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PARTIAL REPLACEMENT OF CEMENT WITH PALM OIL FUEL ASH AND KAOLINITE CLAY IN CONCRETE

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ABSTRACT

Palm oil fuel ash (POFA) is a by-product from the palm oil industry, is disposed off as landfill. Kaolinite is a clay mineral with the chemical formula $Al_2Si_2O_5(OH)_4$. In this paper cement was partially replaced with POFA and kaolinite clay at various percentages. POFA was added at 0, 10, 20 and 30% and to each percentage of POFA kaolinite was added at 0, 2.5, 5 and 7.5 %. The various properties of concrete like compressive strength, split tensile strength were examined. The compressive strength was found to be maximum for 30% POFA and 7.5 % kaolinite mix. The flexural strength of 3m long RCC beams were examined for the control mix and the mix with optimum percentage of these materials The load deflection graphs were plotted. The setting time was slightly affected with the addition of these materials. The optimum percentage of POFA was estimated as 30% and kaolinite was found to be 7.5%. From all these tests it was found that both POFA and kaolinite clay were suitable materials to replace cement.

KEYWORDS: *palm oil fuel ash; kaolinite clay; compressive strength; flexural strength; setting time; RCC beams; POFA*

1. INTRODUCTION

Concrete is an artificial rock like material made from a proportioned mix of hydraulic cement, water, fine and coarse aggregate. Today, it is the most popular and broadly used material in the construction industry. It is because of its durability and compatibility. It has many advantages when compared to other construction materials. Of all the component cement is the major ingredient in concrete. It is typically a bonding agent which helps to keep the materials together. It imparts strength to the mix.

As the construction works increases the demand for cement also increases successively. The manufacturing of cement causes large number of environmental problems when used with reinforcement is capable of taking bending and tension. Cement is the most expensive ingredient in concrete thus it has become essential to find means of economising the use of cement. Because of the significant contribution to the environmental pollution, to the high consumption of natural resources like limestone and the high cost of Portland cement we cannot go on producing more and more cement. There is need to economise the use of cement in concrete production. The waste materials like Fly ash, Ground Granulated Blast-furnace Slag, Silica-fume, saw dust ash, Rice Husk Ash etc. are used in replacement of cement. The cost of concrete production can be reduced by making use of locally available materials. In this paper cement is being replaced by palm oil fuel ash and kaolinite clay. The high silica content in POFA and high alumina content in kaolinite when mixed together with cement results in the formation of CSH gel which helps to improve the strength of the mix. The optimum percentage of POFA and kaolinite clay that can be used is fond out. The flexural strength of RCC beams is estimated in the specimen with optimum percentage of the materials. The durability properties were also examined.

2. EXPERIMENTAL DETAILS

2.1 Materials

2.1.1. Cement

53 grade OPC cement was used. The cement was manufactured by DALMIA as per IS 12330. The basic tests on cement like normal consistency, initial setting time, fineness and specific gravity were performed as per IS code procedure.

2.1.2 Fine Aggregate

Considering the local availability, fine aggregate used in this thesis work is M-sand. It has grain size ranging from 600 micron to 2.36mm. Properties like fineness modulus, specific gravity, water absorption and bulk density were tested.

2.1.3 Coarse Aggregate

Crushed rock of 12.5mm was used as crushed aggregate. Properties like specific gravity, bulk density and water absorption was determined.

2.1.4. Palm Oil Fuel Ash

Palm oil fuel ash is produced (POFA) is produced by burning of fibre, shell and empty fruit bunch of palm oil tree as a fuel to heat steam for electricity and palm oil extraction process. It is disposed in landfills that the amount of ashes increases every year and now becomes a burden. It is estimated that more than 1000 tons of POFA is produced every year in India. The sustainable amount of silica and the fineness of POFA makes it suitable to be used as a substitute for cement.

