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Development of Low Thermal Conductivity Brick using Rice Husk, Corn Cob and Waste Tea in Clay Brick Manufacturing

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Abstract. The consumption of energy for cooling the indoor environment of buildings in Malaysia is high and mostly related to poor thermal performance of the building envelope. It is evident that reducing energy consumption of buildings has become vital, taking into considerations the limitation of conventional energy resources and the adverse effects associated with the use of such type of energy on the environment. Therefore, selecting the proper thermal properties of a building envelope play a major role in determining the energy consumption patterns and comfort conditions in enclosed spaces. The objective of this study is to investigate the potential application of rice husk (RH), corn cob (CC) and waste tea (WT) as an additive agent in a fired clay brick manufacturing to produce an improved thermal conductivity of final brick product. In the execution of this study, these agricultural wastes were mixed together with clay soil in different percentages, ranging from 0 %, 2.5 %, 5 %, 7.5 % and 10 % by weight. Physical and mechanical properties including soil physical properties, density, shrinkage, water absorption, compressive strength as well as thermal conductivity were measured, reported and discussed in accordance with BS 1377: Part 2: 1990, BS 3921: 1985, MS 76: 1972: Part 2 and ASTM C 518. The results show that RH at 7.5 % is the most effective combination to achieve low thermal conductivity of fired clay brick. This finding suggests that RH waste is a potentially good additive material to be used for thermal properties enhancement of the building envelope.

INTRODUCTION

Thermal and mechanical properties of building materials such as brick play an important role in the design of modern buildings. One of the main factors that affect the cooling load in air-conditioned space is the thermal properties of conductivity and material density. A building material with proper physical and mechanical characteristics as well as thermal properties in respect to radiation will contribute towards controlling heat transmission through it. Decreasing thermal conductivity of material is the dominant factor in reducing heat that could be transferred to or from the building [1]. The components of the building envelope, which include walls, windows, doors, roofs, etc., represent the most expensive conduit of heat gain of the building. Different types and thicknesses of walls will have a bearing on the thermal resistance of the building envelope. Therefore, selecting the proper thermal properties of a building envelope plays a major role in determining the energy consumption patterns and comfort conditions in enclosed spaces [2].

Most of Malaysian agricultural waste originates from the oil palm industry [3]. However, the amount of waste from sugarcane, rice husk, coconut, pineapple, corn plants and banana plants are also notably high [4]. It is estimated that 15 % of the total waste generated in Asia is agricultural waste and waste generation in Malaysia is at approximately 0.228 (kg/ cap/ day) in 2014 and projected to reach 0.285 (kg/ cap/ day) by 2025[5]. The generation of agricultural waste is anticipated to be on the rise and if we are unable to efficiently dispose it there would be a great escalation in social and environmental problems. In Malaysia, 1.44 million tons of agricultural wastes such as

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rice husk, banana peel, empty fruit bunch, corn stalk and sunflower stalk are being disposed into landfills annually [5]. Consequently, the government has to assign more hectares of land for the huge waste disposal, leading to further financial losses deriving from transportation and maintenance.

Recycling of waste generated from agricultural and industrial activities as environmentally friendly building materials appears to be a viable solution nowadays not only to curb pollution but also to address the problem of economic design of buildings. Recently, research on the recycling of environmentally friendly materials and energy saving are very important. Numerous studies have been conducted to identify the potential of agricultural waste as suitable poring agents and low in thermal conductivity used in the commercialization of building materials for the construction industry [6].

This study investigates the possibility of incorporating different types of waste and percentage of RH, CC and WT to improve thermal properties of fired clay brick. Also, physical, mechanical and thermal properties of fired clay brick containing this waste were discussed.

EXPERIMENTAL

Preparation of Raw Materials

Clay soil was used as raw material. Clay soil was collected at Kilang Yong Peng Batu Bata Sdn. Bhd., Johor. Upon delivery, the soil was stored in the container before being dried under the sun for three days. The soils then undergo the grinding process by using mechanical grinder machine. The purpose of this process is to ensure that no impurities were mixed with the clay soil and to get smaller sized soil particles which is 0.425 mm. Geotechnical tests, including liquid limit (LL), plastic limit (PL), optimum moisture content and soil classification were carried out according to the British Standard 1377-2: 1990 [7]. The properties of the soil used in producing the fired clay brick are as shown in Table 1.

