Utilization of Coal Bottom Ash in Bricks

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Abstract

Coal combustion products can be categorised into four, which are fly ash, flue-gas desulfurization, bottom ash and boiler slag. These product comprises of combustibles which were embedded during formation of clinkers and stick to hot side walls of a coal-burning furnace during the operation of furnace. These products can play an important role in concrete and bricks production. Out of these four, only fly ash and bottom ash are widely used in industry. Fly ash can be described as very fine, powdery material which contain mostly silica as a product from ground coal boiler. Meanwhile, bottom ash has its own shape, angular and coarse particles which are too heavy to carry by smoke formed at the bottom of the coal furnace. Bottom ash currently used as fine aggregate element in concrete which as many advantages towards strength and resistance. Limited application in major areas making bottom ash overlooked as waste material. Despite recycling, an alternative on making bricks with substitution of coal bottom ash is conducted which goes pre-treatment and non-pre-treatment. Pre-treatment is done to reduce the content of carbon in coal bottom ash. Pre-treatment process is done by using 'sink and float' method. Addition of coal bottom ash as partial replacement of cement resulted an increase in physical performance which altered the properties of the bricks. Based on the result, the utilisation of coal bottom ash as cement replacement gave positive impact compared to normal bricks. It has been discovered that 10% of coal bottom ash is the best quantity used as a replacement for cement as well as it recorded the lowest percentage in water absorption. For ultrasonic pulse velocity the result scored in the between the range of lowest and highest value and highest for compressive test. Overall, the bricks produced passed all the standard requirements for industrial purposes. Therefore, coal bottom ash usage as cement replacement paved new way in saving cost expenses and generate a new type of bricks in the future.

Keywords: Coal bottom ash, cement, strength, bricks

1. Introduction

Coal, a combustible black or brownish-black sedimentary rock composed of carbon, hydrogen, sulphur and nitrogen often being used in a thermal power plant. The combustion of coal in a thermal power plant resulting in two waste products, fly ash and bottom ash. Fly ash, known in United Kingdom as "pulverised fuel ash" is the waste from coal thermal power plant that have been obtained from boiler along with the flue gases. Meanwhile, bottom ash is part of non-combustible residue in the bottom of a furnace or incinerator. Ground coal bottom ash and coal fly ash may be mixed, together from the same coal power plant (Cristina Argiz et al.,2017) Bottom ash, deposited in wet bottom boilers being kept in molten state. The waste will be collected when it flows into the ash hopper below. 10% to 20% of total coal ash is bottom ash and the rest of it will be fly ash. As both fly and bottom ash produced from the same thermal process, the chemical composition will be the same (Vassilev et al., 2005; Argiz et al., 2013). Annually, it is estimated that the production of coal ashes globally is at 600 million tons, 500 million of it was fly ash and the rest are bottom ash (Ahmaruzzaman, 2010).

Various types of materials such as silica fumes, coal fly ash and coal bottom ash has been used in recent studies to replace the Portland cement in production of bricks (I.Kula et sl., 2001). In order to utilize the usage of coal bottom ash, the applicability of coal bottom ash in concrete industry has been studied. The source were supplied from Tunçbilek Power Plant Station in Turkey. In the experiment, up to 25% of coal bottom ash was used as a partial substitution of Portland cement. Coal bottom ash treatment was introduced to reduce the unburned carbon contents in the coal bottom ash (Haldun Kurama, Mine Kaya, 2008). The results show that the maximum addition of coal bottom ash up to 10% yield an improvement to the mechanical properties of the concrete. The discussion of the differences between untreated and treated coal bottom ash are also compiled. The final results of the study shows that the pre-treatment method yield 4.65% of unburned carbon content in a 57.67% of coal bottom ash. The compressive strength test result showed that after 56 days of curing with maximum 10% of coal bottom ash used, increases from 42.65 N/m^2 to 4 .1 /m^2.

(Garth V Tayler, William Daidone, 2011) proposed the commercial usage of coal bottom ash in the clay face brick making. The gained the sources is from Acme Brick Plaza, Fort Worth and Acme Brick Technical Center, St. Denton, Texas. The main idea was due to its high density, the clay face minerals was more sensitive to drying. It also have to have high firing shrinkage. Therefore, to improve the physical properties of the clay face minerals, coal bottom ash used to reduce the defects of the clay face minerals. The discussion regarding the technical and financial advantages of the coal bottom ash usage is also included. The final results showed that the addition of coal bottom ash have positive impact on reducing and stabilizing the drying and firing shrinking effect. The fact now that the plant still benefited the usage of coal bottom ash and its hazardous material status has been revised by EPA and might be commercialized in the future as a non-plastic alternative to improve clay face.

