AN EXPERIMENTAL INVESTIGATION ON STRENGTH PROPERTIES OF CONCRETE WITH CEMENT REPLACEMENT BY PALM OIL FUEL ASH AS NEW CONCRETE

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ABSTRACT:

Rapid growth of infrastructure has led to the use of concrete almost everywhere, and one of the main products required in manufacturing concrete is cement, with the increase in the amount of cement used, with the increase in the amount of cement used, heat of hydration increases which will lead to the formation of cracks in concrete accompanied by shrinkage effect. In order to control this, palm oil fuel ash, an agro waste which contains some amount of silica act as a pozzolanic material is being used as cement replacement and its strength is compared with conventional concrete of grade M25. In this study cement is being replaced with pal oil fuel ash by 5%, 7.5%, 10%, 12.5%, 15%, 17.5% and the strength tests like compressive strength test, tensile strength test, flexural strength test, Sorptivity and RCPT are performed and are compound with the results of conventional concrete of grade.

I. INTRODUCTION

To produce concrete, cement is an essential material that binds together solid bodies but also is the largest producer of carbon dioxide (CO_2) emission. Up to 10% of global CO_2 emission comes from cement production thus making the sustainability of concrete a major issue that needs addressing. The processes of producing concrete consume heavily on natural resources such as sand, gravel, water, coal and crushed rock, mining of which damages the environment. It is however possible, that energy and cost efficiency can be achieved by reducing on the amount of clinker, and in its place utilizing partial cement replacements/pozzolans that require less process heating and emit fewer levels of carbon dioxide. This study investigates the effectiveness of agro waste ash by-product Palm Oil Fuel Ash (POFA) as an alternative material to replace Portland cement (OPC).

Concrete is a very important material and widely used in construction material since an ancient time. Concrete is no doubt is important building material, playing a part in all building structure. It is must environmental friendly construction materials with offer the stability and flexibility in designing all building structures. Concrete are attractive for use as construction materials. Since, there are many advantages of concrete such as built-in-fire resistance, high. Compressive strength and low maintenance. However, concrete also have a disadvantage which is the concrete are inherently brittle material. On the other hand, concrete is also well known of its major problem associated with low tensile strength compared to compressive strength. Because of that, many new technologies of concrete and some modern concrete specifications approach were introduced. There have been many experimental works was conducted by introducing a new material or recycled material as a replacement to aggregate or cement in concrete.

Origin of POFA

Palm oil fuel ash is a by-product produced in palm oil mill. After palm oil is extracted from the palm oil fruit, both palm oil husk and palm oil shell are burned as fuel in the boiler of palm oil mill. Generally, after combustion about *5%* palm oil fuel ash by weight of solid wastes is produced (Sata et al., 2004). The ash produced sometimes varies in tone of colour from whitish grey to darker shade based on the carbon content in it. In other words, the physical characteristic of POFA is very much influenced by the operating system in palm oil factory.

This study concentrated on investigation of compressive strength and durability of palm oil fuel ash (POFA) concrete and plain concrete as a control mix. Each series of concrete were designed for grade 25 with constant water cement ratio (w/c) of *0.5* was conducted. The plain concrete compose of cement, water, aggregate and sand were considered as a control mix without replacing with POFA. A per the series of concrete mix design with POFA as cement replacement were composed as an unconventional mixes comprises of 5%, 7.5%, 10%, 12.5%, 15%, 17.5% from the total, weight of ordinary Portland cement.

II LITERATURE REVIEW

A number of investigations have been carried out with Palm oil fuel ash (POFA), an agro-waste ash, as potential replacement of cement in concrete. Sata et al. (2004) found compressive strength of 81.3, 85.9, and 79.8 MPa at the age of 28 days by using improved POFA with a reduced particle size

