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An Experimental Investigation on Partial Replacement of Cement with Metakaolin and Fine Aggregate with Robo Sand

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Abstract - *Concrete is a compound material made from cement, water, fine aggregate and coarse aggregate. But present researchers are in significance of finding new concrete by using different alternative materials or products produced from industries which are harmful to atmosphere. 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 by using Robo Sand instead of river sand by variable percentages.*

In this project, experimental study was carried out on M-35 grade of concrete. In this concrete mixes sand was replaced by Robo sand in various percentages such as 10%, 20%, 30% 40%, 50%, 75%, 100% 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 sample. From the test outcomes, 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, Cylinders and beams are tested at the age of 7 and 28 days.

Key Words: **Robo Sand, Metakaolin, Compressive strength, Split tensile strength, Flexural strength.**

1. INTRODUCTION

Concrete is perhaps the most extensively used construction material in the world. With the advancement of technology and greater than before 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 magnitude of cement, water, fine aggregate, coarse aggregate, mineral admixtures and chemical admixtures are required. The demand for Portland cement is increasing significantly in developing countries. Portland cement production is one of the major reasons for CO_2 emissions into environment. 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 response of cement and results in additional C-S-H gel which results in increased strength. Metakaolin is obtained by thermal commencement of kaolin clay. This creation will cause a substantial loss of water in its constitution causing a reorganization of its structure. For obtaining adequate thermal activation, the temperature range should be in 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 enrichment. Accumulation depends on the calcining temperature and clay type. It is also possible to obtain improvement in strength, particularly during the strength of curing. The very early strength enrichment is due to a combination of the filler effect and acceleration of cement hydration.

2. MATERIAL STUDY

2.1 MATERIALS

2.1.1 CEMENT: The physical properties of the cement used in present investigation i.e. Ordinary Portland cement of 53 grade (KCP cement) confirming to IS 8112: 2013.

2.1.2 FINE AGGREGTE: Locally available river sand of size less than 4.75 mm was used. The specific gravity of fine aggregate is 2.64, Fineness modulus is 3.2 and Grading Confirming to Zone-II. (Specifications as per IS 383:1970).

2.1.3 COARSE AGGREGATE: The material whose particles are of size as are retained on IS. Sieve 4.75 mm is termed as coarse aggregate. The size of coarse aggregate depends upon the nature of work. The Coarse aggregate used in this experimental investigation is 20 mm size, crushed and angular in shape. Specific gravity of coarse aggregate for 20 mm size is 2.71.

2.1.4 WATER: Water should be easily available and it should be clear and tap water also satisfactory to mix the ingredients and it should not be any alkali and should be free from chlorides of calcium and magnesium.

2.1.4 ROBO SAND: Robo Sand is collected from "Donabanda Quarry" crushing unit. It was initially dry in stipulation 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.

2.1.5 METAKAOLIN: Metakaolin is brought from Astro chemicals, Chennai. Specific gravity of metakaolin 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 healing in the range of 400°C to 500°C, the water is driven away to form an amorphous aluminosilicate called metakaolin. Metakaolin is white in colour and acts as a pozzolanic material. The reactivity of the metakaolin may also be affected by grinding to a finer particle size. The properties of Metakaolin are given below

Table -2.1: Chemical Composition of Metakaolin

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

2.2 MIX DESIGN

M35 grade with nominal mix as per IS: 456-2000 was used. The concrete mix proportion (cement: fine aggregate: coarse aggregate) is 1:1.29:2.30by volume and a water cement ratio of 0.40. It was proposed to investigate the properties of concrete, cast with partial replacement of sand with 10%, 20%, 30%, 40%, 50%, 75%, 100% of Robo sand and cement content was replaced with 5%, 10%, 15% and 20% of proportions of metakaolin.

2.2.1 MANUFACTURE PROCESS OF CONCRETE:

Batching: The measurement of materials for making concrete is termed as batching. In this experimental investigation we are taking into consideration weigh batching. Weighing machine is required to measure the material. Weigh batching facilitates exactness, flexibility and simplicity.

