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# Utilisation of Recycled Concrete Sludge Aggregate and Fly Ash in the Production of Lightweight Foamed Concrete for Environmental Sustainability

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**Abstract.** Waste and recycled materials, namely fly ash and concrete sludge aggregates have been chosen to be a partial replacement for cement and coarse aggregate for the production of lightweight foamed concrete. These new materials play an important role as they can function as reinforcement to enhance the properties of concrete. In this study, the main objectives were to investigate the characteristics and to study the properties of lightweight foamed concrete made from these two key elements. 15% of fly ash and 50% foam were added into concrete with variable amount of concrete sludge aggregates 10%, 30% and 50% as partial replacement of coarse aggregates with mixing ratio of 1:1:2 and foam dilution ratio 1:5. to identify the optimum result. Based on the result obtained, all of the samples achieved bulk density ranged from 1859 $kg/m^3$ to 1884 $kg/m^3$. On the other hand, the characteristic of water absorption for the samples were increased from 12.37% to 14.01% parallel where the amount of concrete sludge aggregates was increased in the concrete. Furthermore, the compressive strength of each samples tested to be in ranged from 11.101 MPa to 13.434 MPa. The results indicate that the utilization of concrete sludge aggregate and fly ash will effectively produced lightweight concrete.

**Keywords:** Foamed concrete, lightweight, concrete sludge aggregate, fly ash, recycle material

## 1. Introduction

Generally, lightweight foamed concrete has lower density and compression strength compare to conventional concrete. Normal concrete has a density of 2,400 $kg/m^3$ while lightweight concrete has a density ranged from 1400 $kg/m^3$ to 2000 $kg/m^3$ [1]. The field application of foamed concrete is still low all over the world. Conventional lightweight concrete were normally made from cement, sand and water. Foamed were injected during the mixing process to produced air bubbles. Nowadays, many researchs have been conducted to figure out most suitable materials in th production of lightweight concrete. Fly ash and concrete sludge aggregate are the most common solid waste that can be found in abundance in Malaysia. Fly ash normally can be collected from thermal incinerator plants. It is estimated that almost 415 million tons of fly ash were produced all over the world and unfortunately, only 16% of the total value have been used as recycled materials [2]. Fly ashes are finely residue from the combustion powdered coal for generating electric purpose. Generally, there are two types of fly ash which are Class C and Class F. These two types of fly ash will give different results as their characteristics are slightly different with one another. Previous research shows that if the composition of fly ash in concrete is greater than 25% the bonding ability between

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the particles will decrease [3]. Therefore this research was carried out to study the suitability of fly ash to be used in the production of lightweight foamed concrete. On the other hand, concrete sludge aggregate (CSA) was also a major solid waste that can be used in the concrete. Due to its debiodegradables characteristic, people find that it is difficult to overcome the waste issues. Normally, CSA will be left at the construction site as leftovers or used as soil back fillers. Concrete recycling is common method to reuse the concrete sludge aggregates in construction. Nowadays, utilization of recycle aggregates in concrete as a construction material to solve the issue of lack of raw material. Thus, this idea will allow the construction using the circulatory system for resource [4]. In the past few years, recycle aggregates play a main key role in reducing the need for landfill waste disposal and converse natural aggregates to protect environment. The recycle coarse aggregates normally will have lower quality than natural aggregates [5].

# 2. Materials and Methods

## 2.1. Mixing Ratio of Lightweight Concrete

In this research, all of the mixtures are designed according to the standard proportion of 1:1:2 with the base volume of 100 mm x 100 mm x 100 mm concrete cube. The dilution ratio of foam with 1:5 is used in this research where one portion of foam agent diluted with 5 portion of water. The water/cement ratio used in the mixture is equal to 0.65. Regarding to the substitution of fly ash and concrete sludge aggregates, all of the materials are measured by volume which can be calculated from the manual of "Design of Normal Concrete Mixes. This study limited the percentage of fly ash to only 15% but the percentage of CSA varies from 10%, 30% and 50%.

