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Lightweight Cement Bricks Manufactured with Additional Rice Husks

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Abstract

The research aims was to study the effect of rice husk ash to properties of lightweight bricks. The size of the brick is 215mm × 103mm × 65mm rectangular mold which is standard size brick. Lightweight bricks have been produced by sintering water, cement and rice husk. The dried rice husks were grinded to small particles and sieved into sizes 1mm while cement was sieved into 90μm to avoid from coagulate. Samples containing 0 wt%, 5 wt%, 10 wt%, 20 wt% and 25 wt% addition of rice husk have been heated in the oven at temperature of 50°C for 4 hours, allowing effective organic burn out. These samples were tested using 4 tests which are bulk density, water absorption, compressive strength and Ultra Pulse Velocity. The result showed that the addition of rice husk increased the porosity of the sintered bricks. The bulk density test showed that the bulk density of the bricks decreases with the increasing of rice husk addition and for the water absorption test showed that the brick sample with 5% of rice husk addition has the lowest percentage of water absorption compared to the other bricks. The results showed the decrease in compressive strength with increasing of rice husk addition. The brick sample containing 5% of rice husk addition produce the best compressive strength compared to the other samples. The UPV test that was conducted showed that the highest pulse velocity measured is from 0% addition of rice husk, at 3030 m/s but it does not fall under the range of good quality bricks. 5% and 10% addition of rice husk reads at 2413 m/s and 2160 m/s which fall under the range. The bricks with addition of 20% and 25% cannot be read due to sensitivity UPV equipment towards the high content of fibre from the rice husk. The conclusion for the tests that have been made showed that 5% addition of rice husk in a brick is the best compared to 0%, 10%, 20% and 25% addition of rice husks.

Keywords: Cement Brick; Cementitious; Rice Husks; Construction Material; Concrete Add mixture

1. Introduction

The increasing demand in infrastructure development causes a high desire on building material industry to meet the requirement. The industrialization and urbanization are some of the major causes of environmental pollution such as global emission of greenhouse gases (Fapohunda et al., 2017). In order to reduce the environmental pollution, the waste materials that are not harmful to the environment need to be convert into useful building materials. The infrastructure development can increase due to the population growth. The increase in the demand of using environmentally friendly, low cost and lightweight construction materials in building industry has brought the need to investigate the material requirements affirmed in the standards. In constructions, the main material used was brick due to the physical properties of brick which are strengthen, durability, loading, compactness and lightweight. Brick is high heat capacity because it easily to transfer heat and keep the heat inside for long time (Sutas et al., 2012). Over the past decade, cement is the primary material for the brick production. Cement as a binder in the production of brick and consumed in huge quantity annually. It also has been considered as very important material next to water (Alex et al., 2016). The amount of inner pores in building bricks is a critical factor to create a lightweight brick. This lightweight brick is usually manufactured by adding combustible additives as a foaming agent to control the appropriate amount of pores, size of particles and the firing temperature. The previous researchers have been applied plastics as an additive in lightweight brick production but it showed that the low density and high water absorption in plasticized lightweight brick resulted in an excessive amount of the pores and decreased compressive strength (Chiang et al., 2009).

The waste materials from industrial and agricultural wastes can be used in brick production because the uses of these materials can reduces the environmental impact due to its improper disposal. Rice husk or rice hull is fundamental agrarian wastes gained from the processing procedure of rice which is the hard protecting coverings of grains of rice (Prusty et al, 2016). Rice husk is a major agricultural waste with high ash silica content. The ash contains above 90% silica and a natural pozzolanic material (Chiang et al., 2009). It is the outer covering of rice kernel that obtained by milling of paddy in Malaysia. It could not be used to feed animal because of the less nutritional value. Rice husk ash has been applied in many materials as an improvement because of its high porous insulating property(Görhan & Şimşek, 2013). The burning of the rice husk can produce silica enriched ash. The firing condition need to be control to produce the perfect appropriate ash for the particular application. Calcium silicate produced was hydrates from pozzolanic reaction that brings to densification of concrete microstructure to increase strength and reduce porosity (Zareei et al., 2017). The successive use of rice husks ash as supplementary cementitious material has been reported by many researchers. The important factors of rice husks ash to be considered as partial replacement of cement are fineness of the particle, temperature of combustion process and time required for chilling process (Alex et al., 2016). The use of rice husks ash in the cement experimentally and observed that the pores of the mortar was filled with rice husks ash increases the mechanical strength of the mortar (Kishore et al., 2011). The high silica content of rice husks ash exhibits the increasing strength of concrete and showed better performance than other natural pozzolanic materials (Al-Khalaf & Yousif, 1984).

