MECHANICAL PROPERTIES OF RICE HUSK ASH (RHA) BRICK AS PARTIAL REPLACEMENT OF CLAY

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Abstract: Clay has been used as main material in fabrication of bricks however the use of waste materials in brick manufacturing has been introduced for conservation of dwindling clay resources, as well as preventing environmental and ecological damages caused by quarrying and depletion of raw materials. Bricks that available in some regions have poor quality, low compressive strength, higher water absorption and uneven surfaces. Therefore in this study, rice husk ash has been utilized for the preparation of bricks in partial replacement of clay. The specimens were cast with different replacement levels of clay varying as 0%, 5%, 10%, 15%, and 20% with rice husk ash. The specimens were tested for water absorption and compressive strength according to Malaysian Standard EN 1008:2010 for 2 hours. Experimental shows that excessive addition of rice husk ash has higher water absorption and low compressive strength as rice husk ash percentage increases. The bonding between the clay particle and the rice husk ash particles is weak. By adding 10% of rice husk ash by weight is the best brick properties which 6.80 MPa of compressive strength and 16.30% of water absorption. The water absorption of RHA brick developed did not exceed 20% hence promoted to be partial replacement of clay.

Keywords: Rice husk ash (RHA), brick, clay

1.0 INTRODUCTION

Rice is the main chain food of Asia and part of the Pacific. Over 90% of the world’s rice is produced and consumed in the Asia-Pacific Region [1]. Due to the population and growth in demands the large amount of paddy production and the development of agro-based in many countries of the world has produced large quantities of paddy residue [2]. Paddy residue consists of paddy straw and rice husk. Both of these deposits are still not fully utilized in Malaysia. Malaysia is distinctive of the prominent producers of paddy. It has gained 0.48 Million tonne of rice husk [3] with 3,176,593.2 tonnes production of rice straw in a year [4]. This residue occupies large areas, where it can self-burn, spreading the ashes and causing tremendous harms to the nature [5]. During the growth of plants, some plants absorb various minerals and
silicates from the soil and accumulate it into their structures. Silicates are found in higher proportions of inorganic materials in annually grown plants than long lived trees. Such plants with a high concentration of silica are therefore rice plant, wheat plant, sunflower, tobacco and sugar cane. Table 1 illustrates the ashes and silica content of some plants as well as those of rice husk, rice straw and bagasse.

### Table 1. Ash and Silica Content of Plants [6]

| Plant      | Part of plant                  | Ash (%) | Silica (%) |
|------------|--------------------------------|---------|------------|
| Sorghum    | Leaf sheath epidermis          | 12.55   | 88.70      |
| Wheat      | Leaf sheath                    | 10.48   | 90.56      |
| Corn       | Leaf blade                     | 12.15   | 64.20      |
| Bamboo     | Nodes (inner portions)         | 1.49    | 57.40      |
| Bagasse    | -                              | 14.71   | 73.00      |
| Lantana    | Leaf and stem                  | 11.24   | 23.28      |
| Sunflower  | Leaf and stem                  | 11.53   | 25.32      |
| Rice Husk  | -                              | 22.15   | 93.00      |
| Rice Straw | -                              | 14.65   | 82.00      |
| Breadfruit tree | Stem                       | 8.64    | 81.80  |

Clay is an abundant raw material with a variety of usages and properties. It is a compound of group of material that consist of minerals commodities, each having somewhat different mineralogy, geological occurrence, technology and applications. They are natural earthy fine-grained minerals of secondary origin that are composed of an aluminates silicate structure with an additional iron, alkali and alkaline earth element. Common clays are sufficiently plastic to allow ready molding and when firing, they vitrify beneath 1000°C [7]. Clay and shale mostly used as raw material to produce brick that widely used in the construction of building walls by bleeding and jointing the bricks into arrangements. Clay bricks are considered one of the most important materials in making a building and fired clay bricks are the best-known type of brick. This material also one of the oldest construction materials. However, the huge usage of this material has resulted depletion of its resources, environmental degradation, and energy consumption [8]. The use of organic materials as alternative candidate to the clay has been considered. This because their biodegradable characteristics and renewable sources. One of organic materials used in production of brick is rice husk ash (RHA). Rice husk ash available locally, relatively cheaper and also more environmental friendly than the existing industrial insulators. Rice husk ash mainly contain silicate and other oxides such as iron, aluminum, calcium and magnesium oxides etc. The chemical analysis of rice husk is shown in Table 2. Several studies indicate that RHA has 90-95% of amorphous silica which able to enhance the workability, strength and permeability of the mixes concrete [8-10]. Addition of rice husk ash will lower initial surface absorption, permeability, absorption characteristics, and increase the resistance of concrete. Hence, this study was subjected to test effect of various mixture condition RHA into clay to the physical changes of the brick.

