

JUNIPER BARK AS AGGREGATE SUBSTITUTE IN CONCRETE

submitted to

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### INTRODUCTION

Wood and wood by-products are being considered as a replacement for sand and gravel aggregates in concrete. The large volumes of concrete produced each year, approximately one ton per person (4), makes concrete an ideal choice for the introduction of waste and/or recycled products. Wood products used in a concrete mix would produce a light weight concrete with some reduction in strength. There are, however, many applications for light weight concrete with low to moderate strength requirements.

It has been shown (1) that wood chunks can be used effectively in concrete creating a relatively strong, lightweight product. Further research on this product, chunkrete, is on-going in an attempt to develop commercial markets. Other researchers have used mineralized wood chips (2) to develop hollow wood-concrete blocks. These blocks are currently being marketed under the trade name of FASWALL. Technology from Finland has also produced a precast extruded concrete panel which contains wood chips(3) and are sawable and nailable.

There is an on-going effort by private groups and public agencies to increase the utilization of Western juniper (*Juniperus occidentalis*) (6). Typically increased utilization concerns such areas as harvesting method, processing, and marketing of the product. Another important aspect of utilization, however, is the use of wood waste and residuals. This report investigates the potential use of Western juniper bark as an aggregate replacement in concrete to make a lightweight concrete product. The intent of this study was preliminary in nature and represents an initial attempt at establishing some baseline information on the viability of juniper bark as an aggregate replacement.

### Methods and Materials

Concrete is a mixture of portland cement, fine aggregate (sand), coarse aggregate (gravel), and water. These four ingredients can be adjusted to meet certain engineering design criteria including strength and durability (5). The fine aggregate, cement, and water combine to form a paste which fills the voids around the coarse aggregate. Over time a chemical process, hydration, occurs forming the semi-liquid mass into a hard, strong engineering material. In this investigation the juniper bark was used as a replacement for the coarse aggregate. Comparisons of compressive and flexural strength and unit weight of test specimens with varying amounts of bark were used in determining the effectiveness of juniper bark as a coarse aggregate

replacement.

In this project concrete, with no bark, was mixed at a design value of 3000. Appropriate amounts of cement, fine aggregate, coarse aggregate were determined. Water was then added to achieve a four inch slump. This mixture was the base mix from which others containing juniper bark could be compared.

Four additional mixtures were prepared using the bark. Bark was substituted into the mix on a volume basis. The four mixes had 75%, 50%, 25%, and 0% of the original coarse aggregate volume which was replaced by bark. To adequately replace equal volumes of bark with the coarse aggregate the bulk density of each material was determined. The coarse aggregate had a bulk density of 165 pcf compared with 21.5 pcf for the bark.

For this initial experiment the bark was used as received from the field. The bark was in long thin strands with some pieces up to an inch wide. The majority of pieces were on the order of one to two inches long and one quarter to one half inch wide. Densities of the bark were obtained with moisture in the cellular structure and not dried. No attempt was made to alter the as received condition of the bark. The proportions of cement, water, fine aggregate, coarse aggregate, and bark for each of the five mixes are shown in Table I.

Table I Mix Proportions for Test Specimens

Sample Number	% Coarse (by volume)	% Bark	Cement (lb)	Fine (lb)	Coarse (lb)	Bark (lb)	Water (lb)
1	100	- 0	37.04	94.6	131.6	0	25.7
2	75	- 25	37.04	94.6	99.0	4.8	28.1
3	50	- 50	37.04	94.6	65.7	9.4	28.3
4	25	- 75	37.04	94.6	33.3	14.2	40.8
5	0	- 100	37.04	94.6	0	18.9	51.8

### *Mixing*

The base mix with zero percent bark had enough water to allow for a four inch slump which represents a workable concrete mixture. Mixes with bark required increased water to develop a workable mix. The long, fibrous nature of the bark made the mixes relatively stiff and extra water was required to develop a mix that could be adequately consolidated and formed. The bark when mixed with the other materials released significant amounts of gas. Small gas bubbles formed during the mixing process indicate a possible

reaction between the bark cement paste.

Unit weights each mix were also determined. The unit weights were performed using ASTM test procedure C-138. The unit weights of each of the samples are shown in Table II.