TABLE 1. Properties of the Soil

Soil Physical Properties	Result
LL (%)	26.00 %
PL (%)	18.37 %
Optimum Moisture Content (%)	19 %
Soil Classification	Silty Clay or Clayey Silt

Rice husk (RH) was collected from Saifulam Agro Farm Sdn. Bhd, located in Pontian, Johor. Waste tea (WT) was collected from the food court at Kompleks Niaga Parit Raja, Batu Pahat, Johor, and corn cob (CC) was collected from Kian Heng Lee Sdn. Bhd, Simpang Renggam, Johor. RH and WT were used in their natural state while CC was undergoing the grinding process by using a milling jaw crusher. Material characterization for clay soil, RH, WT and CC were carried out to determine their main chemical components. Table 2 shows the results of X-ray Fluorescent (XRF) test that was carried out.

TABLE 2. XRF Test on Clay Soil, Cement, RH, WT and CC

Formula	Concentration (%)				
	Clay soil	Cement	RH	WT	CC
SiO_2	57.50	20.30	21.90	3.00	1.76
Al_2O_3	19.50	6.75	-	1.33	0.34
Fe_2O_3	5.89	3.46	0.24	1.88	0.93
K_2O	3.88	1.19	1.50	1.74	1.76
MgO	1.20	1.41	-	0.19	-
C	1.00	0.10	1.00	-	0.10
TiO_2	0.84	0.43	-	-	-
Na_2O	0.14	0.49	-	-	-
P_2O_5	-	-	0.92	0.61	1.66
SO_3	-	2.76	0.68	0.94	0.88
CaO	-	43.5	0.46	5.90	0.70
Cl	-	-	0.38	0.11	0.64

Manufacturing Process of Fired Clay Brick

There were four types of fired clay bricks were manufactured in this study, namely the RH brick, CC brick, WT brick and control brick. To produce a control brick sample, 3 kg of clay soil and 19 % water were weighed and mixed by using an automatic mixer. The same steps were repeated to make RH, CC and WT bricks except the incorporation of 2.5 %, 5 %, 7.5 % and 10 % of the respective wastes into the mixture. The mixtures then were put into 215 mm x 102.5 mm x 65 mm moulds and were pressed by using a mechanical compressed stabilized earth block machine with 900 – 1000 psi pressure.

The newly-produced raw bricks were dried naturally for 24 hours at room temperature before being parched further in a 105 °C oven for another 24 hours to make sure there was no moisture before the firing process in the kiln for another 24 hours at Kilang Yong Peng Batu Bata Sdn. Bhd. [7]. The drying process is an important stage to execute in order to avoid brick cracking and distortion during the firing stage where they were subjected to intensely high temperature. The firing process was done in a tunnel kiln for 24 hours to a temperature of 850 ˚C – 1050 ˚C. The temperature in the tunnel kiln was incrementally adjusted upwards in stages to avoid severe cracking of the bricks due to non-uniform heat propagation. All manufactured samples were tested for dry shrinkage, compressive strength, water absorption and thermal conductivity. The tests were conducted according to the BS 3921:1985 [8], MS 76: 1972 [9] and ASTM C 518 [10].

RESULTS AND DISCUSSION

Dry Shrinkage

As shown in Figure 1, control brick has the lowest value of dry shrinkage, which is at 1.60 %. Addition of agricultural waste into a fired clay brick increases the shrinkage properties since it increases the water content required to maintain the plasticity of the clay-waste mixture [11][14]. The results reveal that RH, WT and CC bricks tend to shrink more during the firing process. Their shrinkage values, however still comply with the preferable shrinkage properties of 2.5 % to 4 % [12].

