Popular Poplar:

Thermal Properties of Poplar Bark

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R-Value Testing of Poplar Bark

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ABSTRACT

Wood shingles have become more prominent for their durability, aesthetic value, and low-maintenance. But one possibility that has not been examined is the benefit of their positive insulating properties. In this study, poplar bark will undergo various thermal property testing. Initially we will observe its thermal conduction. Based on the amount of heat that is able to flow through the bark we will be able to determine the bark's thermal resistance. We will then look at the bark's specific heat and density to further examine its thermal mass. Then, we can compare the poplar bark's properties with well-established siding material and determine whether poplar bark has a thermal advantage that other siding materials do not.

INTRODUCTION

For many wood companies bark is not their main concern, the wood is. As a result most of the bark is disposed of. Instead of throwing away such a valuable material, the bark could be repurposed.

Traditionally, building siding materials serve one main purpose - they protect the inside of the structure from weather conditions such as snow, rain, wind, etc. Similarly, the main purpose of bark is to protect the tree. So there is a reasonable possibility that tree bark could be repurposed as siding. It already has the potential to protect a structure from harsh weather conditions, like standard siding materials, and now it could have the ability to enhance a structure's thermal properties unlike conventional siding.

In order to determine whether bark could serve as an insulating material, we must examine bark's thermal properties and what an ideal insulator is.

Thermal Insulation Properties

The purpose of insulation is to slow the flow of heat entering and exiting a given system. In a building, heat is meant to be kept inside in the winter and outside in the summer. In both situations the heat wants to flow from the system with the higher temperature to the system with the lower temperature. Ideally the insulation slows the heat transfer significantly, which allows the system to stay at an approximately stable temperature with very little heat loss or gain. The determining factor of how effective the insulation is its R-value.

R-Value and Thermal Conductance

As stated above, the R-value is also known as thermal resistance and is very important in understanding the insulation properties of a given material. The R-value is the inverse of thermal conductivity, which is denoted by *U* or *k* (also known as U-value). The thermal conductivity defines the amount of heat that is able to pass through a certain material in a given amount of time. The thermal resistance is a material's ability to resist the heat flow.

$$\frac{Q}{t} = \frac{\kappa A(T_{hot} - T_{cold})}{d}$$

It can be seen in the equation above that thermal conductance (*k*) of a material can be determined by knowing the temperature of both sides of the material (T_{hot}- T_{cold}), the area of the material (*A*), the thickness (*d*), and the rate of heat transferred (*Q/t*). Once thermal conductivity is determined we can determine the R-value by taking the reciprocal.

Knowing the thermal resistance of poplar bark determines how efficiently the material can retain heat compared to other common materials. But the R-value is not the only factor when it comes to determining an object's insulation effectiveness.

Thermal Mass: Density and Specific Heat

The thermal mass is the material's ability to store heat per volume. To find thermal mass we multiply the material's density by its specific heat.

- Density of any object is its mass per volume
- Specific heat of an object is the amount of heat needed to change a 1 g mass of the material's temperature by 1° Celsius.

The density of poplar bark can be determined by placing a sample in a volume of water and measuring the amount of water displaced. Weigh the bark and then dividing the mass by the volume you get density. Obtaining the specific heat of bark is slightly more difficult and will be explained later in the procedure.

The thermal mass contributes information about the bark that cannot be done with the R-value. It determines how much of the heat will be retained by the wood while heat transfer occurs. If a material has a low R-value, but the density and specific heat are high, and thus the thermal mass is high, that means even though a significant amount of heat is leaving the system the material is still able to retain heat within itself, which keeps the system warm. Most wood has a low R-value; if this is the case with the poplar bark then it could still be a useful insulation material based on its thermal mass.

