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Palm Oil Fuel Ash as Partial Replacement of Cement in Concrete

Aiswarya V S, Beyoola Wilson, Harsha V N
Civil Engineering Department
Federal Institute of Science and Technology
Angamaly, Kerala, India

Preethi M
Assistant Professor
Civil Engineering Department
Federal Institute of Science and Technology
Angamaly, Kerala, India

***Abstract*— Cement is the most widely used binding material in all construction works. Due to its high cost and heat liberation property, attempts have been made to replace cement in concrete using agricultural or industrial waste. This study involves partial replacement of cement in concrete by palm oil fuel ash (POFA) which is an agro-waste generated in palm oil industry. POFA is a pozzalanic material which has economical and technical advantage when used in concrete. In the present study compressive strength, flexural strength and split tensile strength test was conducted on hardened concrete by replacing cement with 5%, 10%,15% and 20% of POFA and compared the results with control mix (0%POFA). The grade of concrete adopted was M40. It has been observed that concrete with 10% replacement of POFA gave the highest strength.**

Keywords*— Palm oil fuel ash; compressive strength; flexural strength; split tensile strength

I. INTRODUCTION

Concrete is a manmade material and it is the most widely used building material in construction industry. There has been so much demand on construction materials in many countries around the world. Therefore, the discovery of alternative conventional building material that is 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, can be used in cement replacement.

II. MATERIALS USED

Materials used for this study includes ordinary Portland cement of grade 53, coarse aggregate, fine aggregate, palm oil fuel ash (POFA), superplasticiser Master Glenium SKY 8233, water.

A. Cement

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

B. 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.

C. 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.

D. Superplasticizer

The purpose of superplasticizer is to affect the fresh concrete properties by increasing the workability in concrete. Type of superplasticizer used in this study is Master Glenium SKY 8233. It is an admixture of new generation based on modified polycarboxylic ether. It is free of chlorides and low alkali and compatible with all types of cements. Performance test data is shown in Table 1.

Table1. Performance test data

Aspect	Light brown liquid
Relative Density	1.08 at 25^0C
pH	>6
Chloride ion content	< 0.2%

E. 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 cement without causing any adverse effect on strength and other properties of concrete. In this study, POFA have been collected from Oil Palm India Limited Kottayam. The collected ash were oven dried and passed through 90 micron sieve and used for cement replacement

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F. 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.

III. METHODOLOGY

A. Physical and chemical proerties

Physical and chemical properties of various materials used in the experiment were shown in the table below

Table 2. Chemical composition of POFA

Chemical Composition	% in POFA
Silica	20.10
Iron	8.106
Potassium	3.784
Sodium	0.070
Magnesium	1.800
Calcium	4.058
Aluminium	2.376
Sulphur	0.160

Table 3. Properties of Cement

Property	Test Result
Specific gravity	3.15
Initial setting time	90 min
Consistency	31%
Compressive strength	53 N/mm^2
Fineness	2%

Table 4. 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%

B. 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 40Mpa and water to binder ratio was 0.3, five samples were prepared, in which one is the control mix of 0% POFA. Cement is replaced by 5% 10% 15% 20% in rest of the samples .we have named the mix as concrete palm oil ash and denoted it as CP. The mix design of each sample is given in the table below. The mixing and compaction of the samples were done as per Indian standards.

Table 5. Mix design for 1 m^3 concrete

Cement Kg	Water Kg	Fine aggregate Kg	Coarse aggregate Kg	Super Plasticizer Kg
450	135	783.45	1146.23	0.9

C. Test specimens

Compressive tests were done on cubes of 150mm size for curing periods of 7 days and 28 days. The flexural compressive strength of concrete was determined by beams of 100mmX100mmX500mm of size for curing periods of 28 days and 56days. The split tensile strength is evaluated by cylinders of 150mm diameter and 300mm length for curing periods of 7 days and 28 days. Three specimens were casted for each testing case.

IV. RESULTS AND DISCUSSSIONS

A. Compressive strength

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 100mmX100mm. Curing period adopted was 7 days and 28 days. Average of the compressive strength obtained for various mix for 7 days and 28 days curing are shown in table below. Similarly results are also represented in graphical form.

