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DEVELOPMENT OF BRICK USING THERMAL POWER PLANT BOTTOM ASH AND FLY ASH

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ABSTRACT

This paper reports the results of the investigation done on bricks made using bottom ash and fly ash. Bricks were made with various proportions of bottom ash, fly ash and cement. Tests for workability, density, strength, water absorption and ultrasonic pulse velocity (UPV) were conducted. Results show that the compressive strength ranged from 5.5 MPa to 11.68 MPa, maximum water absorption was 15.7% and the UPV ranging from 2260.2 m/s to 2916.1 m/s. The strength of bricks increases with the increase in fly ash; water absorption, and UPV with the increase in fly ash. It is concluded that bricks of good quality can be made using bottom ash and fly ash whereby contributing to sustainable development.

Keywords: Fly ash; bottom ash; cement; brick; water absorption; UPV

1. INTRODUCTION

Green technology in building industry is becoming increasingly significant now-a-days to address issues of environmental pollution and sustainability. This makes engineers to use waste materials in construction. Coal fired thermal power plants generate large volumes of bottom ash and fly ash which are currently sent to landfills and ash ponds. The scheduled industrial waste generation in Malaysia in the year 2009 is 1,705,308 metric tonnes [1], major components of the wastes are from dross, slag, clinker, ash, gypsum, oil and hydrocarbon. These wastes must be properly managed and disposed without causing any harmful environmental effects. Around 126,288 metric tonnes of industrial wastes are treated by Kualiti Alam Sdn Bhd, Malaysia. Incineration of these wastes produces around 25,000 tonnes of bottom ash (BA) which are sent to secured landfills. But disposal by land filling is not a sustainable solution. Hence various methods of using the bottom ash need to be developed. Incineration bottom ash if reused, will ensure sustainability, reduce pollution and environmental degradation, generate revenue, and preserve the natural virgin resources [2].

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These wastes are effectively used in many applications. Since these wastes are usually disposed of in the form of slurry in the vicinity of the power plant, fly ash possesses significant environmental risk due to the possibility of leaching of these metals into environment. In the brick making industry, there has also been research into how to reuse different waste products in order to manufacture better quality bricks [3-6].

Such risks have paved the way to extensive studies on the physical–chemical properties and leaching behavior of fly ash [7-13]. There is also a large body of work on the utilization of fly ash in cement and brick production [14-29]. The Plasticity Index (PI) value will decrease with the increase of fly ash and the high volume ratio of fly ash will gives high compressive strength and lower water absorption. The collapse load or failure of masonry of a building is clearly a function of the geometry, of the external actions, of the materials properties and finally of the environmental conditions [26]. The maximum water absorption value is 18% and if the percentages of the samples lower than 18% of water absorption, so it is a good sample of brick and will be save to use according to ASTM standards [28]. Bricks are used in the combustion industries for lining furnaces. This type of brick must have good thermal shock resistance, refractoriness under load, high melting point, and satisfactory porosity. The strength of the unfired bricks which is cured in open air are depend on the fineness of the fly ash, the usage of ultra fine fly ash will give an excellent result [30 - 31]. The strength of bricks is mainly dependent on the mixing ratio and the water contained and usage of excessive water will decrease the compressive strength of the bricks. The real issue about Ordinary Portland Cement (OPC) durability is related to the intrinsic properties of the material. It also presents a higher amount of calcium hydroxide, which reacts with acids generating soluble compounds. On the other hand, the disposing of fly ash, a coal burnt by-product is an environmental issue. As a useful mineral admixture, fly ash has been widely utilized in concrete replacing OPC partially all over the world [32]. The change in fineness of fly ash great influenced the air-entraining capacity, water content, compressive strength and drying shrinkage of fly ash concrete [33].

