The Utilization of Fly Ash for the Production of Strengthened Bricks

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Abstract

Modern buildings all over the world are made of either bricks or concretes. The demand of these two materials are so high. Therefore, companies all over the world are squeezing every bit of profit out of the production of these two materials. Cement companies like Lafarge, Holcim and YTL Cement have been producing these materials out of cement, besides discovering new techniques that can enhance the properties of the raw materials. As a result, it turned out to be strengthened. Nowadays, the utilization of fly ash is becoming more and more prominent over time. This is due to the fact that fly ash has cementitious properties. Therefore, it can drastically increase the strength of cement, thus creating strengthened bricks or strengthened concrete. However, fly ash is an additive that can escalate the strength of bricks or concrete. As the name goes, fly ash is only an additive. Thus, removing the main body parts of a brick or concrete, which reducing the amounts of sand can largely reduce its strength. Therefore, the existence of the major components of a brick or concrete is of paramount importance to be taken into consideration before adding any additives, such as fly ash into it for the purpose of strength enhancement. In this study, we are using sand bricks, which include cement bricks and lime-gypsum bricks. The addition of quantities of fly ash are differentiated, but the body parts of the bricks (which include cement, lime-gypsum and sand) are to be kept constant. The strength are then to be tested by using the compression test and the pores inside the bricks are to be identified by using the Ultrasonic Pulse Velocity (UPV) test, compression test and also water absorption test. Fly ash is also known as pulverized fuel ash. The major components of fly ash are silicon dioxide (SiO_2), aluminium oxide (Al_2O_3) and calcium oxide (CaO). When coal is burnt, the remains are bottom ash and fly ash. Fly ash is a coal combustion product composed of fine particles that are driven out of the boiler with the flue gases. On the other hand, the ashes that falls at the bottom of the boiler is called bottom ash. Good quality fly ash generally improves workability with the usage of less water. The reduction in water leads to improved strength. From this findings, it can be found that fly ash bricks have improved the strength of commercialised sand bricks in terms of porosity, compression strength and also water absorption.

Keywords: Fly ash, Gypsum, Cement, Lime, Compression, Strength, Ultrasonic Pulse Velocity, Water Absorption

1.0 Introduction

In thermal power plants, combustion of coal is a common activity for heavy and light industries. For this process producing large amount of waste residues in form of ashes. This ashes are called fly ash which is commonly known as minute and fine ash particles that carried by flue gases and been collected through electrostatic precipitators in thermal power plants. This fine particles can be harmful not only to human health but also affecting the environment. When inhaling the air filled with this kind of residues will cause respiratory problems and even can irritate humans' eyes and skin (Nisham, Sridhar & Kumar, 2016). However, there are some ideas of making this fly ash can be used as potential resource specifically as the value added products preparation.

In other words, fly ash is an industrial waste that produced from combustion of coal in electric power generation plants. When the coal is burned, they form ash which can be categorized into two types which are bottom ash and fly ash. Bottom ash is coarse and heavy particles which allow them to fall to the bottom of the furnace while fly ash is known to be in fine particles (Fauzi et al., 2016). Although fly ash is a by product but it has been used in construction area such as in bricks and concrete making (Cultrone & Sebastián, 2009). This has proven that waste material can be used as alternative raw materials. Moreover, it can cut the cost for raw materials and also reduce our dependent towards natural resources.

Malaysia has been recorded to produce more than 54 million metric tons of fly ash with only 42.6% of it was used while the other remaining that is 57.2% that is equal to 31 million metric tons was stored in the landfills

(Fauzi et al., 2016). This statistic should be worried as too much fly ash can cause environmental problem so, to reduce this negative impact the fly ash should be converted into something more useful instead of being dumped.

There is two type of fly ash which is class C and class F that is grouped according to their composition. Class A fly ash is the product from the lignite and subbituminous coal while class F fly ash is produces from medium and high rank coal. The different in the composition of both class of fly ash is that class C contains more calcium oxide (CaO) than class F by 20% (Suárez-Ruiz et al., 2017).

