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Performence Evaluation of Concrete on Partial Replacement of Cement and Fine Aggregate

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ABSTRACT

Concrete is a widely used composite construction material. Fine aggregate plays a vital role in providing adequate properties to Concrete in its both fresh and hard states. Replacement of river sand (Fine aggregate) by Robo Sand involves determination of some major properties of concrete likeSplit tensile strength, Flexural strength, Compressive strength. Based on various proposed studies, the quality of Robo Sand is found equivalent to that of Natural sand.The non-renewable nature of Natural sand and an exponential increase in demand for natural sand in construction industry was the main cause of concern in developing the manufactured sand. River sand, being one of the basic vital ingredients in the manufacturing of Concrete has become highly scarce and expensive due to its demand. Therefore it became an urgent necessity to find a substitute for River sand. Hence, the crusher dust which is also called as Robo Sand or M Sand can be used as an alternative material for the River sand. The properties of Robo Sand are similar to that of the properties of river sand and hence M Sand is accepted as a building material.Palm Oil Fuel Ash (POFA) has been widely used as a Supplementary Cementitious Material (SCM) in recent years in Construction Industry. POFA is a byproduct obtained when various Palm materials such as Palm kernel shell, Palm oil fiber, Palm oil husk, etc. are subjected to incineration in a Palm oil mill for the purpose of generation of electricity in Palm oil extraction process. As POFA is cannot be reused or recycled in any work, it can be used as a substitute product in replacing the cement partially because it possess high amounts of Silica in it. The partial replacement ofCement with POFA in Concrete improves its workability, durability, compressive strength and reduce shrinkage, segregation and permeability, and is capable of producing durable, economic and light weight Concrete.The durability studies were also carried out to know the performance of Concrete under adverse environment like Sulphuric Acid (H2SO4) and Hydrochloric Acid (HCL). Conclusions are made from the several results and the discussions there on to identify the effect of partial replacement of Cement by POFA and Fine Aggregate with Robo Sand in the design Concrete mix. The results conclude that, the use of POFA-Robo Sand Concrete (POFARSC) has improved the performance of Concrete under various conditions.

Keywords: Hydrochloric Acid, Palm Oil Fuel Ash (POFA), Robo Sand, Sulphuric Acid

INTRODUCTION

The Cement manufacturing Industries and usage of Cement in construction Industry are releasing huge amounts of CO_2 into the atmosphere.A ton of $CO_2$is being released into atmosphere for every ton of clinker produced. Hence there is a significant increase in global warming due to increase in the environmental pollution. Cement plants are a major source in the release of various harmful chemicals like Sulphur oxides, Nitrogen oxide and the Carbon monoxide.

Nitrogen oxidecause various health problems and effects environment like ground-water table, global warming,acid rain and water quality deterioration. Sulphur dioxide in high concentrations cause various breathing problems and cardiovascular diseases. Carbon monoxidecause reduction of oxygen percentage in atmosphere. So there is an urge of finding alternatives for Cement in the present era.

[1] Abdullah M. Zeyad, Megat Azmi Megat Johari, Norazura Muhamad Bunnori, Kamar Shah Ariffin (2012) Palm Oil Fuel Ash obtained from Palm oil mill which is further treated through screening, grinding and heating to improve its Pozzolanic reactivity. The characteristics of the Palm Oil Fuel Ash before and after treatment were observed to assess the changes in its properties. The resulting POFA was then utilized to produce high strength Concrete by replacing the OPC at 0, 20, 40 and 60% on mass-for-mass basis. The results show that the treatment process undertaken reduces the particle size, diminishes the unburned Carbon content and improve workability. The long-term Compressive strength was significantly increased. Further, the Chloride permeability was significantly reduced especially at higher POFA content of 60%, which could be translated into superior durability performance.[2] Sanjeev Kumar , Hasan şahan Arel (2017) Studies indicate that there is a promising future for the use of POFA in any kind of Concrete as it shows high strength, low shrinkage and permeability, high resistance to Carbonation, Chloride, Sulfate and Acidic environments. At high temperatures, POFA Concrete performs better than (OPC) Concrete.

