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Recycling Rice Husk Ash Waste for Clay Bricks

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Abstract: The objective of this study is the recycling of rice husk ash waste as an additive to improve the quality of clay bricks. The amount of rice husk ash waste added to lightweight clay brick was 10, 20, 30 and 40% by weight and the firing temperatures used were 700, 800, 900 and 1000°C. The results show that the addition of rice husk ash increases the porosity and water absorption and, in contrast, reduces the thermal conductivity and bulk density. An increase in firing temperature decreases the porosity and water absorption while yielding higher thermal conductivity and bulk density. Porosity and water absorption were maximized when the rice husk ash content was 40% and the firing temperature was 700°C. Clay brick with the addition of 10, 20 and 30% of rice husk ash and with a firing temperature from 800-1000°C exhibited the density and compressive strength required by the industrial standards of lightweight brick TIS 2601-2013. The addition of 20% of rice husk ash with a firing temperature of 1000°C resulted in the best properties with the sample having a bulk density of 1.42 gcm^{-3}, a compressive strength of 10.11 MPa, a thermal conductivity of 0.46 W/mK and a porosity of 35.81%.

Key words: Lightweight ceramic, clay brick, rice husk ash, conductivity, Thailand

INTRODUCTION

Now a days growing rice around the world uses about 100 million acres and the resulting rice husk amounts to about 700 million tons per year. The number one rice-producing country in the world is China and the second is India. Thailand is number six in terms of production but in terms of rice exports it is number one in the world. Vietnam is the second largest exporter. Rice husk is the waste that remains after producing polished rice and it is considered an important biomass that can be used as fuel for heating in the preparation of steamed rice. Also, it has been used in biomass power plants to produce electricity and as fuel for firing pottery and clay bricks. The process of burning rice husk leaves rice husk ash which is a white or black particulate material. After the rice husk is burned about 20% remains as ash. Because there is yet no way of using this waste, rice husk ash is a problem in rice mill factories and in power plants that use rice husk to produce the electricity. In the past, rice husk has been used to make fertilizer and as a component of concrete. However, there is still a huge amount of rice husk waste (Janbuala *et al*., 2013). A study of the chemical components of rice husk ash showed that the amount of Silica (SiO_2), the major component is about 70-90%. Rice husk has important properties, such as high porosity, low weight, large surface area, absorption capability and low thermal conductivity (Mansaray and Ghaly, 1998).

Clay brick is very important as a construction material and there are many locations around the world where clay bricks are manufactured. From historical evidence we know that clay bricks have been used for a very long time. The fabrication process involves mixing clay with other materials, such as sand and sawdust. The second step is curing all raw materials for about 24 h and extrusion process whichby extrusion machine. Then, the specimen brick are left dry by the heat from natural sun light whichfor 3-5 day which after that all bricks are arranged in the kiln for firing with the use of rice husk or firewood as fuel. The raw materials are generally available in the localities near the manufacturing sites. The process is simple and very well known (Kadir *et al*., 2009). The importance of clay bricks lies in their strength and density as well as durability. However, it is also particularly heavy due to its high density and is both a thermal conductor and a sound carrier. These properties result in low thermal insulation and low sound absorption (Bories *et al*., 2014).

In previous research, various waste materials have been used as components in clay brick. These include

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materials such as waste tea, flay ash (Demir, 2008) water treatment sludge and rice husks (Sutcu and Akkurt, 2009) coffee ground residue (Eliche *et al*., 2011) which Sunflower seed shell, Membrane filtration (Shukla *et al*., 2010) which Sawdust (Devant *et al*., 2011) Brewer's spent grains (Russ *et al*., 2005) slag river sediment (Xu *et al*., 2014; Herek *et al*., 2012) wasted which glasses from structural glass walls (Loryuenyong *et al*., 2009) and sugarcane bagasse ash waste (Faria *et al*, 2012). In this research, the aim is to use rice husk ash waste as a component of clay bricks because it will make the brick lighter by increasing its porosity. This in turn has the effect of improving the thermal insulation properties.

MATERIALS AND METHODS

Characteristics of raw materials: Raw materials in this study are Ayutthaya ball clay and rice husk ash from a clay brick factory in Ayutthaya province, Thailand. The crystalline phases of the clay and bagasse ash were identified by X-ray diffraction (XRD, Model D8). Chemical analysis was performed using x-ray fluorescence (XRF, Model JSM-5800LV). Simultaneous Thermogravimetric and Differential Thermal Analysis (TG-DTA) was used to further characterize the samples.

