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The Effect of Fly Ash On Brick Aggregate Concrete

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Abstract

The current trends in construction materials resources towards a more sustainable development environment are regenerate the industry's waste to become by-product waste as partial replacement purposes. Among these efforts is the utilization of fly ash as a partial replacement of cement in concrete work that is more eco-friendly and creates significant environmental benefits. This paper presents some experimental results and discusses fly ash as a partial replacement in producing brick aggregate concrete. Clay bricks were crushed to produce brick aggregate and replace 50 % of the natural coarse aggregate in producing concrete. The crushed brick aggregate's physical and mechanical properties such as water absorption, density, aggregate impact value (AIV), and aggregate crushing value (ACV) were determined. There are five series of concrete mixtures with 50% brick aggregate were prepared and tested. The concrete mixtures were partially replaced with fly ash ranging from 0% to 30%. A total of 45 cube specimens with the size of 100 x 100 x100 mm were prepared and tested for compressive strength at the age of 10, 28, and 90 days while ten-cylinder specimens with the size 150mm x 300mm were prepared and tested for splitting tensile strength at the age of 28 days. The results indicated that the concrete mix with partial replacement of fly ash gained higher compressive strength during age 28 days but less than control specimens at 90. The splitting tensile strength of concrete containing fly ash overall was lower than the control mix. As expected, the water absorption for the concrete mixture containing fly ash was decreasing. The optimum percentage used of fly ash as a partial replacement for cement for brick aggregate concrete was 15%, where if exceeded, it will decrease the compressive strength. The experimental results obtained and observation made in this study indicated that fly ash possesses the potential used as a strength development agent as a partial replacement for cement in producing concrete.

Keywords — *Brick aggregate, fly ash, water absorption, splitting tensile strength, compressive strength*

I. INTRODUCTION

The sustainable construction environment currently emphasized the construction material resources in producing concrete. The exploration of the alternative ingredient materials such as cement and aggregates using by-product waste generated from industries is an innovative solution for future construction environment sustainability. Aggregate is one of the important materials constitutes in producing concrete. The use of aggregate in producing concrete is significant. About 70% [1] to 75% of the concrete volume is aggregate, and annual production of concrete is estimated to be 7 billion cubic meters worldwide[2, 3]. The massive use of aggregate in the production of concrete industry greatly impacts the environment [4]. The huge amount of natural aggregate consumption in producing concrete may cause the depletion of natural resources.

Currently, brick waste in the construction industry also contributes to a large amount percentage of construction waste. Meanwhile, crushed clay brick can be used to replace natural aggregate in the production of concrete. The use of innovative material in producing concrete has become widespread, contributing to the natural environment's conservation. The by-product mineral such as fly ash is a pozzolanic material that can produce concrete to solve the industrial waste disposal problem to the environment. The previous research showed that fly ash in producing concrete could improve concrete properties such as workability and compressive strength [5].In 2014, the study conducted by [6] on the utilization of crushed clay brick in the concrete industry using crushed clay brick aggregate had shown a high water absorption rate compared to the natural aggregate, and the specific gravity of natural aggregate is 2.56 compared with the crushed clay brick aggregate which is only 2.04 [6].

The previous research on crushed brick concrete had a lower compressive strength, which is about 10% to 35% decreases in compressive strength for recycled coarse aggregate concrete after 28 days [7]. The recycled coarse aggregate concrete's compressive strength is between 20 MPa to 40 MPa, after 28 days. The percentage replacement of coarse and fine brick aggregate should be limited to 25% and 50% to produce the minimum concrete quality [7]. In 2009, [8] have investigated the mechanical properties of brick aggregate concrete, and their findings indicated that the optimum percentages of partial replacement of crushed brick aggregate in producing concrete are 15% where exceeded will reduce the concrete strength [8]. The study conducted by Kesharwani et al. (2017) indicated that the optimum percentage of fly ash as a partial replacement for cement is 25% [9].

