A STUDY ON MECHANICAL PROPERTIES AND CAPILLARY RISE OF CONCRETE WITH PALM OIL FUEL ASH AS CEMENT REPLACEMENT

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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. Palm oil fuel ash which is obtained by burning palm fruit and dry leaves of palm oil tree in palm oil mills is also used to control heat of hydration effect on concrete, after pulverizing and making it into a fine powder. In this study cement is being replaced with pal oil fuel ash by 0%, 2%, 6%, 8%, 10%, 12%, 14% and the strength tests like compressive strength test, tensile strength test, flexural strength test and Sorptivity are performed and are compound with the results of conventional concrete of grade M25 for 14 and 28, 56, 90 days. Satisfactory results have been found at a percentage of 12%. Increase in strength is found at this percentage.

I. INTRODUCTION

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.

Scope of Study

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 composes 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 mix comprises of 0%, 2%, 6%, 8%, 10%, 12% and 14% from the total, weight of ordinary Portland cement.

The concrete was cast and poured into mould and the hardened concrete was taken out from the mould after 24 hours. Then, the hardened concrete was cured in water. For 14, 28, 56 and 90 days for all mixes. The compressive strength tests were conducted after the specimens matured due to curing period for entire specimens. The strength tests called compressive strength, tensile strength and flexural strength test and also durability test Sorptivity

II LITERATURE REVIEW

20th century has been a meaningful one for researchers from Faculty of Civil Engineering of Malaysia when they successfully discovered that the palm oil fuel ash that been considered worthless can actually be made used in construction industry specifically in concrete technology. Starting from the time onwards until this century the POFA use in concrete production continued to be studied and revealed by researchers in Asian region especially.

Until now, some researchers Sata et al., (2004)) that has been diligently studying on POFA use has able to successfully reveal the benefits of POFA in concrete technology in terms enhancement towards the properties of concrete either strength or durability aspect.

Abu the pioneer in POFA research has. embarked on studying agricultural ash in Malaysia and finally acknowledged that POFA is a pozzolanic material and able to be replace as partial cement replacement up to *35%* in mortar mix, that could exhibit similar strength as control mortar.

Abmad et al., one of the potential recycles material from palm oil industry is palm oil fuel ash which contains siliceous compositions and reacted as pozzolans to produce a stronger and denser concrete. There are many experimental works conducted by introducing recycled material likes palm oil fuel ash (POFA) as a replacement of the cement with different percentages to improve the properties of concrete.

III: MATERIALS AND METHODOLOGY

CEMENT

Cement is the most important material in the concrete and it act as the binding material. Ordinary Portland cement manufactured by Ultra Tech cements is used in this investigation. Properties of cement was shown in table.

S.No.	CHARACTERISTICS	VALUE
1	SPECIFIC GRAVITY	3.18
2	NORMAL CONSISTENCY	30%
3	INITIAL SETTING TIME	30 minutes
4	FINAL SETTING TIME	160 minutes

AGGREGATES

The basic objective in proportioning any concrete is to incorporate the maximum amount of aggregate and minimum amount of water into the mix, and thereby reducing the cementious material quantity, and to reduce the consequent volume change of the concrete.

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. The properties of FA are shown in Table

S.No.	CHARACTERISTICS	VALUE
1	ZONE	II
2	SPECIFIC GRAVITY	2.64
3	DENSITY	13.4KN/m^3

COARSE AGGREGATE

Selection of the maximum size of aggregate mainly depends on the project application, workability, segregation, strength and availability. In this research aggregates that are available in the crusher nearby was used. The maximum size of aggregate was varying between 26 -12.5 mm. In this project 20mm size aggregate has been used. Gravels constitute the majority of coarse aggregate used in concrete with crushed stone making up most of the remainder. The properties of CA are shown in Table

S.No.	CHARACTERISTICS	VALUE
1	NOMINAL SIZE	10mm
2	SPECIFIC GRAVITY	2.86
3	DENSITY	1625.83Kg/m^3

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

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	POTASSIUM 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 mixes contained palm oil fuel ash. The following table

Mix proportions values.

Mixture	A0	A1	A2	A3	A4	A5	A6	A7
Cement	448.6	439.62	430.65	421.6	412.72	403.74	394.77	385.8
Palm oil fuel ash (%)	0%	2%	4%	6%	8%	10%	12%	14%
Palm oil fuel ash (Kg/m^3)	0	8.975	17.944	26.916	35.88	44.86	53.83	62.80
Coarse Aggregate (Kg/m^3)	1064.65	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	752.71
Water (lit)	197.4	197.4	197.4	197.4	197.4	197.4	197.4	197.4

Mix proportions details

Mix	Mix details
A0	NORMAL CONCRETE (100%)
A1	98% Cement + 2% Palm oil fuel ash
A2	96% Cement + 4% Palm oil fuel ash
A3	94% Cement + 6% Palm oil fuel ash
A4	92% Cement + 8% Palm oil fuel ash
A5	90% Cement + 10% Palm oil fuel ash
A6	88% Cement + 12% Palm oil fuel ash
A7	86% Cement + 14% 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 test:

- Sorptivity

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)
$I=S.t^{½}$ therefore $S=I/t^{½}$
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.