The following properties of concrete are altered with the addition of rice husk ash:

- The heat of hydration is reduced. This itself help in drying shrinkage and facilitate durability of the concrete mix.
- The reduction in permeability of concrete structures. This will help in penetration of chloride ions, thus avoid the disintegration of the concrete structures.
- There is a higher increase in sulphate and chloride attack.
- Good workability which helps in better placing and compaction.

The palm oil ash required for this project work was calculated from Oil Palm India Limited, Kollam. The ash obtained by burning the bunch of the fruits after the extraction of oil was used. The specific gravity property was obtained from the company as 2.98.

The chemical composition of POFA is given in Table 1.

Table 1. Chemical composition of POFA

CHEMICAL COMPOSITION	% of POFA
Silicon Dioxide	53.82
Aluminium Oxide	5.66
Ferric Oxide	4.54
Calcium Oxide	4.24
Magnesium Oxide	3.1
Sodium Oxide	0.1
Potassium Oxide	4.47
Sulphur Oxide	2.25
Phosphorous Oxide	3.01

Fig.1Palm Oil Fuel Ash (POFA)

The palm oil ash required for this project work was calculated from Kerala Ceramics Limited, Kundura, Kollam. The specific gravity property was obtained from the company as 3.01

2.1.5. Kaolinite Clay

Kaolinite is a clay mineral with chemical composition $Al_2Si_2O_5(OH)_4$ .it is a layered silicate mineral, with one tetrahedral sheet linked through oxygen atoms to one octahedral sheet of alumina.

Heating to 1200 to 1650°F alters its structure, pro ducing a highly reactive supplementary cementitious material that is widely available for use in concrete construction.

The advantages of using kaolinite for the partial replacement of cement are as follows

- Increase resistance to sulphate attack
- Decrease corrosion and permeability
- Increase the strength
- Lower heat of evolution

The concrete with kaolinite shows more workability than the normal concrete for the same water content. The setting time of concrete also tends to show a small decrease. Efflorescence, which appears as a whitish haze on concrete is caused when calcium hydroxide reacts with carbon dioxide in the atmosphere.

The chemical composition of kaolinite clay is given in Table 2

Table 2. Chemical Composition of Kaolinite

CHEMICAL COMPOSITION	% IN KAOLINITE
SiO_2	2
Al_2O_3	40.2
Fe_2O_3	1.23
CaO	51.5
MgO	0.12
Na_2O_3	0.08
K_2O	0.53
TiO_2	2.27

Fig.2. Kaolinite

2.1.6 Water

Locally available potable water from the lab source was used for mixing and curing of concrete. Water used was free from impurities and amount of acid, alkali, salt and organic materials were within the limit.

2.2. Mix Proportioning

In this paper, control mix was designed per Indian Standard specifications IS: 10262-1982 to have 28 day compressive strength of 32.55 MPa. Cement was replaced by POFA at 0, 10, 20, 30, and 40%. For each percentage of POFA, the percentage of kaolinite was varied as 0, 2.5, 5, 7.5 and 10%. The water cement ratio was kept constant for all the mixes to ensure uniform workability.

2.3 Casting of the specimens

Compressive strength and was tested for the cubes of size 150×150×150mm.Cylinders of size 150×300mm were used for testing the split tensile strength. Flexural strength was tested in RCC beams of size 3200×150×200mm.

3. 1 RESULTS

3.1 Basic Properties of materials and Concrete

Table 4. Basic Properties

Item	Test result
Fineness of cement	5%
Normal consistency of cement	36%
Initial setting time of cement	65 minutes
Specific gravity of cement	3.16
Fineness of POFA	5%
Specific gravity of POFA	2.98
Fineness of kaolinite clay	2%
Specific gravity of kaolinite clay	3.01
Slump value	85mm
Compressive strength	32.55N/mm²

3.2 Setting Time

The setting time for the mixes with 0, 10, 20, 30 and 40 percentage POFA and 0, 2.5, 5, 7.5 and 10 percentage kaolinite clay was examined. The results are shown in table 3 (a) and 3 (b).