Fly ash can be used in concrete industry by either replacing cement partially or totally. The partial cement replacement is based on the pozzolonic property of fly ash where the Ca(OH) 2 (calcium hydroxide) will react with aluminate-silicate phase in order to form calcium-silicate-aluminate hydrates while total replacement of cement works when aluminosilicate phases produce structural bond of (-Si-O-Al-O-Si) (Fauzi et al., 2016).

There are many advantages of using fly ash in improving the quality of bricks, such as increasing the strength of the bricks, reduce water absorption, and also does not crack when lime is added. The costs of producing fly ash also lower due to low firing energy (Castellanos et al., 2017). As bricks from fly ash is unfired so its strength is dependent upon the fine particles of fly ash, the mixing ratio and the water content. The quantity of water used should not be taken lightly as excessive water usage can lower the strength of bricks, in fact the suggested water absorption must be lower than 18% to ensure the bricks to be of high quality (Naganathan, 2012)

Therefore, this study has conducted to investigate the performance of fly ash as additive to strengthen bricks. The parameters that have been used in experimental laboratory are crucial to study the best and optimum condition of the raw materials ingredients in order to produce high performance of strengthened bricks. In this study, the parameters that have been used are the composition of fly ash in the ingredients, the temperature used for the drying process and also the time taken used for the curing process. Furthermore, this study is also conducted to identify the ability of fly ash to become an additives to the sand bricks to produce strengthened bricks with higher performances.

2.0 Methodology

2.1 Materials

2.1.1 Fly ash

Fly ash commonly known is the by-product of coal combustion of thermal power stations. Significantly, fly ash contains silicon dioxide (SiO_2), aluminium oxide (Al_2O_3), iron oxide (Fe_2O_3), calcium oxide (CaO) and magnesium oxide (MgO) (Nisham et al., 2016). The composition depending on the type of burned employed and how the coal is burned.

2.1.2 Paste agent :

i. Lime

Lime is used as the paste agent in preparing bricks for this experiments. Quick lime or hydrated lime commonly have minimum 40% calcium oxide content (Shetkar et al., 2016).

ii. Gypsum

Gypsum also is called as hydrated calcium sulphates. Usually, gypsum should have minimum of 35% purity and 5 to 15% may be used (Shetkar et al., 2016).

iii. Cement

Cement is a binding agent especially for building units such as stones and also bricks. Cement generally made up of limestone, sand or clay, bauxite and iron ore.

2.1.3 Sand

Sand is well-known is loose particles of hard broken rock, comprises of grains from disintegrated rock. Sand can provide strength and bulk to construction materials like asphalt and concrete.

2.1.4 Distilled water

Clean water free from suspended particles is used for mixing and also curing process. There is no provision for taking water amount. Therefore, water amount is took (trial and error method) based on the suitability for casting the bricks (Nisham et al., 2016).

2.2 Preparation of Bricks

2.2.1 Mixing of Raw Materials

The fly ash, sand and the paste agent (lime-gypsum and cement) are thoroughly mixed in dry state until it attains a uniform colour in a pan mixer. Once the dry mixture is well-mixed, weighed quantity of water is added into the mixture (Nisham et al., 2016).

2.2.2 Moulding of Fly Ash Bricks

The wet mixture is placed in the mould container for 30 minutes (Nisham et al., 2016). In this laboratory experiments, the size of the mould used to study the strength is 70mm x 70mm x 70mm. The bricks are then being put at room temperature and also several are put in oven to be dried. A total of 42 fly ash bricks are prepared in order to have several test which are compressive test and water absorption test to measure the performance of the fly ash bricks.

