4 CONGRESO DE INGENIERÍA, CIENCIA Y GESTIÓN AMBIENTAL AMICA

5th International Conference of Greening of Industry Network

28, 29 y 30 de octubre de 2019
Instituto de Ingeniería de la UNAM
Ciudad de México

AIDIS · AMICA · The Greening of Industry Network · Instituto de Ingeniería UNAM · University of Twente · Walmart México y Centroamérica · Red Mexicana de Análisis de Ciclo de Vida A. C.

MEMORIAS DE CONGRESO NACIONAL AMICA 2019

ISSN
04-2015-050708040300-203

ID 546 THERMAL PROPERTIES OF BIO-INSULATION MADE FROM WASTE

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Abstract

The dramatic growth of the tourism in Sagarmantha National Park and Buffer Zone has brought the construction of large number of modern building using imported construction materials. Moreover, with the growing tourism industry in the Park, increasing non-renewable solid waste has exacerbated the problem in the Park. Therefore, this research focuses on reusing the waste product such as paper, plastics, wooden grain to make the bio-insulation. The cold weather in the high altitude regions demands high amount of energy for room heating. If the buildings were poorly insulated, a great deal of heat will escape aggravating already poor supply of energy. In order to reduce the amount of energy wastage, there is a need to insulate the buildings properly. The bio-insulation tile made up of locally available material like white soil (Kamero), cow dung and waste product like paper, plastic, wooden grain were tested in two different methods;thermo-Box method and Lee's method. Their thermal conductivity and transmittance were measured and a comparison was done. This paper mainly deals the efficiency of insulation tiles as well as the method used.

Keywords: bio-*insulation, circular economy, thermos box method, Lee's method, thermal efficiency*

Introduction

The construction sector is one of the largest consumers in terms of natural resources, and one of the largest producers of waste (Nuñez-Cacho et al., 2018; Vijayan & Kumar, 2005). As one of the main sectors responsible for global energy consumption and waste production, the construction industry has to and ways to negate or reduce the impact on social, economic and especially environmental factors.

Sagarmatha National Park and Buffer Zone is the most popular destination for tourism in the Himalayan tourist region of Nepal. High tourist influx (300,000 in 2014) in the region has brought the construction of large number of modern building. The modern building is built by using imported construction material such as cement, steel, glasswool, polystyrene (Bhochhibhoya et al., 2017). These materials has to be transported from the capital city, Kathmandu by Helicopter due to the complex terrain. Therefore, commercial material is likely to have a larger environmental and economic burden from a life-cycle perspective than locally available construction material (Bhochhibhoya et al., 2017).

Moreover, with the growing tourism industry in the Park, increasing non-renewable solid waste has exacerbated the problem in the Park. The existing management system is limited compared to the fast growing waste accumulation (Salerno et al., 2009). The solid waste production in the SNPBZ was 2 tons per day (Manfredi et al., 2010). Kitchen waste composed of organic matter that occupied 88% of the total waste and 7% of the waste production is the plastic, 3% for glass and 1% of metal (Manfredi et al., 2010). Most of the non-degradable materials are dumped into the landfill.

On the other hand, the cold weather in the high altitude regions demands high amount of energy for room heating. If the buildings were poorly insulated, a great deal of heat will escape aggravating already poor supply of energy. In order to reduce the amount of energy wastage, there is a need to insulate the buildings properly. This research focuses on how these wastes can regenerate to make the bio-insulation at their highest utility in order to reduce the waste dumped into the landfill.

Method and Materials

The bio insulation tile were made using locally available material like *Kamero* (white soil), cow dung and waste product like paper, plastic, wooden grains. The thermal conductivity of these insulation tiles were tested using two different methods; thermo-Box method and Lee's method.

Determination of thermal conductivity of insulation tile by thermo-box method

To test the thermal transmittance (U- value) of insulation tiles using the thermo-box method, the preparation of the tile are describe below.

