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UTILIZATION OF FLY ASH IN LIGHTWEIGHT AGGREGATE FOAMED CONCRETE

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ABSTRACT

This paper report result of a study conducted on fly ash lightweight aggregates (FALA) in foamed concrete cubes. The type of fly ash used is class C. The effects of using fly ash can be determine by its partial replacement of 5%, 10% and 15% in FALA. The effects of FALA can also be determine by its partial replacement in foamed concrete cubes of 25% and 50%. Three samples for each percentage is made to get the average readings. The test done divided into two which is on FALA and foamed concrete cubes. Among the test are density test, specific gravity test, water absorption test, scanning electron microscope (SEM) test, loading test and compression test. In conclusion for this paper report, the suitable percentage of fly ash that can be used for partial replacement in cement is 15% and 50% for partial replacement of FALA in coarse aggregates. This sample reach the density of 1.498 kg/m^3 that include in the lightweight aggregates category with the compression strength of 13.442 MPa.

Keywords: fly ash, lightweight aggregate, foam concrete, proportion, bubbles.

INTRODUCTION

Foamed concrete officially invented in 1923 (Valore, 1954) and considered to be relatively homogeneous compared to conventional concrete. The properties of foamed concrete depend on the microstructure and its composition that are influenced by the type of binder used, methods of pre-foamation and curing. Fly ash is a by-product from coal-fired electricity production. Recently, fly ash has evolved from the realms of a waste to that of a resource due to its varieties in chemical, mineralogical and morphological properties. Nowadays, fly ash has been widely used in construction, environmental rehabilitation, waste management and polymers. Fly ash does not emit carbon dioxide into the atmosphere and hence reduce the emissions of greenhouse gas compared with cement, which are held responsible for global warming. Furthermore, the usage of fly ash as an artificial aggregate allows mitigation of natural resources shortage as well as providing a productive use for industrial waste. In Malaysia fly ash can be obtained from several well-known sources such as can be collected either from incineration plant, power plant or taken from palm oil mill.

Many researchers have had attempted to utilize this ashes in the production of aggregate such as a study from Awang *et al*. 2014 using oil palm ash. Oil palm ash was collected from the incenaration process at the palmoil mill and the size is selected to be less than 300µm (Awang *et al.* 2014). Lightweight aggregates (LWA) are produced due to the high demand of alternative construction materials in the construction industry due to the limitations availability of natural resources. It is generally classified into two types, natural (e.g., pumice, diatomite, volcanic cinder) and artificial (e.g., perlite, clay, sintered fly ash, expanded shale). Though in several cases, natural and artificial lightweight aggregates may have the same properties. This research aim is to produce FALA in foamed concrete cubes FALA and to study its mechanical also physical properties. Besides that, this studies also to examine microstructure of foamed concrete cubes made from FALA.

MATERIALS AND METHODS

Fly ash

The material of fly ash was collected from Incinerator Heat Treatment Plant at Pulau Langkawi, Kedah. They were tested with X-Ray Fluorescence (XRF) test to know its class type.

FALA

The proportion used to produce FALA is 2 kg of Ordinary Portland Cement (OPC) (with fly ash partial replacement of 5%, 10% and 15%), 1 kg of water and 0.428 kg of foaming agent. After the mixing done, it is poured into tray and slice into 20 mm – 25 mm measurement. Then, heat the mixing for 24 hours in an oven of 105 °C.

Foamed concrete cubes

The making of foamed concrete cubes follow the proportion of 9 kg of sand, 9 kg of OPC (with FALA partial replacement of 25% and 50%), 4.5 kg of water (3 kg to form foam and 1.5 kg to form lightweight concrete) and 1.3 kg of foaming agent. Then the mixing is poured into 15 cubes with 100 mm x 100 mm x 100 mm of measurement. The cube is left for 24 hours before immersed it in curing tank for 7, 14 and 28 days.

Microscopic analysis for aggregate

Microscopic analysis of the lightweight aggregate are carried out by using Scanning Electron Microscope (SEM) which is the device that helps to magnified image of an object. By using equipment model TM3000 Tabletop

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Microscope as shown in the Figure-1, the microstructure in the aggregate can be captured. Thus the porous structure, small and big void in the aggregate can be seen clearly.

Figure-1. Scanning electron microscope (SEM) apparatus.

Water absorption

Water Absorption is the increase in mass of aggregate due to water penetration into the pores of the particles during a prescribed period of time, but not including water adhering to the outside surface of the particles. It is conducted to calculate the change in the mass of an aggregate due to water absorbed in the pore that present in the aggregate (American Standard, 2012).