Characterization of firing samples: The main raw materials, clay and rice husk, were ground until the particle size was about 1 mm. Four compositions were chosen with rice husk compositions of 10, 20, 30 and 40% by weight. The materials for these samples were kneaded by hand for 15 min before adding water to facilitate shaping. Samples were aged for 24 h before being pressed by hand into a plastic mold with length, height and width of 140, 25 and 50 mm, respectively. The clay brick samples were allowed to dry in air for two days before firing in an electric furnace at 700, 800, 900 and 1000°C with a heating rate of 450°C h^{-1} for 3 h. Relevant characteristics of fired specimens are density, porosity, water absorption and compressive strength according to specifications for Thai lightweight clay brick and general standard of common construction brick (Thailand Industrial Standard Institute, 2004). Scanning electron microscopy (SEM, Model M1000/RF-2) was used to investigate the microstructures and a hot disk thermal constants analyzer was used to determine thermal transport properties.

RESULTS AND DISCUSSION

Properties of the clay brick raw materials: Chemical compositions of the clay and rice husk ash are shown in Table 1. The main component of both the clay and the ash is Silicon dioxide (SiO_2) which affects the strength of the brick specimen when fired at high temperature. The second and third major components of the clay are Al_2O_3 and Fe_2O_3, the latter of which gives the samples a reddish color. Considering the chemical composition of the clay, we find that the combination of Fe_2O_3, CaO, MgO and TiO_2 which comprises more than 9% of the clay indicates that the soil in this research has poor refractory properties and cannot tolerate fire. The TG and DTG scans of RHA are shown in Fig. 1. A total weight loss of about 4.98% was observed at a temperature of about 1000°C. The DTG scan also shows the lower rates of mass maximum temperature of 461°C because of the combustion of unburned carbon present in the ash (Thailand Industrial Standard Institute, 2013).

Table 1: Chemical composition of clay and rice husk ash

Chemical composition	Clay	Rice husk ash
SiO_2	60.67	92.00
Al_2O_3	15.18	0.53
Fe_2O_3	7.61	0.74
K_2O	3.12	2.80
MgO	1.15	0.54
TiO_2	1.18	0.07
CaO	0.79	0.87
Na_2O	0.56	0.10
SO_3	0.11	0.55
MnO_2	0.22	0.12
BaO	0.11	0.01
ZnO	0.01	0.04
ZrO_2	0.01	0.01
LOI	8.56	1.62

Liner shrinkage: Figure 2 shows the effect of rice husk ash on liner shrinkage. The effect of increasing the amount of rice husk ash is to decrease liner shrinkage. This is because the effect of rice husk ash, whose main component is non-plastic crystalline silica is to decrease the plasticity of the clay (Faria *et al*, 2012). An increase of the firing temperature causes increased liner shrinkage because alkaline oxides in the clay cause an increase of the melted phase in the structure which results in more shrinkage (Gorhan and Simsek, 2013).

Density and strength: The effect of rice husk ash on the density and compressive strength in the samples is shown in Fig. 3a, b. The figure shows that the density and compressive strength both decrease with the addition of rice husk ash. When the amount of rice husk ash is increased, the density of the brick decreases and the effect is to reduce the strength of specimen. This is because of the decompression of rice husk ash while firing. With greater decompression the porosity of the brick increases and, when the porosity is higher, the density will be lower. This will also decrease the compressive strength. These results are consistent with