## 2.2. Bulk Density Analysis

To start with, the concrete cubes have to be weighted for its mass and the readings were recorded. Next, the volume of the concrete cube can be calculated according to the dimension of concrete (100 mm x 100 mm x 100 mm). To achieve the density of lightweight concrete less than 2000 kg/m$^3$, concrete cubes have to be heated in the oven for 24 hours with the temperature 105 $^0$C. The readings of dry weight concrete are recorded to convert into bulk density of lightweight concrete. All the density analysis for concrete cubes are tested under the BS 1881 [6].

## 2.3. Water Absorption Test

The samples were put into the drying oven with at least 25 mm spacing between each cubes for 72 hours. After that, the concretes were removed from the oven and let it cooled for at least 24 hours in a dry airtight vessel. Next, the specimens were weighted and immersed into water for 30 minutes with 25 mm water over the top of the specimen. Finally, the specimens were taken out and wiped it with cloth to remove the surface water. The specimens were weighted to obtain the weight of the concrete. All the methods, technique and apparatus involve should be following guide given in BS 1881 [7].

## 2.4. Compression Test

Compression test is to identify the concrete cube's mechanical property and fracture mechanism by compressing until reaching the ultimate strength. First, concrete was mixed according to the ratio and poured it into 100 mm x 100 mm x 100 mm size of mold. Then, the concrete mixture will undergo vibration by using tamping method to remove the air bubbles for avoiding honey comb. Next, the concrete mixture will be hardened after 24 hours and the concrete can be taken off from its mold. Now, the concretes will submerge into water tank for curing process at a temperature around 22 ℃. After that, the samples will be taken out from water and undergo compression test at 7th, 14th and 28th day respectively. All the methods, technique and apparatus involve should be following guide given in BS 1881 [8].

# 3. Results and Discussions

## 3.1. Bulk Density Analysis

Fig. 1 presents the bulk density of sample A to C where the partial replacement of the CSA content increases from 10%, 30% and 50%. From this bar chart, it can be noted that, the bulk density of lightweight concrete increased with the increment of CSA. Sample A achieved bulk density of 1859 kg/m$^3$ while sample

B has 1870 kg/m$^3$. The highest density among the three samples is sample C where achieved 1884 kg/m$^3$. The bulk density of the samples are increased due to the physical properties of CSA where the aggregates already covered by a layer of mortar. Therefore, it is heavier and denser compared to normal coarse aggregates.

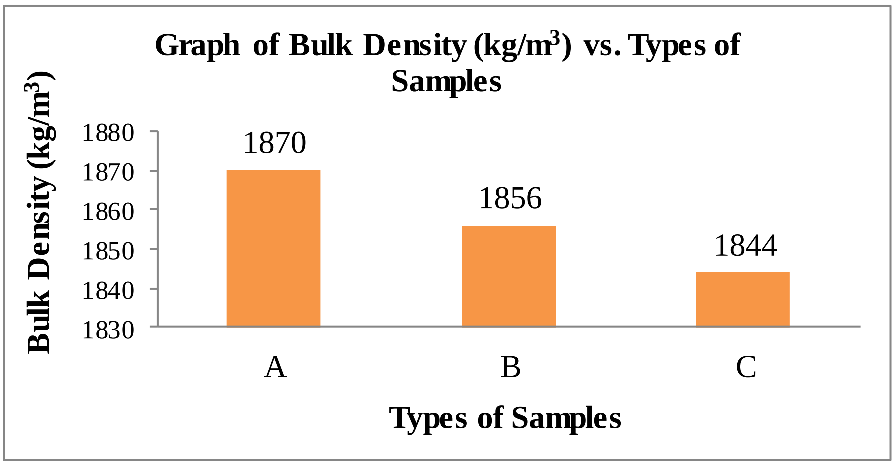


Fig. 1: Bulk Density for Samples A, B and C.

## 3.2. Water Absorption Test

Fig. 2 indicates that as the percentage of CSA in the samples increased, the percentage of water absorption will increased proportionally. This trend has been proved with the result obtained for samples A, B and C where the percentage of CSA increased gradually in 10%, 30% and 50% as partial replacement of coarse aggregates. In sample A, the percentage of the water absorption obtained from the test was 12.372%. Next, it came to sample B where it was achieved 13.102% while sample C had the highest percentage of water absorption with 14.013% compared to the others. Since the CSA physical characteristics were heavy and have bigger size, it enhances the properties of water absorption of the concrete compared to conventional concrete.