The previous researchers state that an experiment was carried out on some of characteristics of rice husks ash and ordinary Portland cement concrete (Kishore et al., 2011). Next, the other researchers worked on rice husk as a stabilizing agent in bricks. Bricks were produced with 0 wt%, 1 wt%, 2 wt%, 3 wt%, 4 wt%, 5 wt% and 10 wt% rice husk. Some of the bricks were burnt in an electric furnace to a high temperature for about 3-4 hours. Compressive strength and absorption tests were carried out and it shows that the addition of rice husk reduces the compressive strength of the bricks and the bricks become lighter (Eliche-Quesada et al., 2017). Other than that, one of the researchers studied the effect of rice husk on the compressive strength and durability of burnt-bricks. The test results show that rice husk has a decreasing effect on the compressive strength of the brick and increasing effect on the water absorption of the bricks (Görhan & Şimşek, 2013). Last but not least, the other researchers carried out a research work on the use of rice husks ash in concrete. The test result indicate that the most convenient and economical temperature required for conversion of rice husk into ash is 500°C. The water requirement decreases as the fineness of rice husks ash increases. The higher the percentage of rice husks ash contents, the lower the compressive strength (Görhan & Şimşek, 2013).

In this current research, rice husks were added to cement, homogenised and sintered to produce lightweight bricks with different properties in order to increase the strength and durability of the lightweight brick. This research is a new research to show that rice husk which is waste materials can be used in the production of the bricks. The properties of the lightweight bricks were affected based on the blending ratio and sintering temperature. The various amounts of rice husks ash were used to investigate the strength development and pozzolanicity behaviour of rice husks ash. From the previous research, they used cement, sand and gravel with additional rice husk. This research brings the lightweight brick used cement and additional rice husk to cut down the cost of using sand and gravel. Furthermore, the bricks were tested to determine the density, water absorption, compressive strength and undergoes Ultrasonic Pulse Velocity (UPV) test.

2. Materials and Methodology

2.1 Materials

The materials used are cement, water and rice husk. The rice husk was collected from a rice production factory at Tanjung Karang, Selangor. Chemical analysis stated that the major chemical compounds of rice husk are silica, ferric and alumina oxide which makes it highly pozzolanic (Prusty et al., 2016).

2.2 Characterization of rice husk

2.2.1 Moisture content

The moisture content of rice husk was determined by using two methods. The method are primary method based on weight measurements like the oven method or an infrared moisture balance and secondary method using an electronic instrument that uses electrical characteristic of rice husk. So the moisture content of rice husk was determined by heating the samples to 105°C for 48 hours. The moisture content is determined by using *ASTM Standards D4643* which is a test method for determination of water (moisture) content of rice husk by microwave oven heating.