of about 10 micron in concrete as replacement of 10%, 20% and 30% of cement respectively. They also reported highest strength at 20% replacement level. Tangchirapat [2009] observed the compressive strengths of ground POFA concrete in the range of 59.5–64.3 MPa at 28 days of water curing and with 20% replacement it was as high as 70 MPa at the end of 90 days of water curing. However, the drying shrinkage and water permeability were noted to be lower than that of control concrete with improved sulphate resistance. Past researchers also depict that both ground and un-ground POFA increase the water demand and thus decrease the workability of concrete. However, ground POFA has shown a good potential for improving the hardened properties and durability of concrete due to its satisfactory micro-filling ability and pozzolanic activity. The use of Paper mill ash (PMA), by product of pulp and paper industry as well as paper recycling mills, as partial replacement of cement in concrete was investigated as an alternative to landfill disposal by employing calcinations processes to make the PMA more pozzolanic (Monosi et al., 2012).
Past investigations (Naik et al., 2003) depict that PMA concrete with 5 to 10% of replacement; show a positive effect on the mechanical performance of the concrete. However, the use of PMA should not be higher than 10% by weight of cement due to the requirement of higher dosage of water. Mohammed and Fang (2011) observed that the concrete containing PMA has improved durability in comparison to class F FA blended concrete when the proper dosage of high-range waterreducing agent was added.
Awal&Hussin, both of them highlighted that POFA concrete gain maximum strength when 30% of the cement was replaced with POFA. It is reported that the maximum strength gain occurred at the replacement, level of .30% but further increase in the ash content would reduce the strength of concrete gradually.
Dunstan, who stated that fly ash should be considered to be the fourth ingredient in concrete, that is in addition to the aggregate, cement and water, and not as a replacement of the cement. Conclusively, whatever is the mode of application all the methods can result in a significant improvement and optimization of certain properties of both fresh and hardened concrete.

III: MATERIALS AND METHODOLOGY

CEMENT

The most common cement used is an Ordinary Portland Cement (OPC). The Ordinary Portland Cement of 53 grade (OPC) conforming to IS: 8112-1989 is used. A cement is a binder, a substance used in construction that sets, hardens and adheres to other materials, binding them together. Cement is seldom used solely, but is used to bind sand and gravel (aggregate) together. The properties of cement are shown in Table.

Properties of Cement.

S.No.	CHARACTERISTICS	VALUE
1	SPECIFIC GRAVITY	3.15
2	NORMAL CONSISTENCY	31%
3	INTIAL SETTING TIME	82minutes
4	FINAL SETTING TIME	205minutes

FINE AGGREGATE

Fine aggregate are basically sands won from the land or the marine environment. Fine aggregates generally consist of natural sand or crushed stone with most particles passing through a 9.5mm sieve.

COARSE AGGREGATE

Coarse aggregates are particles greater than 4.75mm, but generally range between 9.5mm to 37.5mm in diameter. They can either be from Primary, Secondary or Recycled sources. Primary, or 'virgin', aggregates are either Land- or Marine-Won. Gravel is a coarse marine-won aggregate; land-won coarse aggregates include gravel and crushed rock. Gravels constitute the majority of coarse aggregate used in concrete with crushed stone making up most of the remainder.

Water

Water is an important ingredient of concrete as it actually participates in the chemical reaction with cement. Since it helps to from the strength giving cement gel, the quantity and quality of water is required to be looked into very carefully. Water cement ratio used is 0.40 for M25.

Palm oil fuel ash

Palm kernel shells along with fiber wastes are burned together in chimneys to produce heat at a temperature of 450^{o}. After burning the ash generated tries to escape due to less weight, to avoid this water is sprinkled from top and then this is collected, pulverized and passed through IS 90mm sieve. Palm oil fuel ash (POFA), a by-product from the palm oil industry is disposed of as waste in landfills. The properties of POFA are shown in Table

Properties of POFA (Palm oil fuel ash)

S.No.	CHARACTERISTICS	VALUE
1	SILICON DIOXIDE	63.5
2	ALUMINIUM OXIDE	4.5
3	IRON OXIDE	3.9
4	LIME	7.4
5	MAGNESIUM OXIDE	0.49
6	POTTASIUM OXIDE	9.2
7	LOSS OF IGNITION	5.6

MIX PROPORTION

The concrete mix is designed as per IS: 10262 – 2009 and IS 456-2000 for the normal concrete. The grade of concrete adopted is M25 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. The following table.

Table: 3.6 Mix proportions values.

Mixture	A0	A1	A2	A3	A4	A5	A6
Cement	448.6	426.17	414.95	403.74	392.52	381.31	370.09
Palm oil fuel ash (%)	0%	5%	7.5%	10%	12.5%	15%	17.5%
Palm oil fuel ash (Kg/m^3)	0	22.43	33.64	44.86	56.07	67.29	78.50
Coarse Aggregate (Kg/m^3)	1064.65	1064.65	1064.65	1064.65	1064.65	1064.65	1064.65
Fine Aggregate (Kg/m^3)	752.71	752.71	752.71	752.71	752.71	752.71	752.71
Water (lit)	197.4	197.4	197.4	197.4	197.4	197.4	197.4

Table: 3.7 Mix proportions details

Mix	Mix details
A0	NORMAL CONCRETE (100%)
A1	95% Cement + 5% Palm oil fuel ash
A2	92.5% Cement + 7.5% Palm oil fuel ash
A3	90% Cement + 10% Palm oil fuel ash
A4	87.5% Cement + 12.5% Palm oil fuel ash
A5	85% Cement + 15% Palm oil fuel ash
A6	82.5% Cement + 17.5% Palm oil fuel ash

Batching and Mixing

Batching is process of measuring the quantities of concrete either by volume or by mass for preparation of concrete mix. In this weight batching method is adopted to measure the quantities of fine aggregate, cement, coarse aggregate, and POFA. For mix proportion for design were measured by using weighing balance. The ingredients of concrete in the required quantities were enhanced into the capacity laboratory concrete mixer. After through mixing i.e., having achieved uniform colour, workable consistency to concrete, the concrete was shipped into tray for casting specimens.