(D. Kumar et al., 2014) has conducted a research on the potential large scale usage of coal bottom ash scope. Brick manufacturing using coal bottom ash was one of the potentials alongside road construction, drainage media and walls with sound insulators. The factors of underutilization of coal bottom ash was also included in the research. The properties of coal bottom ash was often neglected, therefore limiting its usage and the ash produced was vary in quality. The research was conducted based on National Thermal Power Plant Anpara in Sonbhadra District in Uttar Pradesh, India. The side product of coal bottom ash accumulating in their landfill. The coal bottom ash has high shear strength and low compressibility. In comparison, 80% of coal bottom ash underutilized compared to fly ash. The percentages of coal bottom ash usage as a fine aggregate substitute starts from 10% up to 40% with an increment of 10% each. The brick also has been left curing for 7, 14, 28 and 56 days respectively. The final results of the experiment shows that maximum compressive strength at 40% replacement is 32.14 N/m^2 (7 days), 34.85 N/m^2 (14 days), 36.20 N/m^2 (28 days), 39.16N/m^2 (56 days). For more than 40% replacement, the result of compressive shows decline in value.

(Sivakumar Naganathan et al., 2011) has found a way to utilize coal bottom ash and fly ash in brick manufacturing method. The sources of both fly ash and coal bottom ash is from Kapar thermal power station. The proportions of fly ash, coal bottom ash and cements used were varied throughout the experiment. The brick is then undergoes a set of tests, which were compressive strength, water absorption, density, workability and ultrasonic pulse velocity (UPV). The final result for each test were included as for compressive strength test, it ranged from 5.5 MPa to 11.68 MPa. Maximum water absorption test yielded result of 15.7% and for UPV test, the results value ranged from 2260.2 m/s up to 2916.1 m/s. A remark regarding relative strength and proportions of cement and fly ash also stated, as more cement and fly ash content in the brick, the higher its relative strength, and the brick is comparable to a normal clay brick. Another remark concluded was the water absorption capability increases as the water to powder mixture of cement and fly ash ratio increases. Then, for the UPV test results, the cement and fly ash content in the brick increases its value.

There is a study done on possibility of substitution of natural fine aggregate by using industrial waste products such as waste foundry sand and coal bottom ash. This substitution brings advantages towards technical, economic and environmental (Yogesh Aggarwal, Rafat Siddique, 2014). Coal bottom ash often overlooked as a waste material. Fly ash and bottom ash differs from physical look but they may have the same chemical composition. However, fly ash is more preferable than bottom ash. The usage of coal bottom ash is limited due to its unburned content that is relatively high and different structural properties compared to fly ash. There is also lacking of awareness regarding the properties of coal bottom ash which is later discovered can be used in cement production to gain more strength. Aside than that, safe disposal of coal bottom ash is a concern in thermal plant. If bottom ash being released to a pond, it will affect aquatic organism as well as human's health as it affects water sources. Recycling of coal bottom ash is an alternative to solve this issue. Material which has less density but higher strength is essential in industries, addition of coal bottom ash can be initiative in improving the strength of cement.

The objective of this study is to utilize the usage of coal bottom ash as waste product from thermal power plant by preparing bricks with different composition of cement and coal bottom ash, curing time and pre-treatment process. Pre-treatment process that has been chosen is 'sink and float' test (Haldun Kurama, Mine Kaya, 2008). The purpose of pre-treatment is to test sink and float method as initiative for removing of unburned carbon from the coal bottom ash to improve its application as substitution of cement in bricks. The study also done to observe the effect of addition of coal bottom ash into cement, both pre-treated and non-pre-treated. The performance of coal bottom ash that has been pre-treated and vice versa towards compressive test, water absorption and UPV test also being observed from thi tud .

2. Experimental Procedures

2.0 Materials

The materials were used for preparing bricks formation are Ordinary Portland Cement, Sand as fine aggregate, bottom ash and water. Portland cement has been used as reference materials. Fine grounded coal bottom ash as substituents of cement has been obtained from TNB power plant. The experiment was conducted by using two types of coal bottom ashes. First, the experiment was conducted with coal bottom ash that has undergoes pre-treatment process and compared with untreated coal bottom ash. They were mixed with the cement in four different proportions of coal bottom ash, CBA (0% wt, 5% wt, 10% wt, and 15% wt).

Propertie of Material

Cement: Basic ingredient of concrete. The cement were stored in safe condition. The cement then sieved through 90μm t meet the criteria of high quality cement. Physical properties of cement is shown in Table 1.

Table 1: Physical properties of cement

No.	Physical Properties	Value
	Specific Gravity	3.15
2	Initial Setting Time	15 minutes
3	Final Setting Time	60 minutes
4	Size Produced	90μm

nd (fine aggregate): The fine aggregate that were used for the test is sand. The sand were sieved using 1.18mm ieve. It is conforming to Zone-III (75-100%) based on IS-383. Physical properties of sand is shown in Table 2.

Table 2: Physical properties of sand

o.	Physical Properties	Value
	Specific Gravity	2.65
2	Bulk Density	1.6g/cc
3	Size Produced	1.18-2.0mm

Coal Bottom Ash: CBA is tested to substitute cement in concrete mixture and the sieved through 90µm sieve. Physical properties of coal bottom ash is shown in Table 3.