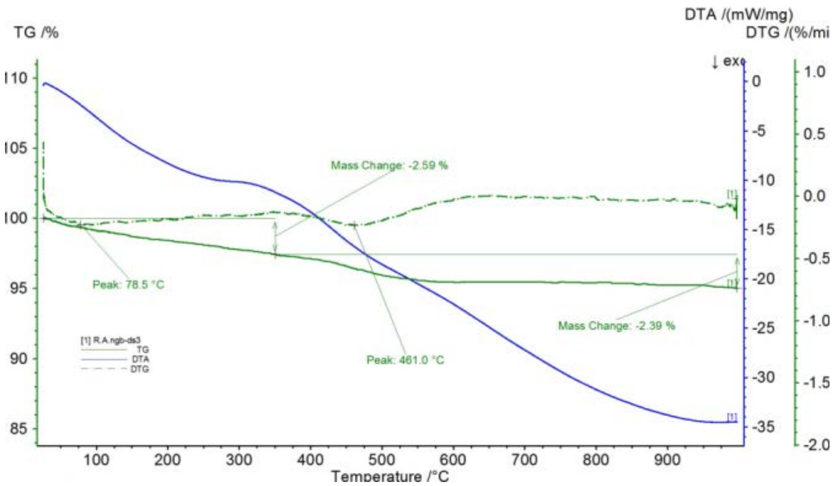

Fig. 1: TG and DTG scans of RHA

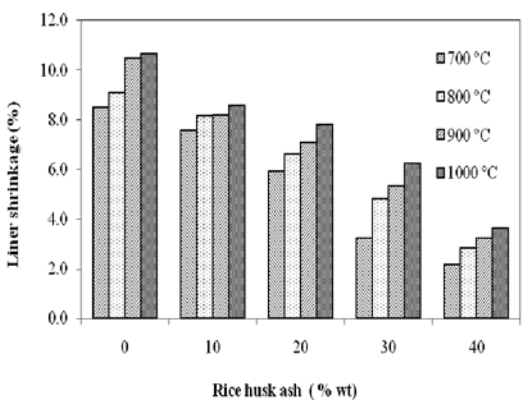

Fig. 2: Liner shrinkage of clay brick specimen with the addition of rice husk ash

previous research where the husk was used as a mixer to increase brick porosity (Jabo and Agbede, 2011). Among the specimens with added rice husk ash, the one with a rice-husk-ash component of about 10% and a firing temperature of 1000°C has the highest density. The lowest density occurs for the sample with 40% rice husk ash and a firing temperature of 700°C. Figure 4a also shows that the specimen density increases as the firing temperature increases. This affects the strength of specimen as well. Increasing temperature will affect the glass phase during the firing process because of flux material in the soil such as K_2O, Na_2O and Fe_2O_3 which will change to the glass phase at temperatures higher than 800°C. This results in linking among the particles in specimen due to liquid phase sintering and consequently gives the specimen higher density. As a result, the compressive strength will increase collectively. The specimen with the highest compressive strength is the one with 10% of bagasse by weight fired at 1000°C. These results show that the addition of 20 wt% rice husk ash and firing at 800-1000°C yield bricks with density and compressive strength that meet the factory specifications of grade C10 lightweight brick. The sample with 20 wt%

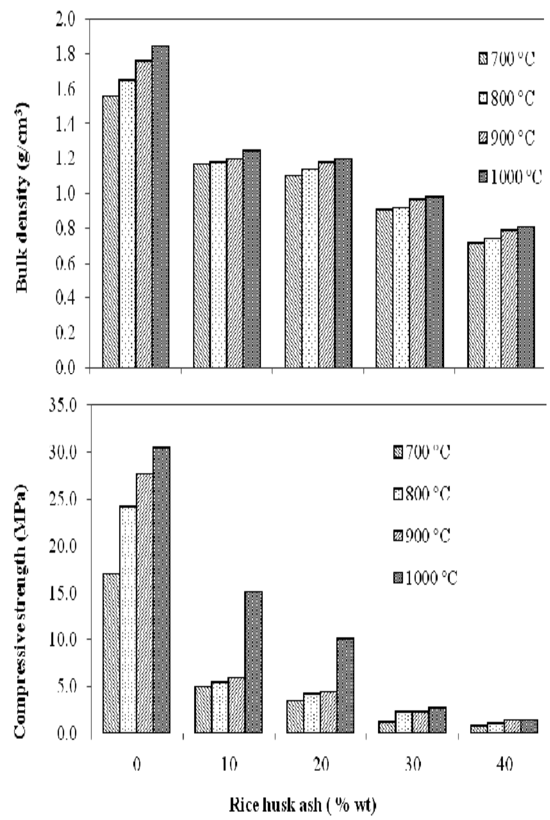

Fig. 3: a) Bulk density and b) compressive strength of clay brick specimen with the addition of rice husk ash

