Incorporation of Industrial Sludge in Bricks Production

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Abstract

Incorporation of industrial sludge as an additional component in clay bricks was investigated in this study. This study aims to assess the effectiveness of utilizing industrial sludge into clay bricks and to evaluate the optimum amount of industrial sludge (by mass ratio) to be added into clay bricks. Clay bricks were produced at different mass ratios of industrial sludge to clay (without considering water mass): 0%, 10%, 20%, 30%, & 40%, known as control, mixture type A, type B, type C, and type D, respectively. The mass of water added to each mixture is 40% of its clay mass. It has been found out that, mixture type A is the strongest clay brick mixture, which able to withstand 18.17 N/mm^2 of compression strength. That finding was supported by the fact that the amount of industrial sludge in the brick is inversely proportional to the compression strength of the brick. The porosity of the clay bricks does affect the water absorption. It has water absorption of 37.87%, and also passed the efflorescence test with no noticeable deposit of efflorescence on its surface. Furthermore, counter-productive data were recorded as the mass ratio of industrial sludge to clay (without considering water mass) increases.

Keywords: clay bricks; compression strength; efflorescence; industrial sludge; water absorption

1. Introduction

In this age of technology, current advancements undergoing in industries brings improvement in terms of production methods and usage of utilities, as well as the problem of waste management. Due to the harmful nature of waste, it is important for us to manage them wisely. Recycling of industrial waste as building materials appear to be a good solution for economic design of the building, as well as in environment pollution problem (Eliche-Quesada et al., 2011) One of the industrial wastes that have been used for the production of building materials is fly ash. Fly ash is generated from thermal power plants and it is used in the production of concrete (Mahalingam et al., 2016)

The focus of this study is about the utilization of industrial sludge in the production of clay bricks. Currently, sludge is usually disposed by methods of land filling, reuse as fertilizers (Alibardi & Cossu, 2016). Apart from that, methods of incineration, ocean disposal, and composting are also applied. (Hara & Mino, 2008). The traditional practice of discharging the sludge directly into a nearby stream is becoming less acceptable because these discharges can violate the allowable stream standards (Tanpure et al., 2017). The industrial sludge used serves as a substitute for common materials such as sand and cement. Its availability and possibility of reducing harmful waste provides a strong logic for use of this industrial waste for building materials.

Brick is one of the most common masonry units used as building material (Abdul Kadir A., 2014). A study that is in our interest is a study on bricks made from sludge by a sintering process. Those bricks exhibit a compressive strength of 1150 kg/cm^2 at 1100°C, which is higher than the Chinese National Standards (CNS) brick no. 1 of 150 kg/cm^2 and the Japanese Industrial Standards (JIS) brick no. 3 of 200 kg/cm^2 (Lin et al., 2006). A fact that should not be overlooked is that China is the largest brick-producing country (Kazmi et al., 2016).

The properties of burnt clay bricks depend upon the nature of material & manufacturing process (More et al., 2014). The addition of pozzolanic material can lower the melting temperature by acting as flux, which in turn increases the strength of the brick (Muñoz Velasco et al., 2014). Previous researches have demonstrated positive effects on the physical and mechanical properties as well as less impact towards the environment for using sludge in the production of bricks (Juel et al., 2017). As of now, studies have been conducted on the utilization of sludge in the manufacture of ceramic bricks (Cusidó & Soriano, 2011).

A previous study also shows some leachability and toxicity tests (outgassing and offgassing) which demonstrate the environmental compatibility of ceramic products produced with sludge, to be used as building materials and even in deconstruction of the building once its useful life is ended (Cusidó & Cremades, 2012). Hence, the utilization of industrial sludge has its potential of producing bricks of good quality while being an alternative method of disposing industrial sludge.

The main objective of the current study is to study the influence of industrial sludge in the production of clay bricks and to evaluate the effects of industrial sludge in the clay bricks by a few of tests which are water absorption test, compression strength test, and efflorescence test.

