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Potential of Bottom Ash as Sand Replacement Material to Produce Sand Cement Brick

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Abstract: Bottom Ash (BA) is a by-product from coal electrical power plant. It was classified as scheduled waste. About 1000 tons/day of BA was produced and create a logistic problem to dispose. BA used as sand replacement material to produce sand cement brick grade C5 and C10. The effect of BA to compressive strength and density of brick containing BA compared containing river sand was identified and discuss in this paper. From results obtained is found that BA is highly potential to be use as sand replacement material in a production of sand cement brick. Even though the compressive strength of sand cement containing BA is lower but the properties is still satisfied standard requirement as stated in British Standard BS3921. Finally it can be concluded that concluded that the BA brick can be introduced as new type of brick in construction industry as it reduce the application of sand and cement in order to produce a good quality bricks with followed requirements.

Keywords: Bottom Ash, sand, cement sand brick, compressive strength, density.

1. Introduction

Sand cement brick is most popular type of brick use. In construction industries demand of sand especially for influencing the cost to manufacture bricks. Higher demand due to rapid development has led to an increase demand for river sand as a source of construction material. This situation has resulted in a mushrooming of river sand mining activities which have given rise to various problems that require urgent action by the authorities [1]. It was reported that the volume of sand being extracted is having a major impact on rivers, deltas and coastal and marine ecosystems, results in loss of land through river or coastal erosion, lowering of the water table and decreases in the amount of sediment supply [2]. Therefore the developing countries are under stress to identify alternative materials to reduce the demand in order to reduce the dependence on natural aggregates as the main source of aggregates in concrete [3]. Furthermore, many researchers' studies BA as alternative material in replacing the use of sand is indeed deem important to be looked into [4].

BA is one of potential alternative material defined as non-combustible material that remains in incinerator during burning process [5]. It has been reported that in Sultan Abdul Aziz Shah electrical power generator in Kapar, Selangor, produces about 15 to 20 tons BA per hour [6]. This material was dumped to a landfill and contributes on-going problem of limited landfill. BA is reported to has a potential to be used in the construction industries [7] but the utilization of this material in the production of sand brick is still limited due to lack of knowledge about this material [8].

Nowadays in construction practice, it is becoming increase common to maximize the use of waste material. Application of brick with the waste material is the common practice by other researchers. It is believed that the bottom ash will be utilized as the main constituents in the bricks [9].

The content of BA in the brick increase, the compressive strength of the brick was decreased [10]. This is due to the water discharge into the mixture of BA and also because of the higher porosity of BA. It also found that B can served as structural aggregate to produce water-permeable bricks with compatible engineering properties [8].

This paper present on the potential of BA as sand replacement material in the production of brick. The property such as compressive strength, water absorption and elasticity was presented and discuss.

2. Materials

The main raw material for this research is BA and Ordinary Portland Cement (OPC) as a binder was used supplied by Tasek cement that complies MS 522. The density of OPC is 1440 kg/m^3 and the average diameter size of cement particles is 0.01 mm. Table 2.1 shows the chemical composition of BA and OPC.

Table 2.1: Chemical composition of of bottom ash and OPC.

ELEMENT	OXIDE (%)	
	BA	OPC
SiO_2	30.29	3.23
Al_2O_3	14.81	2.73
Fe_2O_3	4.47	16.33
MgO	0.94	2.06
CaO	0.83	64.64
TiO_2	0.65	0.00
K_2O	0.60	0.32
SrO	0.08	0.00
ZrO_2	0.07	0.00
MnO	0.07	0.03
V_2O_5	0.02	0.00
ThO_2	0.01	0.00

All materials collected and supplied for this research was place in air tight container and storage under sheltered area in laboratory. Four types of brick were produced in this study. They were referring the testing of compressive strength, density, water absorption, porosity and elasticity test.

3. Methods

Before the mixing process, all materials must prepare according to the mix that being designed. Details for all the mix are shown in Table 2.2. From the Table 2.2 shown that four types of brick have been casted which are namely sand brick C5, sand brick C10, BA brick C5 and BA brick C10.

Table 2.2: Mixes Proportion for one brick production.

