# Effect of fly ash content towards Sulphate resistance of oil palm shell lightweight aggregate concrete

**K Muthusamy, M Y Fadzil, A Z Muhammad Nazrin Akmal, S Wan Ahmad, Z Nur Azzimah, H Mohd Hanafi and R Mohamad Hafizuddin**

Faculty of Civil Engineering and Earth Resources, Universiti Malaysia Pahang, Lebuhraya Tun Razak, 26300 Gambang Pahang

E-mail: khairunisa@ump.edu.my

**Abstract**. Both oil palm shell (OPS) and fly ash are by-product generated from the industries. Disposal of these by-product as wastes cause negative impact to the environment. The use of both oil palm shell and fly ash in concrete is seen as an economical solution for making green and denser concrete. The primary aim of this research is to determine the effects of FA utilization as sand replacement in oil palm shell lightweight aggregate concrete (OPS LWAC) towards sulphate resistance. Five concrete mixes containing fly ash as sand replacement namely 0%, 10%, 20%, 30% and 40% were prepared in these experimental work. All mixes were cast in form of cubes before subjected to sulphate solution for the period of 5 months. It was found that addition of 10% fly ash as sand replacement content resulted in better sulphate resistance of OPS LWAC. The occurrence of pozzolanic reaction due to the presence of FA in concrete has consumed the vulnerable Calcium hydroxide to be secondary C-S-H gel making the concrete denser and more durable.

## 1. Introduction

The global demand of material construction is significantly increasing due to population growth worldwide [1]. The robust growth has increased people request towards housing and infrastructure. As a result, concrete which is the most widely consumed material in the world due to its versatility is in high demand. The high dependence has significantly natural aggregates such as natural sand and granites. Therefore, using alternative sources as replacement for natural aggregates appears to be extremely important. Industrial waste materials such as fly ash (FA) can be used as alternative sources in concrete as they can assist in solving some environmental concerns. Used of recycled industrial waste diminish the problem of waste disposal and reduce the intensive use of energy and natural resources [2]. Concurrently, oil palm shell (OPS) by-product that generated abundantly from palm oil industry are creating an eyesore. Fortunately, these two by-product has huge potential to be utilized as fine aggregate and coarse aggregate replacement in lightweight aggregate concrete. FA is identified as pozzolanic material and can be utilize as partial sand replacement while OPS can replace coarse aggregate in lightweight aggregate concrete. These sustainable building material attempt is seen to benefits both coal and palm oil industry in terms of waste management cost and at the same time assist towards greener construction building material.

## 2. Method of Research

### *2.1. Materials*

For binding purpose, Portland Cement brand that was chosen to be used throughout this experimental research is Orang Kuat cement. This type of cement was conforming to [3] for Portland cement specification and suitable for structural concreting precast, brickmaking and all general purpose applications. Oil palm shell (OPS) obtained from FELCRA palm oil mill factory was used to fully replace conventional coarse aggregate to produce lightweight aggregate concrete. Upon taking from palm oil mill, the oil palm shells were washed thoroughly using tap water to remove impurities, oil and unwanted materials that may affect the concrete strength. After that, the OPS was oven-dried at 110 ± 5°C for 24 hours to remove moisture and prevent from damage. The physical properties of processed OPS is tabulated in Table 1.

**Table 1**. Physical properties of processed OPS.

| Physical Properties | OPS |
|---|---|
| Specific gravity (kg/m$^3$) | 1.37 |
| Water absorption (24 hour) (%) | 12.47 |
| Moisture content (%) | 12.45 |
| Aggregate abrasion value, Los Angeles (%) | 7.6 |
| Bulk density (kg/m$^3$) | 568 |
| Fineness modulus (FM) | 6.53 |
| Flakiness index (%) | 38.63 |
| Elongation index (%) | 98.74 |
| Aggregate impact value (%) | 18.18 |
| Aggregate crushing value (%) | 14.84 |

In this experiment, tap water was used for concrete mixing purpose. Distilled water was used to prepare chemical solution for specimen immersion. The superplasticizer used throughout this research is classified as Type A water-reducing admixtures in accordance to ASTMC494 [4]. Local river sand that was used as fine aggregate. Fly ash (FA) was used as partial lightweight fine aggregate to produce lightweight aggregate concrete in this research. The FA was collected from a coal fire plant located in west Malaysia. FA taken was stored in a clean and dry room to ensure its purity. Table 2 shows the chemical composition of FA. Following the standard in [5], this FA was classified as pozzolanic material.