[3] Venu Malagavelli (2010) Cost of Concrete depends upon the cost of its ingredients which are scarce and expensive, thus leading to usage of substitute materials in its production. This requirement is drawn the attention of investigators to explore new alternatives of ingredients of Concrete. His work focuses on investigating characteristics of M30 Concrete with partial replacement of Cement with Ground Granulated Blast furnace Slag (GGBS) and River sand with the ROBO sand. The cubes and cylinder specimens are tested for both Compressive and Tensile strengths. It is found that by the partial replacement of Cement with GGBS and sand with ROBO sand helped in improving the strength characteristics of the Concrete substantially when compared to normal mix Concrete.[4] Priyanka A. Jadhav, Dilip K. Kulkarni, (2013) studied the effect of Water Cement ratio on fresh and hardened Concrete with partial replacement of Natural sand by means of Manufactured sand. M20 grade Concrete was taken according to Indian Standard code (IS: 10262). Concrete cube and cylindrical specimens are tested to evaluate the strength characteristics. Concrete exhibit excellent strength with 60% replacement of Natural sand and hence can be used in Concrete as vital substitute. [5] B Vijaya and Dr.S.Elavenil, (2013) "Manufactured sand" has been in use in Concrete manufacturing in India, but the percentage of its contribution is still very unimportant in many parts of the country. A well processed manufactured sand as partial or full replacement to River sand is the major requirement in Indian Concrete Industry until other suitable alternative fine aggregate are developed.

2. MATERIALS

Details of various materials used during the experimentation are reported below.

2.1 Cement

Cement is the major ingredient in manufacturing Concrete. The characteristics of Concrete will be greatly affected by varying the Cement content. The Cement used in this project is Ordinary Portland Cement (OPC) of 53 grade.

2.2 Palm Oil Fuel Ash (POFA)

POFA is a byproduct obtained when various Palm materials such as Palm kernel shell, Palm oil fiber, Palm oil husk, etc are subjected to incineration in a Palm oil mill for the purpose of generation of electricity in palm oil extraction process. POFA is a useful mineral admixture for manufacturing of concrete. It influences many properties of concrete in both fresh and hardened states. POFAcontains huge amounts of SiO2 and therefore is a good Pozzolanic material. It improves compressive strength and reduces drying shrinkage of concrete.

Fig :1 **Palm Oil Fuel Ash (POFA)**

2.3 Robo Sand

Robo Sand is also known as manufactured sand or M Sand. It is obtained by crushing natural granite stone. Robo Sand is termed as a crushed granite aggregate produced by crushing the natural granite stone.River sand has become expensive and scarce due to its exponential increase in demand. Therefore when we look out for a substitute to the River sand, the crusher dust, which is also known as Robo Sand can be used as alternative material to the River sand.

Fig :2 **Robo Sand**

3. EXPERIMENTAL STUDY

After the mix design, the casting of specimens is the next step in this experimental study. The various types of specimens, such as Cubes, Beams, and Cylinders, were casted using standard procedures. The prepared samples were tested in the laboratory to determine their strength characteristics according to the standard procedures specified in the respective IS codes.

3.1 Compressive Strength

The main property observed when testing the cubes is compressive strength or crushing strength. Cubes are tested in a Compression Testing Machine to determine their compressive strength. The formula was used to calculate the compressive strength.

Compressive strength equals applied load divided by cross sectional area.

=P/A=load/areaN/mm2

3.2 Split Tensile Strength

The most important property of Concrete is its split tensile strength. Concrete is generally brittle under tension. Split tensile strength is therefore important in improving the tensile behavior of Concrete. It is also useful in preventing the formation of cracks in Concrete. Split tensile strength is calculated using cylinders. The compression testing machine is also used to test the cylindrical specimens. The cylinders are oriented axially with the cylindrical face facing the loading surface. The formula was used to calculate the split tensile strength. Split tensile strength = $2P / \pi ld$; P = failure load (applied load);L = height of the cylinder specimen;D = diameter of mould

3.3 Flexural Strength

The majority of beam failures occur as a result of flexural strength failure. It is critical to predict flexural strength by calculating modulus of rupture in order to reduce failure problems in beams. The main goal of casting beam specimens is to calculate the modulus of rupture in terms of flexural strength. The modulus of rupture is calculated in this case by testing specimens in a universal testing machine. The main important property in formulating the modulus of rupture in this line of facture.

3.4 Durability test

Concrete durability is defined as the ability of Concrete to withstand weathering, chemical attack, and abrasion while retaining its desired engineering properties.Concrete cube specimens with dimensions of 150 mm x 150 mm x 150 mm will be cast using the materials and mix design specified above and cured in potable water for 28 days. After 28 days, the hardened Concrete cubes will be immersed in various concentrations of hydrochloric acid and Sulphuric acid solutions, both completely and partially. Water-cured specimens will be removed after 28 days and allowed to dry in the shade before being immersed in 0% to 10% concentrated acid solutions for 28 and 90 days, respectively, for observation. The weight and compressive strength of the specimens slighty reduce.After removing cubes from acid solutions, there is a slight change in colour that can be seen.The density of Concrete is also affected, as evidenced by the reduction in weight of the cubes

4.0 RESULTS AND DISCUSSIONS

The results obtained form laboratory experimentation were tabulated and are discussed below.

