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## **Analysis and Partial Replacement of Sand by Palm Oil Fuel Ash (POFA) in Concrete**

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### **ABSTRACT**

Palm oil fuel ash (POFA) is a waste material which generally disposed to open fields causing environmental pollution problems to the land. Due to its abundance and high pozzolanic properties, it is highly possible to be used as civil engineering construction materials such as partial sand replacement in concrete. This paper presents the investigation of POFA as partial sand replacement in concrete. This study includes partial replacement of sand in concrete by palm oil fuel ash (POFA) which is an agro-waste generated in palm oil industry. POFA is a pozzolanic material which has economical and technical advantage when used in concrete. In doing so, the method of mixing processes was used namely liquidation methods. The POFA was added in the concrete mix at various dosage levels of 0 %, 5 % and 10 % by weight of sand. The grade of concrete adopted was M25. The compressive strength test was carried out at 7, 14 and 28 days. From the results show that additional of 10 % of POFA by weight of sand is able to increase the strength of concrete at 28 days compared to other dosage levels. Hence, the POFA is given positive impact to be used as sustainable material in construction industry.

**Keywords:** Palm oil fuel ash; compressive strength; Universal Testing Machine

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### **INTRODUCTION**

Concrete is a manmade building material and it is the most widely applied in various building material in construction industry. There has been so much demand on construction materials in many countries around the world. Therefore, the requirement of alternative building material that should be cheaper and accessible becomes a highly critical issue.

Nowadays, the use of waste material as concrete ingredient is gaining popularity. One such material is palm oil fuel ash (POFA). POFA is an agro-waste generated in palm oil industry. It is obtained from the combustion of palm fruit residues of oil palm tree. Generally the wastage

of palm oil from palm oil industry was increasing eventually. It is become a major problem to palm oil power plants because this waste is not reused and recycled in any works. Therefore POFA whose chemical composition contains a large amount of silica in form of oxide, can be used in sand replacement.

POFA had been used as cementitious material in concrete and as lightweight material in production of lightweight concrete. Recently, the use of POFA in concrete has been reviewed by. Some highlights have been addressed. They found that the POFA is able to react well with the other constituent materials and hence able to produce stronger concrete. At the same time, the silica (SiO<sub>2</sub>) content

in Palm Oil Fuel Ash is able to increase the compressive strength of concrete and able to reduce the water absorption. Moreover, the comparison the use of POFA and sand has been done.

From the review they found that the 5 to 10 % of POFA as filler in lightweight foamed concrete improves the compressive strength, flexural strength and tensile strength compared to foamed concrete containing sand only. From the review indicates that the POFA can be used extensively as partially or fully sand replacement to the concrete stated that the  $\text{SiO}_2$  composition in POFA is 49.20 %.

## **MATERIALS USED**

The constitutes used for this study includes ordinary Portland cement of grade 33, coarse aggregate, fine aggregate, palm oil fuel ash (POFA), water.

### **Cement**

Cement is a binder material used as a in concrete in powder form. Portland cement is the most common type of cement generally used in construction field. Several type of Portland cement are available most common being called ordinary Portland cement (OPC) which is grey in colour.

### **Coarse Aggregate**

Uncrushed gravel or stone which is the result of natural disintegration and crushed gravel or stone are usually called the coarse aggregates. These are particles greater than 4.75mm. The size of coarse aggregate used in this study is 20mm and below.

### **Fine aggregate**

Particles that passes through 4.75mm sieve are called fine aggregates. Natural sand is generally used as fine aggregate. The purpose of fine aggregate is to fill the

voids in the coarse aggregate and to act as a workability agent. Manufactured sand is a substitute of river sand for construction purposes and is produced from hard granite stone by crushing. The fine aggregate used in this experimental investigation is M sand of size less than 4.75mm.

### **Palm Oil Fuel Ash (POFA)**

Palm oil fuel ash (POFA), a by-product from the palm oil industry is disposed of as waste in landfills. It not only occupies land but also creates environmental pollution and health hazards. These problems can be reduced to a large extent by using POFA in concrete.

It can be used as a supplementary cementing material upto a certain replacement level of sand without causing any adverse effect on strength and other properties of concrete. By using Palm Oil Fuel Ash in the concrete, it will be cost friendly as POFA is a waste material and do not contain cost. The ash were oven dried and passed through 90 micron sieve and used for sand replacement.

### **Water**

Fresh potable water, which is free from acid and organic substance, was used for mixing the concrete. The chemical reaction between water and cement is very important to achieve a cementing property; therefore it is necessary that water used is not polluted.