**Table 2.** Chemical composition of fly ash.

| Chemical Composition | Percentage (%) |
|---|---|
| Silicon dioxide ($SiO_2$) | 39.0 |
| Aluminium oxide ($Al_2O_3$) | 28.7 |
| Iron Oxide (CaO) | 20.3 |
| Potassium oxide ($K_2O$) | 2.1 |
| Iron ($Fe_2O_3$) | 8.9 |
| Copper (CuO) | 0.1 |
| Manganese (MnO) | 0.1 |
| Loss of Ignition | 2.0 |

### *2.2. Preparation of Testing Samples*
Five concrete mixes consists of 0%, 10%, 20%, 30% and 40% FA by weight of cement were casted in 100 x 100 x 100 mm standard cubes. Plain OPS LWAC with 0% FA was act as control specimen. The concrete mixes were prepared in concrete mixer. Then the mixes were compacted using a vibrating table to achieve better compaction. Specimens were covered by wet gunny sack and left overnight. After 24 h, the concrete was demoulded and water cured for 28 days before ready for durability test.

### *2.3 Testing Method*
Sulphate resistance test was conducted in order to determine the durability performance of OPS LWAC containing FA as partial sand replacement performance towards sulphate attack. The sulphate solution was prepared according to ASTM C1012 [6]. The degree of sulphate attack was evaluated by measuring mass change of samples of 100 x 100 x 100 mm concrete cubes. Then, six specimens from each mix were immersed in 5% sodium sulphate ($Na_2SO_4$) solution as shown in Figure 1. Mass measurement and visual assessment of the concrete were conducted every week until the age of 5 months.

**Figure 1**. Specimens immersed in sulphate solution.

## 3. Analysis and Discussion

### *3.1. Sulphate Attack*
The sulphate resistance of OPS LWAC containing various percentage of fly ash were evaluated by measuring the mass change. The mass change of OPS LWAC with FA upon subjected to sulphate solution is illustrated in Figure 2 and Figure 3. As can be seen in Figure 2, the concrete mass for all specimens keep on increasing until the age of 20 weeks. The least mass change was denoted by 10% sand replacement by FA with 1.89%, The value is lower than control OPS LWAC with 23.7%. Compared to other specimens, OPS LWAC with 10% FA mass starts affected at 10 weeks. Utilization of FA as optimum amount enables pozzolanic reaction that consumes vulnerable calcium hydroxide that can easily be attacked by sulphate ion. The generation of secondary C-S-H gel fills the voids further strengthen the concrete making it stronger, denser, and durable during its service life. Concrete containing pozzolan have better performance in sulphate solutions since the pozzolanic reactions reduce the quantity of calcium hydroxide and increase calcium silicate hydrate gel [7].

It was observed, that mixes containing FA beyond 10% replacement exhibit higher mass change value as amount of FA added increases. The highest mass change was denoted by 40% FA with 2.92. This significant increment in the weight is caused by the ease of sulphate ion invasion into the concrete causing more ettringite and gypsum is produced within the concrete internal structure. This makes concrete containing higher amount of FA exhibit highest value of total mass changes as shown in Figure 3. Conclusively, optimum amount of FA as partial sand replacement is needed to produce OPS LWAC with enhanced durability than control specimen. The result is in line by research done by [9].