Table 1. Compressive strength of Conventional Concrete and the Cement partially replaced with POFA cubes at 7, 28 and 90 days.

Sl. No	% of POFA	% of Cement	7 days strength (MPa)	28 days strength (MPa)	90 days strength (MPa)
1	0	100	24.7	36.84	36.92
2	5	95	24.85	36.97	37.02
3	10	90	25.16	37.56	37.66
4	15	85	25.69	38.24	38.52
5	20	80	26.21	39.14	39.25
6	25	75	26.10	39.00	39.08
7	30	70	25.87	38.82	38.98

The optimum value of POFA was found to be 20%

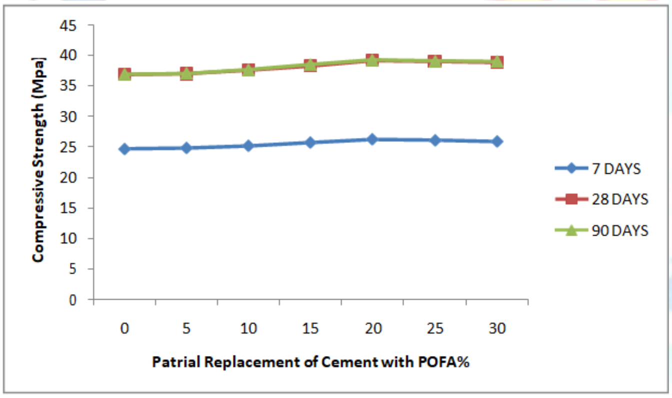

Fig :3 Variation of compressive strength on partial replacement of Cement with POFA at 7 days, 28 days and 90 days .

Table 2 Split tensile strength of Conventional Concrete and the Cement partially replaced with POFA at 7, 28 and 90 days.

Sl. No	POFA %	Cement %	7days Splittensile strength(Mpa)	28 days splittensile strength(Mpa)	90 days split tensile strength(Mpa)
1	0	100	2.10	3.14	3.16
2	5	95	2.19	3.25	3.28
3	10	90	2.31	3.46	3.49
4	15	85	2.46	3.68	3.70
5	20	80	2.61	3.90	3.92
6	25	75	2.52	3.82	3.86
7	30	70	2.48	3.62	3.74

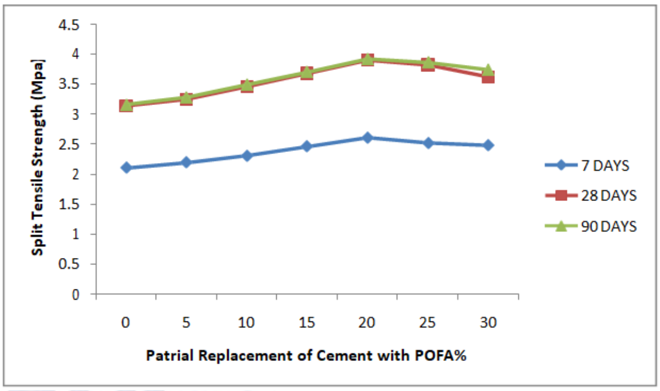

Fig 4 variation of split tensile strength on partial replacement of Cement with POFA at 7 days, 28 days and 90 days

Table 3 Flexural strength of Conventional Concrete and the Cement partially replaced with POFA at 7, 28 and 90 days.

Sl.No	POFA %	Cement %	7days Flexural strength(Mpa)	28days Flexural strength(Mpa)	90days Flexural strength(Mpa)
1	0	100	3.75	5.60	5.61
2	5	95	3.79	5.72	5.79
3	10	90	3.88	5.80	5.82
4	15	85	4.08	6.10	6.12
5	20	80	4.23	6.32	6.33
6	25	75	4.06	6.12	6.21
7	30	70	3.98	5.98	6.00