Table II Unit Weight of Mix Samples

Sample #	Unit Weight (pcf)
1 (100/0)	148.0
2 (75/25)	129.4
3 (50/50)	112.8
4 (25/75)	104.3
5 (0/100)	98.1

### *Cylinders and Beams*

Concrete cylinders were prepared following ASTM C-31 standard procedures. The cylinders were made from standard 6 inch diameter molds. Four test cylinders for each mix were prepared. Three cylinders were to be used for compressive testing and one was to be kept in storage. Flexural test specimens were formed in fabricated molds three inches square by nine inches long. Three molds for each mix were prepared, all to be used during this study.

Both the compressive and flexural test specimens were enclosed in a plastic bag to minimize moisture loss during the curing period. Concrete designs are generally related to the 28 day strength of the material. As the hydration process proceeds concrete will have increased strength over time. Due to time constraints the samples were cured for 21 days prior to testing not 28. A standard concrete mix will reach 90 to 95 per cent of the 28 day strength at 21 days.

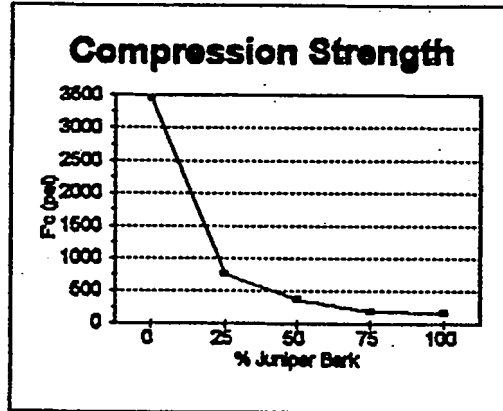
### *Test Results*

#### *Cylinders*

Compression tests on the samples were conducted on a Cal-Teck System 250,000 lb. capacity concrete testing machine. The cylinders were loaded at a uniform rate until a maximum load was reached. Compressive strength was calculated by dividing the maximum load, in pounds, by the cross-sectional area of the 6 inch diameter cylinder. Strain measurements were not recorded during the test.

Compressive strengths were determined by calculating an arithmetic average of the three tests for each mix. Tabulated results of all the tests are shown in Appendix A. Graphical representation of the test results is shown in Figure 1.

Figure 1 Compression Test Results



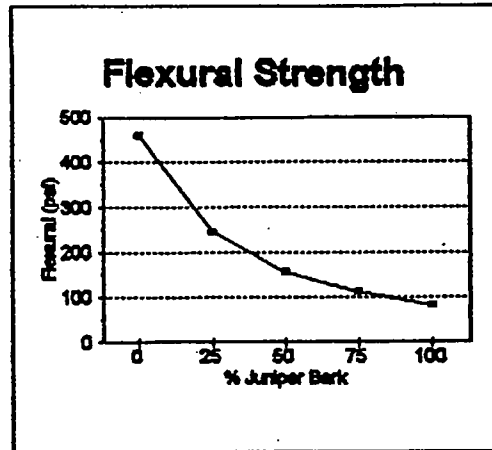
The results indicate a rapid decrease in strength when bark was added to the mix. The base mix had a compressive strength of 3464 psi. while the 25% bark sample had a compressive strength of 752 psi. The 100% bark sample had an average compressive strength of 165 psi. Although strain measurements were not taken it was noted that the samples with bark did not have a brittle failure. Bark samples reached a maximum load but continued to deform without complete failure.

#### *Beam Specimens*

A standard testing machine was used to perform the flexural strength tests. The beams were tested using the simple beam, third-point loading method. As in the compressive strength tests maximum loads were obtained and no strain measurements were taken. Flexural strengths were determined using an arithmetic average of the three test performed for each mix. The results of all the flexural strength tests are shown in Appendix A. A graphical representation of the average strengths is shown in Figure 2.

The flexural test results are similar to the compressive strength results in that a rapid reduction occurs with the addition of bark. The base mix has a flexural strength of 461 psi while the 100% bark strength was 81 psi.

Figure 2 Flexural Strength Results



### Conclusions

Based on this initial study there appear to be significant problems associated with the use of juniper bark in concrete. The loss of compressive strength with only 25% bark indicates that the bark, as received from the field, is not be compatible with producing quality concrete. Examination of the post-test specimens suggests that a reduction of the hydration process may be occurring with an increase in wood fibers. The paste does not appear to be effectively bonding to the bark fibers. During the mixing the presence of gas being released most likely indicate a chemical reaction between the oils in the bark and the cement. This reaction appears to be adversely affecting the ability of the cement paste to bond with the bark.