TESTING METHOD

Apparatus:

Poplar Bark Samples:
-Bark House (barkhouse.com) supplied six 14”x30” poplar panels
-We cut them down to 7”x7.5”
-Thickness: Approximately 0.254m
thickness approximation explained in testing section

Milwaukee Heat Gun:
-1400 Watts
-Provided 1400 joules per second for 60 seconds each trial

General Digi Stem probe thermometer:
-Temp. Max: 392 ºF
-Temp. Error: 1.8 ºF.-Measured temperature of T_{HOT}

Infrared Thermometer DT8380:
-Temp Max: 968 ºF
-Temp. Error: 2% or 2 ºC
-Measured surface temperature of T_{COLD}

Styrofoam Cooler:
Lack of edge insulation resulted in heat escaping around the bark’s edges and increasing the temperature of the outer layer (T_{cold})

To stop heat from escaping around the sides we acquired a Styrofoam cooler (courtesy of Jeffrey Oda, USF Dept of Biology).
A 7”x7.5” rectangle, 0.5” deep, on the outer side was cut out for a piece of bark to be placed while heating. Then a 2”x2” square was cut out on the other side for the heat to transfer through the bark.
This minimized heat escaping around the edges.

Procedure

The bark was placed in the Styrofoam cooler cut-out. Then a probe thermometer was placed in the bark side that was to be heated and the infrared thermometer was placed 5" (0.127meters) away from the outer side of the bark.

> *The Infrared thermometer has a diameter to distance ratio of 1:12. If it is 0.127 meters away from the bark then it will measure the temperature encapsulated by a circle with a diameter of one-twelfth of the distance (0.0106 meters).
> ** Using the circle diameter, we measured the thickness within that circle and that was the thickness for that specific trial

The cooler did not prevent all heat from escaping around the edges of the heated bark sample. Tape was applied to the cooler to guide the heat away from the bark. We then placed the heat gun in a Styrofoam holder and placed the tip of the gun 1 inch from the cooler. The bark was heated for 60 seconds on the high setting of the heat gun and the temperature of both sides was recorded at the 60 second mark. The cooler and thermometer were allowed approximately 10 minutes to cool down back to room temperature, then the procedure was repeated.

The procedure was carried out on poplar bark and two spruce samples with known R-values. Using the other samples with known R-values we were able to determine the average heat added to the system.

Then we determined the R-value for the multiple trials and averaged the value to find the average R-value.

Results and Analysis:

Test Data

Sample	T_{HOT} Before (Fahrenheit)	T_{HOT} After (Fahrenheit)	T_{COLD} Before (Fahrenheit)	T_{COLD} After (Fahrenheit)	Calculated R-value (h·ft²·°F/Btu)
Delta	70	202	69	75	12.30
Delta 2	77	208	70	77	12.68
G	73	212	70	95	3.61
F*	74	247	71	111	3.72
K	75	226	71	103	3.49
Z	74	215	71	104	3.15
L	75	213	72	95	3.36
J*	75	165	72	83	2.33
E	73	202	71	88	3.22
P	74	204	71	85	3.38
A*	74	230	70	81	4.22
H	76	204	74	84	3.39
T	69	205	69	83	3.45
P	70	215	69	73	3.48
C	69	220	71	79	3.30
E	69	220	72	85	3.16
A'*	70	247	74	78	4.80

*Red indicates erroneous data

*Blue indicates spruce wood

Q (heat added to system) was calculated first using: $Q = \frac{k(T_{HOT} - T_{COLD})t}{Thickness}$. In this case, k is the thermal conductivity of delta (spruce), which is 0.12 W/(m*K). The thickness of both spruce samples is 0.0381 m. The spruce was then heated for approximately 60 seconds and the difference in temperature was $T_{HOT} - T_{COLD}$ = 129 °Fahrenheit, which yielded a heat of Q = 825 joules per minute.

The R-value was then determined using: $1/k = \frac{t(T_{HOT} - T_{COLD})}{(Thickness)Q}$ and the data in the above table. Once all of the R-values were calculated for each trial we excluded the outliers and averaged the rest. We found the R-value average of poplar bark was equal to approximately 3.7.