Use of bottom ash and fly ash in brick making will offer many advantages like consuming large volumes of waste whereby reducing the environmental problems caused by dumping these wastes in landfill and ash ponds, enhance the properties of bricks and performance of masonry, and contribute to sustainable development. This will also enable the developers to get green building index (GBI) points. The practice of green building concept shall increase the efficiency of resource use while reducing building impact on human health and the environment during the building's lifecycle, through better sitting, design, construction, operation, maintenance, and removal. Green Buildings should be designed and operated to reduce the overall impact of the built environment on its surroundings. An attempt is made in this investigation to develop bricks using bottom ash, fly ash and cement. Various mixtures of bricks were made using bottom ash, fly ash, and cement. Tests for workability, density, strength, water absorption and ultrasonic pulse velocity (UPV) were conducted and the results discussed.

2. MATERIALS AND METHODS

2.1 Materials used

Locally manufactured Ordinary Portland Cement (OPC) which conforms to MS522 Part 1:

1989 was used for all mixtures of the testing project. All the cement used was from the same source, and met the requirements of MS522 Part1: 1989, Specification for Portland cement. Bottom ash and fly ash is obtained from Kapar Energy Ventures Sdn. Bhd, Kapar thermal power station, Kapar, Selangor, Malaysia. The chemical and physical properties of constituent materials are given in Table 1. The bottom ash contains particles of various sizes from smaller than 2.36mm to 20mm. The bottom ash first dried, then sieved through 10mm sieve to eliminate unsuitable material and particles larger than 10 mm size particle. The grading curve for bottom ash is shown in Figure 1. It is indicated that the grading of both materials fall within the ranges given in BS 882:1992 [34]. Fineness modulus of bottom ash is 2.51.

Table 1: Chemical and physical composition of bottom ash, fly ash and cement.

Material	Chemical composition (%)							Physical composition			
	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	ZnO	LOI (%)	Blaine fineness (cm^2/g)	Density (kg/m^3)	Specific gravity
Bottom ash	9.78	20.75	37.1	11.1	3.2	-	1.8	-	-	890	2.98
Fly ash	56.58	27.83	4.0	4.3	1.4	-	-	-	3000	1155	2.06
Cement	21.54	5.32	3.6	63.6	1.0	2.1	-	2.5	3500	1367	3.15

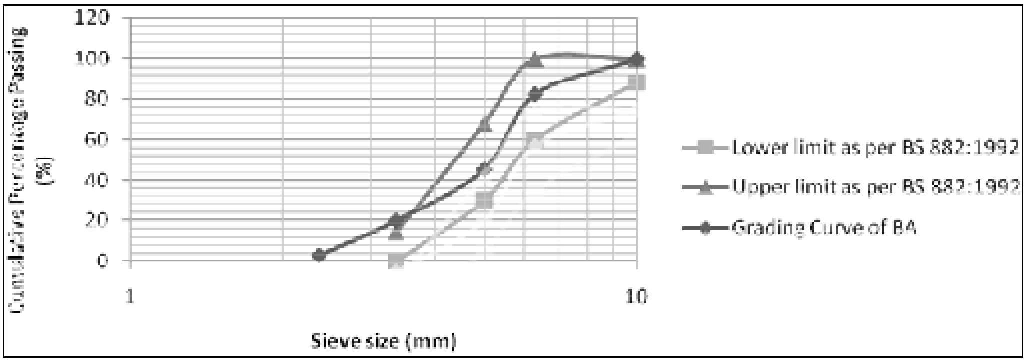

Figure 1. Grading curve for bottom ash

The bottom ash contains particles of various sizes from smaller than 2.36mm to 20mm. The bottom ash first dried, then sieved through 10mm sieve to eliminate unsuitable material and particles larger than 10 mm size particle. The grading curve for bottom ash is shown in Figure 1. It is indicated that the grading of both materials fall within the ranges given in BS 882:1992 [34]. As shown in Figure 1, the grading curve falls in the limit after exceed 20% passing cumulative percentage. The fineness of bottom ash is 2.51.

2.2 Mix proportion, casting and testing

The mix proportions are indicated in Table 3. The materials were weighed according to the given ratio, and mixed in dry state in the mixer machine for 1 minute. Then the water is added until the mix is flow able. After that, the flow ability test is conducted according to ASTM D 6103 [35]. The flow ability of the mixes was kept at 200 $\pm$ 20 mm. The mix was poured into the moulds and the sides of the moulds were tapped gently with an iron rod. Then the moulds were cured in the laboratory condition until the day of test. The brick samples were tested for compressive strength, water absorption, and UPV.

