International Journal of Mechanical And Production Engineering, ISSN: 2320-2092, Volume- 4, Issue-1, Jan.-2016

EFFECT OF THICKNESS OF WOVEN BAMBOO WALL ON THERMAL CONDUCTIVITY COEFFICIENT AND BULK DENSITY

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Abstract— The objective of this study is aimed to investigate experimentally an influence of thickness of woven bamboo wall on thermal conductivity coefficient and bulk density. The woven bamboo wall used as a tested sample in this study is a commercial product which differs in thickness: 3 mm, 4 mm, 6 mm and 8 mm. In practice, there are two main experiments separate from each other to measure the coefficient of thermal conductivity and the bulk density. First, in order to determine the thermal conductivity coefficient, woven bamboo samples were tested under the framework of ASTM C177 standard. The specimen sizes are 30x30 cm^2. The experimental operated by AC 220 Volt with 100 Watt at 57 ^{o}c for more than 3 Hours to achieve a steady state condition. Second, ASTM D2395-93 method B was applied to evaluate a total volume of samples. Specimen sizes are 3x10 cm^2 wrapped with thin plastic wrap. Then thin stick was used to push the specimen down the water level. The result showed that the bulk density and the thermal conductivity coefficient of woven bamboo wall increased with the thickness. In addition, the thermal conductivity coefficient increases when the bulk density increased. The coefficient of thermal conductivity of 3mm thick woven bamboo wall is 1.55 W/m-K, which is the better thermal insulation compared to the other thickness.

Index Terms— Thermal Conductivity, Bulk Density, Woven Bamboo, Thermal Insulation.

I. INTRODUCTION

Chiang Mai is one of the most popular travel provinces in Thailand, because this province has various types of travel activity. Chiang Mai was selected as the Best Destination for Culture Experience price from Lonely Planet Traveler Destination Awards 2013. For this reason, travel business continuous developed. Home Stays become one of the most famous accommodations in Chiang Mai. Many tourists love to living close to nature and local culture. Therefore, some accommodations are designed by using a woven bamboo wall which is local material as a wall of the building for supports tourist's requirement. Moreover, a thermal insulation plays a significant role in many buildings that use air conditioners for a convenience of tourists. The most commonly used thermal insulations in Thailand are fiberglass, mineral wool, and polyurethane [1]. However, they are toxic for human health and environment [2]. On the contrary, agricultural products, i.e. the woven bamboo, are an interesting choice for composite thermal insulation [1], [3], [4], because there is a few problem in health and environment.

In practice, the bamboo woven wall was made of bamboo tissue, which is a thin layer of dry bamboo wood. Such bamboo tissues were weaved together. These bamboo tissues were then merged by special glue. After that, the bamboo tissues were compressed by using a high pressure machine in order to reach a desired thickness and also increase the strength of materials.

Absolutely, more thickness makes more bulk density. In that case, the thermal conductivity coefficient also increases [5]-[7]. Many previous studies which test other material investigated the relation of thermal conductivity coefficient and bulk density. Thermal conductivity coefficient increases when the material's bulk density increased [5]-[7]. So, more the thickness could make more the thermal conductivity coefficient.

In this study, the effects of the woven bamboo wall's thickness on thermal conductivity coefficient and bulk density are experimentally investigated.

II. METHODOLOGY

A. Experimental design for Thermal conductivity coefficient

In order to measure the coefficient of thermal conductivity, our experiments were conducted underlying the ASTM C177 standard [8]. Testing sample was woven bamboo walls size 30x30 cm^2. The samples are commercial product which differs in thickness: 3 mm, 4 mm, 6 mm and 8 mm. Those woven bamboo walls are contain 2 layers, 3 layers, 4 layers and 5 layers of bamboo tissue. The apparatus drawing set up are shown in fig 1. The apparatus heated to testing sample by grade square hot plate size 30x30 cm^2. The apparatus were covered with thermal insulation. 20 thermocouples were used to measure temperature. Data logger model YOKOGAWA MW100 was used to collect temperature data. The grade hot plate operated by AC 220 Volt with 100 Watt at 57 ^{o}c. The experiments were running more than 3 Hours to achieve a steady state condition. Two same thickness testing materials were test in the same time for reduce the testing time. The ambient temperature was control at 25^{o}c. Four thermocouples were applied on each side of testing material. The others were applied outside the apparatus for measured the atmospheric temperature. Four thermocouples were used to record temperatures in each side of sample. Then average temperature per each side would calculate from those temperatures. So, sixteen thermocouples were used to record temperature of sample. The other four thermocouples use to recode ambient temperature of testing. The positions of thermocouple are show in fig2.

