in Oregon Rangelands* (EC 1417), Oregon State University Extension Service, Corvallis, OR.

Eastern Oregon Agricultural Research Center (2020). "Expansion of western juniper," (https://agsci.oregonstate.edu/eoarc/research-abstracts/rangeland/expansion-western-juniper), Accessed 08 December 2020.

Food and Agriculture Organization of the United Nations (2020). “Forestry production and trade,” (http://www.fao.org/faostat/en/#data/FO/visualize), Accessed 08 December 2020.

Haataja, B. A., and Laks, P. E. (1995). “Properties of flakeboard made from northern white-cedar,” *Forest Products Journal* 45(1), 68-70.

Highley, T. L. (1995). “Comparative durability of untreated wood in use above ground,” *International Biodeterioration & Biodegradation* 35(4), 409-419. DOI: 10.1016/0964-8305(95)00063-1

Hiziroglu, S. (2009). “Properties of strandboard panels manufactured from eastern redcedar,” *Materials* 2(3), 926-933. DOI: 10.3390/ma2030926

Hiziroglu, S. (2012). “Some properties of sandwich type composite panels manufactured from eastern redcedar,” *Composites Part B: Engineering* 43(8), 3288-3292. DOI: 10.1016/j.compositesb.2012.02.009

Miller, R. F., Bates, J., Svejcar, T. J., Pierson, F. B., and Eddleman, L. (2005). *Biology, Ecology, and Management of Western Juniper (Juniperus occidentalis)*, (Technical Bulletin 152), Oregon State University Agricultural Experiment Station, Corvallis, OR.

Miyamoto, B. T. (2017). *Establishing Design Values for Potential Utilization of Western Juniper as a Building* Material, Master’s Thesis, Oregon State University, Corvallis, OR.

Miyamoto, B. T., Sinha, A., Leavengood, S., Morrell, J., DeVisser, D., and Kruse, D. (2018). “Mechanical property assessment for establishing design values of western juniper,” *Wood and Fiber Science* 50(2), 167-179. DOI: 10.22382/wfs-2018-018

Morrell, J. J. (2011). “Resistance of selected wood-based materials to fungal and termite attack in non-soil contact exposures,” *Forest Products Journal* 61(8), 685-687. DOI: 10.13073/0015-7473-61.8.685

Morrell, J. J., Miller, D. J., and Schneider, P. F. (1999). *Service Life of Treated and Untreated Fence Posts: 1996 Post Farm Report* (Research Contribution 26), Oregon State University Forest Research Laboratory, Corvallis, OR.

Moya, L., Winandy, J. E., Tze, W. T. Y., and Ramaswamy, S. (2008). “Use of fire-impacted trees for oriented strandboards,” *Forest Products Journal* 58(6), 45-52.

Panshin, A. J., and de Zeeuw, C. (1980). *Textbook of Wood Technology Structure, Identification, Properties, and Uses of the Commercial Wood of the United States and Canada*, McGraw-Hill, New York, NY.

Swan, L., and Connolly, M. (1998). “Processing and finishing western juniper,” in: *Wood Technology Clinic and Show*, Portland, OR.

Swan, L. (1995). “Western juniper: An evolving case study in commercialization, ecosystem management, and community development,” in: *Proceedings of the Desired Future Conditions for Pinon-Juniper Ecosystem*, Fort Collins, CO, pp. 179-183.

Tor, O., Demirel, S., Hu, L., and Zhang, J. (2016). “Effects of driving torques on direct screw withdrawal resistance in OSB,” *Kast. Uni. J. Forest. Fac.* 16(2), 438-446. DOI: 10.17475/kastorman.289754

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