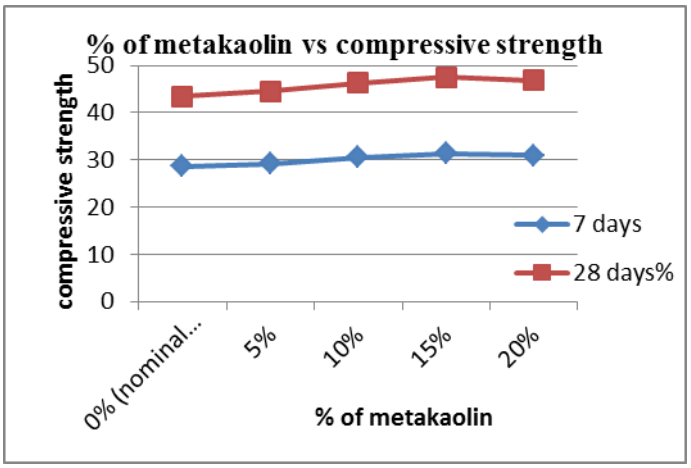
Measurement of water: measurement of water must be done by correctly. Addition of water in terms of liters by using graduated bucket.

2.2.2 CONCRETE CASTING: The samples are made in such a manner as to facility the removal of the mould. Samples without damage and are so maintained that, when it is assembled, the dimensions and inner faces are required to be accurate with in the following limits.

3. TEST RESULTS AND DISCUSSIONS

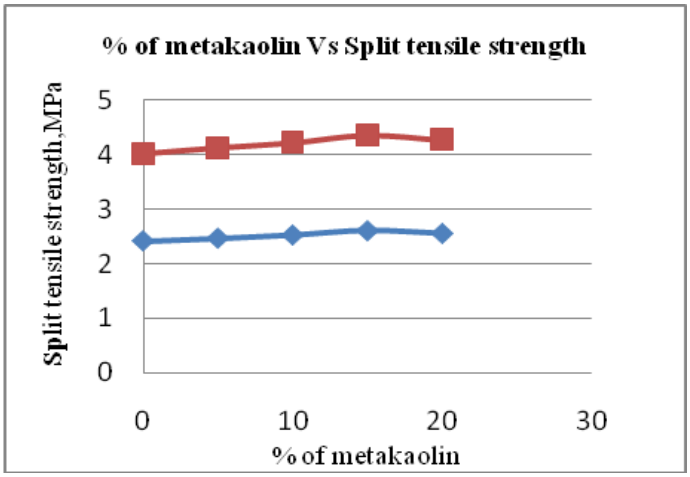
3.1 Compressive Strength (Replacement of cement with metakaolin)

S.No	% replacement of 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



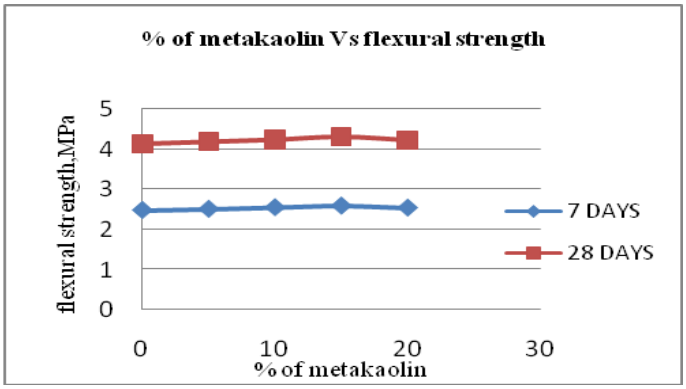
3.2 Split Tensile Strength (Replacement of cement with metakaolin)

S.No.	% replacement of 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



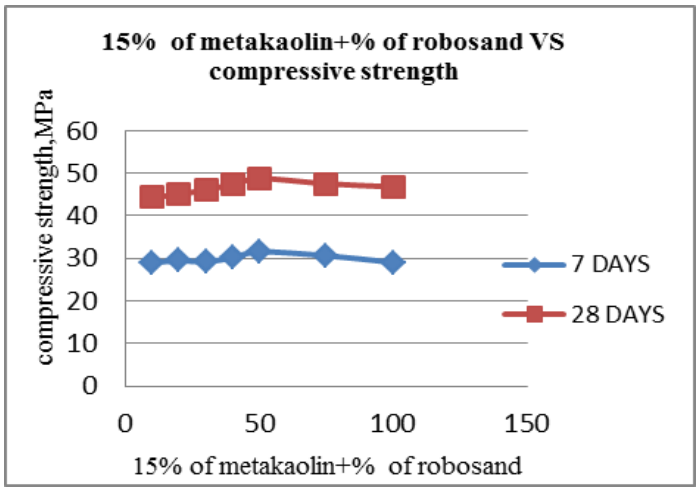
3.3 Flexural Strength (Replacement of cement with metakaolin)