Table 5. Compressive strength test results

Sl.No	Mix Id	Compressive strength(N/mm^2)	
		7 days	28 days
1.	CP0	33.89	40.23
2.	CP5	36.02	41.61
3.	CP10	37.1	43.08
4.	CP15	34.67	40.82
5.	CP20	31.68	39.55

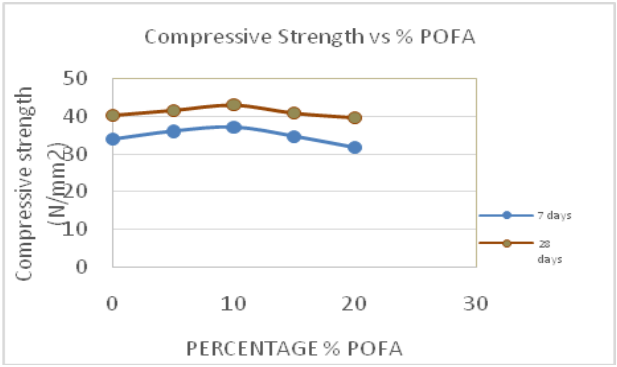

Fig.1 Variation of Compressive Strength

From the table and graph it is observed than that maximum value for compressive strength is obtained for 10% percent replacement. Beyond this optimum point compressive strength began to decrease.

B. Flexural strength

It is also known as modulus of rupture or bend strength. It can be defined as the capacity of a beam of concrete to resist failure due to bending. Flexural strength test was conducted on a test specimen of size100mm X 100mm X 150 mm for a Curing period of 28 days and 56 days. Test results are given below.

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Table 6. Flexural strength test results

SI.No	Mix Id	Flexural Strength(N/Mm^2)	
		28 days	56 days
1.	CP0	3.87	4.09
2.	CP5	3.89	4.13
3.	CP10	4.07	4.36
4.	CP15	3.94	4.21
5.	CP20	3.85	4.10

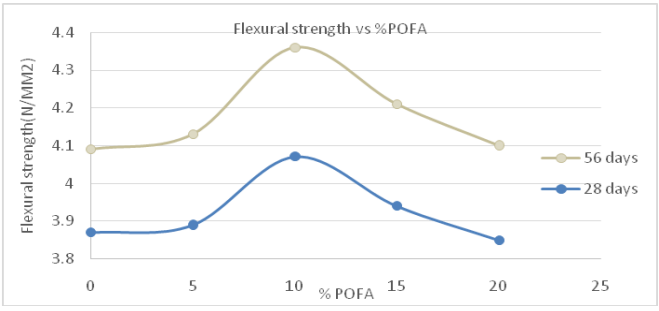

Fig.2 Variation of Flexural Strength

From the table and graph it is evident that flexural strength increases with increase in percentage of POFA. Maximum strength is obtained for 10% replacement

C. Split tensile strength

The tensile strength of concrete is one of the basic and important properties. Test is conducted on cylindrical specimen of diameter 150mm and height 300mm. curing period adopted was 7 days and 28 days. Average split tensile strength for various mixes during 7 day and 28 day curing are shown.

Table 7. Split tensile strength test results

Sl.No	Mix Id	Split Tensile Strength(N/Mm^2)	
		7 days	28 days
1.	CP0	2.56	3.11
2.	CP5	2.56	3.13
3.	CP10	2.81	3.27
4.	CP15	2.69	3.20
5.	CP20	2.55	3.08

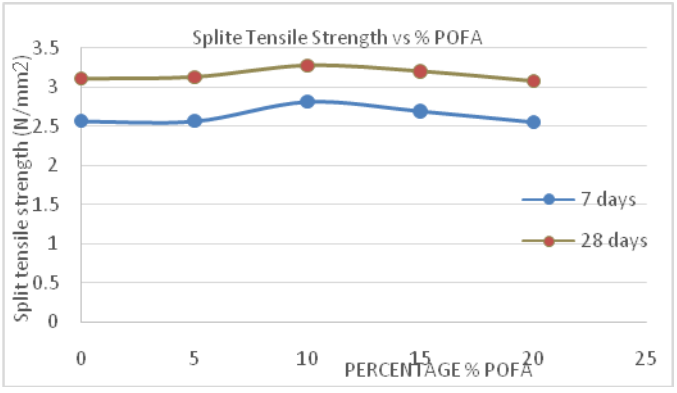

Fig.3 Variation of Split Tensile Strength

The results shows that maximum value of tensile strength is obtained for 10% replacement of POFA

V. CONCLUSION

- Partial replacement of cement with palm oil ash shows variation in strength properties of concrete
- POFA replacement of up to 10% as a cementitious material enhanced the compressive strength, Flexural strength, Split tensile strength of concrete compared to the specimen without POFA in their composition.
- Increase in the POFA replacement beyond certain limit causes decrease in the strength properties
- POFA used as cement replacement increases large utilization of waste products

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