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

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ABSTRACT: The use of pozzolanic materials in substantial development is expanding, and this pattern is required to proceed in the years ahead due to innovative progression and supportable turn of events. Palm Oil Fuel Ash (POFA) is utilized as a beneficial cementitious material to the substantial. Palm Oil Fuel Ash (POFA), a waste material got from consuming of palm oil husk and palm piece shell as fuel in palm oil factory boilers, which has been distinguished as a decent pozzolanic material. Palm Oil Fuel Ash has a place with pulverized fuel Ash accordingly it has high silica content in it and makes the concrete impenetrable, and prompts control in Heat of hydration which further maintains a strategic distance from higher shrinkage. In this investigation, the strength properties of POFA cement of M35 grade in various supplanting level and furthermore contrasts and OPC. Concrete specimens containing 5%, 10%, 15% and 20% POFA were made at a water-concrete proportion of 0.45. In this way adding glass fibre and steel fibre in ideal amount to improve the strength and its Strength properties like compressive strength, flexural Strength and split tensile strength will likewise be contemplated, and contrasted and that of cement containing 100% OPC as control.

KEYWORDS: Palm Oil Fuel Ash, Pozzolanic material, Partial replacement of cement, Pulverized fuel ash

I. INTRODUCTION

Concrete is a cover material utilized in development ventures. It is realized that there are a few reasons for an unnatural weather change, including CO_2 from concrete. Around 5% of complete CO_2 emanation is delivered to environment, with about 0.7–1.1 ton of CO_2 being discharged for each huge load of concrete creation. To take care of this issue, palm oil fuel debris utilized as the most appropriate and less expensive elective material for concrete in concrete. One of the potential reuse materials from palm oil industry is palm oil fuel Ash. Palm oil is separated from the leafy foods of the palm oil tree. After the extraction cycle, side-effects, for example, palm oil filaments, shells, and void natural product informal breakfasts are scorched as biomass fuel to bubble water, which creates steam for power and the extraction interaction in palm oil plants. The silica oxide content in POFA can respond with calcium hydroxide (Ca (OH)₂) from the hydration cycle which is decayed to concrete and the pozzolanic responses produce more calcium silicate hydrate (C-S-H) which is a gel compound just as diminishing the measure of calcium hydroxide. Along these lines, this adds to the strength of the substantial consequently produce more grounded and denser cement. Consequently, Concrete examples containing 5%, 10%, 15% and 20% POFA were made at a water-concrete proportion of 0.45 with optimum level of steel fibre and glass fibre to the mixture is added to enhance its strength. Finally, Strength properties like compressive strength, flexural Strength and Split tensile strength.

II. LITERATURE REVIEW

A literature review is an objective, critical summary of published research literature relevant to a topic under consideration for research.

"Environmental benefits of Incorporating Palm oil fuel ash in cement concrete and cement mortar" by G AJokhio, H M Hamada, "The British University in Dubai and University Malaysia Pahang" in 2020, deals withAdvantages of POFA as a partial replacement of cement in concrete production to increase its strength and durability. "Effect of high-volume ultrafine palm oil fuel ash on the engineering and transport properties of concrete" by Hussein M. Hamada, Alya'a A. Al-attar, "University Malaysia Pahang, Northern Technical University" in2019, deals withthe SEM/EDX result of UPOFA it has a porous texture and semicircular and angular shapes, concrete containing UPOFA recorded low water absorption, comparative study details of GPOFA and UPOFA. "Optimization of Micro and Nano Palm Oil Fuel Ash to



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Determine the Carbonation Resistance of the Concrete in Accelerated Condition" by Wei Le Tang , Han-Seung Lee, "Australia and CurtinUniversity Malaysia in Miri, Malaysia" in 2019, studied withChemical composition of raw POFA and carbonation resistance of concrete are studied."Effect of palm oil fuel ash on compressive strength of palm oil boiler stone lightweight aggregate concrete" by K Muthusamy, N A Zamri A Kusbiantoro , Institute of physics Conf. Series: Materials Science and Engineering, in 2018 deals with Workability properties such as slump value of POFA are taken."Palm Oil Fuel Ash as A Cement Replacement in Concrete" byJonida Pone, Ahmed Ash, 2018 deals with Specimens made with 2.5% and 5% POFA replacement had higher strengths compared to the control at 7 and 28 days; very similar behaviour to silica fume.