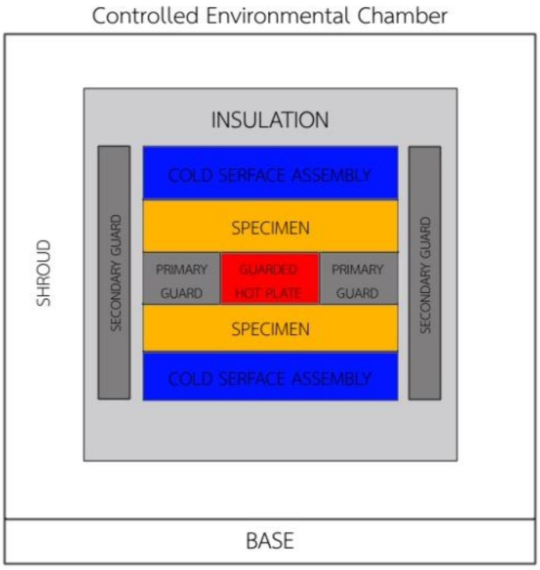

Fig1 the apparatus drawing set up

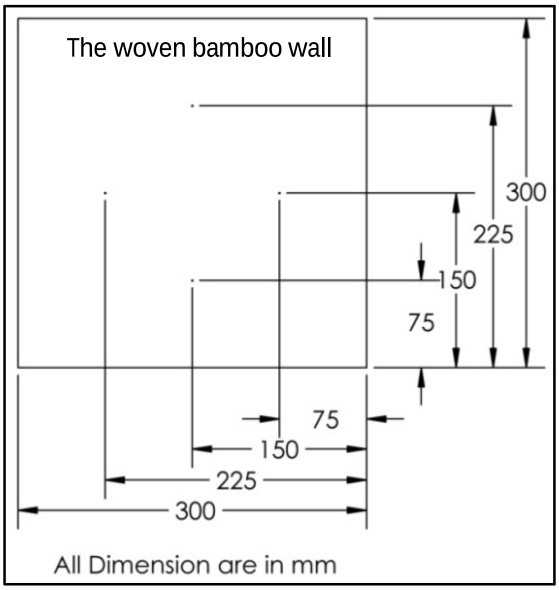

Fig2 Position of thermocouple in each side of sample.

The thermal conductivity coefficient was calculated by the following equation:

$$k = q \times \frac{L}{(A\Delta T)} \qquad (1)$$

Where k is the thermal conductivity coefficient of the specimen in Watt/m-K, q is the heat flow rate through the specimen in Watt. L is the thickness of the specimens in m, A is cross-section area of the specimen in m^2 and ΔT is temperature different through the specimen.

B. Experimental design for bulk density

Bulk density was determined by total mass of sample divided by total volume of sample. Total mass was measured by using digital scales TANITA model 1140. Testing samples size are 3x10 cm^2 weighed by digital scales. Then all of them were wrapped by thin plastic wrap and blow those sample with hot blower for protect water absorb. For find total volume, ASTM D2395-93 Method B [9] was applied. Thin stick was used to push the testing material down the water level. Fig 3 is shown total volume finding method.

Density were calculated by following equation

$$\rho = \frac{m}{V} \qquad (2)$$

ρ is the density of the specimen in g/cm^3. m is the total mass of the specimen in g.
V is the total volume of the specimen in cm^3.

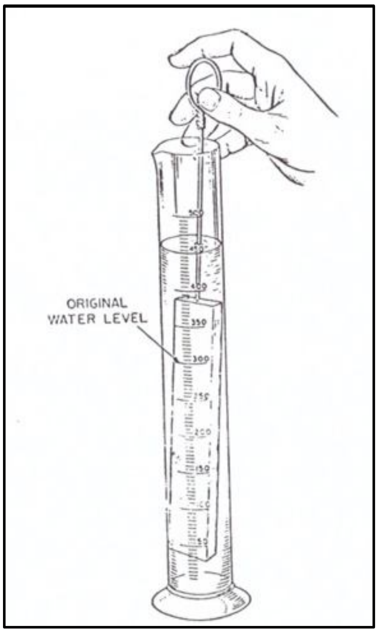

Fig 3 total volume finding method. [9]

III. RESULT

The results of experiments are separate in three parts. (1) Effect of thickness on the bulk density (2) Effect of thickness on the thermal conductivity coefficient and (3) Effect of bulk density on thermal conductivity coefficient. The experiments showed that the thickness of woven bamboo wall had an effect on the thermal conductivity coefficient and the bulk density. Trend of the thermal conductivity coefficient and the bulk density are the same as other research works [1, 6, 7]. The thermal conductivity coefficient and the bulk density increase with the thickness.