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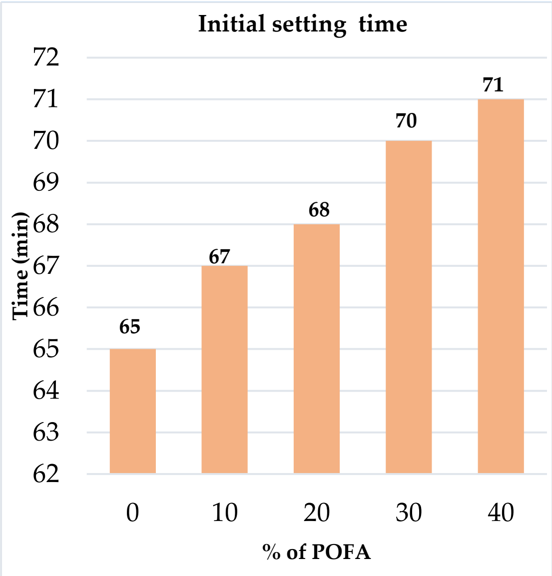

Fig 3 (a) Setting time for mixes with varying % of POFA

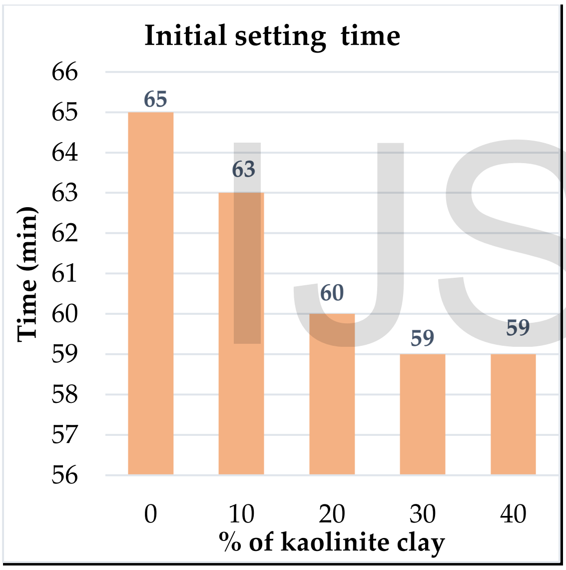

Fig 3 (b) Setting time for mixes with varying % of kaolinite clay

From the figure, it is clear that when POFA was added at different percentages the setting time was found to increase slightly. When kaolinite was added it shows slight decrease in the values. However the variation was considerably small and was within the limit.

3.3 Compressive Strength

The compressive strength of the cubes were tested for 7 and 28 days. The results are given in figures 4 (a) - 4(e).

