Studies on Strength Characteristics of Concrete with Partial Replacement of Fine Aggregate with Robo Sand & Cement with Metakaolin

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Abstract— Concrete is a composite material made from cement, water, fine aggregate and coarse aggregate. But present researchers are in interest of finding advanced concrete by using different alternative materials or products produced from industries which are not ecofriendly. An attempt has been made in the present investigation to evaluate the compressive strength and split tensile strength and flexural strength properties by replacing cement partially with metakaolin and Fine Aggregate with ROBO Sand by Certain percentage. In this project, experimental study was carried out on M-35 grade of concrete. In this concrete mixes Fine Aggregate was replaced by ROBO sand by a constant percentage and cement was replaced by metakaolin in various percentages such as 5%, 10%, 15% and 20%.The results thus obtained were compared and examined with respect to the control specimen. From the test results, it was found that 15% of the Ordinary Portland cement could be beneficially replaced with the metakaolin to improve compressive, split tensile and flexural strengths of concrete. For strength parameters for each grade of concrete Cubes and Cylinders are tested at the age of 7 and 28 days.

Key words: ROBO Sand, Metakaolin, Compressive Strength, Split Tensile Strength, Flexural Strength

I. INTRODUCTION

Concrete is probably the most extensively used construction material in the world. It is an artificial material in which the aggregates are bonded together by the cement when mixed with water. With the advancement of technology and increased field of application of concrete and mortars, the strength, workability, durability and other characteristics of the ordinary concrete can be made suitable for any situation. For this, definite proportions of cement, water, fine aggregate, coarse aggregate, mineral admixtures and chemical admixtures are required.

The demand for Portland cement is increasing dramatically in developing countries. Portland cement production is one of the major reasons for CO_2 emissions into atmosphere. Metakaolin when used as a partial replacement substance for cement in concrete, it reacts with $Ca(OH)_2$ one of the by-products of hydration reaction of cement and results in additional C-S-H gel which results in increased strength. Metakaolin is obtained by thermal activation of kaolin clay. This activation will cause a substantial loss of water in its constitution causing a rearrangement of its structure. To obtain an adequate thermal activation, the temperature range should be established between 600 to 750ºC. The principle reasons for the use of clay-based pozzolans in mortar and concrete have been due to availability of materials and durability enhancement. In addition, it depends on the calcining temperature and clay type. It is also possible to obtain enhancement in strength, particularly during the strength of curing. The very early strength enhancement is due to a combination of the filler effect and acceleration of cement hydration.

A. Metakaolin

Metakaolin is brought from Astro chemicals, Chennai having specific gravity of 2.5 is used in replacement of cement. Metakaolin is a chemical phase that forms upon thermal treatment of kaolinite. Kaolinite's chemical composition is Al_2O_3:$2SiO_2$. $2H_2O$ and as a result of thermal treatment in the range of 400ºC to 500ºC, the water is driven away to form an amorphous aluminosilicate called metakaolin. Metakaolin is white in colour and acts as a pozzolanic material

B. Chemical Composition of Metakaolin

Chemicals	Percentage
SiO_2	62.62
Al_2O_3	28.63
Fe_2O	1.07
MgO	0.15
CaO	0.06
Na_2O	1.57
K_2O	3.46
TiO_2	0.36
LOI	2.00

Table 1:

C. Robo Sand

Robo sand is sand manufactured in the stone quarries. It is a substitute for the river sand used in construction. Robo Sand is collected from "Donabanda quary" crushing unit. It was initially dry in condition when collected and was sieved by IS 4.75 mm. It has shape of particles as Cubical Particle. The specific gravity of ROBO Sand is 2.68, Fineness modulus is 3.34. Grading Confirming to Zone-II.

Robo sand is an ideal substitute to river sand. It is manufactured just the way nature has done for over a million of years. Its numerous advantages over river sand have made it a favorite and must-to-use with quality conscious builders. Robo sand is created by a Rock-Hit-Rock crushing technique usingstate of art plant & machinery with world class technology.

