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## Utilization of fly ash as partial sand replacement in oil palm shell lightweight aggregate concrete

A Z Muhammad Nazrin Akmal<sup>1</sup>, K Muthusamy<sup>1</sup>, F Mat Yahaya<sup>1</sup>, H Mohd Hanafi<sup>1</sup> and Z Nur Azzimah<sup>1</sup>

<sup>1</sup> Faculty of Civil Engineering and Earth Resources Universiti Malaysia Pahang, Lebuhraya Tun Razak, 26300, Gambang, Pahang  
Corresponding author: nazrinakmal89@gmail.com

**Abstract.** Realization on the increasing demand for river sand supply in construction sector has inspired the current research to find alternative material to reduce the use of natural sand in oil palm shell lightweight aggregate concrete (OPS LWAC) production. The existence of fly ash, a by-product generated from coal power plant, which pose negative impact to the environment when it is disposed as waste, were used in this research. The effect of fly ash content as partial sand replacement towards workability and compressive strength of OPS lightweight aggregate concrete were investigated. Four concrete mixes containing various percentage of fly ash that are 0%, 10%, 20% and 30% by weight of sand were used in the experimental work. All mixes were cast in form of cubes before subjected to water curing until the testing age. Compressive strength test were conducted at 1, 3, 7 and 28 days. The finding shows that the workability of the OPS LWAC decreases when more fly ash are used as sand replacement. It was found that adding of 10% fly ash as sand replacement content resulted in better compressive strength of OPS LWAC, which is higher than the control mix.

### 1. Introduction

Fly ash is a type of by-product resulting from the burning of pulverized coal in power plant. Approximately 8.5 million tonnes of coal ash consist of fly ash and bottom ash are produced in Malaysia annually [1]. Due to large production of fly ash, a large landfill area is required for disposal of this solid waste. In addition, the coal industry needs to spend in managing the waste disposal. Dumping of waste in abundance without any treatment would cause negative effect to environment such as land pollution, water pollution, air pollution as well as destruction to flora and fauna. However, these problems are possible to be avoided by utilizing the fly ash in production of construction material that would be benefit to the industry as well as community.

At the same time, the demand for sand supply, which used in construction activity and concrete production is increasing along with the growing construction sector. Natural sand usually obtained from river mining activity. Uncontrolled and excessive sand mining to meet the increasing demand of the construction industry would cause negative impact to the river environment. Excessive river sand mining would cause destruction of flora and fauna as well as bad water quality [2]. Due to the rising demand of sand in construction, government has increased the price of sand in order to restrict the extraction of sand thus increase the overall cost of construction project [3- 4]. It is seen that one of the alternative way to solve this problem is to use another materials to replace or reduce the normal sand use in concrete. Looking at the research in this area, there are researchers [5-7] that looked on the possible use of waste materials to replace fine aggregate in concrete. However, the properties of OPS



lightweight aggregate concrete containing fly ash as partial sand replacement has not received much attention. Therefore, this paper investigates the effect of various percentage of fly ash as partial sand replacement towards workability and compressive strength of OPS LWAC.

## 2. Experimental programme

### 2.1 Materials

The oil palm shell lightweight aggregate concrete (OPS LWAC) prepared for this experimental work were produced using cement, water, river sand, superplasticizer, oil palm shell, and fly ash. Type 1 ordinary Portland cement and Type A water-reducing superplasticizer as stated in ASTM C494-05 [8]. was used in all the concrete mixes. All the cement were stacked well away from damp environment to prevent it from hardened. Tap water were used for concrete mixing and curing purpose. A fixed water to cement ratio of 0.45 was introduced in all the OPS LWAC mixes. A superplasticiser of 1.0% by cement weight was added into the fresh concrete to improve the workability.