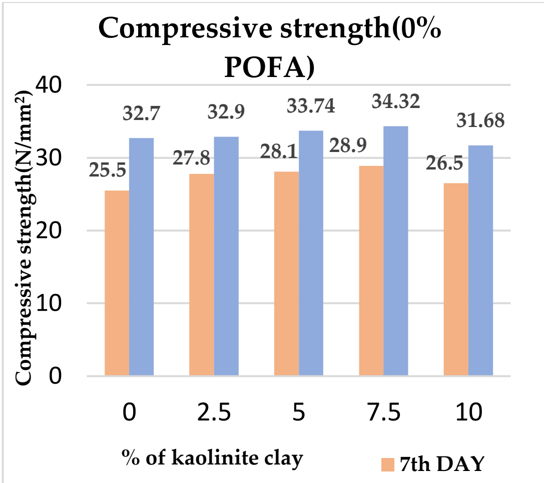

Fig 4(a) Compressive strength for the mix with 0% POFA

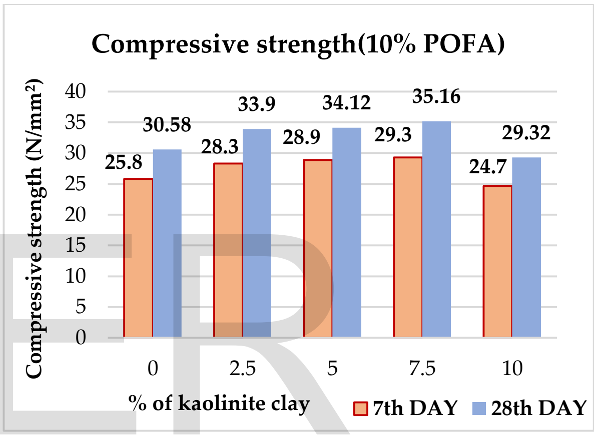

Fig 4(b) Compressive strength for the mix with 10% POFA

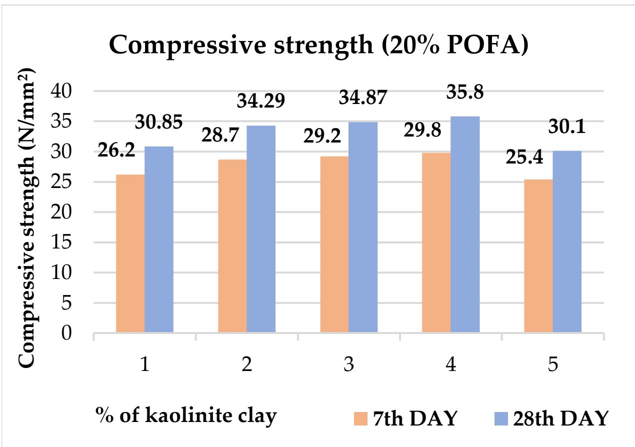

Fig 4(c) Compressive strength for the mix with 20% POFA

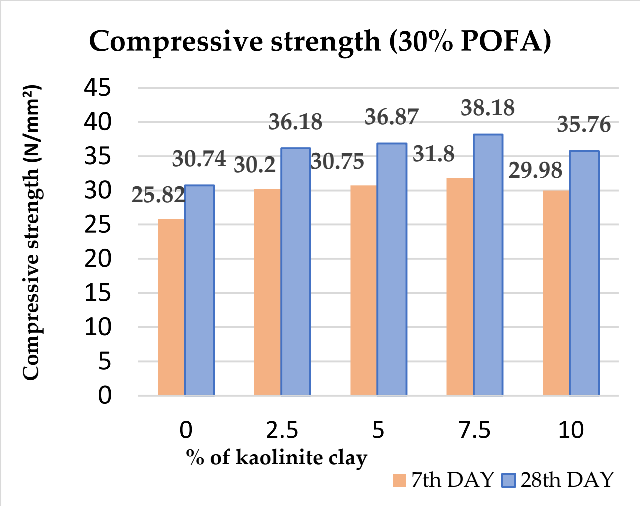

Fig 4(d) Compressive strength for the mix with 30% POFA

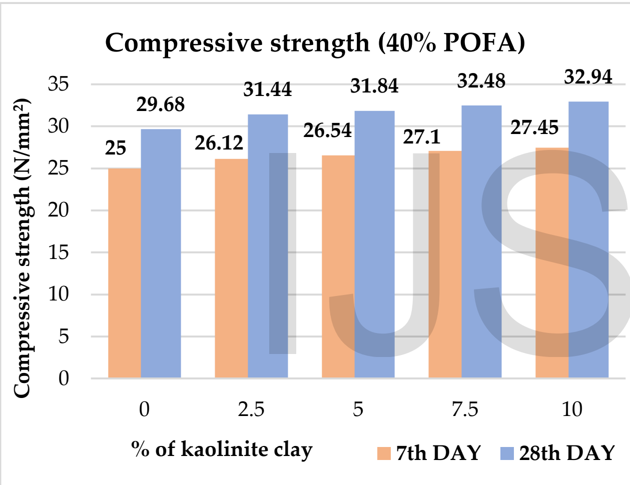

Fig 4(e) Compressive strength for the mix with 40% POFA

The compressive strength of normal concrete was found to be 32.7 N/mm². When POFA was added at different percentages with zero percentage kaolinite vice versa, the compressive strength was found to be decreasing. On increasing the percentages of kaolinite and POFA in the mix, the compressive strength was improved significantly up to a certain limit. The mix with 30% POFA and 7.5% kaolinite was shown maximum compressive strength of 36.87 N/mm². On any further increase in the amount of both materials in the mix, results in the reduction of the compressive strength.