ERROR ANALYSIS:

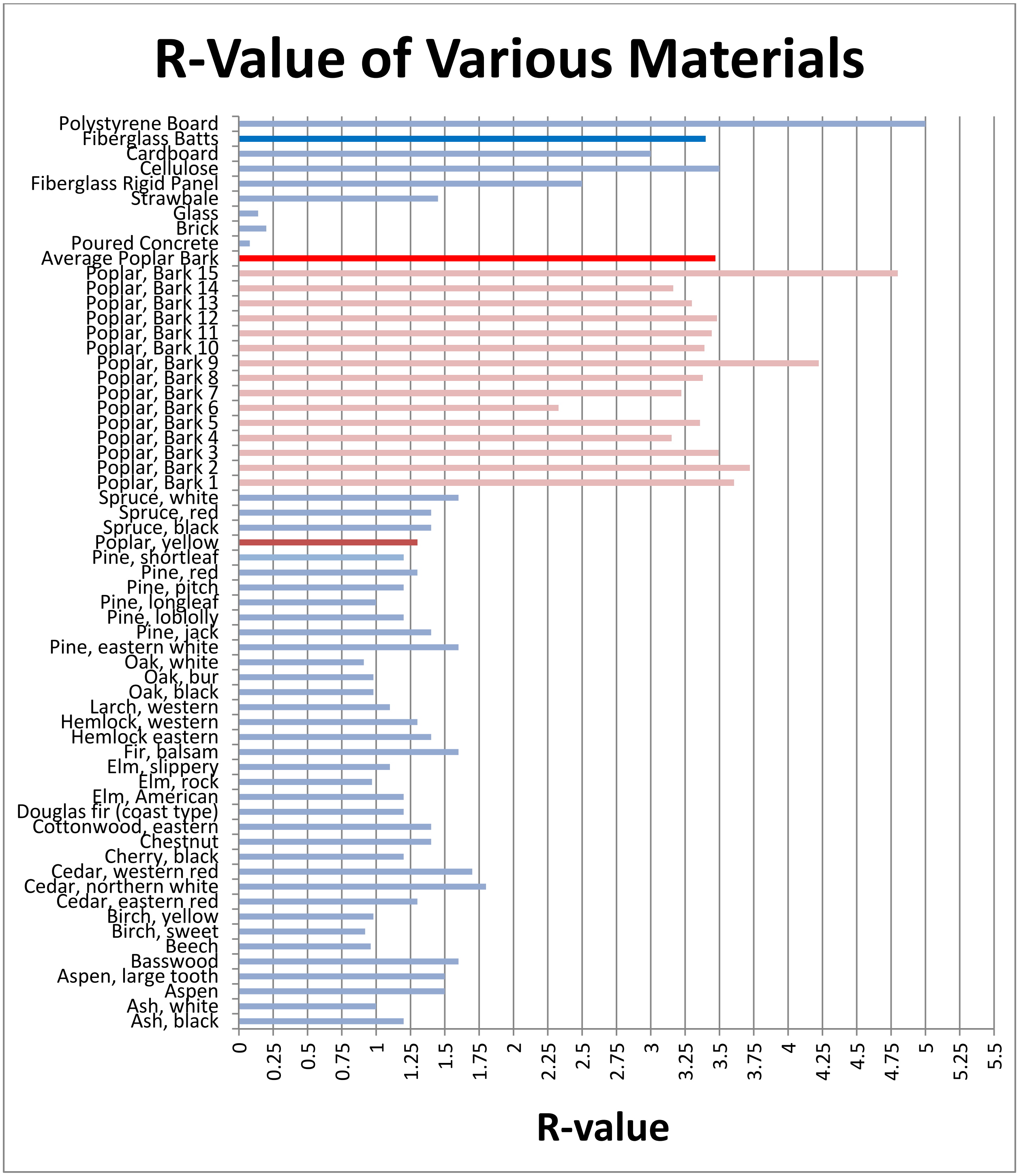
Several testing errors should be mentioned. Various factors contributed to this error, but the majority of the error can be attributed to 1.Edge Insulation, 2.Heat Uncertainty, and 3.Fluctuating Environmental Conditions

1. Edge Insulation: As mentioned before, the infrared thermometer uses blackbody radiation to determine the temperature of a specific location. But because of this an error can be induced by having an increasing room temperature or just a simple flow of heat coming from some area. The lack of complete edge insulation allowed a certain amount of heat to flow in front of the infrared thermometer, which could have increased the temperature read on the thermometer instead of reading the actual temperature change based on the heat passing through the bark. We attempted to minimize the error by redirecting the heat away from the testing apparatus, but we were not very successful.