## **METHODOLOGY**

### **Physical and Chemical Properties**

Physical and chemical properties of material show the character of material. The properties of various materials used in the experiment were shown in the table below

**Table 1. Chemical composition of POFA**

| Chemical Composition                                   | (%)   |
|--------------------------------------------------------|-------|
| Silicon Dioxide (SiO <sub>2</sub> )                    | 49.20 |
| Aluminum Oxide (Al <sub>2</sub> O <sub>3</sub> )       | 5.45  |
| Ferric Oxide (Fe <sub>2</sub> O <sub>3</sub> )         | 5.73  |
| Calcium Oxide (CaO)                                    | 7.50  |
| Magnesium Oxide (MgO)                                  | 3.93  |
| Sulphur Trioxide (SO <sub>3</sub> )                    | 1.73  |
| Sodium Oxide (Na <sub>2</sub> O)                       | 0.90  |
| Potassium Oxide (K <sub>2</sub> O)                     | 5.30  |
| Phosphorus Pent oxide (P <sub>2</sub> O <sub>5</sub> ) | 6.41  |
| Loss on Ignition (LOI)                                 | 13.85 |

**Table 2: Properties of Cement**

| Property             | Test Result          |
|----------------------|----------------------|
| Specific gravity     | 3.15                 |
| Initial setting time | 90 min               |
| Consistency          | 31%                  |
| Compressive strength | 53 N/mm <sup>2</sup> |
| Fineness             | 2%                   |

**Table 3. Properties of aggregate**

| Property         | Test Result |
|------------------|-------------|
| Fine aggregate   |             |
| Specific gravity | 2.66        |
| Fineness modulus | 2.5         |
| Coarse aggregate |             |
| Specific gravity | 2.7         |
| Water absorption | 1%          |

### Mix Proportioning

The proportioning of ingredients of concrete is done as per IS 10262:2009. It depends upon factors like quality and quantity of cement, water and aggregate, batching, mixing, placing, compaction and curing. The target compressive strength was 25Mpa and water to binder ratio was 0.3, threesamples were prepared, in which one is the control mix of 0% POFA. Sand is replaced by 5% & 10% in rest of the samples .we have named the mix as concrete palm oil ash. The mix design of each sample is given in the table below. The mixing and compaction of the samples were done as per Indian standard.

**Table4. Mix Proportion of Concrete Mixes in kg/m<sup>3</sup>**

| Mixing Process | Designation | Cement | Water | Sand | POFA | Sand : | Coarse    |
|----------------|-------------|--------|-------|------|------|--------|-----------|
|                |             | (kg)   | (kg)  | (kg) | (kg) | POFA   | aggregate |
|                |             |        |       |      |      | (%)    | (kg)      |
|                | Control     | 47     | 23.5  | 89.5 | 0    | 100:00 | 79        |
| Liquid Method  | LM5         | 47     | 23.5  | 85   | 4.5  | 95:05  | 79        |
|                | LM10        | 47     | 23.5  | 80.5 | 9    | 90:10  | 79        |

**Table 5. Preparation for Liquidation Method**

| Designation | Water mixes in POFA (kg) | POFA (kg) | Water/POFA |
|-------------|--------------------------|-----------|------------|
| LM5         | 6.7                      | 4.5       | 0.67       |
| LM10        | 13.4                     | 9         | 0.67       |

### Sample Preparation

Compressive tests were done on cubes of 150mm size for curing periods of 7 days 14 days and 28 days. Three samples were made with 0% 5% & 10% POFA replaced with sand. Each samples have water of pH 7.4 and each sample has five number of cubes for the compressive strength test.