Materials (kg)	Sand Brick		Bottom Ash Brick	
	C5 (kg)	C10 (kg)	C5 (kg)	C10 (kg)
OPC	0.42	0.59	0.42	0.59
Sand	2.51	2.35	0	0
Bottom Ash	0	0	2.51	2.35
Water	0.34	0.35	0.34	0.35

Mixes proportion in this study were using water cement ratio 0.34 with design mix ratio 1:6 proportion by weight for grade 5 N/mm^2. However, for grade 10 N/mm^2, the water cement ratio was 0.35 with 1:4 design mix ratio proportion by weight.

The mixture was placed in the mixer and mixed until it uniformly. Water was poured gradually until all the materials were uniformly mixed. Then, the fresh mix was poured into a steal mould. The samples were placed at drying area for 24 hours before the mould can be removed. After removal of the brick samples from the steel mould, the bricks were cured in open air sheltered area until a date of testing.

All tests were performed on brick of dimensions 220 mm x 102.5 mm x 65 mm. The total number of brick unit sample prepared in this study for compressive strength, density, water absorption, porosity and elasticity test was three units for each mix. The test methods were carried out according to standard specified British Standard BS3921 and the average of the three bricks sample is measured, to ensure the reliability of the results.

The samples are tested to identify their properties in compressive strength after 7 and 28 days of curing period. The compressive strength test was carried out in accordance to BS EN 772-1, 2011 [11]. The compressive strength of the brick sample was determined by using Universal Testing Machine (UTM-1000) strength test machine. The average value of compressive strength for each type of the bricks was calculated after the result. Other researcher such as [7], [12] and [13] also done the same method in their studies.

The density of brick with four types of bricks is measured. According to ASTM, the density (kg/m^3) for each sample is calculated by number of six.

The test for determining water absorption and porosity should be in accordance to *Reunion Internationale des Laboratoires D'essais et de Recherches sur les Materiaux et les Constructions (RILEM): CPC 11.3 Absorption d'eau par immersion sous vide / Absorption of water by immersion under vacuum test procedure (1991)*. According to this procedure, the samples were dried under 24 hours in the oven at 105°C and then cooled in a desiccator for the next 24 hours and weighed. The weights of the dry samples were recorded. The desiccator was then filled with de-aired water so that the samples are fully submerged in water. Then the samples were kept under vacuum for 24 hours. Next, the samples were allowed to equilibrate for the next 24 hours under atmospheric pressure. The samples were then weighed in air by using buoyancy balance and the weights were recorded. Then the samples were weighed in water using buoyancy balance and the weights were recorded.

The elasticity test has been conducted based on MS327: part 3: 1997 by using Universal Testing Machine (UTM-1000). The brick was placed centrally on the lower platen. Next, the load was applied and the UTM machine printed the graph of stress-strain reading.

4. Results and Discussion

The result of the testing is evaluated and discuss as shown in Table 2.3.

Table 2.3: The various results for testing of the sample.

Test	Day	Sand Brick		Bottom Ash Brick	
		C5	C10	C5	C10
Compressive strength (N/mm^2)	7	9.04	10.30	3.34	3.83
	28	13.90	15.83	5.13	5.90
Density (kg/m^3)	28	2075	2139	982	1007
Water Absorption (%)	7	14.44	12.35	23.23	19.66
	28	12.11	9.67	18.29	15.77
Porosity (%)	7	33.20	28.38	42.43	37.18
	28	25.70	22.61	36.53	31.14
Elasticity, E (N/mm^2) x 10^2	7	622.74	630.99	355.53	365.59
	28	665.07	686.26	360.91	388.16

4.1 Compressive strength test

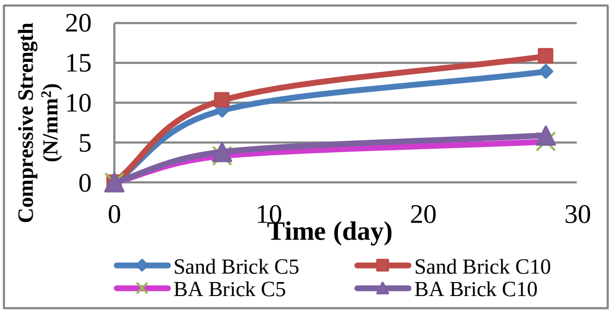

Fig. 1 Variation of compressive strength test results with days.