D. Manufacture of Robo Sand

- Manufacture of robo sand is done in three steps
- Jaw crusher
- Cone crusher
- Vertical shaft impacter(VSI)

E. How Robo Sand Superior to River Sand

Particle shape, High compressive strength, Greater durability, Truckloads of advantages, Does away with construction, defects, Superior quality, Greater economic savings, Easy availability

II. LITERATURE REVIEW

Beulah M. Asst Professor, Prahallada M. C. Professor, Effect Of Replacement Of Cement By Metakalion On The Properties Of High Performance Concrete Subjected To Hydrochloric Acid Attack. This paper presents an experimental investigation on the effect of partial replacement of cement by metakalion by various percentages 0%, 10%, 20%, and 30% on the properties of high performance concrete, when it is subjected to hydrochloric acid attack. The results were compared with reference mix. Test results indicate that use of replacement cement by metakalion in HPC has improved performance of concrete up to 10%.

Dinakar et al. investigated the effect of using local calcined kaolin or MK obtained characteristics of concrete designed for a very low w/b ratio of 0.3.

Jadhav PA, Kulkarni DK. Et al., The effect of water cement ratio on hardened properties of cement mortar with partial replacement of natural sand by Robo sand is investigated. Designed mortar mix having proportion as 1:2, 1:3 and 1:6 with water cement ratio of 0.5 and 0.55 respectively is used in experimental study. Mortar cube specimens are tested for evaluation of compressive strength. The mortar exhibits excellent strength with 50% replacement of natural sand by manufactured sand. This paper puts forward the applications of manufactured sand as an attempt towards sustainable development. It will help to find viable solution to the declining availability of natural sand to make eco-balance.

Nova John in 2013 examined the Strength properties of metakaolin admixed Concrete. This paper presents the results of an experimental investigations carried out to find the suitability of metakaolin in production of concrete. In the present work, the results of a study carried out to investigate the effects of Metakaolin on strength of concrete are presented. The referral concrete M30 was made using 53grade OPC and the other mixes were prepared by replacing part of OPC with Metakaolin. The replacement levels were 5%, 10%, 15% up to 20 %(by weight) for Metakaolin. The various results which indicate the effect of replacement of cement by metakaolin on concrete are presented in this paper to draw useful conclusions. The results were compared with reference mix. Test results indicate that use of replacement cement by metakalion in concrete has improved performance of concrete up to 15%.

Poon et al. investigated the porosity and pore size distribution of high performance cement paste blended with metakaolin and compared them with silica fume (SF) or fly ash (FA) blended cement pastes. This present study was concerned with the MK-blended cement pastes at lower w/c ratios. The cement pastes prepared were MK blended pastes with MK contents of 5, 10, and 20%, SF-blended pastes with SF contents of 5 and 10%, an FA blended paste with a FA content of 20%, and a control PC paste without any pozzolanic replacement. The w/b ratio for all the pastes was 0.3.

T.Subbulakshmi, B. Vidivelli, In their paper entitled “To find the harden properties of concrete by using robo sand using in place of sand”. The natural sand replaced with quarry dust with varying proportions of 0 %, 50% and 100% and cured for 3, 7, 14, 21, 28, and 60 days. The strength will be gradually increasing up to 28 days then remains constant. 50% of quarry dust with sand give maximum strength when compared with nominal mix.

III. EXPERIMENTAL PROGRAMME

A. General

The experimental investigation consists of casting and testing of 5 sets along with control mix. Each set comprises of 6 cubes, 6 cylinders and 6 beams for determining compressive, tensile and flexural strengths respectively. By taking 5%, 10%, 15%, 20% percentage of Metakaolin. From this different percentages optimum at 15%. Maintaining 15% of metakaolin with robo sand of percentages 10%, 20%, 30%, 40%, 50%, 75%, 100% for 7 sets. Each set comprises of 6 cubes, 6 cylinders and 6 beams for determining compressive, tensile and flexural strengths respectively. Optimum at 50% of robo sand.