However, the use of fly ash as partial cement replacement in producing brick aggregate concrete currently more environmentally sustainable due to these materials inexpensive and provide solutions for industrial waste disposal. Therefore, this study investigates the effect of fly ash as partial cement replacement on brick aggregate concrete properties, which will impact reutilizing the waste materials generation in construction materials. The concrete study properties determine the compressive strength, density, water absorption, and splitting tensile strength of brick aggregate concrete with fly ash.

II. EXPERIMENTAL DESIGN

A. Materials Preparation

The research was conducted in two stages: the first stage comprises testing on aggregate's mechanical and physical properties. The second stage is a concrete mix design with the preparation of hardened concrete specimens. Five concrete mixes contain 0%, 7.5%, 15%, 22.5%, and 30% of fly ash as partial replacement of cement was prepared. The hardened concrete specimens were tested for water absorption, compressive strength, and splitting tensile strength. The raw materials used in this study are Ordinary Portland Cement (OPC), coarse aggregate, fine aggregate, crushed clay brick aggregate, fly ash, and water. For the preparation of brick aggregate, the clay bricks were crushed into stone size manually. The crushed bricks were put into the crusher to produce small quantities of crushed clay bricks aggregates. The crushed clay brick aggregate size will be in the range of 4.75mm and 37.5mm in diameter. The particle size distribution of aggregate used in the test is shown in Fig. 1. The fine aggregate has a portion below 4.75mm, where 0.075mm is the minimum size of fine aggregate, and the grading curves are presented in Fig. 2. The size of natural coarse aggregate is prepared to comply with BS EN 12620 [10]. The replacement of fly ash in brick aggregate concrete was 7.5%, 15%, 22.5%, and 30% by weight of the concrete's cement content.

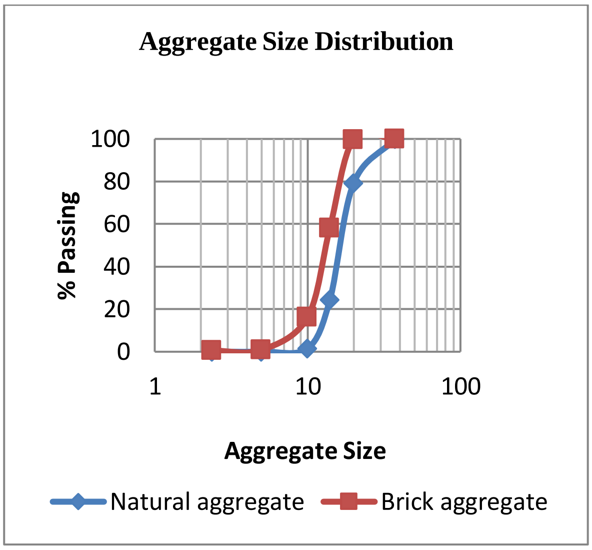

Fig 1: Aggregate size distribution.

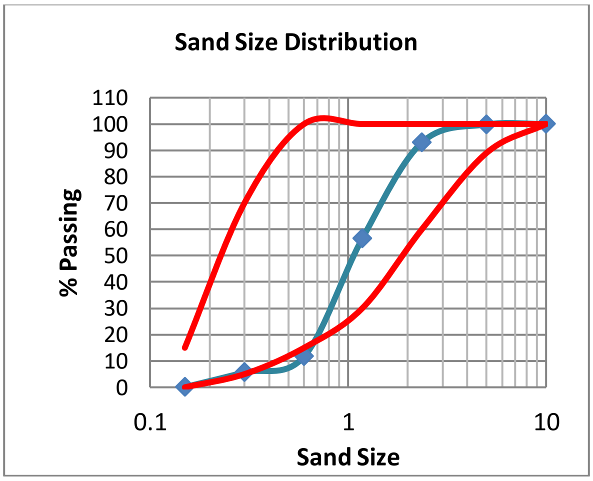

Fig 2: Sand size distribution

The aggregate impact value (AIV) test is carried out to assess aggregate demand regarding the toughness for use in construction work. The aggregate impact value indicates a relative measure of the resistance of an aggregate to a sudden shock or an impact, which differs from its resistance to a slow compressive load in some aggregates. The oven-dried and accurately weighed aggregates are subjected to a total of 15 blows of specified weight and fall, and the percentage of fines formed in terms of the total weight of the sample is expressed as the aggregate impact value. The aggregate crushing value (ACV) is an indirect measurement to determine the aggregates' crushing strength. Low aggregate crushing value indicates the aggregate is strong as the crushing fraction is low. The mean of the crushing value obtained from ACV results in the two tests is reported as the aggregate crushing value. The ACV test limits for cement concrete shall not exceed 30% while wearing surfaces shall not exceed 45% [11, 12].