Casting and Curing of Specimens

As per IS standard cubes, cylinders, and beams were casted i.e., casting in moulds was done by three layers and compacted with tamping rod by giving 25 blows. Before placing the concrete in moulds a thin coat of oil was applied for the walls of the mould inside for easy removal.

The concrete specimens were air dried for 24hours and then the specimens are remoulded and then kept for curing. Making were done on the specimens to identify the percentage of POFA and the specimens were placed in water tank for curing. All specimens have been cured for desired age and then tested.

IV EXPERIMENTAL INVESTIGATION

In the present investigation according to IS standards the following dimensioned specimens were casted

1. 150mm×150mm ×150mm of cubes,
2. 150mm ×300mm of cylinders, and
3. 700mm×150mm×150mm of beams.

The following are the tests which was conducted in the project:

Strength tests:

- Compressive strength test
- Split tensile strength test
- Flexural strength test

Durability tests:

- Sorptivity
- RCPT

COMPRESSIVE STRENGTH TEST

Concrete cubes ofsizes150mm×150mm×150mm were tested for crushing strength. Compressive strength depends on loads of factor such as w/c ratio, cement strength, excellence of concrete material and excellence control during manufacture of concrete. These cubes are tested by compression testing machine after 7 days, 14 days or 28 days curing. The sample is placed centrally on the base plate of machine and the load have to be apply gradually at the rate of 140 kg/cm^2 per minute till the specimen fails.

SPLIT TENSILE STRENGTH TEST

The tensile strength of concrete is one of the basic and important properties. Splitting tensile strength test on concrete cylinder is a method to determine the tensile strength of concrete. The concrete is very weak in tension due to its brittle nature and is not expected to resist the direct tension. The concrete develops cracks when subjected to tensile forces. Thus, it is necessary to determine the tensile strength of concrete to determine the load at which the concrete members may crack.

The splitting of cylinder is shown in figure. The following relation is used to find out the spilt tensile strength of cylinder

$F_t = \frac{2P}{\pi DL}$

Where F_t is split tensile strength,

P= Ultimate load in KN

L = Length of the cylinder in mm, D = Diameter of the cylinder in mm.

FLEXURE STRENGTH TEST

Flexural strength test on concrete beam to determine the strength of concrete. Flexural strength test was conducted by using the method prescribed by IS 516 – 1959. Beams of dimension 700mm × 150mm × 150mm were used for this test, the test specimen is placed in the machine at the bearing surfaces of the supporting and loading rollers.

Modulus of rupture f = PL/BD^2

P is the load in KN.

L, B is the length and breadth in mm.

D is the depth in mm.

f is the flexure strength in N/mm^2

SORPTIVITY TEST

The sorptivity can be determined by the measurement of the capillary rise absorption rate on reasonably homogeneous material. Water was used of the test fluid. The cylinders after casting were immersed in water for 90 days curing. The quantity of water absorbed in time period of 30 minutes was measured by weighting the specimen on a top pan balance weighting upto 0.1 mg. surface water on the specimen was wiped off with a dampened tissue and each weighting operation was completed within 30 seconds. Sorptivity (S) is a material property which characterizes the tendency of a porous material to absorb and transmit water by capillarity. The cumulative water absorption (per unit area of the inflow surface) increases as the square root of elapsed time (t)

I=S.t½ therefore S=I/ t½

Where;

S= sorptivity in mm,

t= elapsed time in mint.

I=Δw/Ad Δw= change in weight = W2-W1

W1 = Oven dry weight of cylinder in grams

W2 = Weight of cylinder after30 minutes capillary suction of water in grams.

A= surface area of the specimen through which water penetrated.

d= density of water.