Collection: Collection of locally available raw materials.
Preparation: Mixing of the raw material (Figure1) usually in one part fresh dung, two parts insulating material (viz; plastic, paper, wood pieces instead of commercial insulation products) and four parts *Kamero*. However, the composition can be varied according to the desired property of the insulating material.
Manufacture: Production of tiles using commercially available machines were used. The produced tiles are of dimensions (9" X 9" X 2") which can be increased for quicker production.
Finishing: Laying of surface finish for additional strength, look, and drying of the tiles for compaction shown in Figure 2.
The insulation tile made up of locally available materials like *Kamero* (white soil), cow dung and waste product like plastic, paper, wooden grain, rice husk may be the effective thermal insulation. Thus to test the thermal transmittance (U- value) of insulation tiles, the preparation of the tile was done shown in Figure 3.


Figure 1. Preparation of material. Figure 2: Insulation tile

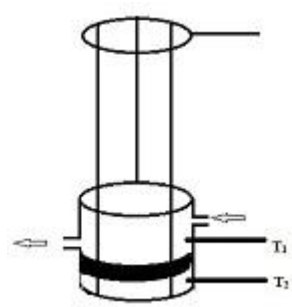
Figure 3: Testing of the insulation tile in thermo box.

The bio-insulation tiles made are of dimensions (230 mm X 230 mm X 51mm) shown in figure 2, which can be increased for quicker production. Thermal properties of the tiles were studied in the thermo box shown in Figure 3. The Styrofoam with the known thermal conductivity was tested for the reference.

Determination of the coefficient of thermal conductivity by Lee's method

Steam is passed from the inlet of the cylindrical until steady state is reached (see Figure 4). The steady state temperature ϴ1 and ϴ2 at T1 and T2 respectively are noted. Then the cylindrical vessel and the metallic disc is brought into direct contact until the disc's temperature is about 10°C above the steady temperature indicated at T2. It is then allowed to cool and temperature is noted in an interval of 30seconds till its temperature falls to about 10°C below ϴ2.

If M is the mass of the metallic disc, s the specific heat of its material, then rate of cooling at θ2 is equal to $Ms\frac{d\theta}{dt}$. Where: $\frac{d\theta}{dt}$ is the rate of fall of temperature at θ2.



Therefore,

$$K\frac{\pi r2(\theta 1-\theta 2)}{d} = Ms\frac{d\theta}{dt}$$

Or,

$$K = \frac{Msd}{\pi r2\,(\theta 1-\theta 2)}\frac{d\theta}{dt}$$

Where, K=coefficient of thermal conductivity
M=Mass of the metallic body (gm)
s=Specific heat of the metal (cal/gm°C)
d=Thickness of the disc (cm)
r=Radius of the disc (cm)
D=Diameter of the disc (cm)
ϴ1=Temperature in thermometer T1
ϴ2=Temperature in thermometer T2

Figure 4: Setup of Tile in Lee's method

Testing of insulation tiles

The insulation tile then tested in the thermo-Box designed and developed at Centre for Excellence in Production and Transportation of Electrical Energy, Kathmandu University (CEPTE/KU), Nepal. The top view of the thermos box is shown in Figure 5. The thermo-Box was designed in such way that cooling system is automatically controlled in outer box to maintain the prescribed lower temperature. On the other hand, an automatically controlled 400W heater was placed inside the thermo Box.