2. The initial part of the experiment was to determine how much heat is transferred to the piece of wood in 60 seconds. The heat gun experiences fluctuations in voltage and power so the heat will fluctuate as well. So when the heat output was approximated to be constant for each 60 second trial we did not factor in the amount of heat fluctuations. There is also an uncertainty of how much heat the spruce wood actually absorbed and if it is comparable to that of poplar. Once the heat hit the bark it is quite hard to know how much heat is truly transferred to the bark. If spruce and poplar do not have similar thermal properties then the transferred heat that we approximated would be very inaccurate.

3. These experiments were held in non-ideal situations; meaning that there were constant room temperature fluctuations as well as the experiment environment changed multiple times while collecting data. Various areas where the experiment was conducted could have had different temperature fluctuation rates and thus affect the data and accuracy.

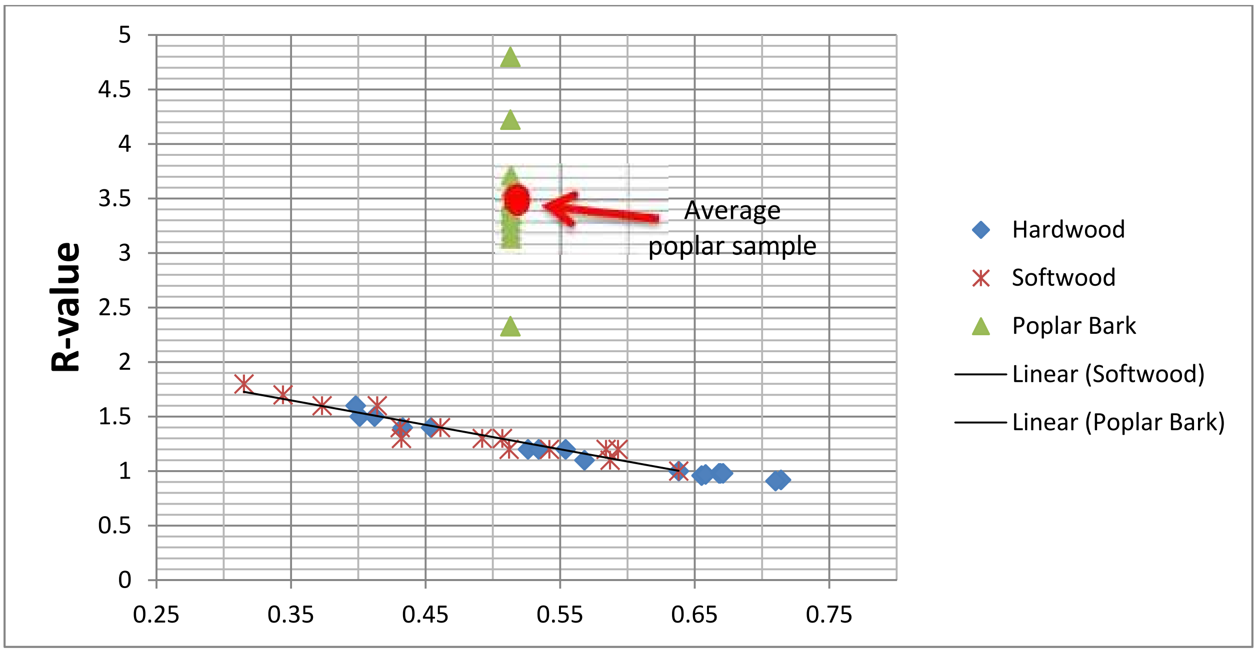
R-VALUE ANALYSIS:



To understand what an average R-value of 3.7 meant we compared it with various woods and common insulation materials. The poplar bark had a higher R-value than we expected and was significantly higher than the poplar wood itself and is higher than most woods, while still very low compared to polystyrene. Interestingly it was very close to the R-value of a Fiberglass Batt, as well as uninsulated floor. 1.5" fiberglass is often used in insulating attics, roofs, and walls. Based on this data Poplar bark could be used as a substitute for or assist fiberglass insulation.

