Possible usage of Jute material for building insulation

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Abstract

Natural fibres can be used in different applications and one of the important applications is building insulation. The low value of thermal conductivity and its natural character provide opportunities to consider the Jute material for thermal insulation in building industry. Different blends comprised with natural Jute also an option to get the standard parameters as required. This paper has discussed the possibility of using Jute as a building insulating material. Purpose of this project was to identify the deviation of raw Jute's insulation properties comparing with a standard insulation material and introducing the ways that Jute could be used for this function, to promote the usage of total ecofriendly insulation material. A sample test has been provided with this and content accompanies with the researched information as well. Insulation test procedures have been discussed, and practically measured values were provided with the calculation methods.

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1. INTRODUCTION

Although the modern trend is for sustainable & ecofriendly building constructions, a heavy usage of synthetic insulation material is still common practice. These synthetic materials are formed based on hydrocarbons and not ecofriendly at all. And during any recycling process, those emit poisonous gases as well. And with the volatile quality of those synthetic materials, unhealthy particles also emit to the surrounding.

With the fast-growing housing and building construction industry in Canada, these natural material applications for insulations will support to go with fully ecofriendly concept. This report provides practically measured values, test arrangements, technical calculation methods/standards and supportive well recognized scientific literature to prove the feasibility of Jute, as a natural insulation material.

The drive towards energy efficiency is a major global concern. The total energy consumption all around the world, is increasing each year. If we fully adhere to eco friendly products for construction insulations, that will be a huge quantitative achievement regarding the eco friendly approach within the industry. Starting from this introduction, this report reveals the context of this approach, related with natural material applications. Next to that, the graphical illustrations of test methods are explained and calculation-based discussions, conclusions are analyzed introducing and encouraging eco friendly insulations [7].

2. Background/Context

This work is focused on analyzing the potential application of 'Jute material' as an alternative for synthetic building envelop material for insulation. Although there are various types of insulating materials used on this behalf, the material manufactured from mineral wool, polystyrene or polyurethane will produce very harmful substances to the environment during their recycling process [1]. Ecofriendly insulation helps in reducing pollutants in a home, it definitely protects the environment, a Canadian survey has shown that 86% of people in Canada would choose an energy efficient eco friendly home & in that sense it increases the value of the home and due to the radiant heat exchange it makes a more comfortable atmosphere[7]

Rubber latex jute composite will make it a more effective on sound absorbing qualities and Fire retardant tests have proven that this material has to high limiting oxygen index value when it is used as a latex jute composite[8].

Since the middle of the 19th century, thermal insulation products have been developed that originally had natural origins. However, artificial materials in the 19th century, mineral wool products, and in the first half of the 20th century, plastic foams also appeared at the same time. They almost completely displaced nature-based materials because their production costs were low until the first oil crisis, and they did not have durability and flammability problems [9].

While the thermal resistant value being the major fact, there are some other technical factors to be considered as well. They are thermal dynamics, heat transfer, fluid dynamics, wave theory, Acoustical dynamics. IR testers can be used to get in-situ values and hot box apparatus can be used for the sample testing. In this experiment the major focus is to obtain a practical thermal conductivity and R value [8].

3. Methodology

3.1 Important measures of an insulation

Thermal Conductivity is sometimes referred to as k-value or lambda value (λ). And it is a measure of the rate at which temperature differences transmit through a material. The lower the thermal conductivity of a material, the slower the rate at which temperature differences transmit through it; there it is more effective as an insulator. The lower the thermal conductivity of a building's fabric, the less energy is required to maintain comfort inside.
R-Value is a measure of the thermal resistance of a material of a specific thickness and it's the resistance to the transfer of heat across it. The higher the R-value of a material, the more effective it is as an insulator R-values enables comparison of the thermal performance of different materials, such as insulation, as part of the calculation of heat transfer across the fabric of a building.

3.2 R- Value Measurement Methods

• ASTM C 177 - Standard Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Guarded Hot-Plate Apparatus [6].

• ASTM C 518 - "Standard Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus [6].

• ASTM C 1363 - Standard Test Method for Thermal Performance of Building Materials and Envelope Assemblies by Means of a Hot Box Apparatus [6].