2.2.2 Heavy metals content

Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) was used to determine the heavy metals content in the materials used for this research. Triplicate of 0.5 ml of rice husk samples were directly placed into porcelain crucible. About 3 mL of concentrated HNO_3–H_2O_2 (2:1, *v/v*) was added to each crucible. The crucibles were covered and kept at room temperature (~35 °C) for about 5 minutes as a pre-digestion time, then placed in a microwave oven. Then, crucibles were heated following a one-stage digestion program at 30 % of total power (900 W). After the digestion was completed within 2 to 3 minutes, the crucibles were left to cool at room temperature and the resulting solution (about 0.5 mL of semi-dried mass) was dissolved by 5 mL of 0.1 mol l^{-1} HNO_3. Then, transferred quantitatively to 10 mL volumetric flasks, diluted with distilled water up to mark and transferred to a polyethylene storage bottle for further analysis. Blank and spike sample solutions were carried out simultaneously through the complete digestion procedures and similar acid matrices. The presence of ca. 0.1 mol l^{-1} HNO_3 in the final solution was necessary to maintain acidic environment and avoid formation of insoluble hydroxides before measurement steps.

2.3 Preparation of materials (Cement and Rice Husk)

Rice husk was dried in open area or exposed to the sunlight for at least in 1 week. The dried rice husks were grinded to small particles and sieved into sizes 1mm while cement was sieved into 90μm to avoid from coagulate. Dried rice husk and cement were blended and mixed to produce homogenous mixes. It contained rice husk additions of 0, 5, 10, 20 and 25 weight% on a dry basis. It is about 33.3 weight% of water was added to the dry powder for prepared compacted samples. The ratio of cement and water for one mold is 2:1 basically based on strength of brick 30N/mm^2 grade with density 1080 kg/m^3 of cement and 540 kg/m^3 of water (Chiang et al., 2009).

2.4 Preparation of bricks

The mixtures of cement and rice husk were pressed at 800 psi to form 215mm × 103mm × 65mm rectangular mold which is standard brick size. The bricks were cured at room temperature for 5 days before heating process. The mold of bricks were then undergoes heating procedure. For heating experiments, the brick entered microwave oven and heated at 50°C for 4 hours. The brick mixture composition was 1080 kg/m^3 of cement and 540 kg/m^3 of water for standard size of brick which is based on strength of brick 30N/m^2. The calculation was made by adding the total volume for 5 molds with 10% additional volume for wastage. The total weight of 5 molds was calculated by multiplying total volume of 5 bricks and additional 10% wastage with total density of cement and water. For 5 molds of brick used 8532 g of cement and 4266 of water. The table 1 shows the mass components inside the brick for 5 molds that represent 1 mold for each test with different percentage addition of rice husk for every sample.

Table 1 Mass Component Inside 5 Molds of Bricks

Sample	Cement (g)	Water (g)	Rice Husk (%)
A	8532.0	4266.0	0
B	8532.0	4266.0	
C	8532 0	4266.0	10
D	8532.0	4266.0	20
E	8532.0	4266.0	25

2.5 Characterization study of bricks

2.5.1 Bulk Density

The density test is to determine the bulk density of brick. The brick was dried in a ventilated oven at a temperature of 105^0 to 115°C until it attains substantially constant mass. The brick was then cooled to room temperature and its mass was recorded. Then the dimensions of the brick were measured accurately and the volume was calculated. The bulk density was calculated as mass per unit volume. The *ASTM C20 Standard Test Methods* were actually for apparent porosity, water absorption, apparent specific gravity and bulk density of burned refractory brick and shapes by boiling water. These properties are widely used in the evaluation and comparison of product quality and as part of the criteria for selection and use of refractory products in a variety of industrial applications. These test methods are used for determining any or all of these properties.

2.5.2 Water Absorption

The water absorption test was conducted to determine the percentage of water absorbed when bricks were soaked into the water. The brick was dried in a ventilated oven at a temperature of 105 to 115°C until it attains substantially constant mass. The brick then cooled to room temperature and obtained its weight (M_1) and the weight of the brick was recorded. Dried brick was immersed completely in clean water at a temperature of 27°C to 29°C for 24 hours. The bricks were then removed and then wiped out any traces of water with damp cloth and weight of the brick was recorded after it has been removed from water (M_2). Water absorption, percent by mass, after 24 hours immersion in cold water is given by the formula. Percentage of water absorption by mass after 24 hours was calculated by using equation (1).