3.4 Split Tensile Strength

The tensile strength of cylinder specimens was tested after curing for a period of 28 days. The results are shown in fig 5 (a)-5(e).

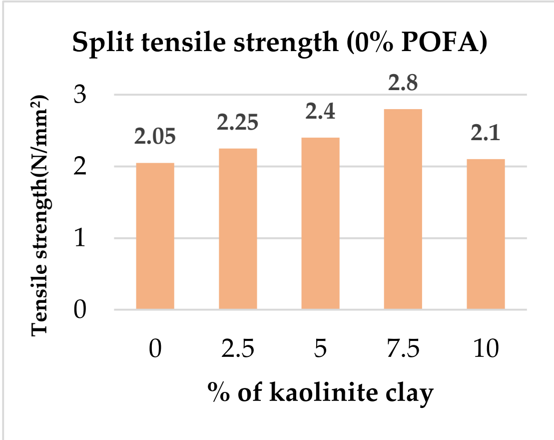

Fig 5(a) Split tensile strength for the mix with 0% POFA

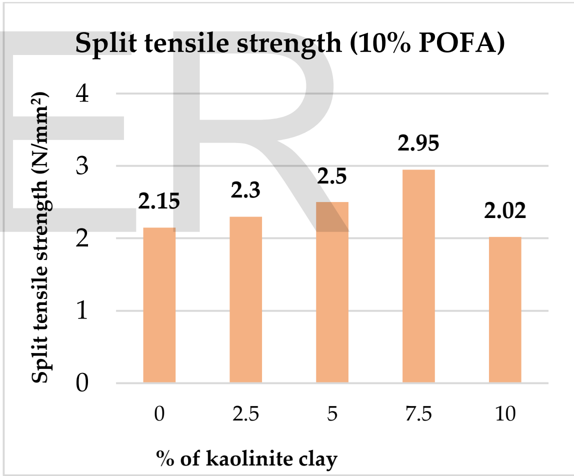

Fig 5(b) Split tensile strength for the mix with 10% POFA

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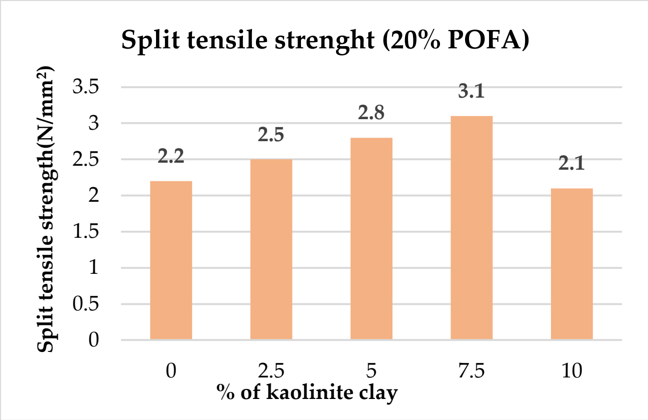