RCPT (RAPID CHLORIDE PERMEABILITY TEST)

Corrosion of reinforcing steel due to chloride ingress is one of the most common environmental attacks that lead to the deterioration of concrete structures. Corrosion-related damage to bridge deck overlays, parking garages, marine structures, and manufacturing plants results in millions of dollars spent annually on repairs. This durability problem has received widespread attention in recent years because of its frequent occurrence and the associated high cost of repairs. Chlorides penetrate crack-free concrete by a variety of mechanisms: capillary absorption, hydrostatic pressure, diffusion, and evaporative transport. Of these, diffusion is predominant. Diffusion occurs when the concentration of chloride on the outside of the concrete member is greater than on the inside. This results in chloride ions moving through the concrete to the level of the rebar. When this occurs in combination with wetting and drying cycles and in the presence of oxygen, conditions are right for reinforcement corrosion. The rate of chloride ion ingress into concrete is primarily dependent on the internal pore structure.

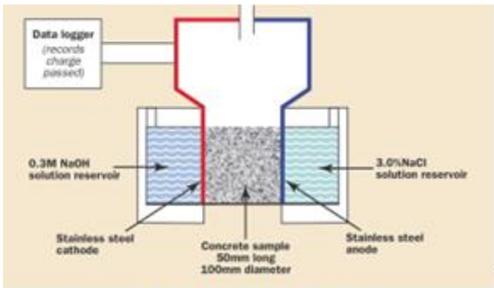


Fig.: The RCPT setup

Fig.: Test specimens for sorptivity test

V. TEST RESULTS

In this project we caught up with the mechanical strength properties like compressive strength, split tensile strength, and flexural strength, along the durability tests Sorptivity Test and RCPT (Rapid Chloride Permeability Test). The results completed in the present investigation are reported in the form of Tables and Graphs for various percentage of POFA as a partial replacement to cement. The following are the percentages replacement of cement i.e. 5%, 7.5%, 10%, 12.5%, 15%, and 17.5%.

COMPRESSION TEST RESULTS

Table .1: COMPRESSION TEST RESULT

Mix ID	% Palm Oil Fuel Ash	Compressive strength at Age of 14 days, MPa	Compressive strength at Age of 28 days, MPa	Compressive strength at Age of 56 days, MPa	Compressive strength at Age of 90 days, MPa
A0	0	19.2	28.4	30.2	31.8
A1	5	25.2	29.2	30.4	32.4
A2	7.5	19.8	26.4	29.5	33.0
A3	10	29.4	30.2	32.4	36.5
A4	12.5	30.2	35.3	38.1	44.8
A5	15	27.5	29.5	32.8	35.4
A6	17.5	25.4	28.6	30.1	35.2

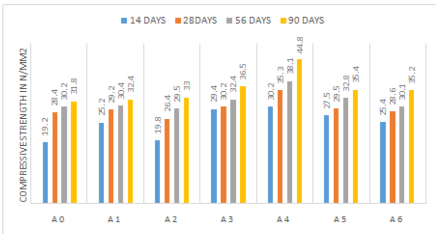


Fig.5.1: Compressive Strength test results

SPLIT TENSILE STRENGTH TEST RESULTS

SPLIT TENSILE STRENGTH TEST RESULT

Mix ID	% Palm Oil Fuel Ash	Compressive strength at Age of 14 days, MPa	Compressive strength at Age of 28 days, MPa	Compressive strength at Age of 56 days, MPa	Compressive strength at Age of 90 days, MPa
A0	0	2.68	3.5	3.62	3.70
A1	5	3.32	3.6	3.85	3.98
A2	7.5	3.37	3.5	4.8	4.84
A3	10	3.62	4.07	4.75	4.85
A4	12.5	3.85	4.56	5.14	5.32
A5	15	2.78	3.56	4.24	4.38
A6	17.5	2.05	2.89	3.58	3.62

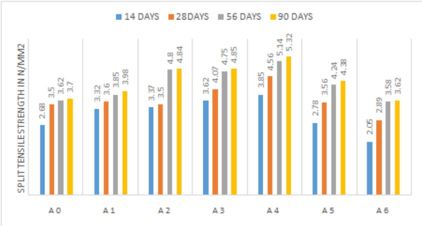


Fig.5.2: Split Tensile Strength test results

FLEXURAL STRENGTH TEST RESULTS

Table 5.3.: FLEXURAL STRENGTH TEST RESULT

Mix ID	% Palm Oil Fuel Ash	Compressive strength at Age of 14 days, MPa	Compressive strength at Age of 28 days, MPa	Compressive strength at Age of 56 days, MPa	Compressive strength at Age of 90 days, MPa
A0	0	9.8	10.4	11.2	11.9
A1	5	10.9	11.84	12.23	12.4
A2	7.5	10.92	12.12	12.68	12.8
A3	10	11.68	13.48	14.2	14.8
A4	12.5	13.2	14.02	15.38	15.5
A5	15	10.85	11.65	12.2	13.2
A6	17.5	10.26	11.25	11.82	12.24