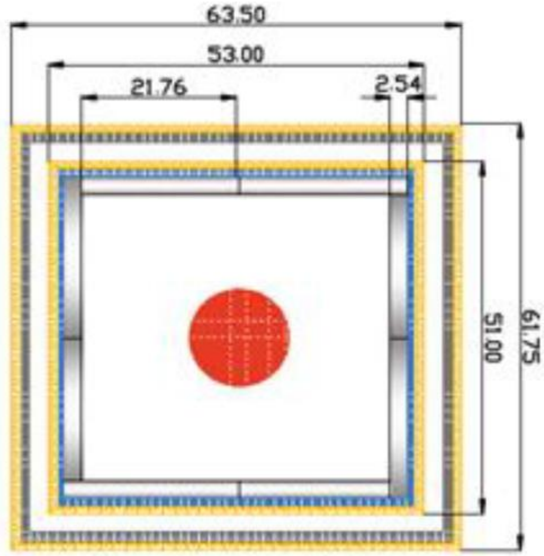


Figure 5: Top view of thermo box

The insulation tiles were then sandwiched between inner and outer boxes. Styrofoam with the known thermal conductivity was tested for the reference values.
The controlled temperatures inside and outside boxes with correspond to ambient temperature were noted. Thermal conductivity of the insulation tile was calculated with the temperature difference between inner and outer temperatures of the boxes. The working formula for calculating thermal conductivity (K) is given by:

$$K= Q\times LA\times \Delta T$$

Where,

Q = amount of heat flowing through surface in unit time (Watt)
L = thickness of the tile (m)
A = area of the tile (m2)
ΔT= temperature gradient (Kelvin)

Further, Thermal Resistance of the insulating tile was calculated with known value of thermal conductivity and thickness of tile.

$$R= LK \text{ (m2K/W)}$$

Thermal Transmittance (U- value) is the reciprocal of R-Value which can be calculated as:

$$U= \mathbf{1}\boldsymbol{R} \text{ (W/m2K)}$$

The thermal transmittance is defined as the rate of heat transfer in watts per square meter of area per degree difference in temperature. Lower the thermal transmittance, better is the insulation value of the structure.

Results and Discussion

Thermal transmittance of Bio-Insulation Tiles

The thermal conductivity of different types of bio-insulation tiles depends on their phyiscial properties and its thickness. The bio-insulation tiles made of different local materials like white soil (*Kamero*), cow dung, rice husks, wooden grains and waste products like paper and plastics were tested by thermo-Box method and Lee"s method to measure it's thermal conductivity. The thermal conductivity of different bio-insulation tiles are given in Table 1.

Table 1: Thermal Conductivity of Tiles

Types of insulating material	**Thickness (m)**	**Thermal Conductivity by thermo Box Method (W/mK)**	**Thermal Conductivity by Lee's Method (W/mK)**
Empty box	0.025	1.023	
Styrofoam	0.032	0.078	0.091
Option 1(*Kamero*, Wooden grain, cow dung)	0.025	0.092	0.165
Option 7 (*Kamero*, Wooden grain, plastic thread, cow dung)	0.032	0.075	0.208
Option 2(*Kamero*, Rice husk, cow dung)	0.025	0.094	0.151
Option 10 (*Kamero*, Tile powder, cow dung)	0.025	0.096	0.140
Option 13 (*Kamero*, paper pulp, cow dung)	0.032	0.075	0.236
Option 11 (*Kamero*, paper pulp, cow dung, baking powder)	0.025	0.089	0.255

The thermal conductivity of option 13 tile made up of *Kamero*, paper pulp and cow dung with thickness 0.032 meter was found to be 0.07 W/mK which is better than other tiles. Option 7 with *Kamero*, wooden grain, plastic thread and cow dung has the thermal conductivity of 0.075 W/mK in 0.032 m of its thickness. For the reference commercial Styrofoam was tested which has a thermal conductivity of 1.023 W/mK.

Retaining temperature using bio-insulation tiles

The average temperature in the thermo box with the bio-insulation tiles increases drastically within few minutes and the tempearute loss in a slow rate as shown in figure 6.