3.3 Test method using steady-state heat flux through specimen

As per ASTM C 177 the steady-state heat flux through homogeneous flat specimens need to be maintained. Two test specimens (as identical as possible) are to be placed on both sides of a "guarded" hot plate and in contact on the other side with a "cold surface assembly". Compliance with this test requires the establishment of steady-state conditions [6].

In this experimental test (*Figure1*), possible attempts have been taken to comply with the ASTM C 177 by.

- Maintaining the steady-state heat flux through the specimen and
- Arranging hot plate end and cold wall (Room temperature) end at the opposite sides of the specimen
- With the cylindrical arrangement used as described below it eliminates the need of "guarded" setting as per ASTM C 177, because no ends are provided there, for any heat

loss. Instead, all the heat does transfer through the specimen. And due to the cylindrical arrangement, there is only one surface (*Figure1*), that transmit heat outwards: so that only one specimen has used.

A specimen sample of natural Jute felt (found form natural Jute rope) was used to test for R value. Here, first the thermal conductivity was tested, and the R value is calculated based on the experimental thermal conductivity value.

Flowing notations and the equations were used.

Temperature difference ΔT
Sample thickness Δx.
Heat flow [output of the supplied electrical power] $\dot{Q}$
Thermal conductivity of the specimen λ

By using the above given parameters,

The heat flow $\dot{Q}=\lambda \cdot A \cdot \Delta T/\Delta x$
Thermal conductivity $\lambda = \dot{Q} . \Delta x / A \cdot \Delta T$

As per the definition; R value = $\Delta x / \lambda$

Once the R value is obtained it can be compared with the standard limitations to consider its capability regarding building insulations.

4. The test for 'λ' & 'R'

The main attribute here for concerning a material to be used in building insulation purpose is its R value. Two thermo couples have been used with its digital reader to get the accurate temperature readings. A Cylindrical arrangement as shown in *figure 2*, was used to pack with jute fiber to control any heat loss for the surrounding. With this arrangement all the heat generated by the element passes through the material. In that way it helps for the accuracy of the calculations. The heat output corresponds to the electrical power supplied to the heating. The maximum wattage of the heat source was 75W and selected 1/30 of if to leave the temperature below the auto ignition temperature of the Jute material.

Basic weight (fabric weight), bulk density, compactness and porosity of the structure are tested for deciding the effectiveness of a nonwoven material, for thermal insulation. The effect of shrinkage properties on heat treatment of the nonwoven materials also a factor to be considered.

4.1. Test instrument arrangement

Following set up (*Figure:* 1) was arranged with the available means for test the R value of the Jute material. The graphical illustration of the arrangement in *figure 2*, including concerned dimensions, are provided below.