Cube specimen dimension is of 15 cm x 15 cm x 15 cm, cylinder specimen dimension is 15 cm x 30 cm and beam specimen is 50 cm x 10 cm x 10 cm. The moulds are applied with a lubricant before placing the concrete. After a day of casting, the moulds are removed. The cubes, cylinders and beams are removed to the curing tank carefully.

The material characteristics that are used in this study given in brief are as follows:

- Ordinary Portland cement 53 grade (KCP cement) with specific gravity of 3.15
- Locally available river sand with bulk density of 1705 kg/m^3 and specific gravity of 2.67 and confirming to zone-II of IS:383
- Coarse aggregate with bulk density of 1675 kg/m^3 and specific gravity of 2.81
- Water confirming to the requirements of water of concreting and curing as per IS:456-2000
- ROBO Sand is collected from “Dona banda quary” crushing unit. The specific gravity of ROBO Sand is 2.63.
- Metakaolin is brought from Astro chemicals, Chennai having specific gravity of 2.50 is used in replacement of cement.

B. Material Properties

Concrete is a composition of three raw materials. Cement, Fine aggregate and Coarse aggregate. These three raw materials play an important role in manufacturing of concrete. By varying the properties and amount of these materials, the properties of concrete will changes.

C. Cement

Cement can be defined as the bonding material having cohesive & adhesive properties which makes it capable to unite the different construction materials and form the compacted assembly. Ordinary/Normal Portland cement is one of the most widely used types of Portland cement.

The name Portland cement was given by Joseph Aspdin in 1824 due to its similarity in colour and its quality when it hardens like Portland stone. Portland stone is white grey limestone in island of Portland, Dorset.

The cement should be fresh and of uniform consistency. Where there is evidence of lumps or any foreign matter in the material, it should not be used. The cement should be stored under dry conditions and for as short duration as possible. Cement is the main ingredient in manufacturing of concrete. The characteristics of concrete will be greatly affected by changing the Cement content. The Cement used in this project is Ordinary Portland Cement of 53 grade confirming to IS 12269 – 1987.

IV. TESTS ON ORDINARY PORT LAND CEMENT

- Normal Consistency test
- Initial and Final Setting test
- Fineness test
- Soundness test
- Specific gravity test
- Fineness modulus of Fine Aggregate and Coarse Aggregate

M-35 Concrete Mix Design		
As per IS 10262-2009 & MORT&H		
1	Stipulations for Proportioning	
1	Grade Designation	M35
2	Type of Cement	OPC 53 grade
3	Maximum Nominal Aggregate Size	20 mm
4	Minimum Cement Content (MORT&H 1700-3 A)	310 kg/m^3
5	Maximum Water Cement Ratio (MORT&H 1700-3 A)	0.45
6	Workability (MORT&H 1700-4)	100 mm (Slump)
7	Exposure Condition	Normal
8	Degree of Supervision	Good
9	Type of Aggregate	Crushed Angular Aggregate
10	Maximum Cement Content (MORT&H Cl. 1703.2)	540 kg/m^3
2	Test Data for Materials	
1	Cement Used	OPC 53 grade
2	Sp. Gravity of Cement	3.15
3	Sp. Gravity of Sand	2.67
4	Sp. Gravity of Combined Coarse Aggregates	2.81
3	Target Strength for Mix Proportioning	
1	Target Mean Strength (MORT&H 1700-5)	43.25N/mm^2
2	Characteristic Strength @ 28 days	35N/mm^2
4	Selection of Water Cement Ratio	
1	Maximum Water Cement Ratio (MORT&H 1700-3 A)	0.45
2	Adopted Water Cement Ratio	0.40
5	Selection of Water Content	
1	Maximum Water content (10262-table-2)	186 Lit.
2	Estimated Water content for 50-75 mm Slump	197 Lit.
6	Calculation of Cement Content	
1	Water Cement Ratio	0.40
2	Cement Content	492.50 kg/m^3,Which is greater than 310 kg/m^3
7	Proportion of Volume of Coarse Aggregate & Fine Aggregate Content	
1	Vol. of C.A. as per table 3 of IS 10262	64.00%
2	Adopted Vol. of Coarse Aggregate	64.00%
	Adopted Vol. of Fine Aggregate (1-0.62)	36.00%
8	Mix Calculations	
1	Volume of Concrete in m^3	1.00
2	Volume of Cement in m^3 (Mass of Cement) / (Sp. Gravity of Cement)x1000	0.156
3	Volume of Water in m^3	0.197
4	Volume of SP is 1.5% to cement content	0.006
5	Volume of All in Aggregate in m^3 1 – (2+3+4)	0.647
6	Mass of Coarse Aggregate Sr. no. 5 x 0.62	1134.57
7	Mass of Fine Aggregate Sr. no. 5 x 0.38	638.20
9	Mix Proportions of Concrete	
1	Mass of Cement in kg/m^3	492.50
2	Mass of Water in kg/m^3	197
3	Mass of Fine Aggregate in kg/m^3	638.20
4	Mass of Coarse Aggregate in kg/m^3	1134.57
5	Water Cement Ratio	0.40