Fig.: Test specimens for sorptivity test

V. TEST RESULTS

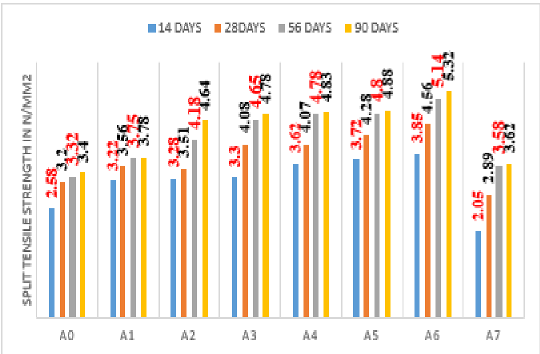
In this project we caught up with the mechanical strength properties like compressive strength, split tensile strength, and flexural strength, along the durability test Sorptivity Test. The results completed in the present investigation are reported in the form of Tables and Graphs for various percentage of POFA as a partial replacement to cement. The following are the percentages replacement of cement i.e. 0%, 2%, 4%, 6%, 8%, 10%, 12% and 14%.

COMPRESSION TEST RESULTS

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	2	20.8	24.2	26.8	28.9
A2	4	24.2	28.2	30.8	31.4
A3	6	24.9	26.48	30.0	32.80
A4	8	29.4	30.12	32.14	36.51
A5	10	29.89	31.8	33.3	38.2
A6	12	30.2	35.3	38.1	44.8
A7	14	25.4	28.6	30.1	35.2

SPLIT TENSILE STRENGTH TEST RESULTS

Mix ID	% Palm Oil Fuel Ash	Tensile strength at Age of 14 days, MPa	Tensile strength at Age of 28 days, MPa	Tensile strength at Age of 56 days, MPa	Tensile strength at Age of 90 days, MPa
A0	0	2.58	3.2	3.32	3.40
A1	2	3.22	3.56	3.75	3.78
A2	4	3.28	3.51	4.18	4.64
A3	6	3.30	4.08	4.65	4.78
A4	8	3.62	4.07	4.78	4.83
A5	10	3.72	4.28	4.80	4.88
A6	12	3.85	4.56	5.14	5.32
A7	14	2.05	2.89	3.58	3.62



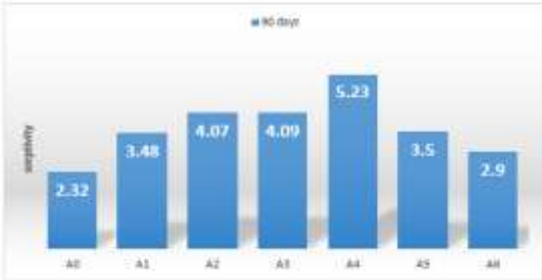
FLEXURAL STRENGTH TEST RESULTS

Mix ID	% Palm Oil Fuel Ash	Flexural strength at Age of 14 days, MPa	Flexural strength at Age of 28 days, MPa	Flexural strength at Age of 56 days, MPa	Flexural strength at Age of 90 days, MPa
A0	0	3.48	4.02	5.62	6.2
A1	2	3.68	4.35	5.78	7.09
A2	4	3.8	4.82	6.2	8.32
A3	6	3.85	4.95	6.38	8.89
A4	8	4.2	5.0	6.57	9.82
A5	10	4.6	5.21	6.78	10.83
A6	12	4.9	5.38	7.95	11.68
A7	14	4.6	5.2	6.58	10.56

DURABILITY TESTS

SORPTIVITY TEST RESULTS

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	2.22
A1	2	948.5	950	3.48
A2	4	908.5	910.35	4.17
A3	6	909.0	911.01	4.29
A4	8	918	920.25	4.31
A5	10	918	920	5.43
A6	12	867	878.25	3.60
A7	14	879	882.0	2.80



CONCLUSION

Based on limited experimental investigation concerning the strength tests i.e. compression, split tensile and flexural strength along with the durability test i.e. sorptivity 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.
- ❖ The physical and chemical properties of POFA are favorable for concrete production. POFA can be used to substitute a significant amount of Portland cement without affecting the properties and durability of concrete.
- ❖ POFA can be used as a supplementary cementing material with a content up to 14% by weight of cement. However, the optimum POFA content is 12.0%. A POFA content higher than 12.0% may adversely affect the properties of concrete. It means the strength decreases eventually.

- The fineness of POFA plays an important role in concrete. The high fineness of POFA improves its micro-filing ability and pozzolanic activity, and thus contributes to improve the hardened properties and durability of concrete.
- POFA concrete shows a comparable and sometimes a better performance than OPC concrete.
- In making this no advanced tools are required and it is easy to use this also it reduces the cost of concrete as there is replacement of cement with palm oil fuel ash.
- With this there will be also reduction in the damage of environmental disturbances created by the spread of palm oil fuel ash.
- From the above results it has been drawn that at 12.0% of palm oil fuel ash there is increase in the compressive strength, after the 12.0 % 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% 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% 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% replacement of POFA.

The chloride permeability is more in case of Normal concrete then it is decreased while adding POFA 0%, 2%, 4%, 6%, 8%, 10%, 12% and 14% to the concrete for 28 days, 60 days and 90 days of curing. The chloride permeability of concrete with 12.0% of cement with POFA is less while compared with the all proportions for 28, 60, 90 days

SCOPE OF FUTURE WORK

- SCC is favorably suitable especially in highly reinforced concrete members like bridge decks or abutments, tunnel linings or tubing segments, where it is difficult to vibrate the concrete, or even for normal engineering structures. So, introducing POFA in SCC leads to better results.
- The improved construction practice and performance, combined with the health and safety benefits, make POFA a very attractive solution for both precast concrete and civil engineering construction.

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