III. COLLECTION OF SAMPLES AND MATERIAL TESTING

1. Cement

Ordinary Portland cement of 43 grade available in local market is used in the investigation. The cement used has been tested for various properties as per IS: 4032. The specific gravity of cement was 3.15 and fineness was 3200/cm²/g. 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.

2.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. The specific gravity of coarse aggregate was 2.62 and fineness modulus was 4.17.

3. 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, here River sand was used as fine aggregate. The specific gravity of fine aggregate was 2.64 and fineness modulus of 4.37 was found in the investigation.

4. Palm Oil Fuel Ash

Palm kernel shells along with fibre wastes are burned together in chimneys to produce heat at a temperature of 450° . 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 and the specific gravity of palm oil fuel ash is 2. 9.

5. Steel fiber

Fiber is a small piece of reinforcing material possessing certain characteristics properties. They can be circular or flat. The fiber is often described by a convenient parameter called "aspect ratio". The steel fiber type used here is hooked end with 30mm fiber length and 0.5mm diameter. The aspect ratio of the fiber is the ratio of its length to its diameter and generally the aspect ratio ranges from 30 to 150 and here the aspect ratio of the steel fiber is 60.

6. Glass fiber

It is material made from extremely fine fibers of glass Fiberglass is a lightweight, extremely strong, and robust material. The glass fiber type used here is A-R glass with 50mm fiber length and 0.1mm diameter. The aspect ratio of the glass fiber is 500.

7.CHARACTERISTICS OF PALM OIL FUEL ASH

Palm Oil Fuel Ash is a main chemical composition of Silicon dioxide particles with high fineness POFA is a good pozzolanic material. The average physical and chemical characteristics of Palm Oil Fuel Ash waste are as follows:

Table 11 Hysical Characteristics of 1 and On Fuel Ash								
Property	Cement	POFA	Testing method					
Specific gravity	3.15	2.9	-					
Setting time			IS:4031 1088(part 4)					
Initial (min)	50	90	13.4031 – 1988(part 4)					
Final (min)	460	292						
Fineness(%)	3.6	2	IS:4031 – 1968(part 2)					
Soundness(mm)	0.5	0.45	IS:4031 – 1968(part 3)					

Table 1 Physical Characteristics of Palm Oil Fuel Ash



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Property	OPC(%)	POFA (%)	Testing method
- F = -5	()	- ()	
SiO ₂	16.4	62.5	IS: 3812(part II)-2013
CaO	69.6	7.7	IS: 3812(part II)-2013
Al ₂ O ₃	4.7	4.68	IS: 3812(part II)-2013
Fe ₂ O ₃	3.7	3.73	IS: 3812(part II)-2013
MgO	1.22	3.69	IS: 3812(part II)-2013
SO ₃	2.65	2.06	IS: 3812(part II)-2013
K ₂ O	0.67	9.0	IS: 3812(part II)-2013
LOI	2.2	6.5	IS: 3812(part II)-2013
$\mathbf{SiO}_2 + \mathbf{Al}_2\mathbf{O}_3 + \mathbf{Fe}_2\mathbf{O}_3$	24.8	70.91	IS: 3812(part II)-2013

Table 2 Chemical characteristics of Ground Palm Oil Fuel Ash

III. METHODOLOGY

After collecting literature reviews and with the reference, samples are collected. The physical and chemical characteristics of Palm oil fuel ash of them are studied and their test results are tabulated. The Optimum level of cement replacement by palm oil fuel ash are calculated by compression test and to enhance the concrete strength minimum amount of Glass fibre and steel fibre are added and compared with test results.