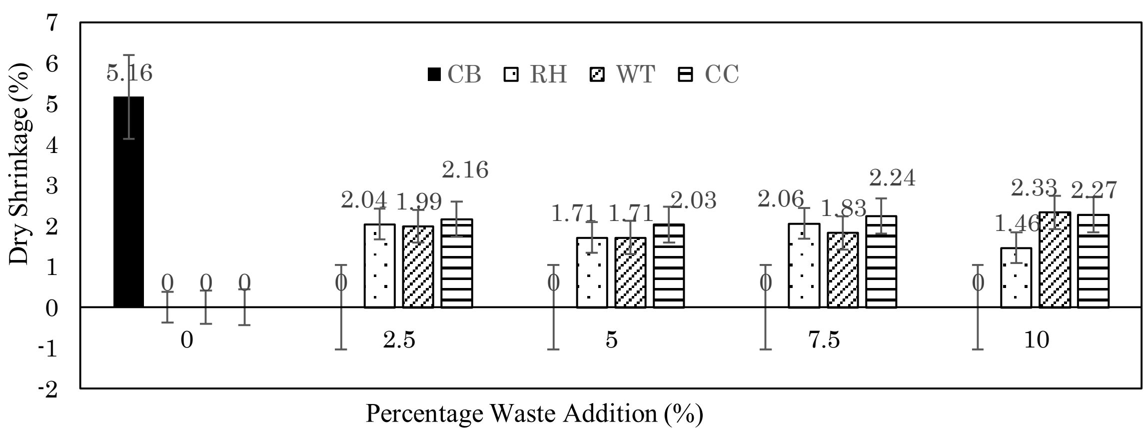

FIGURE 1. Effect of Dry Shrinkage by Percentage of Waste

Dry Density

Figure 2 shows that the control brick has the highest dry density (1974.03 kg/m^3). Bricks with a high percentage of fibres become lower in density because the natural fibres in them tend to burn away at high temperature during the firing process. Being less dense, the bricks become more porous. Generally, brick with higher density has better compressive strength. However, lower-density bricks due to their lower thermal conductivity will promote greater thermal comfort of building inner spaces. The fibre bricks with lower densities are potentially useful for thermal isolation of the building envelope, especially in tropical climates that receive more solar heat gain all year. The CC brick with 10 % waste records the lowest density value.

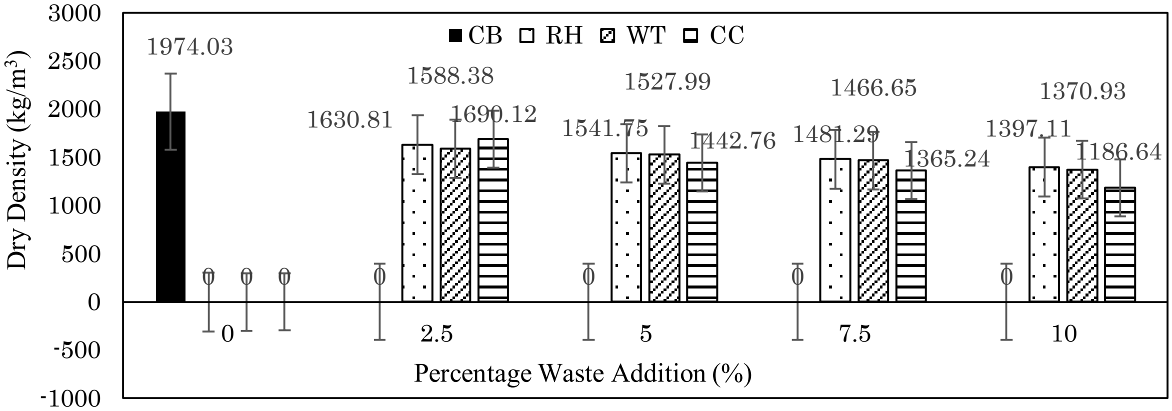

FIGURE 2. Effect of Dry Density by Percentage of Waste

Water Absorption

The water absorption test was performed on RH, CC, WT and control bricks. As shown in Figure 3, there is a direct correlation between increase and decrease of water absorption and density of the bricks. The control brick has the lowest water absorption, which is at 13.52 %. Based on MS 76: 1972: Part 2 [9], the percentage of water absorption shall be not more than 15 % by weight. Generally, water absorption increases when additional percentage of waste (RH, WT and CC) increases. The waste was burnt during the firing process and causes greater porosity. The porosity and water absorption increase with the increase of waste addition.