Table 2: Mix proportion

No.	Ratio (BA:FA:cement)	Bulk composition (kg/m^3)				Fresh density (kg/m^3)
		BA	FA	Cement	Water	
1	1.0 : 0.5 : 0.25	691.6	345.8	172.9	368.5	1580
2	1.0 : 0.75 : 0.25	525.0	393.7	98.5	480.4	1530
3	1.0 : 1.0 : 0.25	506.5	506.5	126.6	555.2	1695
4	1.0 : 1.25 : 0.25	440.8	551.1	137.4	368.3	1500
5	1.0 : 1.5 : 0.25	394.2	591.4	147.7	404.7	1540
6	1.0 : 1.0 : 0.15	527.4	527.4	79.4	386.7	1520
7	1.0 : 1.0 : 0.35	481.2	481.2	168.3	395.8	1500
8	1.0 : 1.0 : 0.45	462.0	462.0	208.0	412.0	1530

The compressive strength test is done according to ASTM C 140–02 [36] using the 1000 kN compression testing machine. Tests were done at 14, 28, and 56 days. Three samples were tested on each day and average value reported. The UPV test is done according to ASTM C67-03 [37]. The pundit is smeared with grease and placed at the two end corners of the brick, and then the reading is taken from the equipment. The water absorption test is done according to ASTM C20 – 02 [38]. The samples were soaked in water for an hour. The weight of the brick is taken before and after the test to find the amount of water that the brick absorb.

3. RESULTS AND DISCUSSION

The various properties observed are given in Table 3. It is noted that the density varied from $1500kg/m^3$ to $1695kg/m^3$. The relationship between fresh density and water-powder ratio (w/p) is shown in Figure 2. It is indicated that increasing w/p ratio increases the density of the mix. The relationship between fresh density and powder – bottom ash ratio (p/BA) is shown in Figure 3. The relationship between strength and w/c is shown in Figure 4. It is clear that excessive water addition will affect the strength of the brick. From Figure 5 it is clear that fresh density increases with increase in p/BA ratio.

The more cement used will result in high compressive strength. From Figure 11, it is indicated that the strength is highest for mix 8 and lowest for mix 6. Mix 8 has more cement used and mix 6 has the lowest cement used. Hence addition of cement increases the strength. The strength of bricks at 28 days ranged from 4.3MPa to 10.96MPa. The minimum strength for class 1 bricks is 6.9 MPa [39]. Hence it is concluded that the bricks developed are comparable to that of normal clay bricks.

Table 3: Properties of bricks

Compressive strength (MPa) at day			Hardened density (kg/m^3) at day			Water absorption (%)	UPV (m/s)
14	28	56	14	28	56		
6.27	10.96	11.0	1519	1540	1575	5.45	2556.1
4.73	5.62	6.4	1630	1665	1695	2.04	2260.2
7.41	7.6	7.79	1475	1555	1770	12.55	2715.2
6.95	7.2	7.9	1400	1435	1550	15.7	2916.1
7.1	8.51	9.67	1553	1569	1597	9.7	2458.0
3.85	4.29	5.5	1597	1636	1654	13.2	2785.3
7.21	8.79	10.5	1565	1580	1602	14.9	2891.4
9.11	10.38	11.68	1622	1658	1683	13.8	2819.8