IV EXPERIMENTAL TECHNIQUES

1.CASTING OF SPECIMENS

The 150 mm size concrete cubes, concrete beams of size 100 mm x 100 mm x 500 mm and cylinders of 150×300 mm size were used as test specimens to determine the compressive strength and flexural strength and Splitting Tensile Strength respectively. After casting, all the test specimens were finished with a steel trowel. All the test specimens were stored at temperature of about 30°C in the casting room and are demoulded after 24 hours for water curing. When the test age is reached, they are tested for Compressive strength, Splitting tensile strength and Flexural Strength

1 able 5 Mix proportion by ratio									
Details	MP1(CB)	MP2	MP3	MP4	MP5				
Cement	1.0	1.0	1.0	1.0	1.0				
Fine aggregate	1.89	2.10	2.11	2.10	1.88				
Coarse aggregate	3.7	3.46	3.5	3.6	3.7				
Water	0.4	0.4	0.4	0.4	0.4				

2. COMPRESSIVE STRENGTH TEST

Compressive strength test was performed on compression testing machine using the samples. The comparatives studies were made on the partial replacement of cement with Palm Oil Fuel Ash as the experimental investigation consists of casting and testing of 9 sets along with control mix. By taking different percentage of POFA, along with steel & Glass fibers individually as a partial replacement of cement will be replaced accordingly with the different percentages by weight of ash and different percentages by weight of steel fiber and Glass fiber. The concrete was filled in layers and compacted. The specimens were removed after 24 hours and submerged in water for curing. After a curing period of 7 and 28 days specimens were taken out andtested. The compressive strength of cubes gives us the information of the potential strength of the concrete mix from which it is sampled. After curing for required period the specimen is to be tested using compressive testing machine.

Compressivestrength(N/mm²) = Maximum load (N) / Cross sectional area (mm²)



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Table No 4 Compressive strength test result

Sl.no	Samples	Replacement of Palm Oil Fuel Ash (%)	Average ultimate compressive strength (N/mm ²)	
			(7 days)	(28 days)
1.	MP1(CB)	-	25.6	43.75
2.	MP2	5%	26.5	44.45
3.	MP3	10%	27.15	44.56
4.	MP4	15%	28.36	47.04
5.	MP5	20%	26.5	43.51

Figure 1 Compressive strength with % POFA



From the test results, **the optimum percentage replacement of POFA was found to be at 15%**. It is observed that the properties of can be maintained with **POFA as partial replacement of cement at15%**.

Sl.No	POFA	% Of	7days(N/mm ²)	28	S1.	POFA	%	7 days	28days
	%	Steelfiber		days(N/mm ²)	No	%	Of	(N/mm^2)	(N/mm^2)
							glass	(10,11111)	(10,11111)
							fiber		
1	15	0	31.6	44.75	1	15	0	31.6	44.75
2	15	0.5	35.32	48.61	2	15	0.1	34.88	47.16
3	15	1	36.41	49.43	3	15	0.2	36.24	50.23
4	15	1.5	37.3	51.13	4	15	0.3	35.14	48.22
5	15	2	35.41	48.31	5	15	0.4	34.33	47.74

Table No 5 Compressive strength with steel fibre and Table 6 Compressive strength with POFA and glass fibres

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Figure 2 Compressive strength with POFA and steel fibres for 7 and 28days and Figure 3 Compressive strength with POFA and glass fibres for 7 and28days



3. SPLIT TENSILETEST

This is an indirect method of testing tensile strength of concrete. In direct tensile test, it is impossible to apply true axial load. There is always some eccentricity present. Cylinder specimen of size 300mm height and 150mm diameter are to be cast for the mix proportion. After testing the concrete (split tensile strength) for M35 grade concrete separately for replacement of POFA, glass & steel fiber by cement respectively finally combined percentage of POFA & steel fiber mix, POFA & glass fiber mix in which maximum strength is obtained was used to get optimizedstrength. After curing for required period the specimen is to be tested using compressive testing machine.