Density analysis

In this study, loose bulk density were determined according to the standard of ASTM C29/C29M as the aggregate are below the maximum size, 37.5 mm. For the loose bulk density, it is the mass of non-compacted aggregates required to fill the container of a unit volume after aggregates are batched based on volume. Loose bulk density is determined by shovelling method (American Standard, 2009).

Specific gravity

Specific gravity can be known as the ratio of the weight of a given volume of aggregate to the weight of an equal volume of water. It can be measured by using a device called densimeter. Densimeter is an instrument for measuring the specific gravity of a solid or liquid substance.

Compressive strength

One of the mechanical properties of aggregate is compression. Compression test are done in order to identify it ultimate strength. For LBA, before the test is conducted the batch is poured into 100 mm x 100 mm x 100 mm mould. Then the cube undergoes 24 hours of oven dry. Next it is ready to be tested. Meantime for foamed concrete, the test is done after the concrete cube are mixed and poured into 100 mm x 100 mm x 100 mm mould.

Aggregate impact value (AIV)

The aggregate impact value is a test to determine aggregate impact value of coarse aggregate that is conducted by using apparatus name Aggregate Impact Value Tester.

RESULTS AND DISCUSSIONS

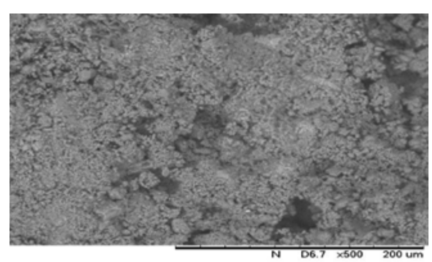
The characteristics of fly ash are presented in Table-1 below. It is important to classify the fly ash according to its chemical constituents and compare it with ordinary Portland cement. The elements were determined by using X-Ray Fluorescence (XRF). From the table it can be noted that the fly ash is in Class C.

Table-1. Fly ash composition using XRF.

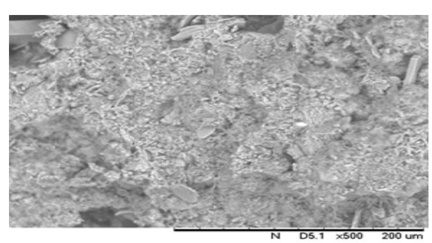
Chemical Element	Fly Ash (%)	Portland Cement(%)
Silicon Dioxide (SiO_2)	6.71	9.2
Aluminium Oxide (Al_2O_3)	3.31	2.3
Ferric Oxide (Fe_2O_3)	4.62	4.49
Calcium Oxide (CaO)	64.92	78.47
Potassium Oxide (K_2O)	1.97	0.35
Sulfur Oxide (SO_3)	5.21	2.85
Phosporus Oxide (P_2O_2)	2.23	0
Titanium Dioxide (TiO_2)	3.18	0.23
Other chemical element	7.95	2.11
Total	**100**	**100**

Microstructure of FALA

Figure-2 shows the microstructure of three samples of FALA based from 5%, 10% and 15 % of fly ash content in the aggregate. It can be noted that the size of pores are small and scattered uniformly.



(a)



(b)

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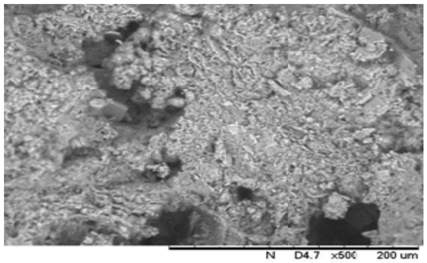

(c)

Figure-2. Pore distributions of aggregate containing (a) 5% of fly ash, (b) 10% of fly ash and (c) 15% of fly ash.

In 5% of fly ash in FALA, the pore size is smaller and less isolated pores distribution due to the lower content of fly ash hence the water absorption. However in 15% of fly ash in FALA, the pore size is bigger and more isolated pores distribution in it due to the higher fly ash content. The pore size and isolated pores distribution for different partial replacement of fly ash can be seen in Figure 3. Hence, the water absorption is lower than others in 15% of Fly Ash in FALA. While in 10% of fly ash the pore size and isolated pores distribution is in medium rate.