A. Thickness VS Bulk density

Effects of the thickness on the bulk density are shown in fig 4. The bulk density increases when the thickness. It can be seen that more thickness uses more bamboo tissue to merge, see in fig 5, so a weight of testing material thus increases but total volume decreases cause of compressing in assembly process. The bulk density of testing material also increases.

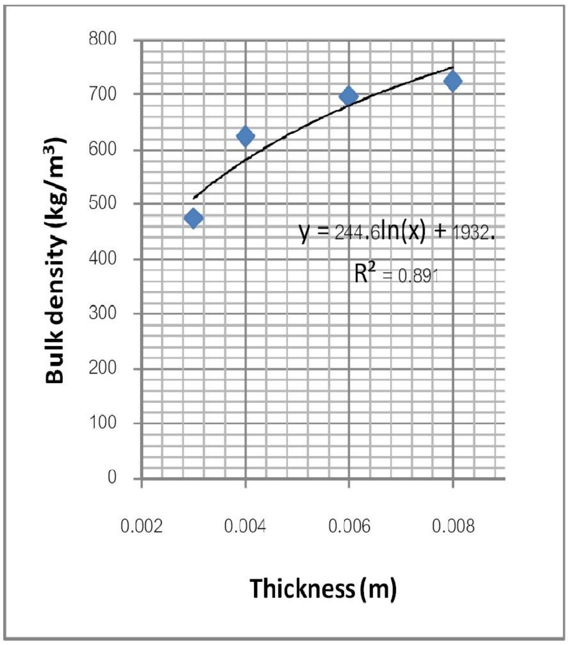

Fig4 Thickness VS Bulk density

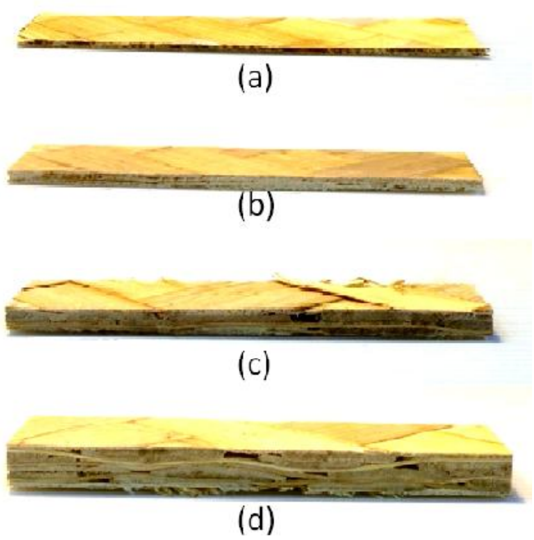

Fig 5 Pictures of woven bamboo wall in different thickness. (a)3mm, (b)4mm, (c)6mm and (d)8mm

B. Thickness VS Thermal conductivity coefficient

Effects of the thickness on the thermal conductivity coefficient are shown in fig 6. It was observed that more the thickness makes the thermal conductivity coefficient increases. A reason is that there is more bamboo tissue in high thickness woven bamboo wall and the air gaps are reduce cause of compressing in assembly process. So the spaces were reducing. Fig 5 presents a picture of woven bamboo wall in different thicknesses. Table 1 show number of bamboo tissue layers and thermal conductivity coefficients in different thicknesses

Table1
Number of bamboo tissue layers and thermal conductivity coefficients in different thicknesses

Thickness (mm)	Number of Layers	Thermal conductivity coefficients (W/m-K)
3	2	1.5533
4	3	1.7093
6	4	1.8764
8	5	2.1991

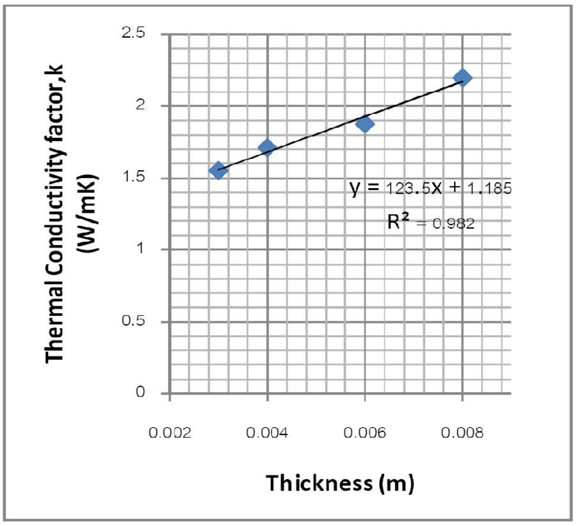

Fig 6 Thickness VS Thermal conductivity coefficient.