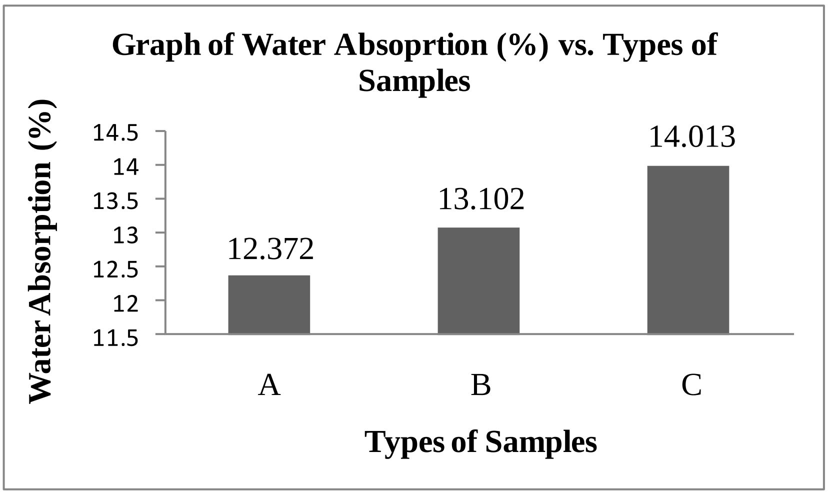


Fig. 2: Water Adsorption for Samples A, B and C.

## 3.3. Compression Test

Fig. 3 shows that the highest compression strength among the three samples at the age of 28 days is sample B which has 13.434 MPa while second highest comes to sample A which has 12.38 MPa where sample A is almost 8.51% greater than sample A. Inversely, sample C has the lowest strength which has only

11.101 MPa and it drops 17.37% when compared to sample B which has 13.434 MPa. Through the observation, it shows that CSA will improve the compression strength of thelightweight foamed concrete to its optimum value of only 30%. The higher amount of CSA will not help to increase the compression strength. According to [9], a study had made on the feasibility of the usage of crushed concrete as coarse aggregates and stated that within a range of CSA instead of normal aggregates will produce acceptable quality of concrete.

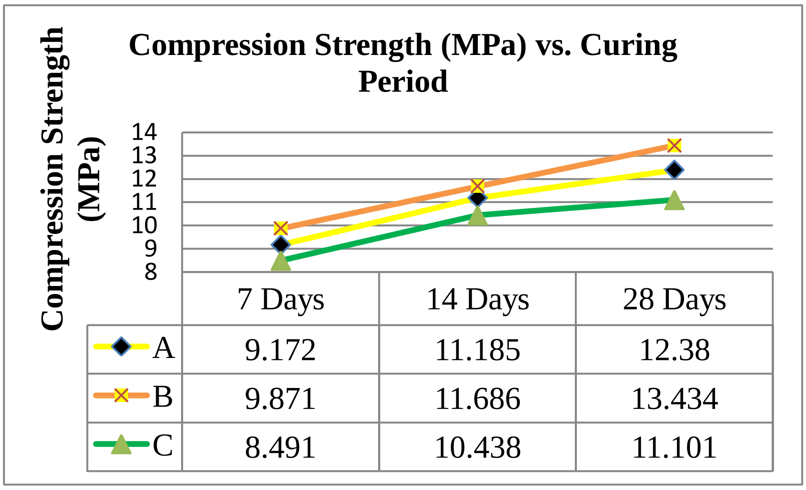


Fig. 3: Compression Strength for Samples A, B and C.

## 4. Summary

From this study, it can be found that the utilization of fly ash and CSA will contribute to lower density of concrete with acceptable compressive strength. Based on the experimental results it can be concluded that the optimum content of fly ash and CSA that can be used was 30% as partial replacement of cement and CSA to achieve optimum compressive strength. Besides that, lightweight foamed concrete can be produced by using foaming agent with dilution ratio 1:5 and mixed with 50% of total volume of foam into concrete to form foamed concrete. It also highlighted that lightweight foamed concrete with 50% CSA content has higher bulk density compared to other samples. CSA will improve the compression strength of the concrete at the optimum strength of 13.434 MPa. This strength was obtained from sample B that contained 30% of CSA.

## 5. Acknowledgements

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