The fly ash used in this research was obtained from a coal fire plant located at West Malaysia. Fly ash of 0%, 10%, 20% and 30% by sand weight was added as fine aggregate replacement. Oil palm shell (OPS) was use to fully replace conventional coarse aggregate to produce oil palm shell lightweight aggregate concrete (OPS LWAC). The OPS was used in this research was procured from a local palm oil extraction factory as illustrated in figure 1. At the laboratory, the shells shown in Figure 2 were cleaned from impurities before using. OPS having a moisture content, water absorption, fineness modulus and specific gravity value of 12.45%, 12.47%, 6.53 and 1.37 kg/m<sup>3</sup> were used respectively. The bulk density of OPS used in this research is 568 kg/m<sup>3</sup> which is in the range of 500-600 kg/m<sup>3</sup>. This value is in line with the OPS bulk density done by previous researchers [9,10]. The physical properties of the OPS used in this study are tabulated in Table 1.



**Figure 1.** OPS at the palm oil mill.



**Figure 2.** Oil palm shell (after cleaning).

**Table 1.** Physical properties of oil palm shell.

Physical properties	OPS
Moisture content (%)	12.45
Water absorption (%)	12.47
Fineness modulus	6.53
Specific gravity (kg/m <sup>3</sup> )	1.37
Bulk density (compacted)	568
Los Angeles abrasion (%)	7.6
Aggregate impact value (%)	18.18
Aggregate crushing value (%)	14.85

### 2.2 Mix proportions

The amount of constituent materials such as ordinary Portland cement (OPC), OPS, water and superplasticizer (SP) is kept constant except for the sand and fly ash. The effect of sand replacement with 0%, 10%, 20% and 30% of fly ash were studied in this research. Four concrete mixes proportions of OPS LWAC containing fly ash as partial sand replacement are shown in Table 2.

**Table 2.** Mix proportion of OPS LWAC mixes.

Mix design	Cement (kg/m <sup>3</sup> )	Sand (kg/m <sup>3</sup> )	Fly Ash (kg/m <sup>3</sup> )	OPS (kg/m <sup>3</sup> )	Water (kg/m <sup>3</sup> )	Superplasticizer (kg/m <sup>3</sup> )
FA0	500	800	0	360	225	5
FA10	500	720	80	360	225	5
FA20	500	640	160	360	225	5
FA30	500	560	240	360	225	5

### 2.3 Specimen preparation and testing method

For mixing process, firstly, the OPC, OPS, sand and fly ash were blended in mixer for a while to make sure that the materials is well distributed. Then, half of water and superplasticizer were added to the mixture. After few minutes, remaining water and superplasticizer were added and mixed until the fresh concrete become a uniform mixture. Fresh concrete workability was investigated by conducting slump test in accordance to BS EN 12350:2 [11]. For the determination of compressive strength, 100 mm cubes were prepared as illustrated in figure 3. Then, the specimens were demoulded after 24 hours. Then, all the specimens were immersed in water for curing purpose until the testing date. The compressive strength test as shown in figure 4 was conducted at 1, 3, 7 and 28 days following the procedure in BS EN 12390:3 [12].



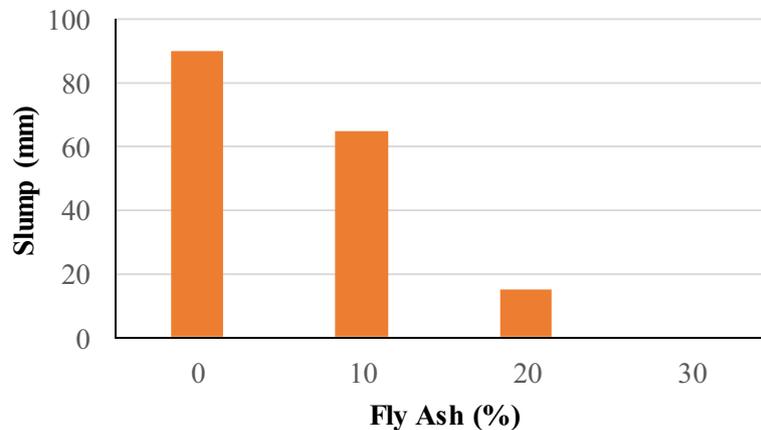
**Figure 3.** Concrete mixes was filled in cube mould. **Figure 4.** Compressive strength test in progress.