B. Concrete Mix Design

There are five concrete mixes design based on a previous study with different fly ash proportions as partial replacement of cement by weight in 50% brick aggregate concrete. The cement over water ratio is 0.57 used in this study. The concrete mix design was shown in Table 1. The concrete slump test is used to determine the concrete mix's workability, where the test was carried out according to B.S. 1881-102:1983 [13]. The concrete compressive strength test will conduct according to the BS EN12390-3:2002 [14]. For the concrete splitting tensile strength, the test is conducted based on the BS 1881 117-83 [15], while for the water absorption test, it is determined by using the BS 1881-122 [16].

TABLE I
Concrete mix design

Mix designation	Mix proportion				
	M0	M1	M2	M3	M4
Cement (kg/m^3)	6.14	5.68	5.22	4.76	4.30
Water (litre)	3.50	3.23	2.98	2.71	2.45
Sand (kg/m^3)	11.13	11.13	11.13	11.13	11.13
Coarse aggregate (kg/m^3)	5.57	5.57	5.57	5.57	5.57
Crushed clay Brick aggregate (kg/m^3)	5.57	5.57	5.57	5.57	5.57
Fly ash (kg/m^3)	0	0.46	0.92	1.38	1.84
W/C (by weight)	0.57	0.57	0.57	0.57	0.57

III. RESULT AND DISCUSSION

A. Material Bulk Densities

The bulks densities of raw materials for this research are summarized in Table2. The crushed brick aggregate was 14.4% lighter than natural coarse aggregate for loose bulk density based on the bulk density. In contrast, for compacted bulk density, it was about 13.6% lighter compared with natural 20 mm sieve size coarse aggregate. The specific gravity of natural aggregate and crushed brick aggregate are found at 1.62 and 1.07, respectively.

TABLE 2
Bulk Densities of Raw Materials

Materials	**Loose Bulk Density (Kg/m³)**	**Compacted Bulk Density (Kg/m³)**	**Specific Gravity**	**Water absorption (%)**
Cement	921	-	-	-
Natural fine sand	1280	1328	-	-
Natural coarse aggregate (37.5 mm)	1530	1615	1.62	3.2
Crushed brick aggregate (37.5 mm)	1310	1395	1.07	13.1

B. AIV and ACV

The mechanical properties of crushed brick aggregate test results for the AIV and ACV tests were tabulated in Table 3. The experimental result showed that the ACV value for crushed brick aggregate was 28.06%, while the AIV value was 26.30%. The result also indicated that ACV and AIV percentage were in the range of 25% to 30% and are similar within close limits. A low percentage of the aggregate crushing value indicates the aggregate is strong as the crushing fraction is low. The aggregate impact value indicates a relative measure of the resistance of an aggregate to a sudden shock or an impact, which differs from its resistance to a slow compressive load in some aggregates. The AIV test showed that the aggregate was not significantly affected by the impact load, which is only 26.3% only and can be classified as concrete for non-wearing surfaces less than 30% (British Standard Institution, 1992).

TABLE 3
Aggregate impact value (AIV) and aggregate crushing value(ACV) of crushed brick aggregate

Aggregate Crushing Value (ACV)		**Aggregate Impact Value(AIV)**		**BS 882:1992 Classification (Not exceeding %)**
Physical Properties	**Crushed brick Aggregate**	**Physical Properties**	**Crushed brick Aggregate**	
Aggregate Crushing Value (ACV) (%)	28.06	Aggregate Impact Value (AIV) (%)	26.30	< 25 (Heavy duty concrete floor finishes) < 30 (Pavement wearing surfaces) 50 (Others)

C. Concrete Workability

The brick aggregate concrete workability was measured by using the slump cone test. The results obtained were shown in Fig. 3. The result obtained indicated that the highest slump was obtained with the partial replacement of 30% fly ash in concrete mixes. It was observed that the workability of concrete increases with the partial replacement of fly ash with the weight of cement for the water-cement ratio of 0.57. The spherical shaped particles of fly ash provide a lubricant within the concrete mix, thereby enhancing the workability of fresh concrete.