The mixing and consolidation of the samples also created some difficulties. Increased water demands for the mixing were required with the addition of bark. The increased water to cement ratio would also contribute to strength reductions. The consolidation of the mix into the cylinder and prepared beam molds was difficult. The size of the bark specimens created difficulties in properly consolidating the samples. Air voids in the mix were not measured, however, it is probable that increased entrapped air occurred with an increase in bark. This condition would also reduce the strength of the concrete product.

## Recommendations

Untreated juniper bark as evaluated in this project does not appear to have a use in developing light weight concrete alternatives. A concurrent study by Hansruedi Walter of Insul Holz-Beton, see Appendix B, indicates that by using their K-X process the bark is mineralized and could be turned into a free aggregate for use in developing a potential marketable product. A concrete specimen using bark treated with the K-X process was examined. The sample contained cement, treated bark, and water. No fine aggregate was used in the mix. The bonding of the treated bark was superior to the non-treated specimens. These results that a concrete/ juniper bark product could be developed.

A treatment process such as the K-X process would have to be included if juniper bark is to be used in a concrete product. In the K-X treatment process the best results were achieved on their Sample A. In Sample A the material was screened and 1" to 1 1/2" long fibers were used. However, this screening eliminates some of the material and would not, therefore, consume all of the bark. In essence the process would still have some waste. The cost of the treatment process and the amount of total bark used would have to be identified to evaluate the economic feasibility of producing a quality concrete product using juniper bark.

If a concrete product can be generated with juniper bark the an application and market for the product should be established. To date the only application discussed for this product has been for use as a ceiling tile. Other applications may have to be identified and investigated.

Literature cited

- 1) Arola, R.A., Chunkrete: an alternative to concrete, U.S. Dept. of Agriculture, Forest Service, North Central Forest Experiment Station, Houghton, Michigan.
- 2) FASWELL: Adding Value for Profit, Wood Recycler, July 1994.
- 3) Hurd, M.K., 1989, Home built with wood fiber concrete panels, Concrete Construction, August, pp. 703-707
- 4) Mehta, P. 1986, Concrete Structure, Properties, and Materials, Prentice Hall, Inc.
- 5) Portland Cement Association, Design and Control of Concrete Mixtures, 13 ed., Portland Cement Association, Chicago, Il.
- 6) Western Juniper Utilization and Marketing Project, Interim Report, July 4, 1993.



**APPENDIX A**

### Compression Test Results

Sample	Test 1 (psi)	Test 2 (psi)	Test 3 (psi)	Average (psi)
1	3457	3557	3379	3464
2	968	643	645	752
3	303	396	416	372
4	175	181	209	188
5	163	163	170	165

### Flexural Test Results

Sample	Test 1 (psi)	Test 2 (psi)	Test 3 (psi)	Average (psi)
1	560	405	438	461
2	260	326	188	244
3	226	88	172	155
4	139	85	112	112
5	74	79	92	81

APPENDIX B



INSUL HOLZ-BETON  
INTERNATIONAL INC.

Mr. Larry Swan  
USDA  
Wenema National Forest  
2819 Dahlia Street

Klamath Falls, Oregon 97601

7-25-1994/hrw

Dear Larry,

With separate package I mailed you report and samples of the interesting K-X test using the bark from the Western Juniper tree.

Also enclosed you will find the latest issue of the "WOOD RECYCLER" with an article about our K-X and FASWALL program.

I hope you can use the result of the test. We bill you \$ 150.00 for our expenses and time.

Sincerely

*Hans*  
Hansruedi Walter/ CEO

Sorry if again some word is incorrectly spelled.

need to cut  
-screen depending  
use: 3/4"

1) cement particle bed - would  
very flexible

2) roofing felt  
recycled felt  
Salthem  
WJ Bark = 10%  
Bark = 7%  
3) maybe not wall form block  
need mm board. WJ bark  
4) more like a hair. Good  
for extruding. Good for  
roof tiles or other roofing  
products. Maybe  
insulation sheets (2-3"  
thick). Maybe 480 pounds.

relative  
Kanting

K-X Test Report

# 06154  
USDA7-25-1994/ HRW  
usdarep.d-----  
Preface:

In the K-X process the wood chips should have a maximum moisture content of 35 % before the treatment. If the moisture is higher the material has to be dried. Recycled pinchips have mostly low moisture (10-18%), which is ideal for the K-X free aggregate production.