### RESULTS AND DISCUSSIONS

Compressive strength is the most important property of concrete. It is the

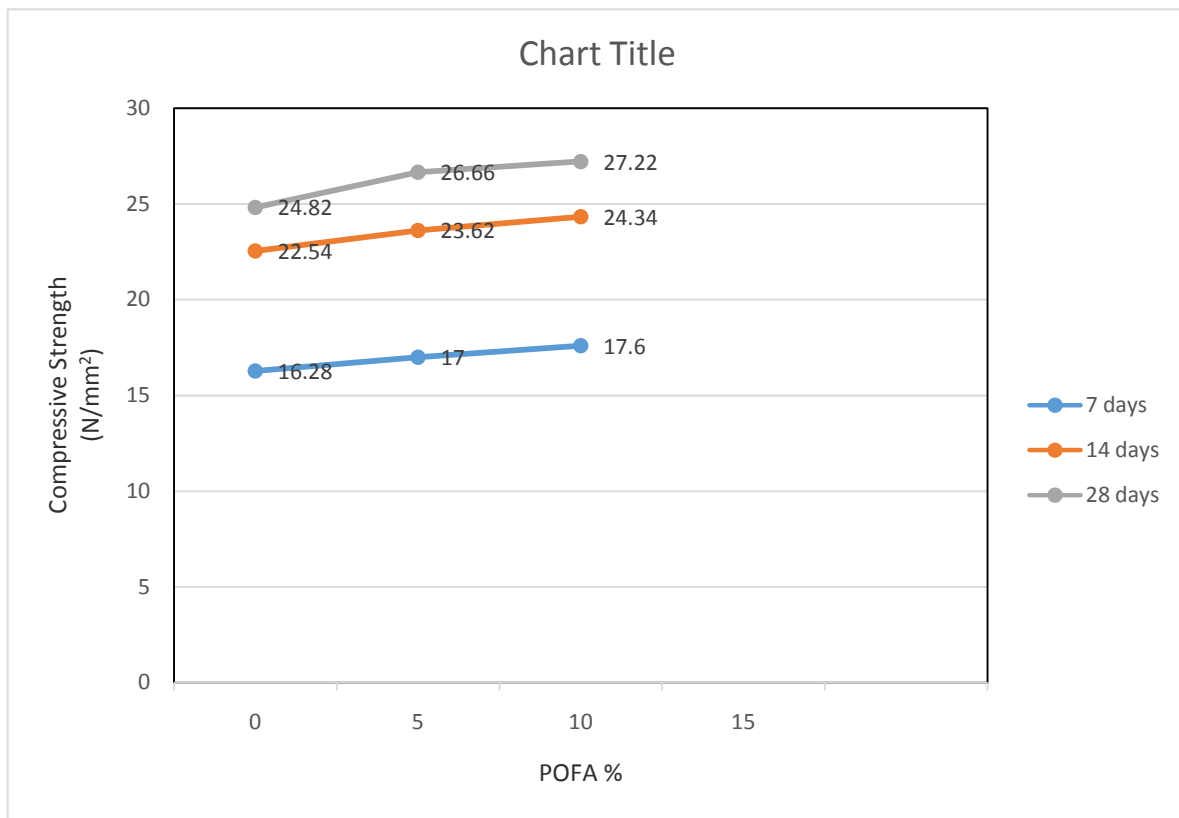
maximum compressive stress that, under a gradually applied load, a given solid material can sustain without fracture.

Test was conducted using test specimen of size 150mmX150mmX150mm. Curing period adopted was 7 days 14days and 28 days. Average of the compressive strength obtained for various mix for 7 days 14 days and 28 days curing are shown in table below. Similarly results are also represented in graphical form.



The strength of the concrete prepared with the different dosage levels of POFA as partial sand replacement for 7, 14 and 28 days. It is found that the LM5 represents the average strength with the value of 17 MPa at 7 days and 23.62MPa & 26.66MPa at 14 days 28days respectively. The LM10 represents the average strength with the value of 17.26MPa at 7 days and 24.34MPa & 27.22MPa at 14 days 28days respectively. From this early strength of concrete, it shows that liquid method contains POFA as partial sand replacement with dosage level of 10 % of sand weight is able to increase the strength of the concrete more compared to control sample. It is due to C-

S-H gels in the POFA generates bonding between aggregates and cement which contributes to the increment of concrete strength. At the same time, the fine particle in POFA is beneficially used as a filler to fill the void in the concrete. Hence it would increase dense of the concrete, which induces its strength. In contrast, liquid method with dosage level of 10 % POFA contributes the highest effective strength to the concrete performance. It can be inferred that concrete containing POFA at various dosage levels and mixing methods would increase the strength of concrete.