2. Methodology

2.1 Material

The clay used in this study was collected from Tampok, Pontian, Johor. It was taken at 20 cm to 1 m level below the ground. The clay was sun-dried for 1 week before crushing process and was further dried using the oven for about 2-3 hours at 110 °C to ensure minimal water content. This was also to ensure that the clay is manageable during the crushing process. The clay was crushed and then was sieved by using 1 mm sieve to filter out foreign components from the clay and to achieve fine grains of clay. The wet sludge used was taken from a company in Pasir Gudang industrial area. The sludge did not undergo any drying process. It was used in its unaltered state throughout the experiment.

2.2 Bricks mixture preparation

Table 1: Bricks formulation with wet sludge

Brick types	Brick Clay (wt %)	Wet Sludge (wt %)
Control	100	0
Type A	90	10
Type B	80	20
Type C	70	30
Type D	60	40

The weight percentage of every component used in preparing the bricks mixture is tabulated in Table 1. Water was added in each respective mixture in the amount of 40% of its clay weight to achieve the optimum plasticity. The bricks mixture was later placed in a 70 × 70 × 70 mm mould and the mixture was then pressed from the open face of the mould. These moulded bricks were sun-dried for 3-5 days before being burned in a muffle furnace (NUVE MF 106) at a temperature of 900°C for 8 hours. Fired bricks were then allowed to cool for 2 days.

2.3 Bricks Testing and Characterization

2.3.1 Density Test

The density of each brick samples was calculated to see the differences. The weight of each brick samples was measured and recorded. The size of mould which is 70 × 70 × 70 mm was taken as the volume of the bricks. After the weight and volume were obtained, the density of brick samples were calculated using the following formula:

$$Density = \frac{mass\ of\ bricks}{volume\ of\ bricks} \tag{1}$$

2.3.2 Water Absorption Test

The bricks were dried in the oven at 100°C for 4 hours to ensure that there are no water content inside the bricks. The bricks were cooled in room temperature and the weight of bricks were recorded. The water absorption test was conducted to determine the percentage of water absorbed after being immersed in water. The bricks were immersed in 600 mL of water at room temperature for 24 hours. After that, the bricks' weights were recorded. The amount of water absorbed by the bricks was calculated by following equation:

$$\%\ Water\ absorbed = \frac{mass\ of\ wet\ bricks\ (g) - mass\ of\ oven\ dried\ bricks\ (g)}{mass\ of\ oven\ dried\ bricks\ (g)} \times 100\% \tag{2}$$

2.3.3 Compression Strength Test

The purpose of compression strength is to test the bricks' capability to withstand loads. The bricks were tested by using the rebound hammer (EN 12504-2) to measure the compression strength of the bricks in N/mm^2.

2.3.4 Efflorescence Test

The purpose of efflorescence test on bricks is to determine if the bricks contain any soluble salts in it. If any soluble salt is present, it will cause efflorescence on the brick. The bricks were immersed in 600 mL of water at room temperature for 24 hours. After that, the bricks were dried in the shade and their surfaces were observed thoroughly. If the brick surface have any white or grey deposits, it means that soluble salts are present and the brick is not suitable for construction.

Table 2: Indication result for efflorescence test (Wahid, 2015)

Results	Details
Nil	When there is not perceptible deposit of efflorescence
Slight	Not more than 10% area of the brick covered with a thin deposit of salt
Moderate	Covering up to 50% area of the brick
Heavy	Covering 50% or more but unaccompanied by powdering or flacking of the brick surface
Serious	When there is heavy deposit of salts accompanied by powdering and/or flaking of the exposed surface

3. Results and discussion

3.1 Bricks Density

Fig. 1 shows the density data of the bricks across all mixture types; control, type A, B, C, and D. Based on the data, the density of control brick is 0.83 kg/m^3, type A brick is 0.75 kg/m^3, type B brick is 0.65 kg/m^3, type C brick is 0.58 kg/m^3, and type D brick is 0.50 kg/m^3. It is clearly seen that the density of the clay bricks decrease gradually with the increment of industrial sludge. This is primarily due to the addition of industrial sludge which contributes to the decrement of weight-to-volume ratio of the clay bricks. Next, the density also decreases when the apparent porosity increases. This is caused by the increase in the number of pores produced by the dissociation of clay minerals and the industrial sludge, and also by the decaying of carbonaceous matter as well as combustion of the organic matter (Bories et al., 2014).