### Table 2. Chemical composition of RHA [10]

| Constituent   | % Composition |
|---------------|---------------|
Bricks are produced in numerous classes, types, materials and sizes which vary with region and time period, and are produced in bulk quantities. Two most basic categories of bricks are fired and non-fired brick. Meanwhile, type of bricks include concrete bricks, calcium silicate brick and clay brick [11]. Study by Ikpong and Okpala [12] on the variation of workability of concrete of designed strengths with the incorporation of RHA concluded that to attain the same level of workability, the mixes containing rice husk ash required higher water content than those containing only ordinary Portland cement as the binder. Meanwhile, Bui et al. investigated the influence of rice husk ash on the slump of concrete mixtures by using regular Portland cement and adding superplasticizer [13]. The found that partial replacement of Portland cement by RHA leads to an increased water demand, which can be compensated for by the use of a superplasticizer. Saraswathy and Song [14] investigated the effect of partial replacement of cement with rice husk ash (RHA) on the porosity and water absorption of concrete concluded that porosity values is decreased with the increment of RHA content because small RHA particles improved the particle packing density of the blended cement, leading to a reduced volume of larger pores; and coefficient of water absorption for rice husk ash replaced concrete at all replacement levels was found to be less when compared to control concrete.

2.0 METHODOLOGY

2.1 Sample preparation
Rice husk in this study were collected from northern region of Malaysia and burnt in a furnace with controlled temperature to establish the optimum burning temperature and burning time. In the first part of this study, the temperature was increased by 50°C per hour [15]. It is already reported that burning rice husk at controlled conditions below 700°C yielded amorphous ash and temperature greater than 800°C resulted in crystalline ash. The burnt ash was heaped and left to cool for 24 hours, which is sufficient to turn most of the burnt ash into white ash (amorphous material). The white ash was then ground for 30 minutes to achieve the minimum surface area of pozzolanic materials [16]. The ash collected was then sieve through standard sieve size 75 µm and the colour of the ash collected is grey/white. There are 4 primary steps in producing a brick which are preparation of clay, moulding of brick, drying of brick and lastly burning of the bricks.

| Sample | RHA (%) | RHA (g) | Clay (g) | Sand (g) | Water (g) |
|--------|---------|---------|----------|----------|-----------|
| 1      | 0       | 0       | 800      | 600      | 50        |
| 2      | 5       | 50      | 750      | 600      | 50        |
| 3      | 10      | 100     | 700      | 600      | 50        |
| 4      | 15      | 150     | 650      | 600      | 50        |
| 5      | 20      | 200     | 600      | 600      | 50        |

A total of 5 specimens were prepared in various range of RHA. The specimens of standard rectangular shape were cast with and without RHA. Earlier researches have shown that the replacement of clay with
30% RHA resulted in reduction of strength. Hence specimens were cast with different replacement levels of clay varying as 0%, 5%, 10%, 15%, and 20% with RHA. The details of the samples and mixtures are shown in Table 3. The molded size for the brick was 225×162×68 mm cubes as illustrated in figure 1. The last process in manufactured of the brick in where the brick was burnt in a furnace with 950 oC for 2 hours as presented in figure 2 [8, 11].

\[
W = \frac{M_2 - M_1}{M_1} \times 100
\]

where:
- \( W \) = Water absorption (%) 
- \( M_1 \) = initial weight 
- \( M_2 \) = final weight
2.3 Compressive strength
To determine the compressive strength of the samples, the samples were tested by standard ASTM C67 with a capacity of 500 kN accordingly [18]. The bricks were tested for their compressive strength by imposing the bricks to compression load until failure (Figure 3). To reduce friction caused by irregularities of the surface of the bricks to be loaded, the bricks, placed in the machine were packed between two pieces of plywood sheets, cut about 10mm bigger all round than the dimensions of the brick. A fresh piece of plywood was used for every test.