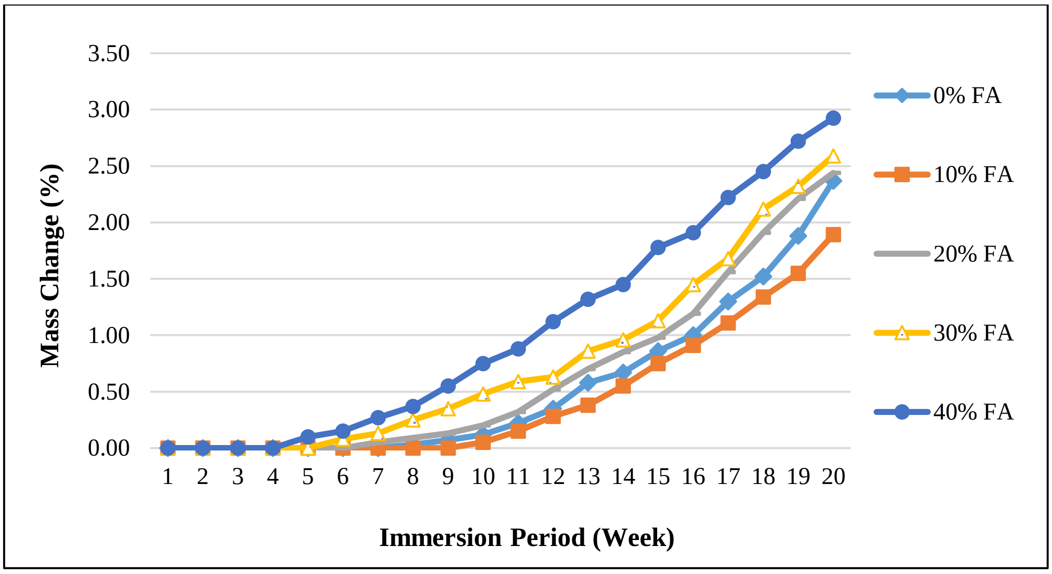


**Figure 2.** Mass change vs immersion period of OPS LWAC with FA.

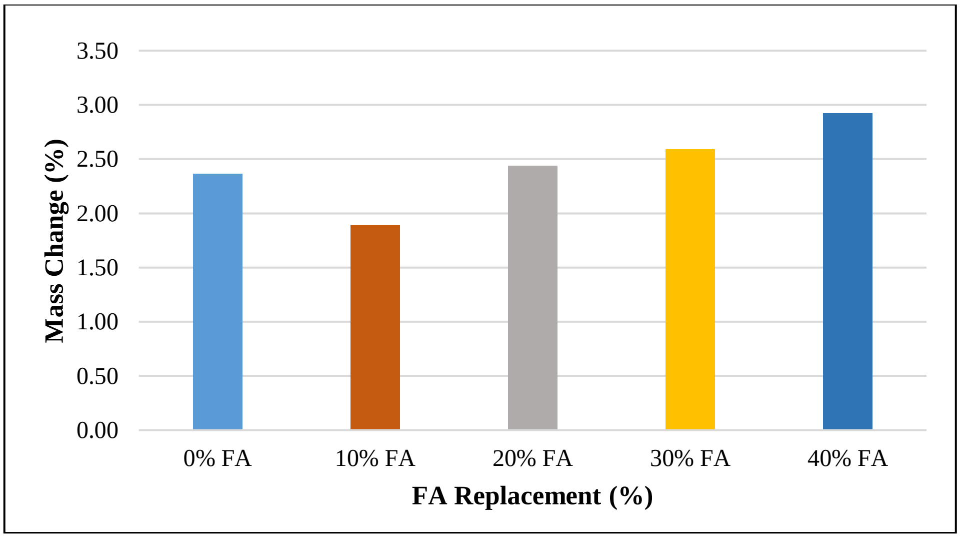


**Figure 3.** Mass change of OPS LWAC with FA.

## 4. Conclusion

The results obtained demonstrate that the partial sand replacement by FA in OPS LWAC is advantageous when optimum amount of FA is used. Replacement of 10% FA would assist towards increasing OPS LWAC durability towards sulphate attack owing to the pozzolanic reaction that takes place between the silica of FA with calcium hydroxide produced from the hydration process. However, incorporation of high amount of FA reduces the concrete durability against sulphate attack.

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