	Table 7	Spli	t tensile streng	th with	POFA	
DOD	o./				•	

S. No	POFA %	7 days (N/mm ²)	28 days (N/mm ²)
1	0	4.95	5.54
2	5	5.11	5.7
3	10	5.2	5.8
4	15	5.4	5.9
5	20	5.17	5.65







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Table 8 Split tensile strength with POFA and steel fibres and Table 9Split tensile strength with POFA and glass fibres

S.No	POFA	% OfSteel	7 days	28 days	S.No	POFA %	%	7 days	28 days
	%	fiber	(N/mm^2)	(N/mm^2)			OfGlassfiber	(N/mm ²)	(N/mm^2)
1	15	0	3.95	4.54	1	15	0	4.95	5.54
2	15	0.5	4.51	4.87	2	15	0.1	5.48	5.96
3	15	1.0	4.67	4.99	3	15	0.2	5.63	6.12
4	15	1.5	4.73	5.22	4	15	0.3	5.5	5.89
5	15	2.0	4.54	5.09	5	15	0.4	5.34	5.79

Figure 5Split tensile strength with POFA and steel fibres for 7 and 28days and Figure 6 Split tensile strength with POFA and glass fibres for 7 and 28days



4. FLEXURAL STRENGTH TEST

Also known as modulus of rupture or bend strength. The flexural strength represents the highest stress experienced within the material at its moment of rupture. It is also defined as a material's ability to resist deformation under load. The Casted Beam would be subjected to 3-point Flexure test in the testing machine.Flexural test was performed on beams of $(500 \times 100 \times 100)$ mm size by placing them on universal find out the flexural strength. After testing the concrete (flexural strength) for M35 grade concrete separately for replacement of POFA, glass steel fiber by cement respectively finally combined percentage of ash & steel fiber mix, slag & glass fiber mix in which maximum strength is obtained was used to get optimized strength.

11 DODA

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	Table 10 Flexural strength with POFA								
S.No	POFA%	7 days (N/mm ²)	28 days (N/mm ²)						
1	0	5.97	6.95						
2	5	6.01	7.02						
3	10	6.12	7.21						
4	15	6.42	7.23						
5	20	6.01	6.93						

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Table 11 Flexural strength for steel fibre and Table 12 Flexural strength for glass fibres

S.NO	POFA %	% OF STEEL FIBER	7 days (N/mm ²)	28 days (N/mm ²)	S.NO	POFA %	% Of Glass Fiber	7 days (N/mm ²)	28days (N/mm ²)
1	15	0	4.97	5.95	1	15	0	5.97	6.95
2	15	0.5	5.49	6.18	2	15	0.1	6.54	7.26
3	15	1	5.69	6.31	3	15	0.2	6.63	8.05
4	15	1.5	6.08	7.14	4	15	0.3	6.56	7.12
5	15	2	5.54	6.34	5	15	0.4	6.35	7.06

Figure 8 Flexural strength with POFA and steel fibres for 7 and 28days and Figure 9Flexural strength with POFA with glass fibres for 7 and 28 days



IV. CONCLUSION

The supplanting of concrete with 5%,10%,15% and 20% Palm Oil Fuel Ash and the mix design of cement are determined, henceforth by the test outcomes the most extreme strength of cement accomplished at the phase of 15% substitution of palm oil fuel ash. The substantial combination with 15% Palm oil fuel ash and 1.5% steel fiber has the best in compressive strength, Flexural strength and Split Tensile strength. Though the substantial blend with 15% Palm oil fuel ash and 0.2% of Glass fibre has the best in compressive strength, Flexural strength as the best in compressive strength and Split tensile strength, henceforth in this examination steel fibre is more compelling than glass fibre. Palm oil fuel ash alongside steel fiber and

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glass fiber can be utilized in concrete as an appropriate substitution of concrete to make the substantial stronger in compression and strain to make substantial more efficient.

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