Table 3: Physical properties of coal bottom ash

o.	Physical Properties	Value
	Specific Gravity	2.12
2	Bulk Density	0.641g/cc
3	Size Produced	90µm

2.1 Pre-treatment of Coal Bottom Ash

The pre-treatment method used sink and float test. Materials that are needed for this test was 100 ml mixture of chloroform and ethanol and 50g of coal bottom ash sample. Apparatus that used was 250ml glass flax. 150ml of chloroform and 150ml of ethanol have been mixed to form a mixture. The mixture was poured into 1000ml glass flax. Then, 150g of coal bottom ash sample was added into the solution. The solution is remained in room temperature for 24 hours. After that, the floating coal bottom ash then were removed, washed and dried in oven at 100°c for 30 minutes. The pre-treatment of coal bottom ash completed and used for formation of brick.

2.2 Concrete Mix Proportions

Eight out sixteen bricks were prepared by mixing cement with pre-treated coal bottom ash in four different proportions of coal bottom ash 0% wt, 5% wt, 10% wt, and 15% wt. Other eight cements were prepared by mixing untreated coal bottom ashes in four different proportions of coal bottom ash 0% wt, 5% wt, 10% wt and 15% wt. The bricks will collected at 7 and 28 days to measure properties of bricks in terms of compression test, water absorption and ultrasonic pulse velocity, UPV test.

2.3 Sample Preparation

Composition for each materials was calculated including cement, coal bottom ash, sand and water. The sand, water, cement and coal bottom ash were weighed and mixed. Prepare cement-coal bottom ash according to ratio and followed by water and sand. Cement-water mixture were stirred at low speed for 30s before sand were added and mixed for 5 minutes. Moulding with dimensions of 70mm x 70mm x 70mm was done in three layers. Each layers were tamped for 10 times. When the layers were filled, it will be smoothen out and samples has been made sure to be compact and dense. The samples were let dry within 24 hours and were removed from the mould. After the sample had dried, curing process was done for 7 days. After that, samples were test for its compressive strength, water absorption and UPV test were done to investigate the strength of the concrete. Repeat the same procedure on day 28. Table 4 and 5 below show the composition of cement mix.

Table 4: Pre-treatment CBA composition

SAMPLE	CONTROL	CBA5	CBA10	CBA15
Cement (g)	150	142.5	135	127.5
Sand (g)	435	435	435	435
CBA (g)		7.5	15	22.5
Water (g)	90	90	90	90

Table 5: Non Pre-treatment CBA composition

SAMPLE	CONTROL	CBA5	CBA10	CBA15
Cement (g	150	142.5	135	127.5
Sand (g)	435	435	435	435
CBA (g)		7.5	15	22.5
Water (g)	90	90	90	90

2.4 Performance of brick

2.4.1 Compressive strength test

The samples should be removed from the water on day 7, 30 minutes prior to the testing. It should be totally dried before test. Sample were tested using compressive test machine as shown in figure 1. Calculation for compressive test were performed using equation 1.

$$Compressive\ strength = \frac{Maximum\ Load\ Applied\ (kN)}{Cross\ Sectional\ Area\ (mm^2)} \qquad \text{.......... (Equation 1)}$$

Figure 1 Compressive Test Machine

2.4.2 Water absorption test

The samples will be weigh and initial weights are recorded. Immerse the samples in water tanks for 24 hours. The samples will be taken out and final weights are recorded to calculate the absorption of brick in water. Calculation for water absorption were performed using equation 2.

$$\text{Percentage \% of water absorbed} = \frac{Final\ weight\ (g) - Initial\ weight\ (g)}{Initial\ weight\ (g)}\ x\ 100$$

$$= \frac{W_2 - W_1}{W_1}\ x\ 100 \qquad \text{.......... (Equation 2)}$$

2.4.3 UPV test

Ultrasonic Pulse Velocity, UPV test is done to assess the quality of brick via the machine. Testing is done using instruments that use sound or stress waves in order to determine the properties of bricks non-destructively. It also used to check the compaction, uniformity of bricks, determine of cracks, presences of honey comb and strength estimation. The UPV test is conducted according to ASTM C67-03. Silica gel is put at the end of both pundit and placed it at the both side of the brick, and then the reading is taken. UPV usually only used for finding cracks and discontinuities. There are three basic ways of transducer arrangement in implementing the test either direct transmission through opposite faces, indirect transmission at the same face and semi-direct through adjacent faces. As the samples 70mm x 70mm x 70mm which is quiet small, we used the direct transmission to check the reading. Calculation for ultrasonic pul e velocity test were performed using equation 3.

$$Pulse\ Velocity\ \left(\frac{km}{sec}\right) = \frac{Path\ length\ (m)}{Transit\ time\ (microsec)} \qquad \text{........ (Equation 3)}$$