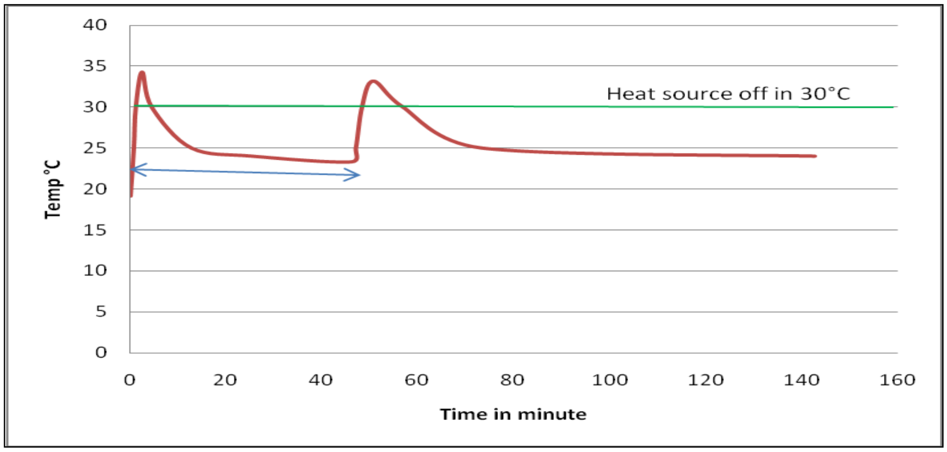


Figure. 6: Retaining temperature

The graph indicates that the insulation tiles can retain heat of 5 minutes for a period of 50 minutes in comfortable temperature in first round. In second round, the heat retain is even longer compare to the first round. Thus, less amount of heat energy is require to keep the room warm for the longer period of time.

Comparison of Thermal transmittance and Cost of Insulation Materials

The bio-insulation tiles were compared with commercial insulation materials like glass-wool, polystyrene, wooden planks etc in terms of thermal transmittance and cost shown in figure 8. Lesser the U-value, more efficient is the insulation materials. Plywood has a high U-value as well as the high cost. The commercial insulation material like thermocole and glasswool is relatively better insulation due to low U-vlaue but have higher cost compare to the bio-insulation tile.

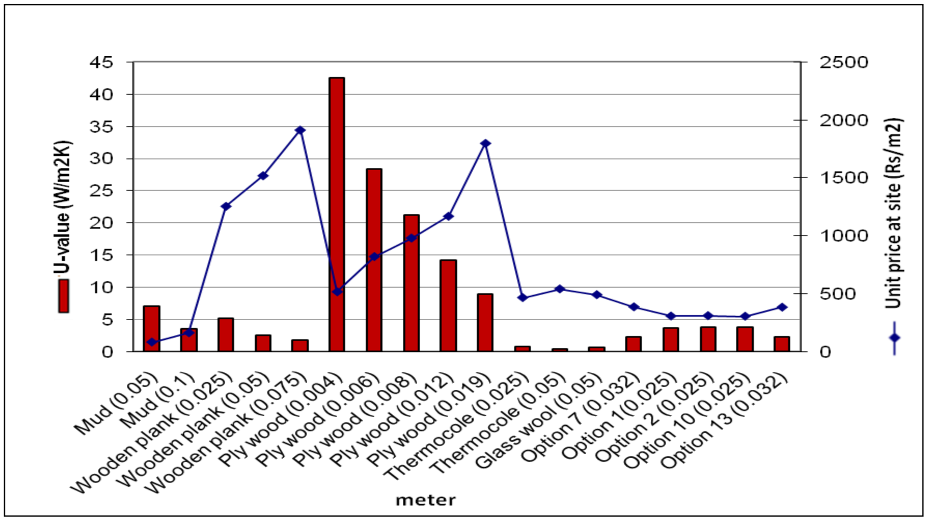


Figure 8: Comparison of U-value and Price of Different Insulation Materials

The figure shows that the insulation tile prepared from locally available materials, reused waste products, etc. are efficient both economically and thermally efficient.

Conclusion

This study shows the possibility of reusing the waste to make valuable product like bio-insulation in order to reduce landfilling the waste. In the same time, reduce the use of commercial material that has to be imported to the region from the capital city by helicopter. Moreover, the energy consumption for space heating could be reduced by achieving a lower U-value bio-insulation tile. This article emphasis on making and testing the bio-insulation tile. The results show that the bio-insulation made of waste product and locally available materials are thermally and economically efficient compare to the commercial insulation.

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