S.No.	% replacement of 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



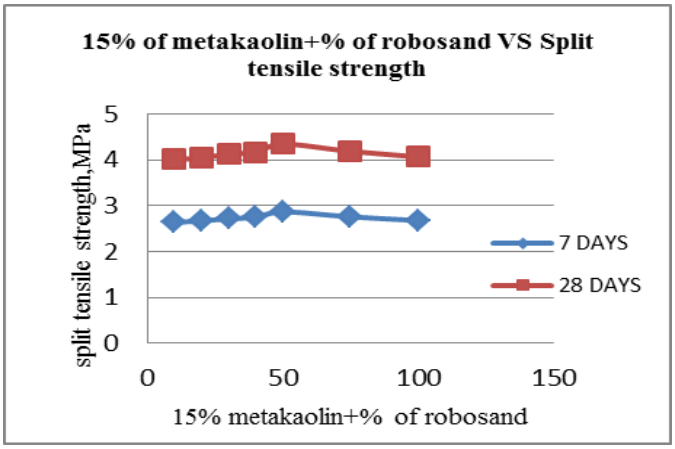
3.4 Compressive Strength (Replacement of cement with metakaolin and river sand with robo sand)

S.No.	% replacement of cement with metakaolin	% replacement of 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



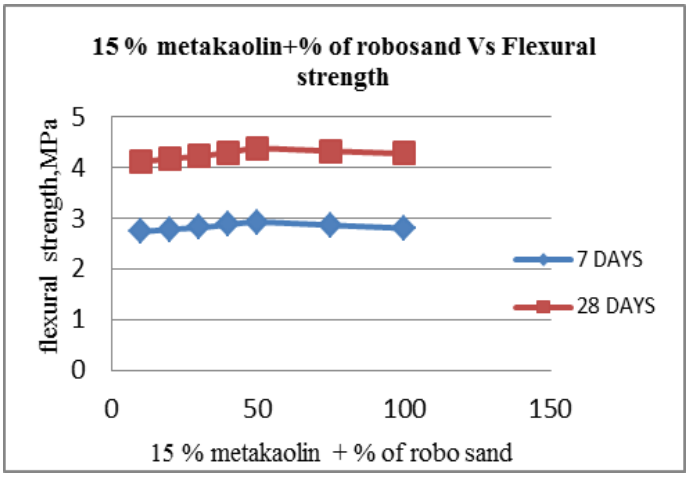
3.5 Split tensile strength (Replacement of cement with metakaolin and river sand with robo sand)

S.No.	% replacement of cement with metakaolin	% replacement of 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



3.6 Flexural strength (Replacement of cement with metakaolin and river sand with robo sand)

S.No.	% replacement of cement with metakaolin	% replacement of natural sand with robo sand	Flexural 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



4. DURABILITY STUDY

Cement is not completely impervious to acids. Most corrosive arrangements will gradually or quickly break down Portland bond concrete contingent on the sort and convergence of corrosive. The strength of cement in this test work was completed by measuring corrosive resistance at various periods of curing. The solid corrosive resistance was seen by two sorts of tests named as Acid assault component test and Acid toughness variable test. The convergences of acids in water are 5% HCl and 5% H_2SO_4.concrete can be assaulted by fluids with pH esteem under 6.5 and assault is extreme when pH quality is underneath 5.5. At pH esteem beneath 4.5, the assault is exceptionally extreme. As the assault continues, all the concrete mixes are split down and drained away. Here HCl andH_2SO_4which are having pH esteem 3.01 and 2.75 which cause an exceptionally extreme assault is utilized to consider the sturdiness properties.

Concrete with Ordinary Portland Cement is the main composition in present constructional activities. A concrete structure was good in strength can also be good in providing service life. Durability is of concrete structure is acceptable only when it shows reliability in its life time. The concrete under marine environment and exposed to destructive chemical attack through water are the major problems in reducing the life time of structure. To defeat this problem, proper durability studies are required for concrete before concreting a structure.

4.1 Requirements:

To ensure the Acid resistance of concrete Hydro Chloric acid (HCl), Sulphuric Acid (H_2SO_4) is selected. The concentrations of acids in water are taken as 5%. The standard specifications for this study are IS 516-1959 and ASTM C666-1997.

Summary of brief details for durability study

Acids used	HCL, H_2SO_4
Concentrations for trails	5% in water
Number of days of testing	and 28 days

4.2 TEST RESULTS:

Durability studies of compressive strength of concrete effected with 5% of H_2SO_4 and HCl acid is studied at maximum value of Compressive Strength Test Results (Replacement of cement with 15% of metakaolin and river sand with 50% of robo sand).

Compressive 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

5. CONCLUSIONS

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.

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