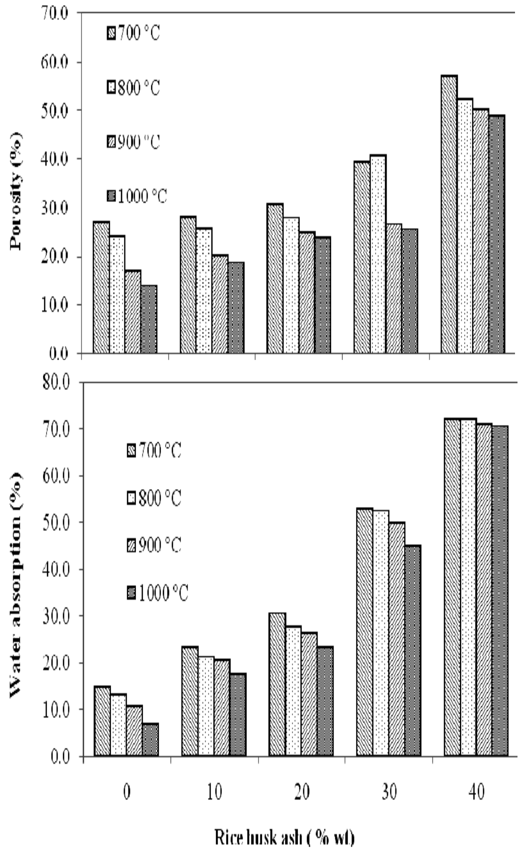

Fig. 4: a) Water absorption and b) porosity of clay with the addition of rice husk ash

rice husk ash fired at 1000°C is of good quality with high density and strength. It meets the required specifications of 1.2 g cm^{-3} and 10.11 MPa. for the density and compressive strength, respectively (Thailand Industrial Standard Institute, 2013).

Water absorption and porosity: The effect of rice husk ash on water absorption and porosity is shown in Fig. 4a, b. The addition of rice husk ash increases the absorption and porosity of the specimens which corresponds to a decrease in density. This is because while firing, the organic material in the rice husk will be released in the form of carbon dioxide. As a result, adding rice husk will give the specimen greater porosity (Musthafa *et al.*, 2010).

The porosity and water absorption of the specimen decrease as a function of increasing temperature because of a glass phase transition during the firing process at a temperature of 850°C. This transition widens the pores of the specimen. The decrease in porosity corresponds to an increase in density (Marras *et al.*, 2000). The specimen with 20 wt% rice husk ash fired at 900-1000°C exhibits a percentage of water absorption that meets factory standards of grade C10 lightweight brick. The minimum required rate of absorption is 21.29% at 1000°C (Thailand Industrial Standard Institute, 2013).

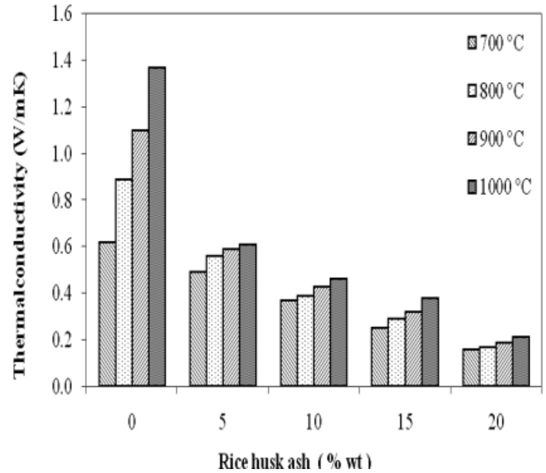

Fig. 5: Thermal conductivity of clay brick with the addition of rice husk ash

Thermal conductivity: The effect of rice husk ash on heat conduction in the specimens is shown in Fig. 5. The figure shows that the thermal conductivity of specimen decreases with the addition of rice husk ash. This is because adding rice husk ash to the specimen increases the porosity because of decompression of rice husk ash during the firing process. This decreased heat conduction is lowest for the sample with 40 wt% rice husk ash fired at 700°C; the value of the thermal conductivity in this case is 0.16 W/mK.

Increasing the firing temperature causes an increase in the thermal conductivity. This is because the higher temperatures will affect the porosity of specimen because of the higher density which increases heat conduction.