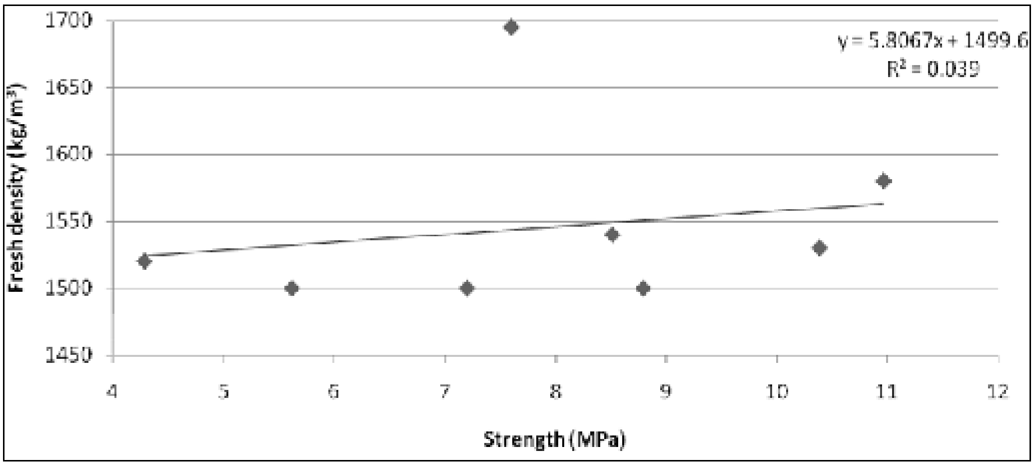

Figure 2. Relationship between fresh density and strength

From Figure 2, based on the linear straight line, it is noted that the increment of fresh density will increase the strength of 28 days brick. This is because the higher the density, the more powder contains that will creates paste which will occupy all the voids in the mix. The relationship between strength and w/c ratio is indicated in Figure 3. It is shown that the strength is decreasing with the increase of w/c. The strength is mainly dependent on the mixing ratio and the water contained. If excessive water is used, then the strength will decrease [32].

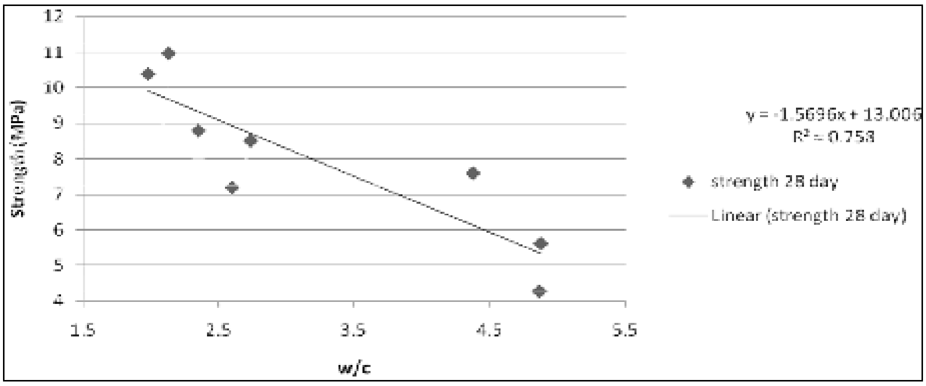

Figure 3. The relationship between strength and w/c

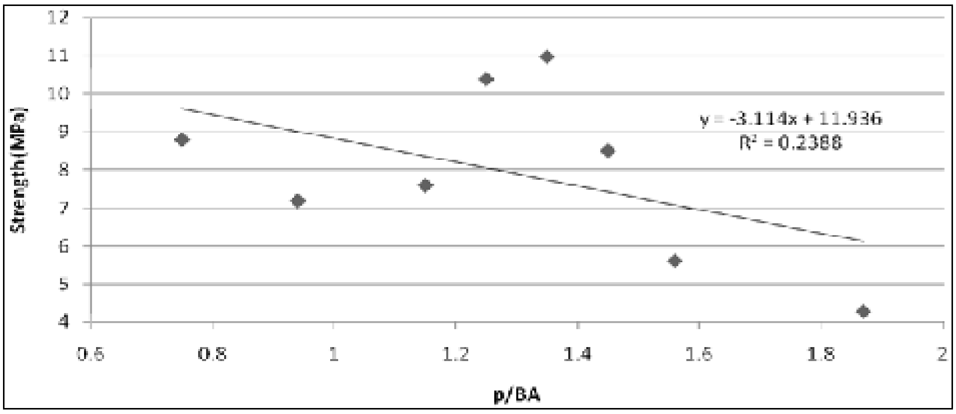

Figure 4. The relationship between strength and p/BA ratio.