In the K-X process we add 10 % more moisture to the wood particle, spraying them during thoroughly mixing cycles with the mineral solutions.

During the following 2 days the aggregate has to mature on a pile or in a container, before being mixed with portland cement. The free K-X aggregate is now a impregnated wood fiber and will not decay for a long time.

The latest test confirms that after we have filled in June 1990 a metal box (on the top open to air) with K-X aggregate shows no signs of decay, and we can use the material in the wood concrete production any time.

An other test shows the same portion of K-X aggregate and untreated chips after being a year in a jar filled with water. The water in the jar with the untreated chips is dark brown and smells bad. In the jar filled with the K-X aggregate the water is very clean and clear.

The raw material used for K-X aggregate has to be clean wood chips without sawdust, dirt and no more then 2% bark content. The metal parts (recycled pallets) have to be collected by a magnet after the screening of the raw pin chips.

In the wood concrete products as FASWALL permanent wall forms and for the cast of the highway sound absorption panels, we use 1/4" - 1" long wood sticks which are much stronger then the flex shavings or chips and planner shavings mixed.

Too fine fiber and sawdust in the aggregate would absorb to much of the cement, needed for the coating of the pinchips to make a strong product.

In the K-X process we do not soak the wood fibers in chemical

solution as used in early wood-cement technologies.

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1. Tested material mailed by Mr. Larry Swan, USDA Long bark strands from Western Juniper grown in the Wenema National Forest, Klamath Falls, Oregon, dry and strong smelling.

We have cut the up to 12" long hairy strands in smaller pieces. We screened out in 1" - 1 1/2" long fibers for test A and in shorter fiber including the fine dust for test B.

2. K-X process: June 14, 1994

Both mixes have resisted to absorb the moisture. *The bark has to protect the tree and as a protective shield is not porous.*

We have diluted the mineral solutions by 20%, so doing it was possible to moist the hairy fiber already in the first treatment so the second coating would penetrate better. After a prolongation mixing time of total 4 minutes for each cycle, we achieved the desired K-X aggregate.

3. Wood concrete mixing: June 16, 1994. Temperature 89 ° F K-X aggregate could mature in this 2 days and was again dry.

#### A - Sample:

The A mix with the longer and dust free bark fibers was reacting normal. After cement was added with the water we have observed a faster hydrating as with wood fibers. Cement ratio 2 = 1 weight volume oven-dry fibers, 2 weights of portland cement and 1 weight volume of water.

The mix was very moist so the flex fibers could be filled better into the 9" round form. We were able to compact the mix about for 45% of the volume. During the 12 hours we noted a temperature on the green test sample of 95° F (a violent hydration phase) after 18 hours the sample has hardened enough to be handled but was still very moist and warm.

After the 34 days seasoning the sample has been cut in 2 pieces. We would give 9 points (best 10 points). We can see a good distribution of the cement and we could produce a strong panel if the necessary compacting is used.

#### The B sample

The B mix (1/2 sawdust + 1/2 fine fibers) was more difficult to mix because of the very fine flex and hairy material.

Including even some longer but thinner fibers the cement has been absorbed at last for 33% by the dusty material forming so clusters of cement (see cut sample). We have taken the same cement formula as for test A, adding 1/3 more water.

It was very difficult to fill the 10" form and we compacted the form the same way as sample A. The mix was very flex and elastic but the fibers have not been coated enough.

Despite this facts the green sample did heat up to 90° F which is the sign for a good hydration and bonding of the product. After 18 hrs the product was still very flex (it is still today) but we could handle it which is a good sign. We would give the note 6.

We have cut the sample in two after 34 days the 7-20-1994. You can observe very good the different texture and distribution of the two samples.


Of course the fire rating of the B sample is not as good because the coating of the wood fibers is not sufficient. This panel is still flex and elastic.

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Feasibility to manufacture light roof tiles using extruding equipment is positive if the fiber is not long (1-1 1/2") and the sawdust and superfine fibers are eliminated. In a roof tile as in any other wood concrete product we do not need fine filler material.

Please contact me for further tests. I believe this bark material is showing again the value of the K-X process even in extreme cases as this.

Sincerely



Hansruedi Walter/ CEO