Table 2:

V. CASTING OF SPECIMENS

Fig. 1:

VI. TESTING OF SPECIMENS

A. Compressive Strength Test Results (Replacement of cement with metakaolin)

S. No.	% of replacement cement with Metakaolin	Compressive strength (Mpa)	
		7 days	28 days
1.	0% (nominal mix)	28.69	43.47
2.	5%	29.16	44.54
3.	10%	30.58	46.34
4.	15%	31.37	47.51
5.	20%	30.91	46.84

Table 3:

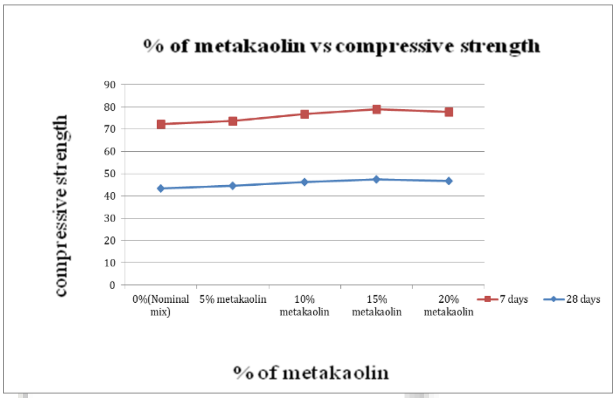

Fig. 2:

B. Compressive Strength Test Results (Replacement of cement with metakaolin and river sand with robo sand)

S.No.	% of replacement cement with metakaolin	% of replacement natural sand with robo sand	Compressive strength (Mpa)	
			7 days	28 days
1.	15%	10%	28.99	44.34
2.		20%	29.45	45.02
3.		30%	29.21	46.17
4.		40%	30.15	47.32
5.		50%	31.54	48.78
6.		75%	30.63	47.56
7.		100%	29.04	46.81

Table 4:

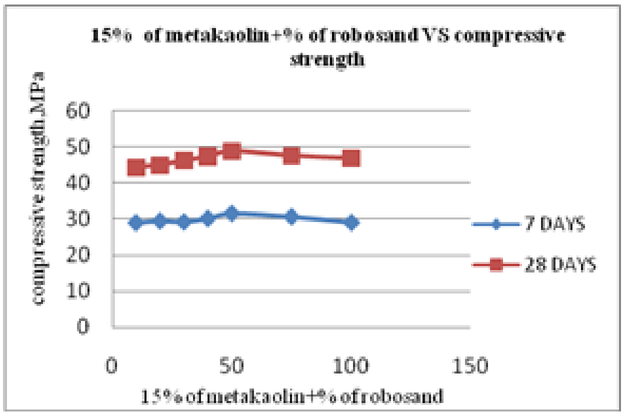

Fig. 3:

C. Split Tensile Strength Test Results (Replacement of cement with metakaolin)

S.NO	% of replacement cement with Metakaolin	Split tensile strength (Mpa)	
		7 days	28 days
1	0% (nominal mix)	2.42	4.02
2	5%	2.47	4.11
3	10%	2.53	4.18
4	15%	2.61	4.26
5	20%	2.56	4.19