The compressive strength test results are shown in Fig. 1. From this figure it is found that sand brick C10 is the highest compressive strength with 15.83 N/mm^2 and the lowest value of compressive strength is BA brick C5 with 13.9 N/mm^2 at age 28 days. It is also found that the result indicated the compressive strength of sand brick C5 is increased than BA brick C5 at 63.09% and decreased than sand brick C10 at 12.19% BA brick C10 is increased than BA brick C5 at 13.06% and decreased than sand brick C10 at 62.73% respectively. From the result obtained, it is showed that sand brick C10 is having a better compressive strength as normal material in production of solid brick compared to bottom ash brick. The compressive strength of brick can depend strongly on the production technology which is the height and shape of the specimen [18]. From the result obtained it is also found that all mixes is having a compressive strength higher than requirement Standard Specification for Building Works, 2005 which is 5.2 N/mm^2. This finding shows that a brick made bottom ash has a potential. Other researcher also agreed that BA can increased compressive strength due to calcite deposition on the surface and voids of bricks [20].

4.2 Density

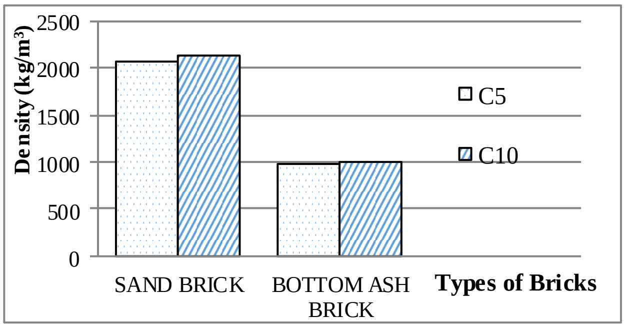

Fig. 2 The density test results

Fig. 2 are shown the density test results. Based on Figure 2, it can be categorized that sample sand brick C5, sand brick C10 BA C5 and BA C10 by using different material whereas sand and BA. From Fig. 2 it can be extracted that the density of brick containing sand is higher than BA. For grade strength C5, it shows that the density of sand brick C5 is 2075.09 kg/m^3 and BA brick C5 is 982.4 kg/m^3.

Sand brick C10 is having density of 2138.76 kg/m^3 while bottom ash brick C10 is having density of 1007.41 kg/m^3. From this result it is found that the differential density of sample containing of sand and BA is 52.66% for brick of grade C5, 52.90% for brick grade C10. From the resulted obtained, it found that bottom ash particles are more porous and weak than natural sand particles. It then causes the demand of mixing water increased on its use in brick as sand replacement and further causes the density of brick to become low [17].

4.3 Water absorption

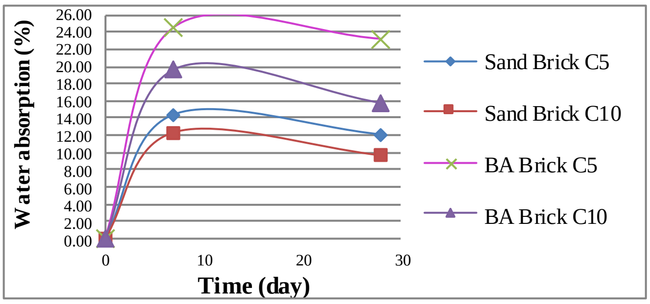

Fig 3. Results of water absorption by 7 days and 28 days.

The water absorption of sand brick and BA brick C5 and C10 based on age of testing which are 7 and 28 days are shown in Fig. 3. At the age of 7 days the water absorption of grade C5 sand brick is 14.44%, grade C10 sand brick with 12.35% while the water absorption of grade C5 BA brick is 23.23%, grade C10 BA brick with 19.66% At the age of 28 days, grade C5 sand brick retained of 12.11% water absorption, while grade C10 sand brick with 9.67% and grade C5 BA brick retained of 18.29% water absorption, while grade C10 bottom ash brick with 15.77%.

From Fig. 3, it can be observed that the water absorption for all grade C5 sand brick and grade C10 sand brick at the age of 7 days are the highest compared to the water absorptions at the age 28 days. It was also found that the water absorption of grade C5 sand brick will decreased about 16.14% and C10 (sand) is 21.70% from the age of 7 days to the age of 28 days. While the BA brick grade C5 bottom ash brick decreased 21.27% and C10 bottom ash brick about 19.79% from the age of 7 days to the age of 28 days. From the result observed, it showed that the BA brick with grade C5 and C10 had the minimize level water absorption values as compared the maximum water absorption for bricks under severe weather exposure is 17% [18]. Low values of water absorption are often found with high strength bricks and vice versa, but this should not be automatically assumed [19].