Water absorption

Based on Table-2, the percentage of water absorption of FALA in sample 5F with 5% of fly ash partial replacement is 20.48% but in sample 10F with 10% of fly ash partial replacement, the water absorption only 19.71% and in sample 15F with 15% of fly ash partial replacement, the water absorption is 17.07%. The percentage of water absorption of foamed concrete cubes for 5% of fly ash partial replacement in 5F25A and 5F50A with 25% and 50% of FALA partial replacement are 18.80% and 18.57% respectively. While the percentage of water absorption of foamed concrete cubes for 10% of fly ash partial replacement in 10F25A and 10F50A with 25% and 50% of FALA partial replacement are 18.71% and 17.84% respectively.

Finally, the percentage of water absorption of foamed concrete cubes for 15% of fly ash partial replacement in 15F25A and 15F50A with 25% and 50% of FALA partial replacement are 17.69% and 17.18% respectively. Then the controller for the water absorption is in sample normal foamed concrete cubes with 18.89%. These prove that the ability of water absorption reduced as the percentages of fly ash and FALA increased as the pore size and distributions in both materials are higher.

Table-2. Water absorption test results.

FALA			
Sample Name	**A** (kg)	**B** (kg)	**Water Absorption** (%)
5F	1.636	1.971	20.48
10F	1.634	1.956	19.71
15F	1.640	1.920	17.07
Foamed Concrete Cubes			
Sample Name	**A** (kg)	**B** (kg)	**Water Absorption** (%)
5F25A	1.399	1.662	18.80
5F50A	1.486	1.762	18.57
10F25A	1.384	1.643	18.71
10F50A	1.463	1.724	17.84
15F25A	1.385	1.630	17.69
15F50A	1.466	1.718	17.18
Normal			18.89

Density test

Based on the results obtained on FALA in Table-3, sample 5F has loose bulk density of 455.09 kg/m^3 and bulk density of 589.06 kg/m^3 while sample 10F has loose bulk density of 434.72 kg/m^3 and bulk density of 553.21 kg/m^3 and sample 15F has loose bulk density of 413.21 kg/m^3 and bulk density of 519.06 kg/m^3. Partial replacement of FALA in foamed concrete cubes, sample 5F25A and 5F50A has density of 1.442 kg/m^3 and 1.532 kg/m^3 respectively. While sample 10F25A and 10F50A has density of 1.413 kg/m^3 and 1.517 kg/m^3 respectively. Finally, sample 15F25A and 15F50A has density of 1.405 kg/m^3 and 1.498 kg/m^3 respectively. The controller has density of 1.577 kg/m^3. The results show that with higher content of fly ash partial replacement, the density of FALA and foamed concrete cubes reduced. This is due to the properties of fly ash which lighter than cement. Therefore, the foamed concrete cubes are included in lightweight concrete category as it lies below the range of 2000 kg/m^3.

Table-3. Density test results

FALA (Volume = 0.0053 m^3)				
Sample Name	**Mass** (kg)	**Loose Bulk Density** (kg/m^3)	**Mass** (kg)	**Bulk Density** (kg/m^3)
5F	2.412	455.09	3.122	589.06
10F	2.304	434.72	2.932	553.21
15F	2.190	413.21	2.751	519.06
Foamed Concrete Cubes (Volume = 1 m^3)				

Sample Name	Mass (kg)	Density (kg/m^3)
5F25A	1.442	1.442
5F50A	1.532	1.532
10F25A	1.413	1.413
10F50A	1.517	1.517
15F25A	1.405	1.405
15F50A	1.498	1.498

Specific gravity

Table-4 indicates the specific gravity for each sample. Sample 5F has an average of 1.600 kg/m^3 while 10F and 15F are 1.516 kg/m^3 and 1.388 kg/m^3 respectively. Fly ash occupied the empty voids in FALA hence by the results shown in table it is proven that with the increment of fly ash content in FALA; its specific gravity will be reduced.

Table-4. Specific gravity test results.

FALA			
Sample Name	**5F** (kg/m^3)	**10F** (kg/m^3)	**15F** (kg/m^3)
1ST	1.572	1.408	1.440
2ND	1.692	1.517	1.300
3RD	1.534	1.622	1.425
Average	1.600	1.516	1.388

Compression test

The graph shown in Figure-3, the compression strength of FALA increases as the percentage of fly ash increases.