Fig 5(c) Split tensile strength for the mix with 20% POFA

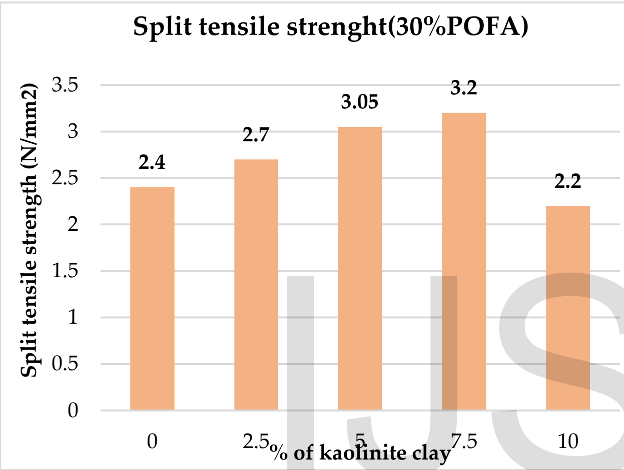

Fig 5(d) Split tensile strength for the mix with 30% POFA

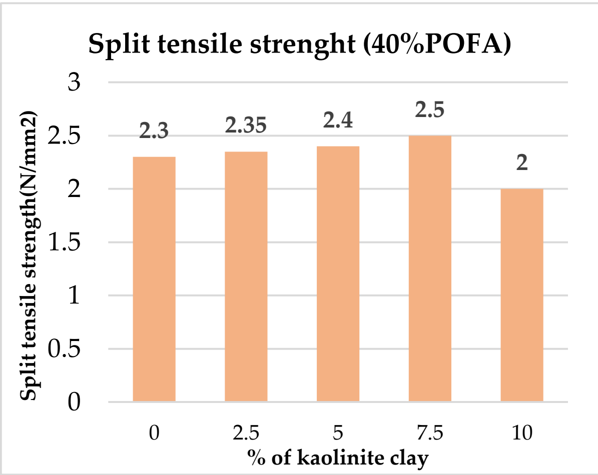

Fig 5(e) Split tensile strength for the mix with 40% POFA

The tensile strength was found to increase with the addition of both the materials. The optimum percentage of POFA and kaolinite was found to be 30 and 7.5% respectively. The tensile strength was found to increase by 51.219% than the conventional sample. On further increasing the percentages of both the materials the strength was found to decrease.

3.5. Flexural Strength of beams

The flexural strength of reinforced concrete beams of size was 3200×150×200mm. The tests were conducted for the control specimen and the specimen with the mix of 30% POFA and 7.5% kaolinite. The load deflection graph was plotted for the same. The results are shown in fig 6.

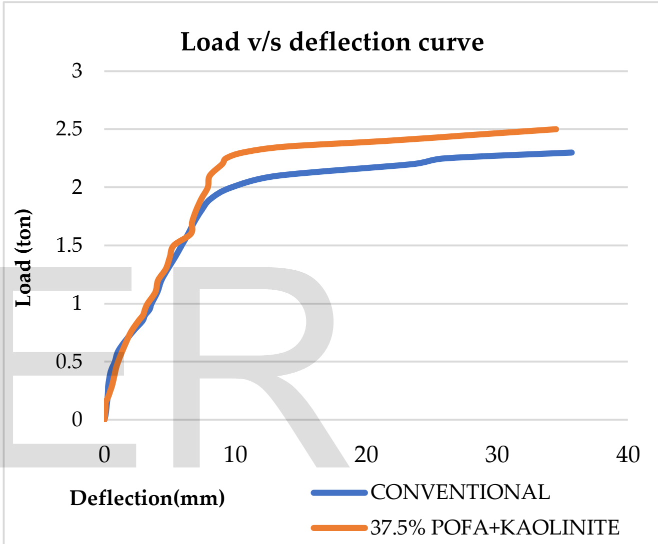

Fig 6 : Load v/s deflection curve

For the control mix the load for the maximum load was found to be 2.1 and it was found to be 2.35 for the sample with POFA and kaolinite. For the same load the beam with POFA and kaolinite showed lesser deflection compared to control beam. The number of cracks formed was more in case of beam with POFA and kaolinite than the control beam.

4. CONCLUSIONS

The basic properties of POFA and kaolinite was found to be similar to that of cement, thus could be used as a partial substitute for cement. By the addition of POFA and Kaolinite the strength parameters was found to increase satisfactorily. The optimum percentage of POFA and kaolinite that can be used to replace cement was found to be 30 and 7.5% respectively. On using these materials to replace cement, the construction becomes economical and light weight structures can be developed.

5. REFERENCE

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