4.4 Porosity

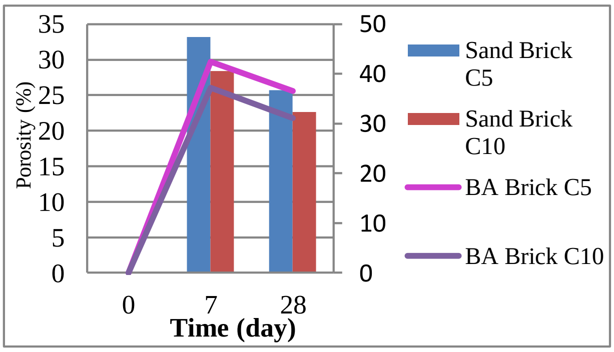

Fig. 4 Porosity of bricks at age 7days and 28 days

The result of porosity between sand cement brick and BA cement brick for grade C5 and grade C10 based on types of brick is illustrated in Fig. 4. From Fig. 4 found that the porosity of BA brick C5 is higher 42.43% while the lowest is sand brick C10 is 28.61% at age 7 days. Moreover the porosity value is same for BA brick C5 is higher 36.53% and the lowest is sand brick C10 is 22.61% at age 28 days. From Figure 4 shows that the porosity of sand brick decreased from age 7 days to 28 days for grade C5 is 22.59%, sand brick C10 decreased about 20.33%, bottom ash brick C5 decreased about 13.91% and bottom ash brick C10 decreased about 16.25 %. From Figure 4 it can be extracted that porosity is the measure of volume of voids in brick which affects the strength of brick. The porosity of brick decreased due to pore decreased and thus causing the water absorption also to be decrease [7].This explained the reason why water absorption and porosity of bricks are decreased concurrently. It can be concluded this by reported that higher the volume of voids the higher the water absorption and porosity [20].

4.5 Elasticity

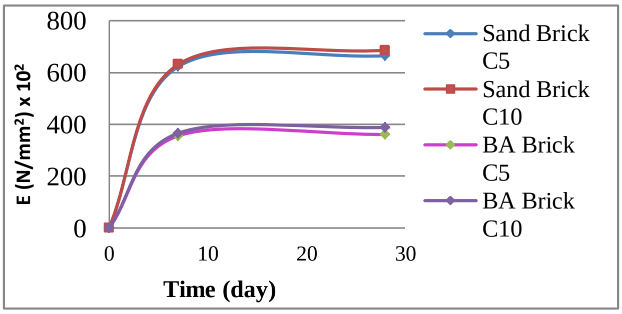

Fig. 5 Values of elasticity versus time.

Fig. 5 shows the values of elasticity of bricks against the time. Based on Figure 5, it shows that the elasticity values of all the bricks are increasing as the number of day brick ages increase. The highest value of elasticity is 630.99 x 10^2 N/mm^2 and the lowest value is 355.53 x 10^2 N/mm^2 at 7 days. In addition, Figure 5 also presented that the highest value of elasticity is 686.26 x 10^2 N/mm^2 and the lowest is 360.91 x 10^2 N/mm^2 at 28 days. From the result obtained, it is showed that the increasing of elasticity values of bricks at day 7 to day 28 may due to the bricks are still gaining their strength at early days. Similarly, the elasticity value of the brick also in development progress since as the compressive strength increase, the elasticity also increases. It is proven by modelling of mechanical behavior of earthen earth and research experimental analysis that when compressive strength increase, elasticity also inrease [21].

5. Summary

This study was carried out to evaluate the significance of utilizing industrial waste such as bottom as potential material to production of sand brick with developing the brick containing Bottom Ash. From the result obtained of this study, conclusions can be drawn as the following:

- The result of this research proves that bottom ash brick is suitable to be used in the industry as it passed the strength and density requirement besides being advantageous due to its lightweight characteristic.
- Bottom ash cement brick has higher water absorption and porosity than sand cement brick and it effect the compressive strength of brick and water absorption and porosity of brick are decreased uniformly as the age of testing is getting longer.
- It is found that composite strength system gave positive effect to the elasticity and density value of brick containing Bottom Ash and elasticity and density value of bottom ash brick reduces when the sand is replaced with bottom ash.
- It is concluded that the Bottom Ash brick can be introduced as new type of brick in construction industry as it reduce the application of sand and cement in order to produce a good quality bricks with followed requirements.

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