The relationship between strength and powder to bottom ash ratio (p/BA) is shown in Figure 4. The strength decreases with increase in p/BA. This happens because the more fly ash addition and less BA addition will make the powder volume in the matrix to increase and weakening bond.

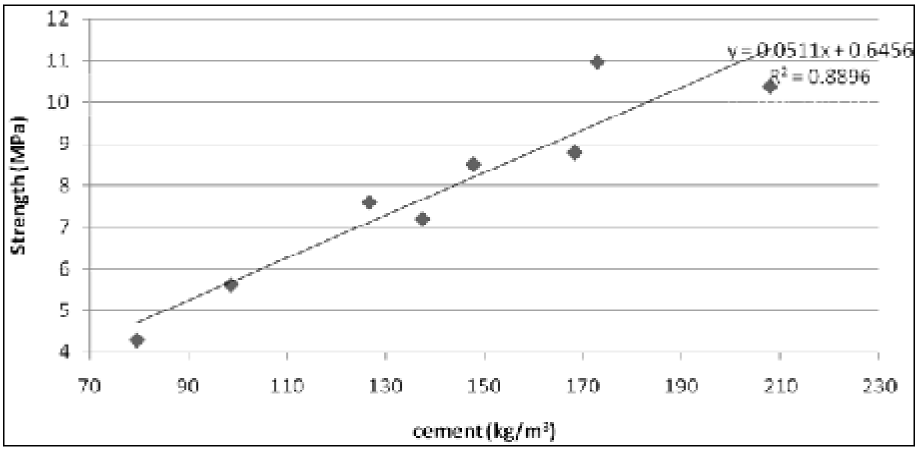

Figure 5. The relationship between strength and bulk composition of cement

The relationship between strength at 28 days and cement content is given in Figure 5. It is noted that the increase of cement content increases the strength of the brick. This is because the strength is directly influenced by cement. The results of UPV test is presented in Table 4. The UPV ranges were from 2260.2 m/s to 2916.1 m/s. The relationship between UPV value and c/BA is shown in Figure 6. The UPV test is done according to ASTM C67-03 [37]. The UPV through a material is a function of the elastic modulus and density of the material. The pulse velocity can therefore be used to assess the quality and uniformity of the material. The following procedures were applied to obtain UPV values: the UPV value of a masonry block is determined by placing a pulse transmitter on one face of the block sample and a receiver on the opposite face. The UPV value for bricks is in the range of 1453 m/s 2758 m/s [40]. Based on the UPV value obtained, the bricks produced in this investigation performed well.

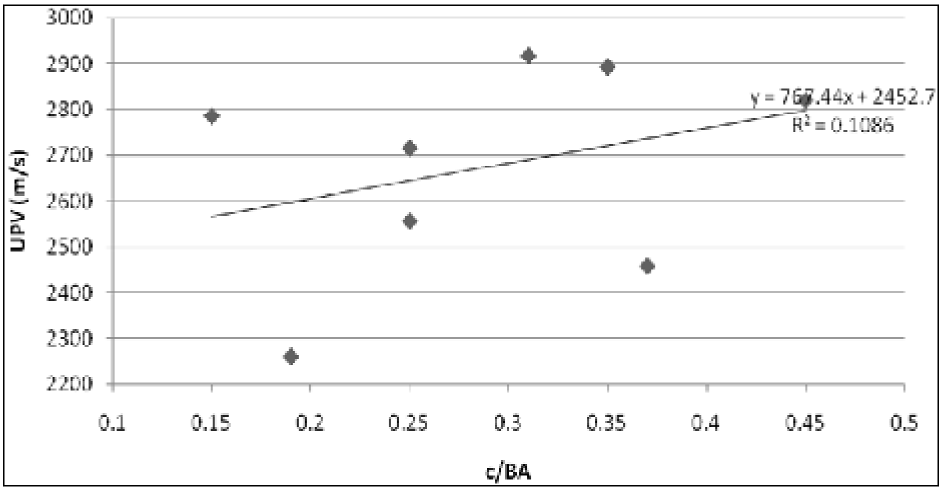

Figure 6. The relationship between UPV and c/BA

Figure 6 reports the relationship between UPV and c/BA. From the Figure 6, it is noted that based on the linear straight line plotted, the increment of c/BA will increase the UPV value. The more cement we use over bottom ash the higher UPV value obtained because the cement particles which are small will fill the voids and hence increase the UPV.