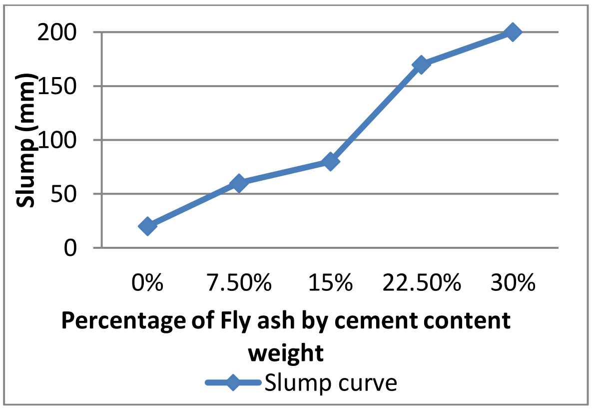

Fig. 3:Concrete slump

D. Compressive Strength

The compressive strength test was conducted at the ages of 10, 28, and 90 days using a compression testing machine. The compressive strength development for the brick aggregate concrete with different fly ash percentages, as shown in Fig. 4. Based on the results obtained in Fig. 4, it was observed that the compressive strength of concrete increases with age. The compressive strength of control specimens, M0 at 10 days, produced the highest strength among the five series of the mix, 25.6 MPa. At the age of 28, the brick aggregate concrete with 7.5% partial replacement of fly ash produced the highest strength, 34 MPa. The result also indicated that the percentages of partial replacement of fly ash increases would reduce the early age [17]. At the age of 90, control specimens (M0) have the highest compressive strength, followed by M2, M1, M3, and M4, respectively. Based on the results at the age of 90, all of the concrete mix with differences fly ash percentage content had achieved 30 MPa, which can be used for structural purposes. It improves strength over Time and performed better strength [18]. Therefore, it can be concluded that the fly ash will take effect on the concrete strength over a long period compared with the early stage.

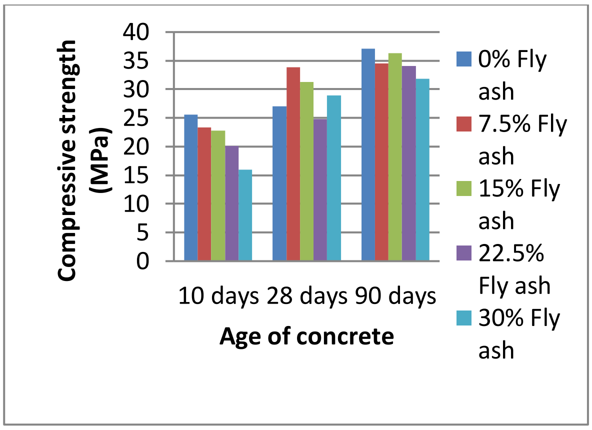

Fig. 4: Compressive strength of brick aggregate concrete with different fly ash content.

E. Splitting Tensile Strength

The increase of fly ash percentage as partial cement replacement showed decreased tensile strength than the control specimens, as shown in Fig. 5. The result obtained indicated that specimen without fly ash partial replacement, M0 has developed the highest tensile strength among the five mixes, which was 3.31 MPa for M0, 3.09 MPa for M1, 2.82 MPa for M3, 2.76 MPa for M2, and 2.28 MPa for M4. The results showed that the opposite behavior between fly ash and tensile strength represented that the concrete content more percentage of fly ash tended to reduce the concrete tensile strength. This scenario has been mentioned by the previous researcher for concrete containing fly ash will reduce the splitting tensile strength of concrete [19].