However, the poplar bark's high R-value was initially very perplexing. We decided to compare the woods with their densities to see if there is a relation between how dense a material is and how well it can retain heat. We found the following:

Material R-value vs. Density

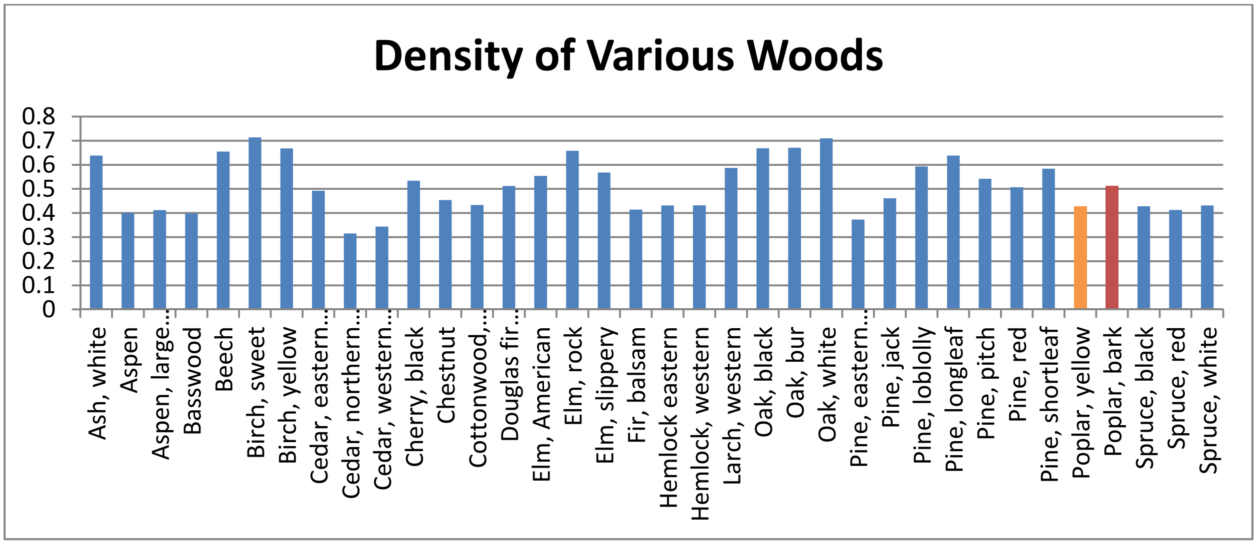


There seems to be an inverse relationship between the wood's R-value and density. When wood's density is high we see that the R-value tends to be lower and the opposite occurs when we look at lower density materials. Poplar bark had a density close to 0.525 g/ml, yet it did not have an R-value close to 1.25 like the correlation predicts it would. Instead the poplar bark's R-value is over two times as large as any wood on the graph.

The fact that poplar bark does not seem to follow this relationship shows us that it has both a high R-value and density, which could be a unique strength of this specific material. It can reduce heat conduction as well as retain much of its heat due to its density. Now we will examine the thermal mass to further determine its thermal properties.

Thermal Mass According to Density:

In order to determine the density of poplar bark the technique described previously was used. On average the density was 0.513g/ml. I compared that to the density of various woods:



Then looking at various building materials such as fiberglass insulation (0.032 g/ml) and comparing them with the density of various woods, fiberglass' density is proven to be quite low and wood's density is high. Again notice how large poplar bark's density is considering its R-value as well. Since density is directly related to thermal mass, poplar bark can retain a significant amount of heat within itself, thus reducing heat loss enormously.

CONCLUSION:

The R-values of insulating materials are very important, but more importantly we must consider the thermal mass of the materials. If we consider both of these properties the quality of insulation can be determined. In the case of wood, the R-values tend to be on the lower side of the spectrum, but they are still able to function as very good insulators because of their high density and specific heat. Although they do not have a thermal resistance, they are able to absorb the heat and maintain a close to constant temperature.

When poplar bark was examined we found that the R-value was quite high at about 3.7, high for a material with such a high density. With both a high density and high R-value this material shows much promise as an insulation material as well as regular house siding.

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