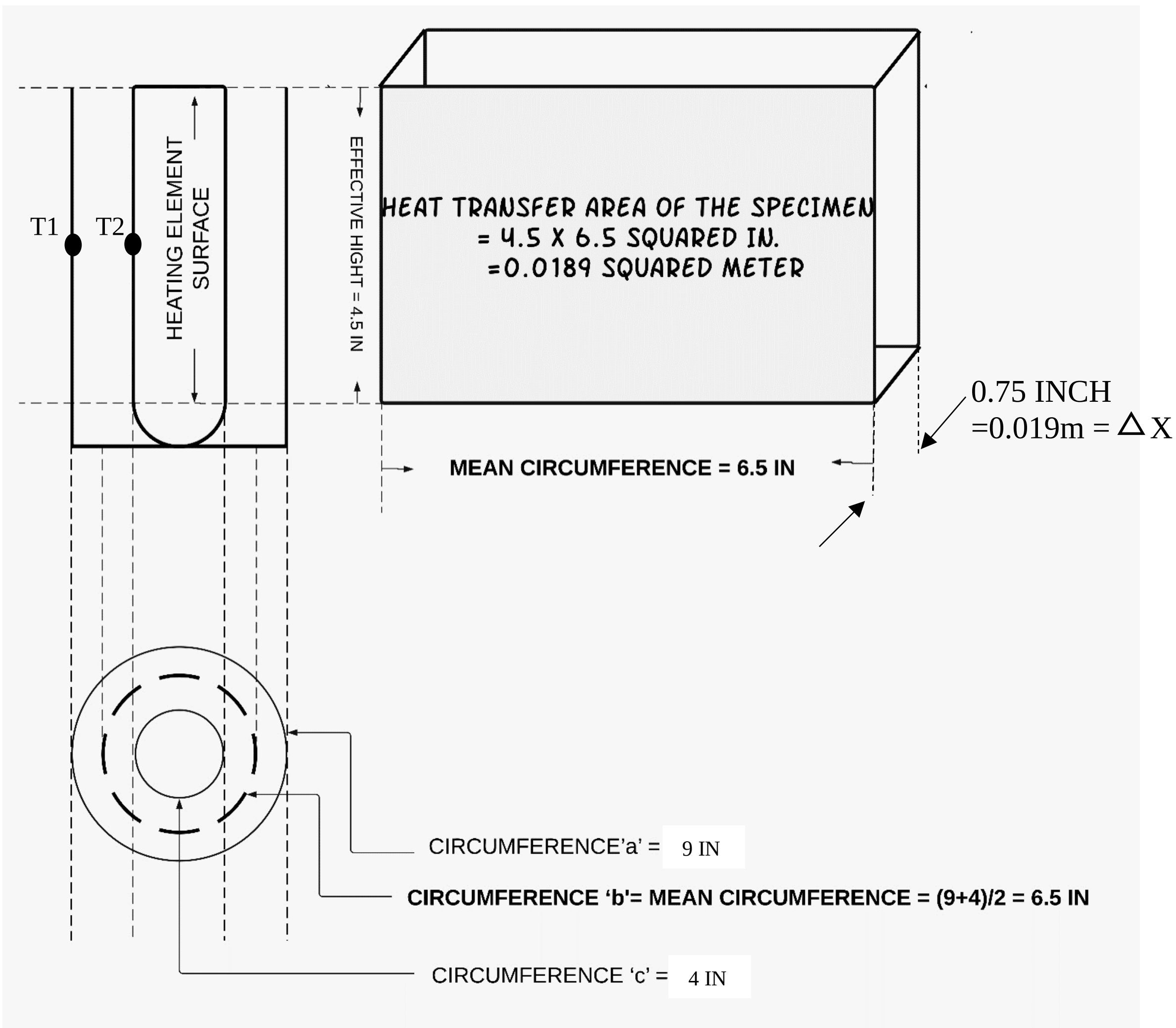

Figure1: Test arrangement diagram

Source: Author generated

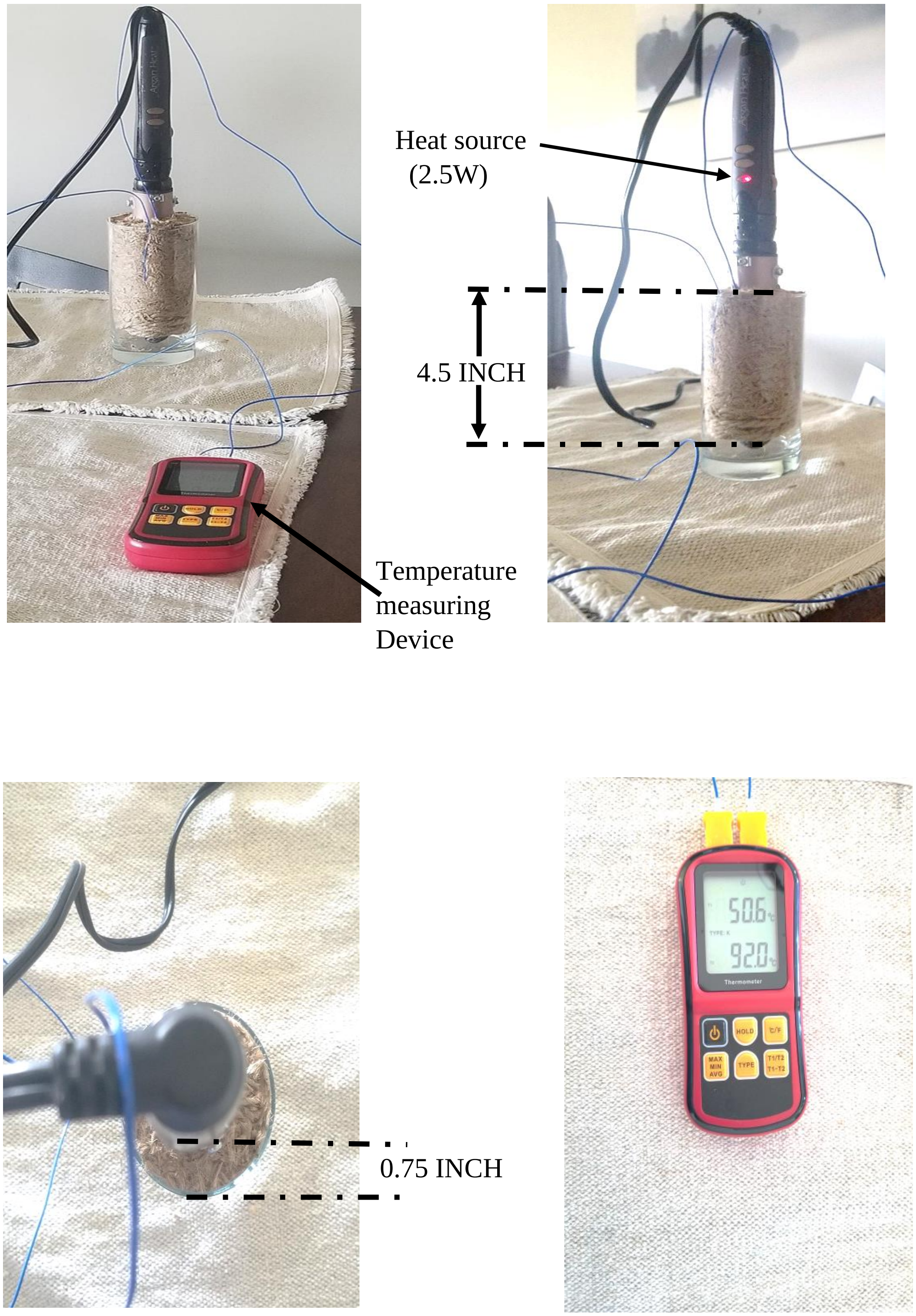

Figure 2: *Heat source, Jute sample and Temperature measuring device*
Source: Author generated

Figure 2 shows the practical test arrangement prepared as per the theoretical demonstration provided ay *Figure 1* .

Table 1 shows the values measured for T1 and T2.

Table 1: Test results

Heat Applied	Temperature(^{0}C)	
	T1	T2
2.5W	50.6	92

Source: Author generated

As per the table shows, the 2.5W heat source *(Figure 2)*, has been used to dynamic heat flow stability through the Jute material. And the T1 and T2 were measured at the points arranged as noted in *Figure 1*.

4.2. Calculation

Calculating Thermal conductivity (λ) value,

The heat flow $\dot{Q} = \lambda \cdot A \cdot \Delta T / \Delta x$ (As per the thermodynamics equations)

(where $\Delta T = T2 - T1$; $\Delta x = 0.019m$; $A = 0.0189m^2$ as shown in *Figure 1*)

$$2.5\ W = \lambda \times 0.0189m^2 \times (92.0 - 50.6)^0C/0.019m$$

Thermal conductivity $\lambda = 41.1821\ W/m^{-1}\ K^{-1}$

Calculating the (R) value,

R value is explained as $\Delta x / \lambda$ as per the thermodynamics equations,

$= 0.019\ m / 41.1821\ W/m^{-1}\ K^{-1}$ (where $\Delta x = 0.019m$ as shown in *Figure 1*)

R value $= 0.06\ m^2K/W$

By this it shows that observed R value is among the typical R values for building insulations [9].

Table 2: Sample of R values of different materials including building insulations