Table 5:

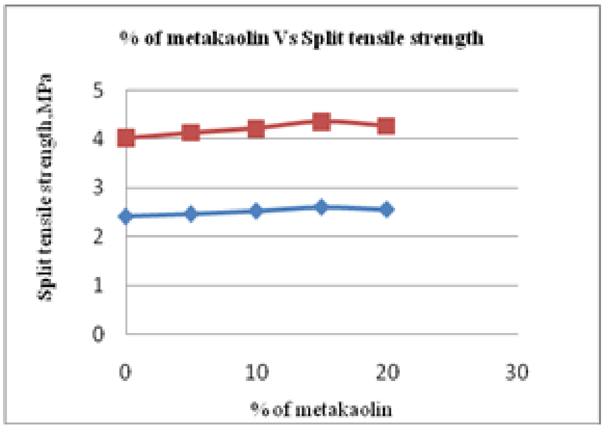

Fig. 4:

D. Split tensile strength Test Results (Replacement of cement with metakaolin and river sand with robo sand)

S.No.	% of replacement cement with metakaolin	% of replacement natural sand with robo sand	Split tensile strength (Mpa)	
			7 days	28 days
1.	15%	10%	2.64	4.01
2.		20%	2.67	4.05
3.		30%	2.72	4.13
4.		40%	2.75	4.17
5.		50%	2.87	4.35
6.		75%	2.76	4.19
7.		100%	2.68	4.07

Table 6:

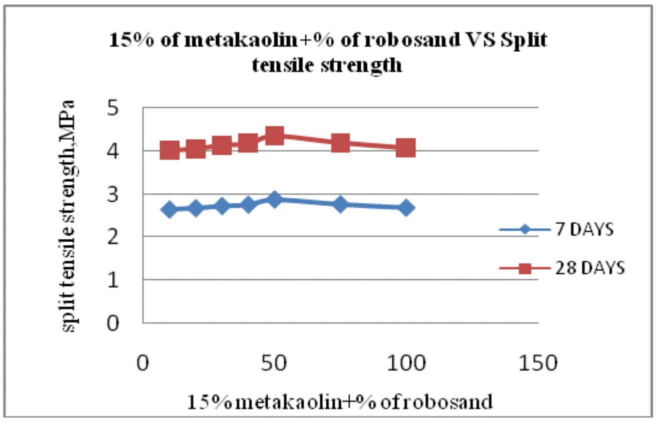

Fig. 5:

E. Flexural Strength Test Results (Replacement of cement with metakaolin)

S.No.	% of replacement cement with metakaolin	Flexural strength (Mpa)	
		7 days	28 days
1.	0% (nominal mix)	2.48	4.07
2.	5%	2.51	4.14
3.	10%	2.55	4.21
4.	15%	2.59	4.29
5.	20%	2.54	4.22

Table 7:

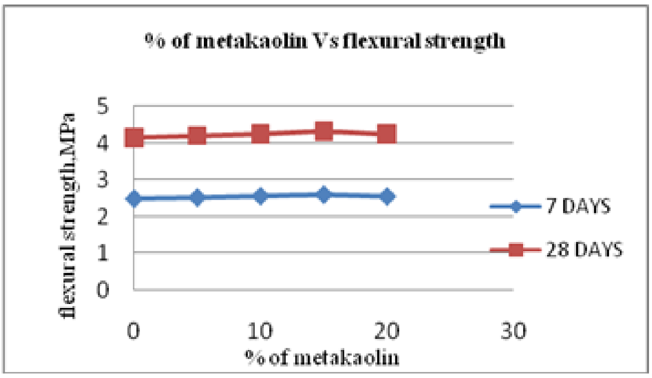

Fig. 6:

F. Flexural strength Test Results (Replacement of cement with metakaolin and river sand with robo sand)

S.No.	% of replacement cement with metakaolin	% of replacement natural sand with robo sand	Flexxural strength (Mpa)	
			7 days	28 days
1.	15%	10%	2.73	4.11
2.		20%	2.78	4.17
3.		30%	2.81	4.22
4.		40%	2.87	4.29
5.		50%	2.92	4.37
6.		75%	2.86	4.32
7.		100%	2.80	4.27