## 3. Result and discussion

### 3.1 Workability

Figure 5 shows that the workability of concrete mix decreases as the amount of fly ash used becomes higher. The reduction of concrete mix workability when fly ash is added is attributed to the physical properties of fly ash which is porous and tends to absorb water. The characteristic of fly ash being porous and causes difficulties during mixing process has been highlighted by researcher elsewhere [13]. In this experimental work, the slump is still in good working range for lightweight concrete when

10% fly ash was added. However, when the percentage of replacement is increased up to 20 and 30%, the slump value dropped significantly. Inclusion of 30% produces a very dry concrete mixture making it difficult to be mix and compacted.

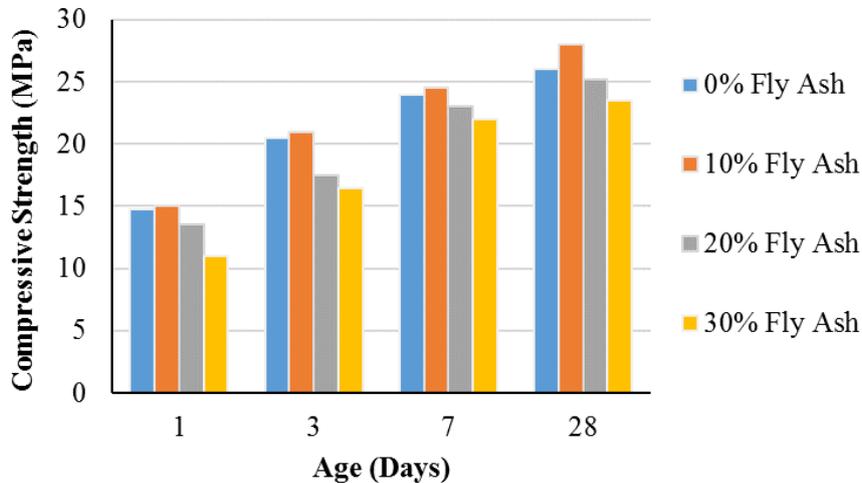


**Figure 5.** Slump value vs fly ash percentage.

### 3.2 Compressive strength

The compressive strength of OPS LWAC concrete containing fly ash as partial sand replacement is shown in Figure 6. Generally, all concrete mixes exhibit strength increment as the curing time become longer. Application of continuous water curing has allowed undisturbed hydration process which is important for formation of calcium silicate hydrate gel that contribute to densification of concrete internal structure resulting in strength increment [6]. As for the effect of using fly ash as partial sand replacement on the compressive strength of concrete, it is observed that replacing river sand with fly ash with adequate amount has resulted in higher compressive strength. Excessive use of fly ash although appears more environmental friendly but it causes significant drop in strength of concrete.

It is interesting to note that, fly ash replacement of 10% by sand produces strength higher than control mixes of about 7% at 28 days. This increase probably attributed to filling effect of fly ash making the concrete denser and capable of resisting higher load as compared to control specimen. Past researcher [14] noted that use of fine fly ash particles contribute to better packing of concrete ingredients when the particles fills the voids between the cement particles. However, it is noticed that the presence of fly ash beyond 20% replacement of sand, evidently reduces the concrete strength till 7% at 28 days. This shows that replacement of more than 10% did not significantly improve the mechanical properties. This probably due to the addition of more fly ash makes the mix become drier causing difficulties during compaction. As a result, a non-homogenous concrete possessing lower strength were produced.



**Figure 6.** Compressive strength vs fly ash percentage.

#### 4. Conclusion

The effect of fly ash as partial sand replacement in OPS LWAC at various percentages was investigated. Based on the investigation, the used of fly ash decreases the workability of OPS LWAC containing fly ash due to porous fly ash properties that tends to absorb water during mixing process. However, the slump workability is still in the range of good workability for lightweight concrete when 10% fly ash is used as partial sand replacement. Interestingly, it was found that adding of 10% fly as partial sand replacement increases the compressive strength of oil palm shell lightweight aggregate concrete (OPS LWAC) as compared to control specimen. Fly ash that act as filler enhanced the compressive strength with more than 7% higher than the control mix. The increment of fly ash of more than 10% in the mixes however lowered the strength by 3% and 9% for fly ash replacement of 20% and 30%.

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