$$Water\ absorption = \frac{M_2 - M_1}{M_1} \times 100\% \quad (1)$$

2.5.3 Compressive Strength Test

Compressive strength of a brick was determined by testing the brick under standard conditions using a Compression Testing Machine. The procedure to determine the compressive strength of brick work used was as mentioned in IS 3495 (Part 2). The brick was placed and prepared with flat faces horizontal and mortar filled faces upward between 3mm plywood sheets and carefully centred between plates of testing machine. The plywood sheets were to ensure that the load is transferred uniformly. Axial load was applied at a uniform rate of 14 N/mm^2 (140 kgf/cm^2) per minute until failure occurs. The compressive strength of brick was calculated by using equation (2).

$$Compressive\ strength = \frac{Maximum\ load\ at\ failure\ (N)}{Average\ of\ bed\ face\ (mm^2)} \quad (2)$$

2.5.5 Ultrasonic Pulse Velocity Test

The quality and continuity of the bricks can be determined by ultrasonic pulse velocity test (UPV). The higher the velocities show good quality and continuity of the bricks. If the velocities slower, it shows that the bricks with many cracks or voids. The test was managed by passing an ultrasonic wave pulse through the brick and measured the time taken by pulse to go through the pile. The procedure of ultrasonic testing was outlined in ASTM C597-09. Test was done using instruments that use sound or stress waves in order to determine the properties of brick or concrete and other materials non-destructively. It was used to assess the quality and strength of in-situ brick in structural member. It also used to check the compaction and uniformity of brick or concrete, determination of cracks, presence of honey combs, level of deterioration and strength estimation. The Portable Impact-Echo System (PIES) was an advanced instrument for non-destructive detection of flaws and defects in a variety of civil infrastructures ranging from bridges, parking structures and building to dams, piles, tunnels, tanks and marine structures. Ultrasonic testing equipment was pulse generation circuit, electronic circuit to generate pulses and transforming electronic pulse into mechanical pulse by a transducer that will have range 40 kHz to 50 kHz of oscillation frequency. A pulse reception circuit received the signal. The transducer, oscillation circuit, power source and clock were used in UPV test. Place the transducers at the opposite sides of the brick, after the calibration of standard sample of brick with the known properties. Pulse velocity was measured by a simple equation (3).

$$Pulse\ Velocity = \frac{Width\ of\ structure}{Time\ taken\ by\ pulse\ to\ go\ through} \quad (3)$$

3. Results and discussion

3.1 Characteristics Study of Raw Materials

The metal contents of the cement and rice husk were determine by using Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES). The composition of element in raw material for brick is analysed and it shows that the most of raw material of cement compose of calcium oxide (CaO), silicon dioxide (SiO_2) and aluminum dioxide (Al_2O_3). As for raw material of rice husk. the most composition is Silicon Dioxide and Potassium Oxide. The mixture between the Silicon Dioxide in the rice husk and Calcium Oxide from the cement strengthens the brick because of the reaction that produce Calcium Silicate hydrates. This chemical composition can fill up the porosity in the brick and cause the increases of strength in the brick. Table 2 shows the properties composition of raw materials (Al-Khalaf & Yousif, 1984).

Table 2 Characteristics study of raw materials

Properties	Cement	Rice husk
Moisture (%)	0.7 ± 0.4	0.32 ± 0.14
Total metal content (mg/kg)		
Zn	120.00 ± 00.00[b]	25.76 ± 2.28
Pb	40.00 ± 0.00[a]	< 0.18
Cu	6.[illegible] ± [illegible][a]	6.68 ± 0.47
Cr	47.00 ± 1.00[a]	< [illegible].12
Cd	*<QL	< 0.16
Chemical composition (dry weight %)		
SiO	21.45	93.4
[illegible]	4.45	0.05
[illegible]	3.07	0.06
[illegible]	0.11	0.8
	63.81	0.31
	0.83	1.4