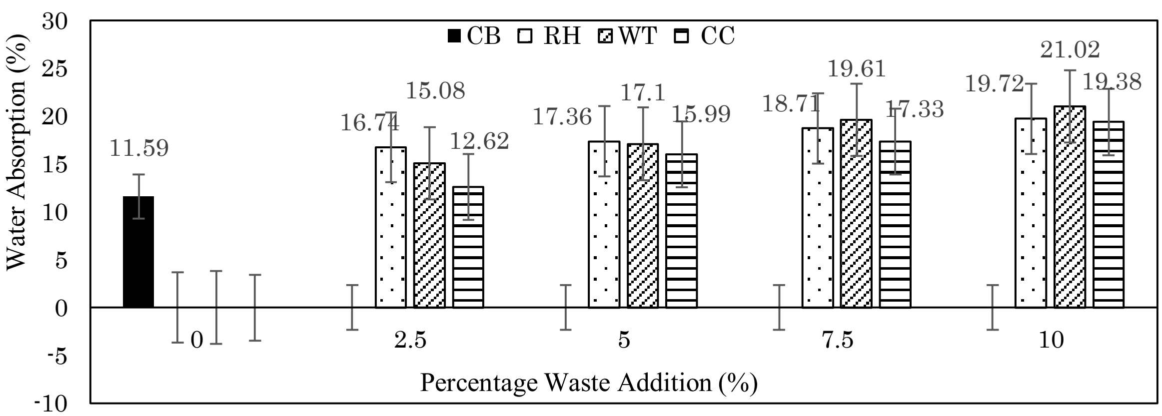

FIGURE 3. Effect of Water Absorption by Percentage of Waste

Compressive Strength

Figure 4 shows the control brick have the highest compressive strength which is 23 N/mm^2. The minimum requirement for a brick should be not less than 5 N/mm^2 (BS 3921: 1985) [8]. The maximum percentage of waste that still meets the minimum requirement of compressive strength based on BS 3921: 1985 is 7.5 % waste, namely RH brick (5.8 N/mm^2) and WT brick (5.1 N/mm^2). In general, a brick with a higher density corresponds with higher strength and lower water absorption. The CC brick has the lowest compressive strength compared to RH, WT and control bricks. In any case, increased porosity reduces the compressive strength of a brick due to lower density. It can be concluded that by increasing the percentage used of RH, WT and CC in brick manufacturing, the compressive strength and density of the bricks will completely decrease due to increased porosity.