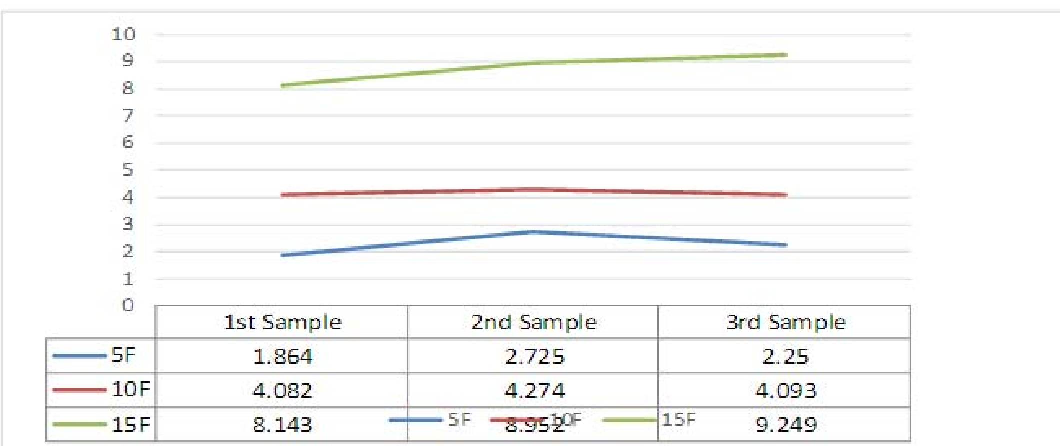

Figure-3. Compressive strength of FALA.

The samples of 5F has an average of 2.280 MPa while 10F and 15F are 4.150 MPa and 15F 8.781 MPa respectively. This proves that the percentage of fly ash is directly proportional to the compression strength of FALA.

From the graph shown in Figure-3, the normal foamed concrete cubes act as a controller has an average reading of 3.216 MPa at 28 days.

The highest compression strength at 28 days among the samples is sample 15F50A with 13.442 MPa while the lowest compression strength is sample 5F25A with 7.813 MPa. Then the second highest compression strength is sample 15F25A with 11.514 MPa followed by sample 10F50A, 10F25A and 5F50A with 9.946 MPa, 8.249 MPa and 8.325 MPa respectively. The trends indicate that with an increasing amount of fly ash and FALA, the compression strength will also increase.

Compressive strength of foamed concrete cubes using fly ash as a partial replacement resulted in higher strength of density ratio. The increment of strength with fly ash is not pronounced at lower density range majorly at lower ages. This is because at lower density range its foam volume controls the strength rather than material properties (Nambiar and Ramamurthy, 2006).

Aggregate impact value (AIV)

AIV test are done towards FALA to know its toughness against shock. The value of AIV will represents the strength of aggregate produced. The results for 5F are the highest with 59% followed by 10F with 58% and finally 15F with 56%. This indicates that as the amount of fly ash increases, the loading impact reduced showing 15F is better in handling impact than 10F and 5F. In this test, it is obvious that fly ash act as a binder to the cement in the concrete that holds its structures to withstand the impact.

CONCLUSIONS AND RECOMMENDATIONS

The suitable percentage of fly ash that can be used for partial replacement in cement is 15% and 50% for partial replacement of FALA in coarse aggregates. This sample reaches the density of 1.498 kg/m^3 that include in the lightweight aggregates category with the compression strength of 13.442 MPa.

Based on the SEM Test carried out, the amount of isolated pores of foamed concrete cubes with FALA partial replacement is much higher than conventional concrete hence reduce the permeability of particle. The air voids within it is also decreased which reduced the specific gravity. Due to this, foamed concrete cubes with FALA partial replacement has higher compression strength because of the low water absorption within it.

Besides that, foamed concrete cubes with FALA partial replacement achieved its target of lower density than conventional concrete. The substitution of fly ash decreasing the density of foamed concrete cubes with FALA partial replacement as the density of fly ash itself is lower than cement.

The characteristic of fly ash also related to the toughness of foamed concrete cubes with FALA partial replacement to resist impact. The results indicate that the existence of fly ash reduced the loading impact of foamed concrete cubes with FALA partial replacement. Based on the results of the research, it can suggest that fly ash is suitable for the partial replacement in LWA.

The LWC can also be used for the partial replacement in lightweight concrete cubes. Even though its mechanical strength is not superior enough to resist heavy loading but still it can be used in construction industry such as load bearing, tiles, wall panels and supplementary cementing materials.

Foamed concrete has been known as weak and non-durable with high shrinkage properties. Unstable foams resulted foamed concrete having a characteristic unsuitable for reinforced, structural applications. The voids in unprotected reinforcement of aerated concrete may interconnected and be vulnerable to corrosion even when the exterior attack is not severe. It is important to make sure the air entrapped into the foamed concrete is contained in stable bubbles and remain intact and separated to increase the cement paste permeability between voids.

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