Microstructure: The microstructure of specimens with different additions of rice husk ash is shown in Fig. 6. For specimens fired at 900°C, the addition of rice husk ash increases the porosity because of the composition. The release of organic material in the form of carbon dioxide during the firing process affects the density and compressive strength of specimen. Comparing specimens with and without the addition of rice husk ash, we find that with the addition of 20% rice husk the porosity decreases with increasing temperature as shown in Fig. 7,

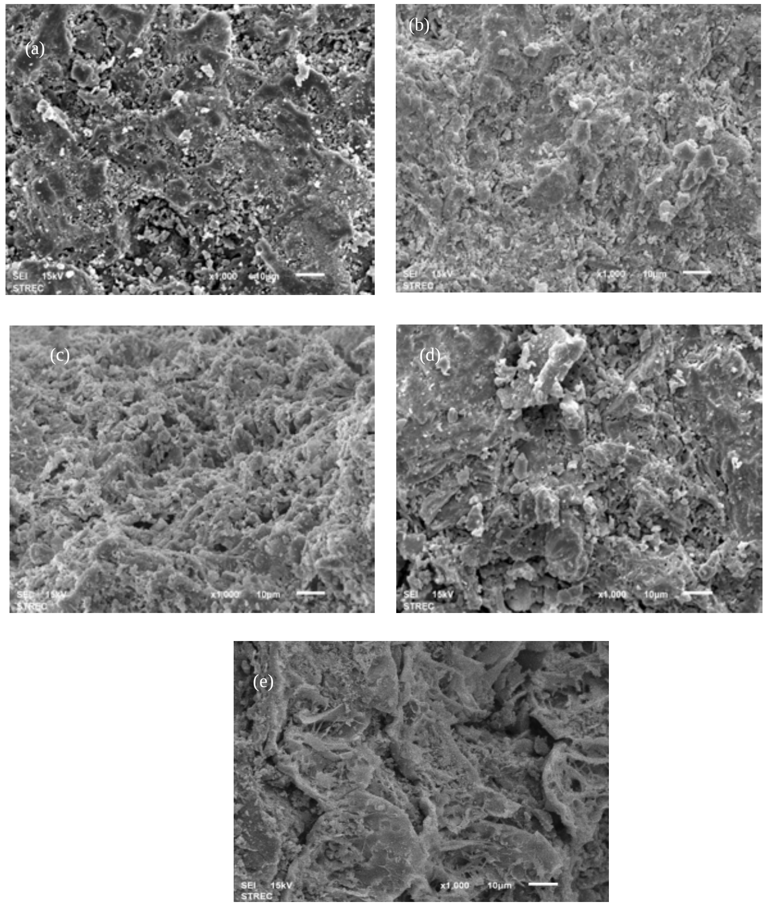

Fig. 6: Microstructure of clay bricks fired at 900°C with added rice husk ash at: a) 0 wt%; b) 10 wt%; c) 20 wt%; d) 30 wt% and e) 40 wt%

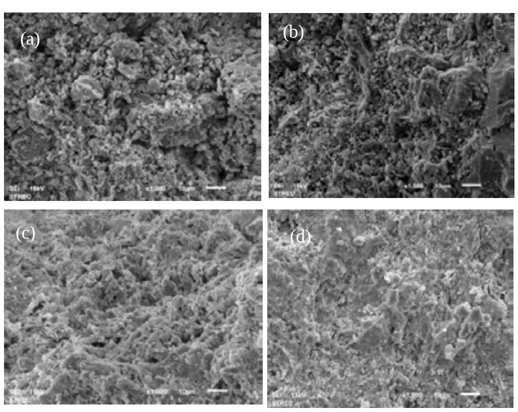

Fig. 7: Microstructure of clay brick with addition of 20 wt% rice husk ash and firing temperatures a) 700°C, b) 800°C, c) 900°C and d) 1000°C

because of the glass phase transition that occurs during the firing process. This results in a liquid phase that helps reduce the porosity of the specimen yielding a higher specimen density (Milheiro *et al*., 2005; Raut *et al*., 2008).

CONCLUSION

Adding rice husk ash waste to clay brick will increase its porosity and, consequently, decrease its density. Water absorption increases and heat conduction decreases. However, the strength decreases with the addition of rice husk ash up to 20% by weight and firing at 1000°C. The specimen will have good properties because of the low weight and high strength, with a density of 1.2 gcm^{-3} and compressive strength of 10.11 MPa. The percentage of water absorption is 21.29% and the coefficient of heat conduction is 0.46 W/mK. These results suggest a useful application for waste material in the fabrication of clay brick construction material.

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