2.2.3 Method of Curing

Once the bricks are completely dried, the bricks are kept for air drying (Nisham et al., 2016). Water curing is the next step and the method been used is water curing. For water curing, the bricks are submerged in water and left for 7 days (Shetkar et al., 2016). Water curi6ng is important so that they can absorb sufficient and fill the most of their pores with it (Jianmin & Xiandong, 2014).

2.3 Characterisation of Treated and Untreated Bricks

To determine the effect of fly ash in strengthening commercialised sand bricks, there are several parameters will be tested to get the best and ideal strength of fly ash bricks. The parameters included are the percentage of fly ash, the temperature needed to dry the bricks and the time taken needed to dry the bricks.

2.3.1 Different percentage of fly ash

Table 2.1 and Table 2.2 show the proportions in preparing bricks according to the percentage of fly ash, paste agent and also sand.

Table 2.1: Fly ash bricks with different composition of fly ash – Lime & Gypsum

Bricks	Fly ash	Lime	Gypsum	Sand
A1	40%	15%	15%	30%
B1	30%	15%	15%	40%
C1	20%	15%	15%	50%

Table 2.2: Fly ash bricks with different composition of fly ash – Cement

Bricks	Fly ash	Cement	Sand
A2	40%	30%	30%
B2	30%	30%	40%
C2	20%	30%	50%

2.3.2 *Temperature for Combustion*

The temperature for drying process are tested with 3 different temperatures which are 300°C, 400°C and 500°C. The temperature are different for each experiment. The combustion process is done in oven and the time is fixed at 1 hour.

Table 2.3: Fly ash bricks with different temperature for combustion

Bricks		Temperature (°C)	Time (hr)
Lime-gypsum	Cement		
A1	A2	300	
A1	A2	400	
A1	A2	500	

2.3.3 *Time taken needed for Curing Process*

These strengthened bricks are cured in curing tank. This will be compared with commercialised sand bricks to find out how fly ash affect the strength of the bricks.

Table 2.4: Fly ash bricks with different days for curing process

Bricks		Time (days)
Lime-gypsum	Cement	
A1	A2	1
A1	A2	7
A1	A2	14

2.4 Performance of Bricks

2.4.1 *Compression Test*

This test is the most important test in order to test the suitability of the bricks prepared for construction work. This test is worked within the help of compression testing machine. For the compression machine, the bricks is placed in a compression testing machine. It is pressed till it breaks (Nisham et al., 2016). The strength of the bricks is calculated by using the Equation (1):

$$\text{Compressive strength}\left(\frac{N}{mm^2}\right) = \frac{\text{max load at failure } (N)}{\text{avg area of bed face } (mm^2)} \quad (1)$$

Figure 2.1: Compression test machine

Figure 2.2: The brick after failure

2.4.2 Water Absorption Test

This test is conducted to determine the amount of water absorbed by the bricks. The bricks are immersed in water for 24 hours period. In this case, bricks should not exceed 20% of weight of dry bricks (Shetkar et al., 2016). The absorption of water for the bricks is calculated by using the Equation 2:

$$\%\ of\ water\ absorption = \frac{M2 - M1}{M1}\ X\ 100\% \qquad (2)$$

$M2 = mass\ of\ the\ bricks\ after\ been\ immersed\ for\ 24\ hours$
$\mathbf{M1} = Mass\ of\ bricks\ before\ been\ immersed\ for\ 24\ hours$

Figure 2.3: The prepared bricks were immersed in water for water absorption test.

2.4.3 Ultrasonic Pulse Velocity (UPV) Test

There are three types of setting of the transducer location which are direct transmission, semi direct transmission, and indirect transmission (Bayan et al., 2015). The transmission that we use to obtain the pulse velocity is direct transmission. To perform the test, first of all, hair gel applied to both sides of the bricks as coupling agent where the transmitter and receiver placed. The transducer and the wall of bricks must have firm contact before the reading can be recorded. The averages for three readings of each bricks were taken as direct velocity measurement. The pulse velocity can be determined using equation (3):