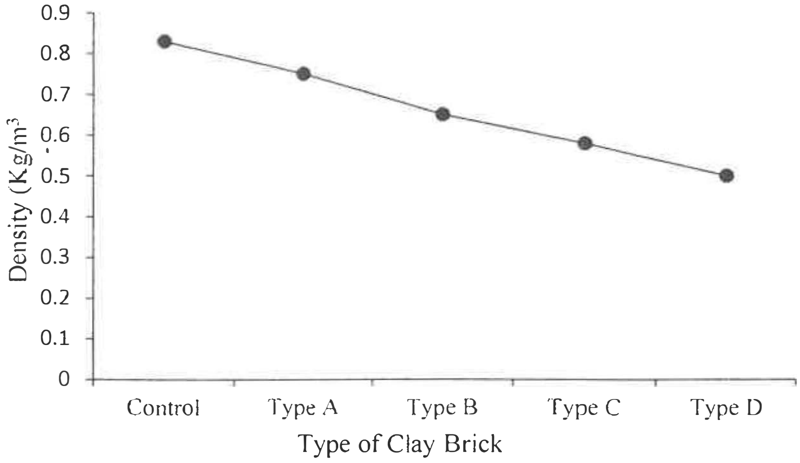

Fig. 1: Density of clay bricks by type

3.2 Water Absorption

Fig. 2 shows the water absorption data for five types of bricks; control, type A, type B, type C and type D where 0%, 10%, 20%, 30% and 40% of wet sludge is added in the bricks mixture, respectively. According to the data, control brick shows water absorption of 28.74%, type A brick is at 37.87%, type B brick is at 44.07%, type C brick at 48.92% and type D brick is at 56.77%. This shows that the water absorption is directly proportional to the amount of sludge in the brick. The high water absorption percentage is due to the porous nature of sludge (Tantawy & Mohamed, 2017). The lesser of the amount of water absorbed into the bricks means that it has high durability and improved resistance to harmful substance (Zhang & Zong, 2014). Type D brick shows the highest value of percentage for water absorption (56.77%). According to the ASTM C20, water absorption should be in the range of 17-22% (Abbas et al., 2017). However, water absorption percentage of 20-30% is still acceptable in many parts of the world Based on the data provided, control brick is in acceptable range of water absorption while the other four types of brick exceed the maximum value of acceptable range of water absorption percentage.

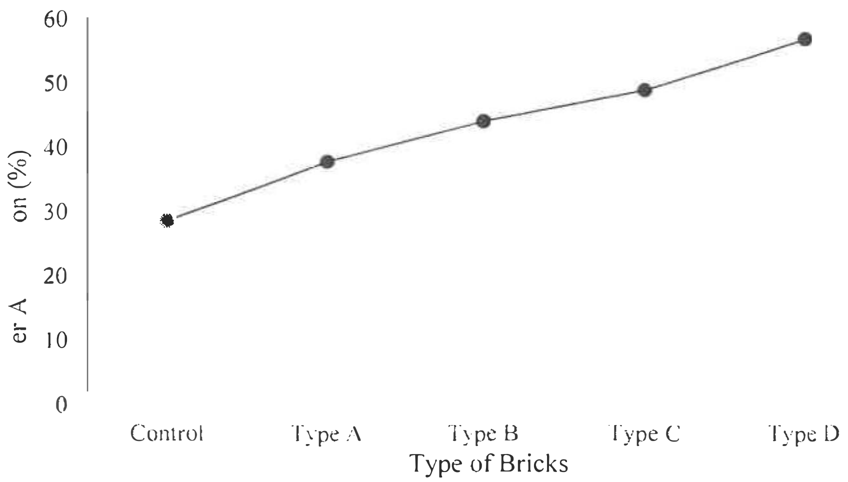

Fig. 2: Water absorption percentage of bricks by type

3.3 Compression Strength

Fig. 3 presents the data of compression strength of the five types of bricks. According to the data provided on the compression strength, it is clear that the amount of industrial sludge in the brick is inversely proportional to the compression strength. Type A brick recorded the highest value of compression strength among the other sludge mixed brick which is 18.17 N/mm^2. Furthermore, brick type B shows a significant amount of compression strength which is at 17.70 N/mm^2. As stated early, the trend continues to decrease in compression strength, as type C brick has a recorded value of 15.21 N/mm^2 and brick type D has a recorded value of 13.20 N/mm^2. The minimum requirement of compressive strength for the bricks according to the Pakistan Building Code is 8.25 N/mm^2 (Abbas et al., 2017). Other than that, the minimum requirement of compressive strength for standards around the world is 5 to 10 N/mm^2 (Eliche-Quesada et al., 2012; Eliche-Quesada & Leite-Costa, 2016)