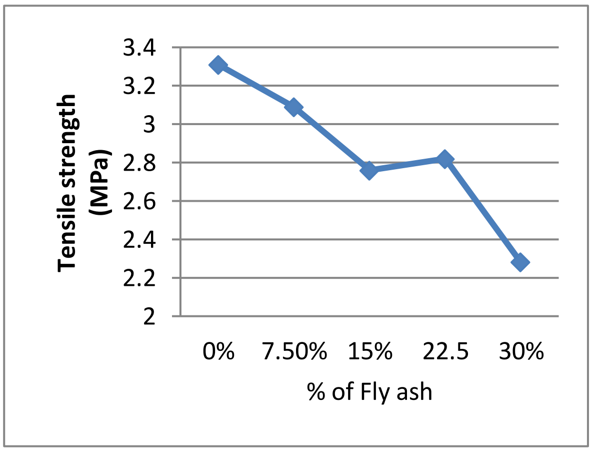

Fig 5: Splitting Tensile strength at 28 days

F. Water Absorption

The result of water absorption percentage versus the Time of brick aggregate concrete containing fly ash was showed in Fig. 6. Based on the result obtained, all the hardened concrete specimens exhibit increment of water absorption over the testing period. The M0 and M2 specimens have the highest water absorption value, which is 5.5% during 210 seconds.

Specimen M2 shows the greatest increment of water absorption, where it has 0.9% at 10 minutes and increases to 5.5% at 210 minutes. Specimen M1 and M3 have slightly lower water absorption than M0 and M1, which were 5.4% and 4.9%. The water absorption percentage of M4 with 30% fly ash replacement is the lowest among 5 series of concrete mixes, ranging from 1.9% to 4.0% for six durations: 10 minutes, 20 minutes, 30, 60 120 minutes, and 210 minutes. The water absorption of the concrete containing fly ash is low due to the fly ash behaving as the pore filler in concrete.

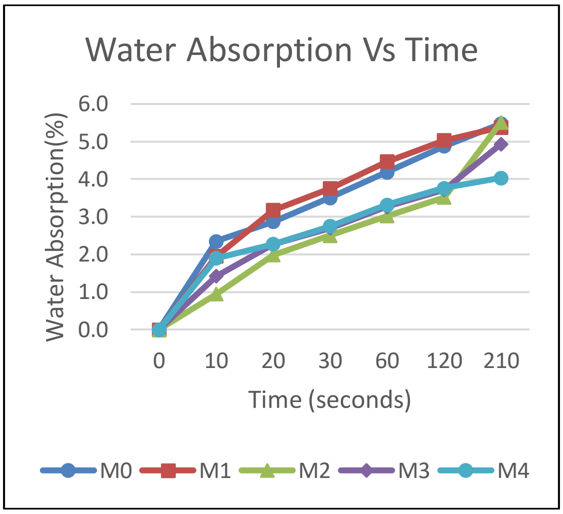

Fig 6: Water absorption vs. Time

IV. CONCLUSIONS

The study on the effect of fly ash on crushed brick aggregate concrete can be drawn and summarized as follows:

1. The principal mechanical properties of crushed brick aggregates for ACV and AIV values were at the range of 25% to 30%, which comply with BS882. This indicated the suitability for use in construction work to resist the aggregate itself's impact and crushing strength.
2. Fly ash as a partial replacement for cement in brick aggregate concrete has improved concrete workability. The spherical shaped particles of fly ash provide a lubricant within the concrete mix and thereby enhance fresh concrete's workability.
3. Compressive strength of the hardened specimens for all mixes with or without fly ash increases along the curing period. The specimens with the highest fly ash partial replacement have the lowest compressive strength at an early age.
4. There is the opposite relationship between splitting tensile strength and fly ash where brick aggregate concrete without fly ash content produced the highest compressive strength but lowest compressive strength with fly ash content.
5. The water absorption percentage decreases with the increase of fly ash content in the concrete mix due to the fly ash react as pore filler in concrete.
6. The optimum percentage of fly ash as the partial cement replacement for brick aggregate concrete was 15%.

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