Based on the results, the water absorption range from 2.04 % to 15.7 %. When the w/p ratio increases, the water absorption also increases. The maximum water rate of the samples should be lower than 18% of water absorption, so it is a good sample of brick and will be save to use according to ASTM standards. If the water absorption falls in range 33% to 40 %, then the quality of the brick is low [28]. Figure 7 shows the relationship between water absorption and c/BA. The relationship between water absorption and c/BA is clear that the increase of cement increases water absorption. The relationship of water absorption and the bulk composition of BA are shown in Figure 8. It is noted that more BA used, less water absorbed. Figure 9 represent the relationship between water absorption and FA content. It is noted that the increase of FA, the water absorption rate increases. The relationship between water absorption and (c + FA) represented in Figure 10. The more cement and FA used, the higher the water absorption rate. The brick samples performed good because the water absorption rate were lower than 33% [28]. This is because addition of solids increases the weight.

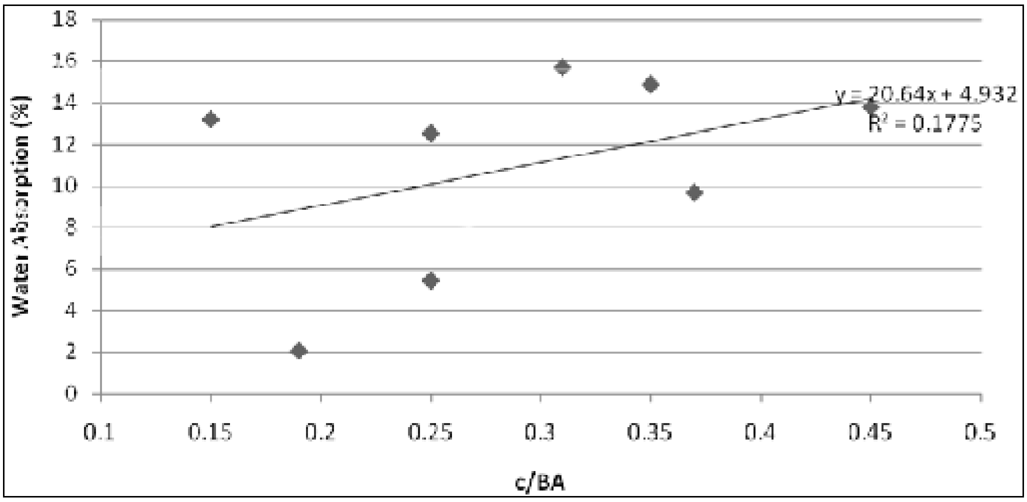

Figure 7. The relationship of water absorption and c/BA

The relationship between water absorption and c/BA is given in Figure 7. From Figure 7, it is clear that the increase of cement increases water absorption. It happens because the brick is cured in open air in the laboratory. The water added in fresh state was evaporated and the matrix was basically dry, hence the moment it was immersed in water, the bricks absorbed water. This aspect needs to be further investigated to study the influence of constituent materials on the water absorption. From Figure 8, it is noted that the more bottom ash used the less water is absorbed. This happens because when the more bottom ash used, the more fly ash will contain and fills the voids and limits the water being absorbed.