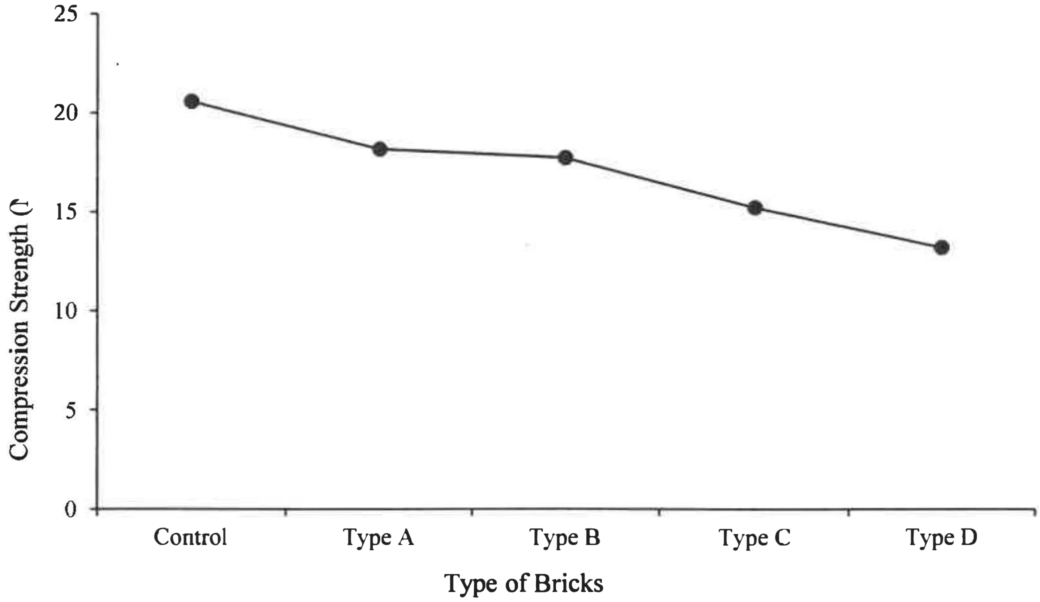

Fig. 3: Compression strength of clay bricks by type

3.4 Efflorescence Test

Fig. 4 shows the condition of the bricks after 24 hours while Table 3 shows the efflorescence test on five types of bricks. In accordance to the data observed from the bricks, the bricks are suitable for construction. The efflorescence that may appear on bricks is caused by crystallized salts accumulating on the brick surface. Salt efflorescence mostly concerns whitish deposits of water soluble salts, such as alkali sulphates or sodium chloride, which will usually appear soon after the erection of the facade due to their high solubility (Chwast et al., 2015). Efflorescence affects the integrity and durability of the material of the bricks as well as the aesthetic appearance of the facades (Morillas et al., 2015). Efflorescence appearance is also influenced by external factors such as climatic and land condition (Andrés et al., 2009).

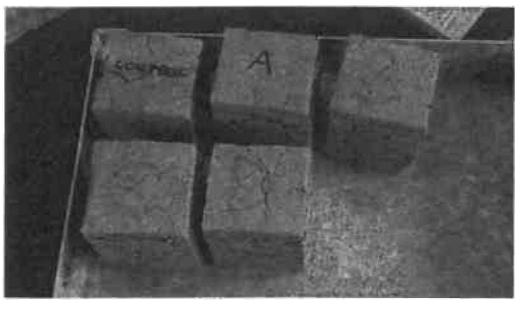

Figure 4: The condition of the bricks after 24 hours