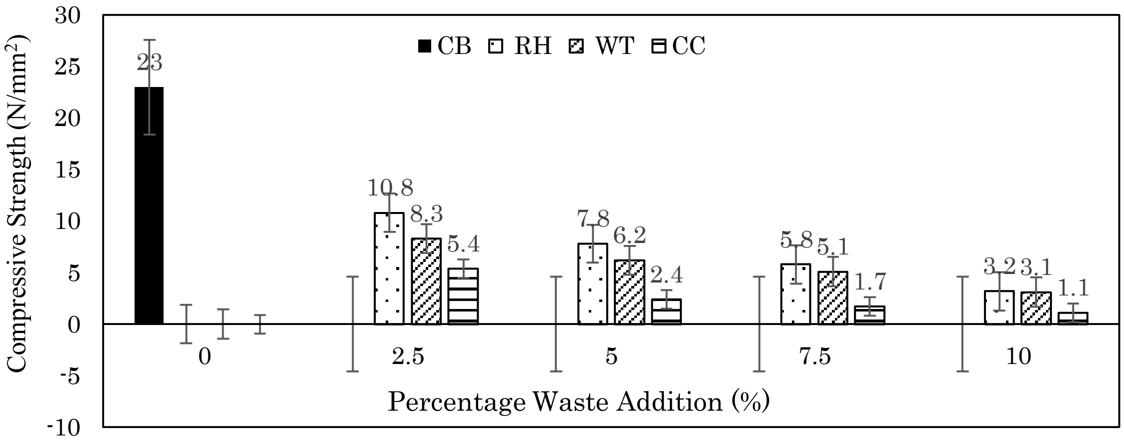

FIGURE 4. Effect of Compressive Strength by Percentage of Waste

Thermal Conductivity

Figure 5 shows the control brick as having the highest thermal conductivity at 0.63 W/m/K. Earlier we have seen that increasing the percentage of waste will cause greater porosity of bricks. The burning out of waste additive and the corollary gasification during the firing process will form pores in the brick body. This will decrease its thermal conductivity [13]. It can be concluded that thermal conductivity decreases with a decrease in density and an increase in porosity. The higher the porosity, the lower the heats transfer, thus improving the thermal insulation of the materials.

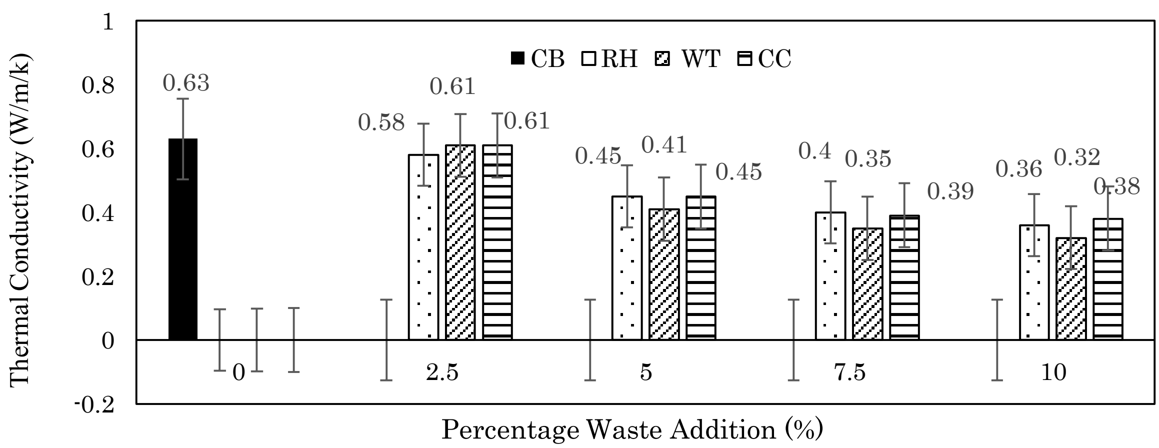

FIGURE 5. Effect of Thermal Conductivity by Percentage of Waste

CONCLUSIONS

Due to the increase general need for energy conservation and the pressing competition in the building industry in the use of sustainable building materials, the question of whether fired clay bricks can be made to be more thermally accommodative has come to the fore. This study used three agricultural waste materials, namely RH, CC and WT to make low thermal conductivity clay bricks. It concludes that the mixing of additives improves the insulation property of bricks as compared to the control brick. These bricks are a good resource for thermal insulation. The employment of renewable agricultural waste as pore forming additives could lead to industrial scale advantage and this could be a prospective area of continuing research in the brick industry. The mechanical property of the RH brick that incorporates 7.5 % of additive is significantly enhanced and shows higher performance than other waste alternatives. Overall, the selection of 7.5 % of RH additive is the most effective in respect of compressive strength

(5.8 N/mm^2) that meets the minimum requirement of the British Standard (BS) 3921: 1985, which is at 5 N/mm^2. In terms of dry density (at 1,481.29 kg/m^3), the RH brick is less dense when compared to the control brick (CC) but it offers greater advantage over normal density bricks in achieving better thermal insulation. Thermal conductivity (at 0.4 W/m/K) is lower than that of the control brick (at 0.63 W/m/K). Due to the aforementioned reasons, it is recommended that the 7.5 % RH be used to enhance the thermal viability of the fired clay brick. While some of its properties decrease by incorporating the RH, the overall results suggest that the final brick output complies with the standard requirement and is suitable for non-load bearing purposes. The next stage of research work is to build a small-scale wall to compare the thermal performance of RH brick with the control brick.

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