![Figure 3. Specimens being compressed to maximum load.](image)

3.0 RESULT AND DISCUSSION
The percentage of water absorption of the samples at each half hours is shown in Table 4. Based on table 4, there is a trend of increasing in water absorption when RHA is added to the mixture. From the results, the initial water absorption for control brick is 14.80%. The addition of RHA increased by 5% for each sample. After 5% of RHA is added to the mixture, the water absorption increased to 15.94%. The water absorption value of bricks increased to 20.73% when 20% of RHA is added to the mixture. The water absorption increases due to the plastic limit of the clay.

| Sample | Immersion time (min) |
|--------|----------------------|
|        | 30       | 60       | 90       | 120      |
| 1      | 1.43     | 2.86     | 8.00     | 14.86    |
| 2      | 1.45     | 2.91     | 4.94     | 15.70    |
| 3      | 1.47     | 3.53     | 5.00     | 16.18    |
| 4      | 1.50     | 4.49     | 6.59     | 18.56    |
| 5      | 1.55     | 6.21     | 9.32     | 20.81    |

De Silva and Perera in 2015 stated that the addition of the RHA to 2% to 4% produce a good stable structure and it is explained that under the availability of the silica, later strength can be achieved hence the pores of the clay brick reduced and the water absorption reduced due to the activeness of better recrystallization [19]. This is supported by Fernando in 2017, the water absorption ability of bricks is highly related to the porosity of brick. The porosity values increased with the increasing in RHA
replacement percentage [20]. Since the increasing in RHA replacement materials will led to high porous structure of brick, therefore the brick ability to store water become higher. The increase of water absorption capacity indicates that the less recrystallization and less strength. According to the plastic limits the increase of the water content increase with the addition of the RHA content. Hence the peak reaction temperature increases, and it may occur a reduction in stable structure development or recrystallization. This effect indicates that the less recrystallization and less strength of the material. According to Brick Development Association, 1974 and IS 7077:1992, the water absorption of bricks should not surpass 20%. Thus, bricks that contain less than 15% RHA fulfilled the requirement. Figure 4 illustrated the relationship between water absorption by the RHA brick, and the percentage of RHA.

Figure 4. Water absorbed by RHA brick.

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Table 5. Compressive strength for RHA brick

| Sample | 1     | 2     | 3     | 4     | 5     |
|--------|-------|-------|-------|-------|-------|
| Thickness (mm) | 68.00 | 68.00 | 68.00 | 68.00 | 68.00 |
| Width (mm)     | 112.00| 112.00| 112.00| 112.00| 112.00|
| Compressive Strength at Maximum Load (MPa) | 8.34560 | 7.48650 | 6.80851 | 6.39512 | 5.56391 |
| Time of rupture (mins) | 5.60  | 4.80  | 4.50  | 4.20  | 3.55  |

Table 5 presents the result of the compressive strength for the various mixes. For sample without RHA, it was found that the compressive strength increases up at 0 and 10% replacement of RHA, however, at 15% and 20% replacement the strength decreases as compared to control brick. At 5% RHA the compressive strength is 7.5 MPa, at 10% it is 6.8 MPa, at 15% it is 6.4 MPa and at 20% it is 5.6 MPa. So, from the above-mentioned values by increasing the percentage of RHA the compressive strength
decreases. By addition of RHA up to 20% the strength was slightly decreasing, and all the values are below 5 MPa (As per IS: 1077-1975). Beyond 20% RHA the compressive strengths are drastically decreasing and are lies below 5 MPa. At lower percentages of RHA, the clay characteristics are very much dominating than the RHA's characteristics, so the bonding between the materials is very high [21]. While the RHA percentage increases RHA characteristics predominate, the bonding between the clay particle and the RHA particles is weak. The compressive strength values are somewhat similar for all other RHA’s as the chemical properties (lime content & silica content) of all the RHA’s are almost similar [22]. Due to the addition of RHA the weight of the brick reduced at higher the percentage of RHA, the weight of the brick reduced considerably. As the weight of the brick reduces considerable so as the weight of the super structure and the weight which falls on the soil reduces.

4.0 CONCLUSION
The usage of rice husk ash in light weight clay brick improved certain aspect in the brick itself in term of properties and strength. This investigation had demonstrated a feasible way of using incinerated RHA as brick clay to produce a high-quality brick. According to test results, the higher the amount of RHA added into the mixture the lower the strength of the brick as it can promote cracks due to low particle bonding and, consequently reduce the mechanical strength. Usage of RHA material in the clay mixture improved the physical and mechanical properties. The results for water absorption obey the condition and it is indeed can used as a replacement of clay.

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