C. Bulk density VS Thermal conductivity coefficient

Effects of the bulk density on the thermal conductivity coefficient are shown in fig 7. The thermal conductivity coefficient increases when the bulk density increased. This behavior was also the same as other previous studies that use different materials [1, 6, 7]. This is because of porosity in low density material incur avoid between layers of material [6]. In high bulk density, there is more bamboo tissue that reduces air space between bamboo layers.

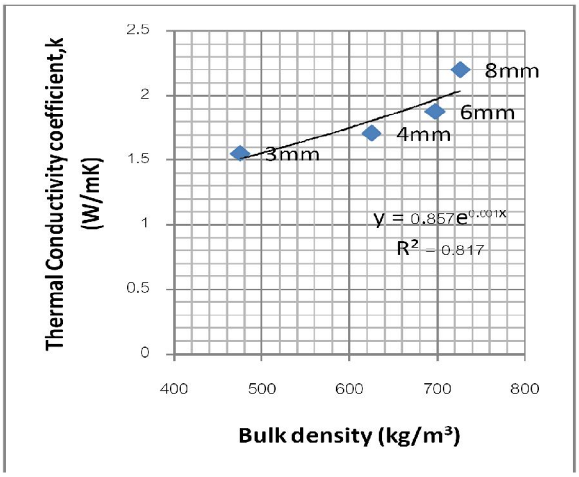

Fig 7 Thermal conductivity coefficient VS Bulk density

CONCLUSION

The effects of thickness of woven bamboo wall which are commercial product in Thailand on thermal conductivity coefficient and bulk density were experimentally investigated in this study. The ASTM C177 was applied to determine the thermal conductivity coefficient, while the ASTM D2395-93 Method B was used to evaluate the total volume of the testing material. The results can be concluded as follows:

-The bulk density of woven bamboo wall exponentially increases when the thickness increased. The equation is y = 244.67 In(x) + 1932.2 and R^2 is 0.8912.

-The thermal conductivity coefficient of woven bamboo wall linearly increases with the thickness. The equation is y = 123.59x + 1.1857 and R^2 is 0.9823

-The thermal conductivity coefficient of woven bamboo wall exponentially increases when the bulk density increased. The equation is $y = 0.8577e^{0.0012x}$ and R^2=0.8172

-The 3mm thick woven bamboo wall is the best thermal insulation compare to 4mm, 6mm and 8mm in thickness. The thermal conductivity coefficient of 3mm thick woven bamboo wall is 1.5533 W/m-K.

ACKNOWLEDGEMENT

The Author would like to be thankful for the financial support from the Graduate School, Chiang Mai University and the Energy Policy and Planning Office for education and research.

REFERENCE

[1] Satta Panyakaew, Steve Fotios. New thermal insulation boards made from coconut husk and bagasse. Energy and Buildings, Vol.43, 2011: 1732-1739

[2] P.F.Infante, L.Schuman, J.Huff. Fibrous glass and cancer. American Journal of Industrial Medicine, Vol.26, 1994: 559-584

[3] Pacheco-Torgal F, Jalali S. Cementitious building materials reinforced with vegetable fibers: a review. Construction and Building MATERIALS,Vol.25, 2010: 575-581

[4] Salas J, Alvarez M, Veras J. Lightweight insulation concrete with rice husk. International Journal Cement Composite Lightweight Concreat, Vol.8, 1986: 171-180

[5] Alavez-Ramirez R., Chinas-Castillo F., Morales-Dominguez V.J., Ortiz-Guzman M. Thermal conductivity of coconut fiber filled ferrocement sandwich panels. Construction and Building MATERIALS, Vol.37, 2012: 425-431

[6] Bentchikou Mohamed, Guidoum Amor, Scrivener Karen, Silhadi Kamel, Hanini Salah. Effect of recycled cellulose fiber on the properties of lightweight cement composite matrix. Construction and Building MATERIALS, Vol.34, 2012:451-456

[7] Binici Hanifi, Aksogan Orhan, Bodur Nuri Mehmet, Akca Erhan, Kapur Selim. Thermal isolation and mechanical properties of fiber reinforced mud bricks as wall materials. Construction and Building MATERIALS, Vol.21, 2007:901-906

[8] ASTM C 177, 2000, Standard Teat Method for Steady–State Heat Flux Measurements and Thermal Transmission Properties by Means of the Guarded-Hot-Plate Apparatus, Vol. 04,

[9] ASTM D 2395-93, 1997, Standard Teat Method for Specific Gravity of Wood and Wood-Based Materials, Vol. 04.

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