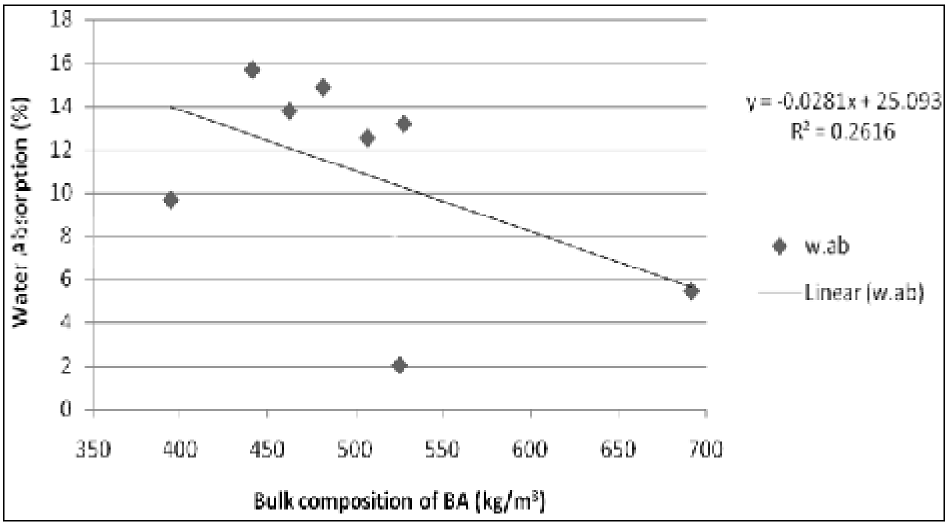

Figure 8. The relationship between water absorption and the bulk composition of BA

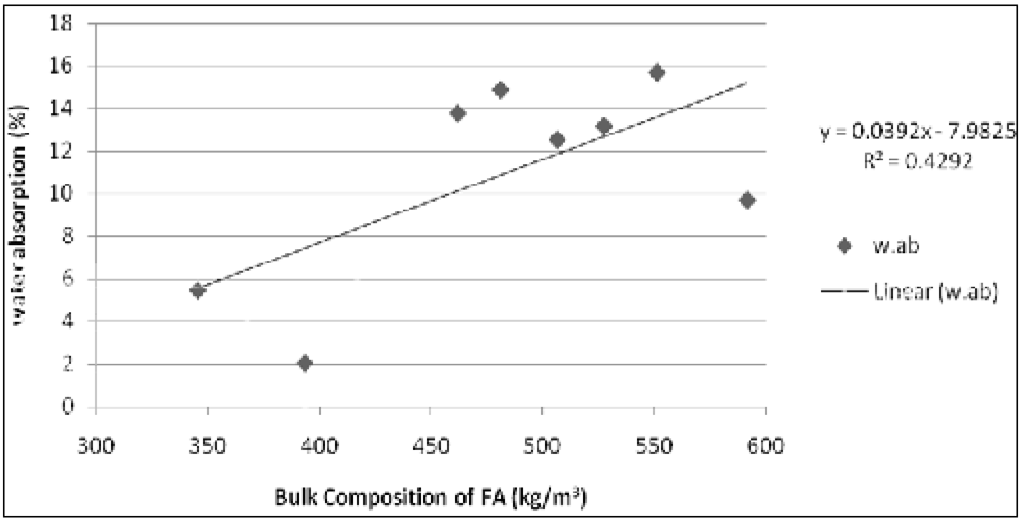

Figure 9. The relationship between water absorption and bulk composition of FA

From Figure 9, is illustrates that the increment of fly ash directly will increase cement content. The higher amount of cement used will caused shrinkage in the brick which will increase the water absorption rate.