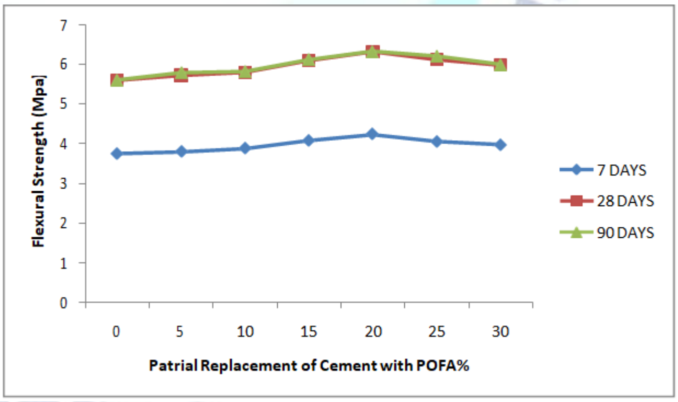

Fig 5 Variation of flexural strength on partial replacement of Cement with POFA at 7 days, 28 days and 90 days

Table 4 Compressive strength of Concrete with POFA and the Fine aggregate partially replaced with Robo Sand cubes at 7, 28 and 90 days. (Mpa)

Sl.No	Cement % + POFA %	Robo Sand %	7 days compressive strength(Mpa)	28 days compressive strength(Mpa)	90 days compressive strength(Mpa)
1	80+20	0	27.10	40.20	40.22
2	80+20	10	27.33	40.80	40.81
3	80+20	20	27.75	41.42	41.44
4	80+20	30	28.24	42.16	42.17
5	80+20	40	28.70	42.84	42.85
6	80+20	50	29.40	43.88	43.90
7	80+20	60	28.56	42.62	42.64

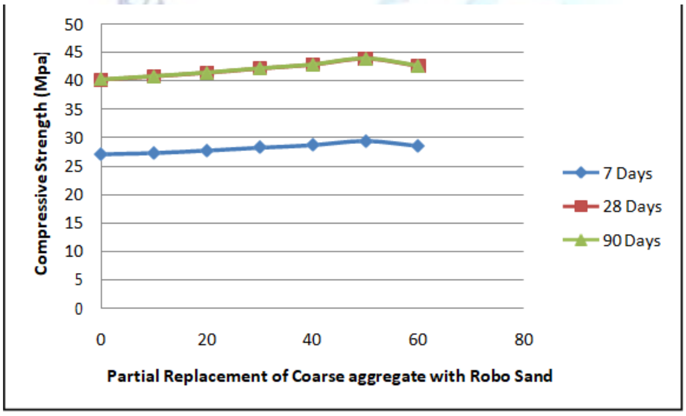

Fig 6 variation of compressive strength of POFA (20%) added Concrete on partial replacement of Fine aggregate with Robo Sand at 7 days, 28 days and 90 days

Table 5 Split tensile strength of Concrete with POFA and the Fine aggregate partially replaced with Robo Sand at 7, 28 and 90 days. (Mpa)

Sl.No	Cement %+ POFA %	Robo Sand %	7 days split tensile strength(Mpa)	28 days split tensile strength(Mpa)	90 days split tensile strength(Mpa)
1	80+20	0	2.89	4.32	4.34
2	80+20	10	3.18	4.76	4.77
3	80+20	20	3.51	5.24	5.25
4	80+20	30	3.93	5.88	5.90
5	80+20	40	4.18	6.24	6.25
6	80+20	50	4.59	6.86	6.88
7	80+20	60	3.91	5.84	5.86

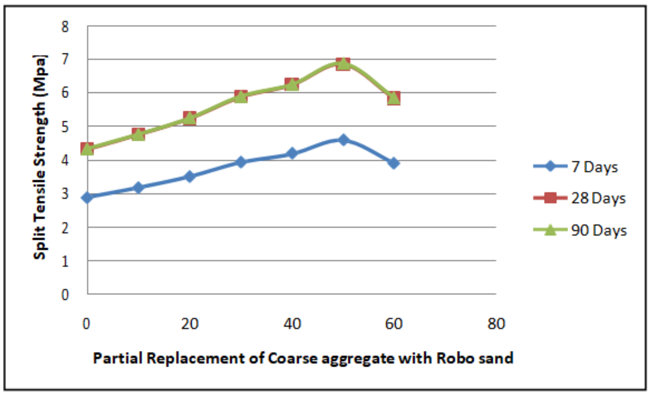

Fig 7 Variation of Split tensile strength of POFA (20%) added Concrete on partial replacement of Fine aggregate with Robo Sand at 7 days, 28 days and 90 days

Table 6 Flexural strength of Concrete with POFA and the Fine aggregate partially replaced with Robo Sand at 7, 28 and 90 days. (Mpa)