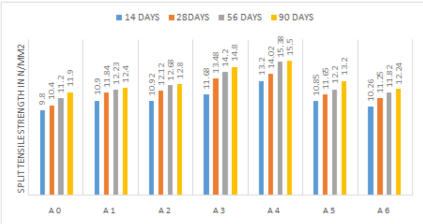


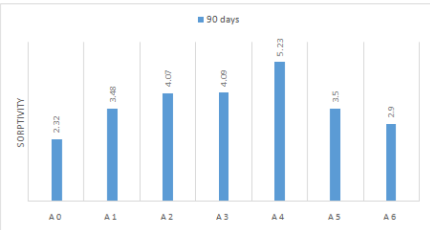
Fig.5.3: Flexural Strength test results

5.3. DURABILITY TESTS

5.3.1. SORPTIVITY TEST RESULTS

Table 5.4.: SORPTIVITY TESTRESULT

Mix ID	% Palm Oil Fuel Ash	Dry wt. in grams (W1)	Dry wt. in grams (W1)	Sorptivity value in 10^{-5} mm/min$^{0.5}$
A0	0	979	980	2.32
A1	5	948.5	950	3.48
A2	7.5	908.5	910.35	4.07
A3	10	909.0	911.01	4.09
A4	12.5	918	920.25	5.23
A5	15	918	920	3.50
A6	17.5	877	878.25	2.90



5.3.2. RCPT (RAPID CHLORIDE PERMEABILITY TEST) TEST RESULTS

Table 5.5.: RCPT TESTRESULT

MIX ID	% Palm Oil Fuel Ash	CHARGE PASSED (COULOMBS)		
		28 DAYS	60 DAYS	90 DAYS
A0	0	1652.5	1286.7	1186.7
A1	5	1652.5	1286.7	1086.7
A2	7.5	1435.4	1058.5	958.5
A3	10	1173.6	953.55	852.5
A4	12.5	1058.7	735.89	653.2
A5	15	1175.6	985.3	852.2
A6	17.5	1178.5	990.2	852.3

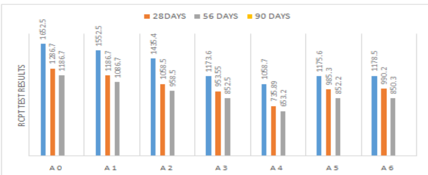


Fig.5.5: RCPT test results

CONCLUSION

Based on limited experimental investigation concerning the strength tests i.e. compression, split tensile and flexural strength along with the durability tests i.e. sorptivity and RCPT of concrete, the following observations are made regarding the resistance of partially replaced POFA with percentage of replacement in M25 concrete:

The following salient conclusions can be drawn based on the findings from the review on the utilization of POFA @ percentages in concrete:

- The use of POFA as a supplementary cementing material in concrete can solve the disposal and health problems caused by the ash generated in palm oil industry, decrease the environmental pollution caused by the cement factories, and reduce the cost of concrete.
- POFA can be used as a supplementary cementing material with a content up to 17.5% by weight of cement. However, the optimum POFA content is 12.5%. A POFA content higher than 12.5% may adversely affect the properties of concrete. It mean the strength decreases eventually.
- From the above results it has been drawn that at 12.5% of palm oil fuel ash there is increase in the compressive strength, after the 12.5% increase in percentage leads to decrease in the strength of the cube.
- By using POFA tensile strength is higher than the normal concrete, particularly at 12.5% of mix the tensile strength also increases accordingly, after this value increase in percentage of POFA makes the decrement in the tensile strength.
- From this report it is noted that the flexural of normal concrete is crossed by adding POFA @ percentages, the final inference is that at 12.5% replacement of POFA with cement will give maximum values, then after the value decreases with increment in percentage of POFA in concrete.
- The water sorptivity of POFA concrete shows higher sorptivity than traditional concrete and we get maximum value particularly with 12.5% replacement of POFA.
- The chloride permeability is more in case of Normal concrete then it is decreased while adding POFA 5%, 7.5%, 10%, 12.5%, 15%, 17.5% to the concrete for 28 days, 60 days and 90 days of curing. The chloride permeability of concrete with 12.5% of cement with POFA is less while compared with the all proportions for 28, 60, 90 days

SCOPE OF FUTURE WORK

- Further research should be carried out to confirm the beneficial effects of POFA on several concrete properties and durability issues, and thus to encourage the use of POFA in concrete.

- Additional research should be conducted to extend the use of POFA in high performance and self-consolidating concretes.

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