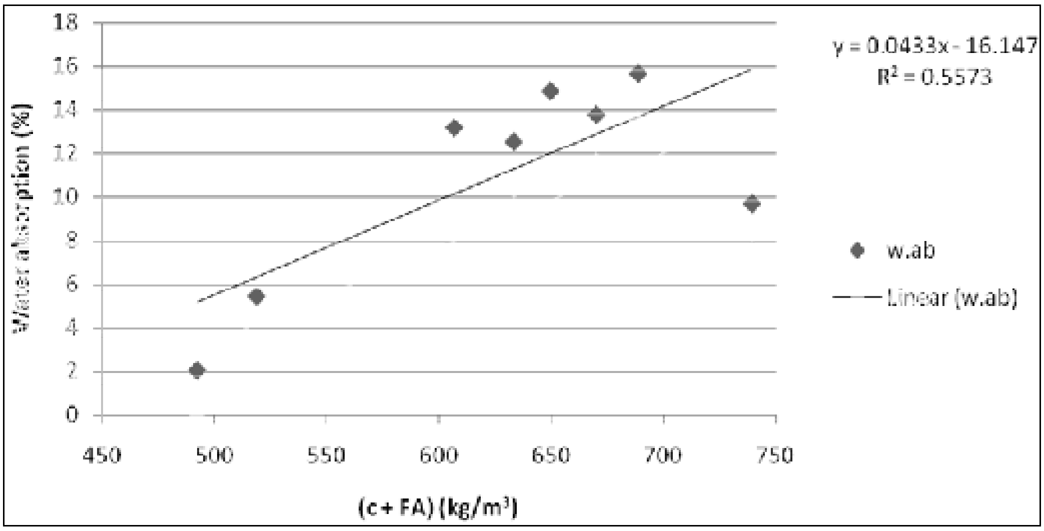

Figure 10. The relationship between water absorption and bulk composition (c + FA)

From Figure 10, it is noted that based when the amount of cement and fly ash is increasing, the water absorption is also increasing. This happens because the addition of more powder increases the paste in the matrix which absorbs water when immersed in water from the dry curing condition in the laboratory.

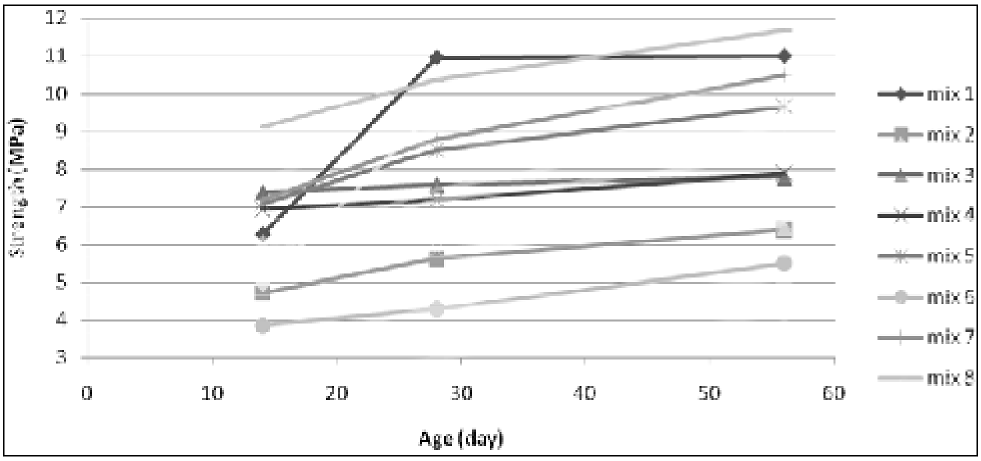

Figure 11. The relationship between the strength and the age of the brick

From Figure 11, it is illustrated that the strength increases from the day 14 until day 56. This happens because the brick develop the strength depend on the age of the brick, the longer its age, the higher the strength of the brick. The brick need longer time to reach the ultimate strength because the brick is cured in open air [30]. Mix number 8 shows the highest strength whereas mix number 6 shows the lowest strength because the cement content for mix id 8 is high and for mix 6 is low.

4. CONCLUDING REMARKS

The following conclusions are made from the results obtained:

- The bricks developed in this investigation are comparable to that of normal clay bricks. The strength increases with increase in cement and FA.
- Fresh density increases with increase in p/BA ratio. The more addition of FA and cement the higher the fresh density value, which is because the powder creates paste that, will occupies the air void and increases the weight.
- Water absorption increases with increase in w/p and decreases with increase in p/BA ratio.
- The increase in cement also increases the water absorption.
- The increasing of cement and FA will increase the UPV value.

LIST OF ABBREVIATION

BA	Bottom Ash
FA	Fly Ash
c	Cement
p	Powder (cement + fly ash)
UPV	Ultrasonic Pulse Velocity

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