Sl. No	Cement % POFA %	Robo Sand %	7 days flexural strength(Mpa)	28 days flexural strength(Mpa)	90 days flexural strength(Mpa)
1	80+20	0	4.39	6.56	6.58
2	80+20	10	4.52	6.76	6.76
3	80+20	20	4.67	6.98	7.01
4	80+20	30	4.72	7.16	7.16
5	80+20	40	4.94	7.38	7.40
6	80+20	50	5.03	7.52	7.54
7	80+20	60	4.77	7.34	7.36

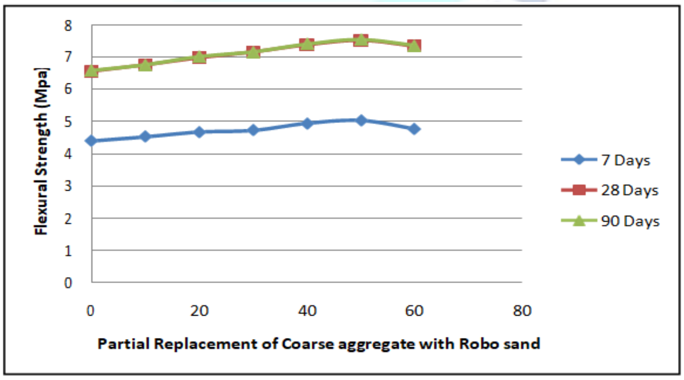

Fig 8 variation of flexural strength of POFA (20%) added Concrete on partial replacement of fine aggregate with Robo Sand at 7 days, 28 days and90 days

Table 7 Durability of Concrete with POFA (optimum value) and the Fine aggregate partially replaced with Robo Sand at 28 and 90 days.

S.No	% of HCl in water	Compressive Strength Values for	
		28 days	90 days
1	0%	39.14	39.25
2	5%	39.00	39.04
3	10%	38.46	38.98

S.No	% of H2SO4 in water	Compressive Strength Values for	
		28 days	90 days
1	0%	39.14	39.25
2	5%	38.98	39.00
3	10%	38.74	38.98

Based on the experimental analysis,the enhancement of strength is mainly because of formation of C-S-H gel and accordingly the better bond developed and the voids were filled with fine materials.

5. Conclusions

1. The optimum dosage of POFA to replace the Cement was found to be 20%.
2. There is a gradual increase in various strength parameters of Cement partially replaced with POFAConcrete.
3. The percentage increase in compressive strength at 7, 28 and 90 days of Cement partially replaced with 20% POFA were found to be 6.11%, 6.13% and 6.31%.
4. The percentage increase in split tensile strength at 7, 28 and 90 days of Cement partially replaced with 20% POFA were found to be 24.3%, 24.20% and 24.05%.
5. The percentage increase in flexural strength at 7, 28 and 90 days of Cement partially replaced with 20% POFA were found to be 12.8%, 12.85% and 12.83%.
6. The percentage decrease in compressive strength from durability tests on Concrete specimen cubes by using 20% of POFA at 28 and 90 days respectively is found to be 0.41% & 0.53% when immersed in 5% concentration of HCL.
7. The percentage decrease in compressive strength from durability tests on Concrete specimen cubes by using 20% of POFA at 28 and 90 days respectively is found to be 1.73% & 0.69%when immersed in 10% concentration of HCL.
8. The percentage decrease in compressive strength from durability tests on Concrete specimen cubes by using 20% of POFA at 28 and 90 days respectively is found to be 0.41% & 0.64% when immersed in 5% concentration of H2SO4.
9. The percentage decrease in compressive strength from durability tests on Concrete specimen cubes by using 20% of POFA at 28 and 90 days respectively is found to be 0.1% & 0.68% when immersed in 10% concentration of H2SO4.
10. This research concludes that POFA can be a novel supplementary Cementitious material. The use of POFA in Concrete can reduce the costs of Coal and Thermal industry disposal.
11. Furthermore, when the Coarse aggregate was replaced with varying percentages of Robo Sand, the strength parameters were slightly improved. The optimal percentage of Robo Sand to replace Coarse aggregate was discovered to be 50%.
12. The Compressive strength, Split tensile strength, and Flexural strength of both Cement and Coarse aggregate treated Concrete were found to be 43.88Mpa, 6.86Mpa, and 7.52 Mpa at 28 days, respectively.
13. Based on the above findings, Robo Sand can be used as an alternative material for Fine aggregate. Robo Sand qualifies as a cost-effective substitute for River sand.

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