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Experimental Investigation on Partial Replacement of Cement by Palm Oil Fuel Ash in Concrete

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Abstract*:* The utilization of pozzolanic materials in concrete construction is increasing, and this trend is expected to continue in the years ahead because of technological advancement and the desire for sustainable development. Palm Oil Fuel Ash (POFA) is used as a supplementary cementitious material in concrete. However, use of supplementary cementitious materials leads to control in heat of hydration which further avoids higher shrinkage. Palm Oil Fuel Ash (POFA), a waste material obtained from burning of palm oil husk and palm kernel shell as fuel in palm oil mill boilers, which has been identified as a good pozzolanic material. Palm Oil Fuel Ash which contains siliceous compositions produces a stronger and denser concrete. In this study, the strength properties of POFA concrete of M30 grade in different replacement level and also compares with control concrete. Concrete specimens containing 10%, 20%, 30% and 40% POFA were made at a water-cement ratio of 0.45. Strength properties such as compressive strength, flexural Strength and splitting tensile strength will be studied, and compared with that of concrete containing 100% OPC as control. It is revealed that the optimum replacement level of OPC by POFA is 20% for a good strength in compressive test.

Keyword: Palm Oil Fuel Ash, pozzolanic material, Partial replacement of cement, Compressive strength.
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I. INTRODUCTION

Cement is a binder material used in construction industries. It is known that there are several causes of global warming, including CO2 from cement. Approximately 5% of total CO2 emission is released to atmosphere, with about 0.7–1.1 ton of CO2 being emitted for every ton of cement production. To solve this problem, palm oil fuel ash used as the most suitable and cheaper alternative material for cement in concrete. One of the potential recycle materials from palm oil industry is palm oil fuel ash. Palm oil is extracted from the fruit and copra of the palm oil tree. After the extraction process, waste products such as palm oil fibers, shells, and empty fruit brunches are burnt as biomass fuel to boil water, which generates steam for electricity and the extraction process in palm oil mills. The silica oxide content in POFA can react with calcium hydroxide (Ca (OH) 2) from the hydration process which is deteriorated to concrete and the pozzolanic reactions produce more calcium silicate hydrate (C-S-H) which is a gel compound as well as reducing the amount of calcium hydroxide. Thus, this contributes to the strength of the concrete thus produce stronger and denser concrete.

II. LITERATURE REVIEW

- Tay et al., (1990) investigated that replacing 10–50% ash by weight of cementitious material in blended cement had no significant effect on segregation, shrinkage, water absorption, density, or soundness of concrete.
- Hussin et al., (1996) studied the compressive strength of concrete containing POFA. The results revealed that it was possible to replace at a level of 40% POFA without affecting compressive strength. The maximum compressive strength gain occurred at a replacement level of 30% by weight of binder.
- Sukantapree et al., (2002) have found that POFA can be used in the construction industry, specifically as a supplementary cementitious material in concrete.
- Tangchirapat et al., (2003) reported that the chemical composition of POFA contains a large amount of silica and has high potential to be used as a cement replacement.
- Sata et al., (2010) investigated that the strength development of POFA concretes with w/c ratios of

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0.50, 0.55, and 0.60 tended to be in the same direction. At early ages, concretes containing POFA as a cement replacement of 10, 20, and 30% had lower strength development than control concretes while at later age 28 days, the replacement at rates of 10 and 20% yielded higher strength development.

III. Materials Used

A. Cement

Ordinary Portland Cement 53 grade conforming to IS 12269-2013 was used. Its properties are shown in table.1.

Table.I Cement test results

S.No	Characters	Experimental Value
1	Consistency of cement	26%
2	Specific gravity	3.15
3	Initial setting time	40 mins
4	Final setting time	8 hours

B. Palm Oil Fuel Ash

Palm Oil Fuel Ash is the product of burning palm oil husk and palm kernel shell in the palm oil mill. POFA obtained from Godrej agrovet limited, varanavasi in ariyalur district was used in this investigation. The specific gravity of Palm oil fuel ash was 2.9.

Fig.1 Palm fruit

Fig.2.Palm oil residue

Fig 3.Sieved Palm Oil Fuel Ash

C. Fine Aggregate

Sand is commonly known as Fine aggregate and should comply with coarse, medium, or fine grading needs. The fine aggregate was saturated under surface dry conditions to ensure the water cement ratio is not affected. The maximum size of fine aggregate was taken to be 4.75 mm with specific gravity 2.62.

D. *Coarse Aggregate*

The coarse aggregate was air dried to obtain saturated surface dry condition to ensure that water cement ratio was affected. Few characteristics of aggregate that affect the workability and bond between concrete matrixes are shape, texture, gradation and moisture content. Coarse aggregate was used with 12mm and 20mm nominal size and specific gravity 2.64.

E. *Water*

The chemical reaction between water and cement is very significant to achieve a cementing property. Hydration is the chemical reaction between the compounds of cement and water yield products that achieve the cementing property

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after hardening. Fresh potable water, which is free from acid and organic substance, was used for mixing the concrete.