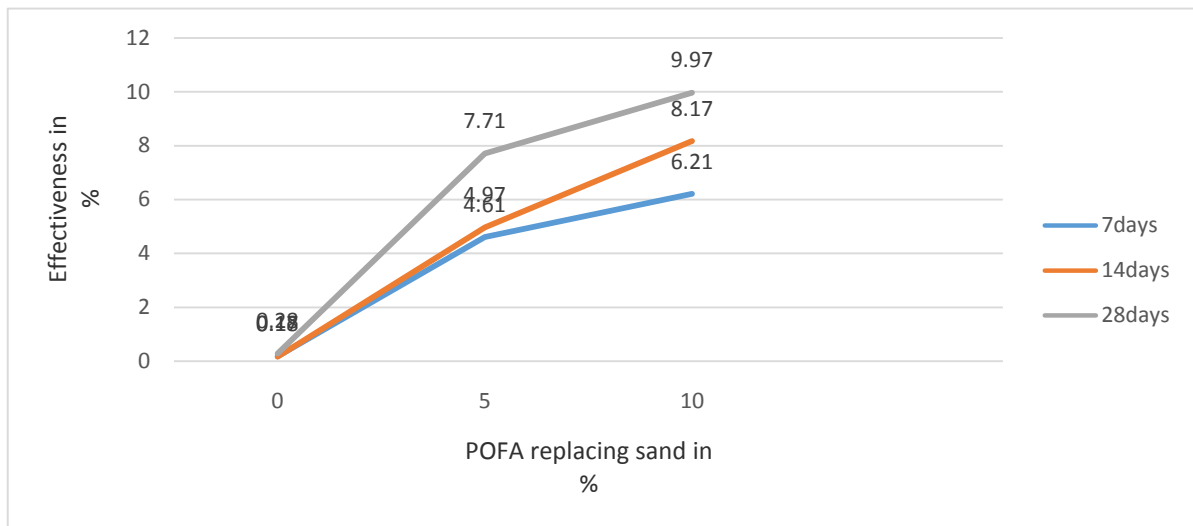
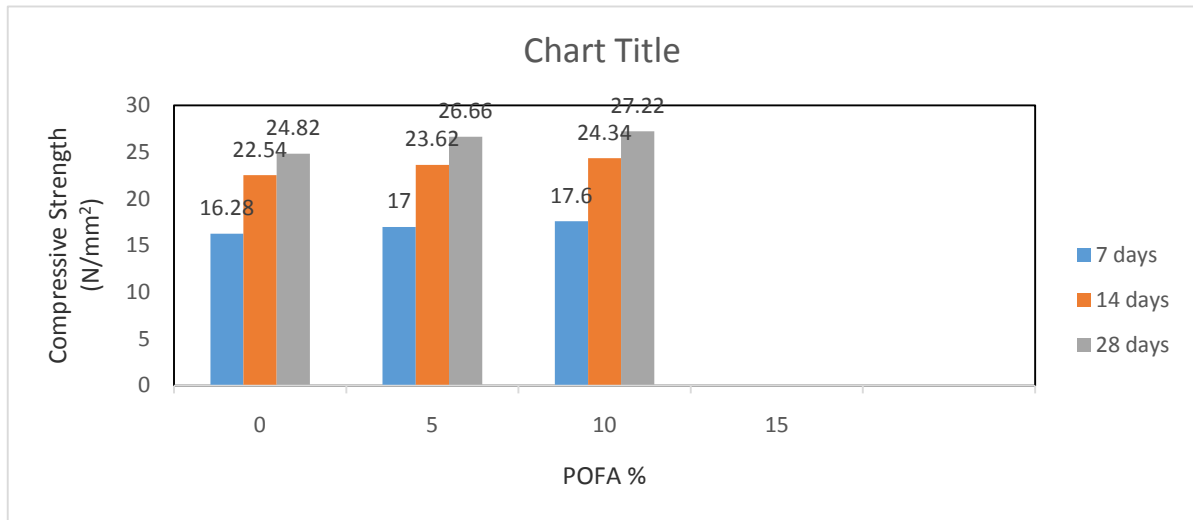


**Table 6: Compressive Strength Test Results**

| S.No. | Age (days) | POFA (%) | Compressive Strength (N/mm <sup>2</sup> ) | Effectiveness (%) |
|-------|------------|----------|-------------------------------------------|-------------------|
| 1.    | 7          | 0        | 16.28                                     | +0.18             |
|       | 14         | 0        | 22.54                                     | +0.17             |
|       | 28         | 0        | 24.82                                     | +0.28             |
| 2.    | 7          | 5        | 17                                        | +4.61             |
|       | 14         | 5        | 23.62                                     | +4.97             |
|       | 28         | 5        | 26.66                                     | +7.71             |
| 3.    | 7          | 10       | 17.26                                     | +6.21             |
|       | 14         | 10       | 24.34                                     | +8.17             |
|       | 28         | 10       | 27.22                                     | +9.97             |

In a nutshell, the workability and compressive strength of concrete containing POFA as partial sand replacement with different dosage levels of POFA were presented. The compressive

strength test was carried out on the hardened concrete at 7, 14 and 28 days. It can be inferred that the liquidation method produced good workability whether in low dosage or high dosage of POFA.



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