Table 8:

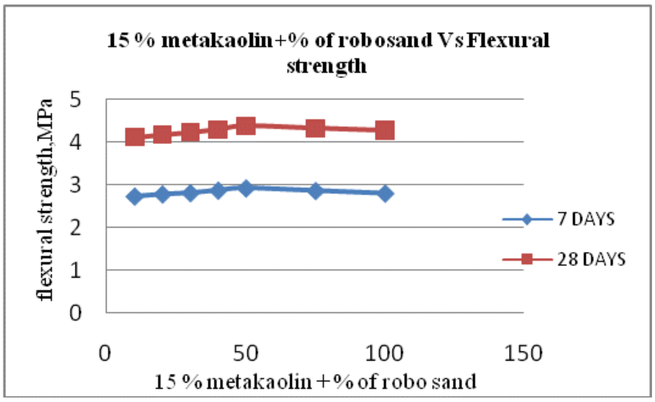

Fig. 7:

– Durability Studies

G. Strength for M35 grade concrete after H_2SO_4 and HCl acid curing

% of metakaolin	% of steel robo sand	Compressive strength(N/mm²)	
		28days 5% H_2SO_4	28days 5% HCL
15%	50%	45.34	46.54

Table 9:

VII. Conclusion

1) The concrete mixture with 15% metakaolin has the highest compressive strength (47.51Mpa), flexural strength (4.29Mpa) and split tensile strength (4.26Mpa) performance at all ages.
2) Partial replacement of cement by Metakaolin increases workability of fresh concrete; therefore use of super plasticizers is not substantial.
3) The concrete mixture with 15% Metakaolin and 50% Robo and has the highest compressive strength (48.78Mpa), flexural strength (4.37Mpa) and split tensile strength (4.35Mpa) performance at all ages.
4) The effect of acid on metakaolin and robo sand concrete decreases the resultant values very slightly.
5) In durability the strength loss is higher in H_2SO_4 than in HCl.
6) The compressive strength of concrete with Robo sand is marginally higher (7% - 11%) when compared to the concrete with river sand.

References

[1] Ilangovan, R., N. Mahendran, and K. Nagamani, "Strength and durability properties of concrete containing quarry rock dust as fine aggregate", ARPN Journal of Engineering and Applied Sciences, vol. 3, pp 20-26, May 2008.
[2] Kou, S.C. and C.S. Poon, "Properties of concrete prepared with crushed fine stone, furnace bottom ash and fine recycled aggregate as fine aggregates", Construction and Building Materials, vol. 23, pp. 2877–2886, 2009.
[3] Celik, T. and K. Marar, "Effects of crushed stone dust on some properties of concrete", Cement and Concrete Research, vol. 26, pp. 1121-1130, July 1996.
[4] Wild, S., J.M. Khatib, and A. Jones, "Relative strength, pozzolanic activity and cement hydration in super plasticized metakaolin concrete", Cement and Concrete Research, vol. 26, pp. 1537-1544, Oct. 1996.
[5] Curcio, F., B.A. DeAngelis, and S. Pagliolico, "Metakaolin as a pozzolanic micro filler for high performance mortars", Cement and Concrete Research, vol. 28, pp. 803–809, June 1998.

A. List of IS Codes

[6] Indian standard Code of Practice for Plain and Reinforced Concrete, IS- 456: 2000, 4th Revision, Bureau of Indian Standards.
[7] Indian standard recommended guidelines for Concrete Mix Design, IS 10262: 2009. 1st Revision, Bureau of Indian Standards

[8] Indian standard Specifications for coarse and fine aggregates from natural sources for concrete, IS 383-1970, Bureau of Indian Standards.
[9] IS: 12269-1987: Specifications of 53 grade OPC
[10] IS: 2386-1963: Methods of Testing Aggregates for concrete
[11] IS 516-1959: Methods of Test for strength of Concrete