Material	RSI-value ($m^2 \cdot K/W$)
Aerated/Cellular Concrete (5% moisture)	0.18
Brick	0.030
Cardboard	0.52–0.7
Cellulose loose-fill[58]	0.52–0.67
Cellulose wet-spray[58]	0.52–0.67
Cementitious foam	0.35–0.69
Closed-cell polyurethane spray foam	0.97–1.14
Cotton batts (Blue Jean insulation)[55][56]	0.65
Drywall[49]	0.15
Extruded expanded polystyrene (XPS) high-density	0.88–0.95
Extruded expanded polystyrene (XPS) low-density	0.63–0.82
Fiberglass batts[54]	0.55–0.76
Fiberglass loose-fill[59]	0.44–0.65
Fiberglass rigid panel	0.44
Foil faced Polyurethane rigid panel (pentane expanded)	1.1–1.2
Foil-faced polyisocyanurate rigid panel (pentane expanded) initial	1.20
Foil-faced polyisocyanurate rigid panel (pentane expanded) aged 5–10 years	0.97
Glass[50]	0.025
Hardwood (most)[64]	0.12
High-density fiberglass batts	0.63–0.88
Home Foam[52]	0.69
Icynene loose-fill (pour fill)[51]	0.70
Icynene spray[51][57]	0.63
Molded expanded polystyrene (EPS) high-density	0.70
Molded expanded polystyrene (EPS) low-density	0.65
Open-cell polyurethane spray foam	0.63
Papercrete[63]	
Perlite loose-fill	0.48
Phenolic rigid panel	0.70–0.88
Phenolic spray foam	0.85–1.23
Polyethylene foam	0.52
Polyisocyanurate spray foam	0.76–1.46
Polystyrene board[50]	0.88
Polyurethane rigid panel (CFC/HCFC expanded) aged 5–10 years	1.10
Polyurethane rigid panel (CFC/HCFC expanded) initial	1.23–1.41
Polyurethane rigid panel (pentane expanded) aged 5–10 years	0.97
Polyurethane rigid panel (pentane expanded) initial	1.20
Poured concrete[50]	0.014
Rice hulls[53]	0.50
Rock and slag wool batts	0.52–0.68
Rock and slag wool loose-fill[59]	0.44–0.65
Silica aerogel	1.76
Snow	0.18
Softwood (most)[64]	0.25
Straw bale[62]	0.26
Thinsulate clothing insulation[48]	0.28–0.51
Urea foam[50]	0.92
Urea-formaldehyde foam	0.70–0.81
Urea-formaldehyde panels	0.88–1.06
Vacuum insulated panel	5.28–8.8
Vermiculite[61]	0.38
Vermiculite loose-fill	0.38–0.42
Wood chips and other loose-fill wood products	0.18
Wood panels, such as sheathing	0.44

Source:. https://en.wikipedia.org/wiki/R-value_(insulation)#Typical_R-values

4.3. Further tests for a commercial product

Calculating the R-Value of the material is a major factor here and it provides the idea about the comparison of two materials regarding thermal performance. The apparatus for that is well described by the document ‘Development of a New Hotbox Apparatus to Measure Building Enclosure Thermal Performance’[3].Requirement of thermal conductivity & specific heat considerable characteristics of a thermal insulation material and being the thermal resistant has been discussed by the document ‘Assessing the Thermal Performance of Building Enclosure Materials Using a Medium-Size Hot Box Chamber’[6].In-situ thermal properties are to be measured for comparing data. The related code standards are described by the journal, ‘In situ measurement of thermal transmittance and thermal resistance of hollow reinforced precast concrete walls, vol. 842014132141, 2014’[5].The document ‘Standard Test Method for Steady-State Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus[4] explains many other options of calibration procedures and explanation of necessary formulas. And it provides the procedures to follow if the tests are going to be followed in a regular basis like in a laboratory. The research document ‘Natural thermal-insulation materials composed of renewable resources[8]**,** provides a complete test scenario which was done to determine the potential ability of using Date Palm waste as thermal insulation material has been explained methodically here in this document. They describe the preparation of the material, water uptake, density measurement, tensile test & thermal conductivity test. This research paper provides more closer set of steps that can be followed my may other similar types of material. This is one of the incredibly supportive documents for further research and experiment on Jute material.

5. Conclusion

It is found from the study that the Jute material has got a R value of 0.06 m^2K/W. By this it shows that observed R value stays among the typical R-value range as shown in *Table 2*. Based on this result, it can be decided that there is a huge potential for using raw Jute material as building insulation material. Again, this experiment needs to be confirmed by a well-equipped lab facility for the perfect results. With the limited access of laboratory practices due to the COVID situations, maximum effort was taken to practically represent the technical experimental arrangements. As a second step, the rest of the tests (Eg: fluid dynamics, wave theory, Acoustical dynamics) need to be tested in a standard lab facility. Bi-component fibre can also be considered for further experiments. This experiment has provided a positive outcome for the starting hypothesis.

6. Recommendations

A laboratory test process is highly recommended for the above scenario. And considering a mean temperature value of a multi point sensing arrangement can be recommended. Jute can carry a large amount of unnoticeable water concentration. So it is very advisable to have jute dried enough before the tests for having better results.

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Appendices