III. Mixing Proportions

The concrete mix is designed as per IS: 10262 – 2009 and IS 456-2000 for the normal concrete. The grade of concrete adopted is M30 with a water cement ratio of 0.45. Five mixture proportions were made. First was control mix (without palm oil fuel ash), and the other four mixes contained palm oil fuel ash. Cement was replaced with palm oil fuel ash by weight. The proportions of cement replaced ranged from 10% to 40%.

IV. Results And Discussion

A. Compressive Strength

The most valuable property in concrete is the concrete compressive strength because it gives the overall definition of the quality concrete strength that relates to the hydrated cement paste.

$$\text{Compressive strength} = \frac{\text{maximum load}}{\text{Cross sectional area}}$$

Table.II Compressive strength test results

Concrete composition with POFA replacement	Average compressive strength (N/mm^2)		
	7 Days	14 Days	28 Days
Control concrete	28.07	32	36.89
10%	28.89	33.33	33.33
20%	29.78	33.78	36.44
30%	25.78	28.89	29.33
40%	20	24	26.22

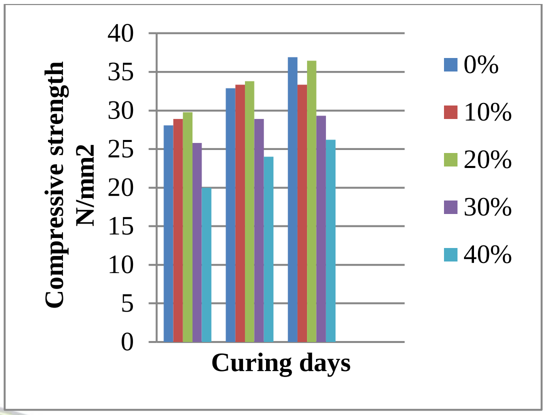

Fig. 4 variation in compressive strength

B. Flextural Strength

Flexural strength can be described as the capacity of a beam or even a slab of concrete to resist failure due to bending. This flexural strength is also known as *Modulus of Rupture*. The effect of concrete with various percentage of POFA on flexural strength is shown on table 3. The flexural strength was tested on 7, 14 and 28 days of curing. The results showed that the flexural strength of the concrete increased as the percentage of the POFA increased in the mix ratio. It was observed that the concrete flexural strength of the beam specimens increases with increasing age.The flexural tensile strength or modulus of rupture, f_b can be calculated as follows:

$$f_b = \frac{PL}{bd^2}$$

where, *P* is maximum applied load in kg,
b is average width of specimen at the point of fracture
d is average depth of specimen at the point of fracture.

Table.III Flexural strength test results

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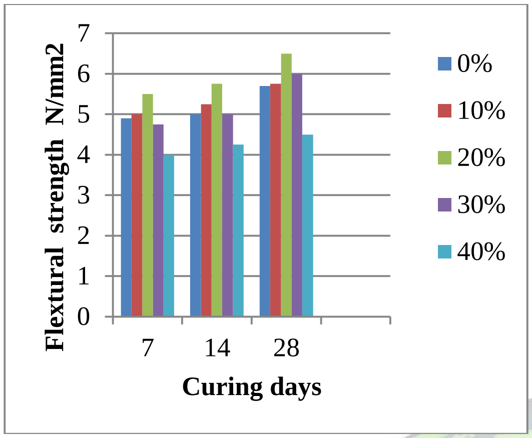

Fig.5 Variation in flextural Strength

Concrete Composition With POFA Replacement	Average flextural Strength (N/mm^2)		
	7 Days	14 Days	28 Days
Control Concrete	4.9	5	5.7
10%	5	5.25	5.75
20%	5.5	5.75	6.5
30%	4.75	5	6
40%	4	4.25	4.5

C. Splitting Tensile Strength

The splitting tensile strength of the concrete specimens was determined at 7, 14 and 28 days.

Table .IV Splitting tensile strength

Concrete composition with POFA replacement	Average splitting tensile strength (N/mm^2)		
	7 Days	14 Days	28 Days
Control concrete	4.9	5	5.7
10%	2.12	2.41	2.68
20%	2.26	2.69	2.97
30%	1.84	2.26	2.55
40%	1.42	1.84	1.98

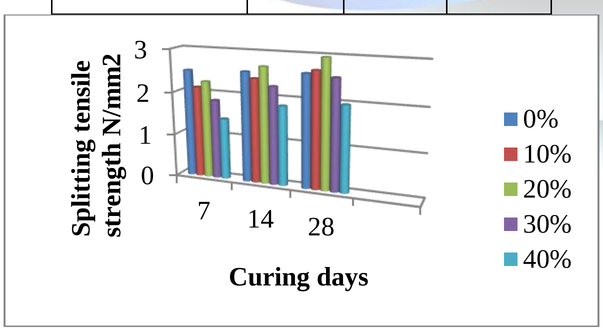

Fig.6 Variation in splitting tensile strength

VI. CONCLUSION

- This investigation reveals that there is a promising potential for the use of palm oil fuel ash as partial cement replacement in concrete production.
- Strength characteristics like compressive, splitting tensile and flexural strengths tests shows an increase in strengths up to the replacement level of 20% of Palm Oil Fuel Ash.
- Palm Oil Fuel Ash used as Cement replacement enables the large utilization of waste product.
- Consuming POFA as cementing materials in construction industry will reduce the environmental problems associated with disposing of it in landfill.

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