EXPERIMENTAL STUDY ON STRENGTH PROPERTIES OF CONCRETE BY PARTIAL REPLACEMENT OF CEMENT BY METAKAOLIN AND FINE AGGREGATE BY ROBO SAND FOR M30 GRADE

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Abstract - *Concrete is the most extensively used construction material in the world, which consumes natural resources like lime, aggregates and water. The worldwide production of cement has greatly increased, due to this production environmental pollution increases with emission of CO_2 gas. To reduce this effect cement was replaced by some supplementary materials like Metakaolin(MK), Fly ash, Bottom Ash, Ground Granulated Blast Furnace Slag (GGBS) and Rice Husk etc.. In this content Metakaolin was a pozzolanic material used in wide range in replacement of cement. Metakaolin is dehydroxylated aluminum silicate, due to its pozzolanic activity the strength properties and durability properties of concrete increases and reduction in porosity and permeability also.*

The compressive strength, split tensile strength, shear strength and flexural strength of conventional concrete for preparing cubes, cylinders and beams at 28 days. Partially replaced (metakaolin and robo sand) in concrete found to be 25.42%, 18.37%, 17.22% and 13.12% higher strength than that of the conventional concrete respectively for M30 grade of concrete.

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

1. INTRODUCTION

Concrete is a composite material which is predominantly used all over the world. It is obtained by mixing cementing materials, aggregates and water in required quantities. The word "concrete" is originates from the Latin verb "concretus" which means to grow together. The strength characteristics of concrete depends upon the properties of constituent of material and their combined action. In the production of cement CO_2 gas emission is more, due to these results in damage of natural climatic conditions. To reduce the consumption of cement partial replacement of cement with some supplementary cementitious materials like Metakaolin, fly-ash, bottom ash, rice husk, GGBS and silica fume etc., are used in concrete mix. Metakaolin is a dehydroxylated form of clay mineral Kaolin. Stone having high percentage of kaolinite are known as china clay (or) kaolin was traditionally used in manufacture of porcelain i.e. ceramic material. Metakaolin reacts with $Ca(OH)_2$ one of the bi-product of hydration reaction of cement and results in C-S-H gel , which results in increasing strength of the concrete. By replacing cement with Metakaolin increase in strength and durability and reduces the porosity in concrete and permeability also. Fine aggregate is one of the important constituent material as far as strength characteristic of concrete is concerned. Increase in demand and decrease in natural sources of fine aggregate for the production of concrete has resulted in the need to identify new sources of fine aggregate. River sand which is most commonly used as fine aggregate in the production of concrete and mortar poses the problem of acute shortage in many areas. At the same time increasing quantity of ROBO sand (Crusher sand) is available from crusher waste. The disposal of ROBO sand (Crusher sand) is a serious environmental problem. If it is possible to use ROBO sand in making concrete and mortar by partial replacement of natural river sand, then this will not only save the cost of construction but at the same time will solve the problem of disposal of this dust. Concrete made with this partial replacement can attain the same compressive strength, comparable tensile strength and flexural strength. For satisfactory utilization of this alternative material, the various phases of examination have to be technical feasibility, durability of processed concrete and economic feasibility. With the ongoing research being done to develop appropriate technology and field trials to monitor the performance and assessment of concrete quality with use of this alternative materials i.e. MK and RS will become more viable.

1.1 METAKAOLIN

Metakaolin, generally called "calcined clay" is a reactive alumina-silicate pozzolana produced by heating kaolinite at a specific temperature regime. Kaolinite is the clay mineral which provides the plasticity of the raw material and change during firing to produce permanent material. Kaolinite chemical composition is $Al_2O_3.2SiO_2.2H_2O$ and as a result of thermal treatment in the range of 450-750^0 C, the water is driven away to form an amorphous alumina silicate called Metakaolin ($Al_2O_3.2SiO_2$). Metakaolin is a pozzolanic material used in the concrete industry as a partial replacement for Portland cement.

The concrete performance depends mainly on environmental conditions, the micro structure, and the chemistry of the concrete. The two later factors are strongly affected by concrete components. It is obvious that Metakaolin performance affects the concrete performance. Metakaolin thermally activated alluminosilicate material with high pozzolanic activity comparable to or exceeded the activity of silica flume. Metakaolin is quite useful in improving concrete quality, such as enhancing strength, shortening setting time, decreasing autogenous shrinkage, controlling alkali aggregate reaction, reducing risk of chloride-induced corrosion of embedded steel, controlling hydride transformation of high alumina cement, and improving the durability of concrete.

Fig.1: Metakaolin

1.2 ROBO SAND

ROBO sand is an ideal substitute to river sand. It is manufactured just the way nature has done for over a million years. ROBO sand is created by a rock-hit-rock crushing technique using state-of-the art plant and machinery with world class technology. ROBO sand is the environmental-friendly solution that serves as a perfect substitute for the fast depleting and excessively mined river sand, which is so essential and percolating and storing rain water in deep underground pockets and protects the ground water table.

ROBO sand having size from 0-4.75mm is suitable for all concrete preparation and is used across in all segments such as independent houses, Builders, RMC plants, concrete batching plants and infrastructure concrete works. Production generally involves crushing, screening and possibly washing.

2. MATERIALS AND TEST PROCEDURE

2.1 PHYSICAL PROPERTIES OF METAKAOLIN

S.No	Property	Value
1	Bulk Density (gm/cm^3)	2.45
2	Particle shape	Spherical
3	Color	White
4	Specific gravity	2.60

2.2 PHYSICAL PROPERTIES OF ROBO SAND

S.No	Test Particulars	Requirement as per IS: 383	Results
1	Water absorption (%)	-	1.5
2	Fineness Modulus	2-3.5	3.148
3	Specific gravity	2.6-2.7	2.66
4	Moisture content (%)	-	0.9

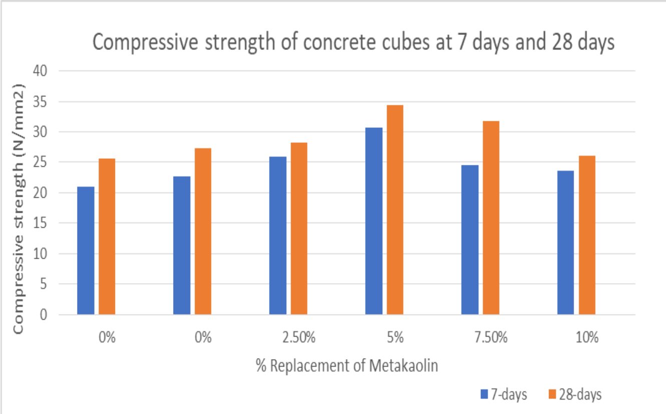
3. RESULTS AND DISCUSSIONS

3.1 Compressive strength test results (7 Days)

SL NO	% OF MK +RS REPLACEMENT	FAILURE LOAD (KN)	COMPRESSIVE STRENGTH 28 DAYS (N/mm^2)	AVG COMPRESSIVE STRENGTH (N/mm^2)
1	0%	460 490 470	20.44 21.78 20.89	21.04
2	2.5%+50%	570 600 580	25.33 26.67 25.78	25.92
3	5%+50%	690 700 680	30.67 31.11 30.22	30.67
4	7.5%+50%	540 570 550	24.00 25.33 24.44	24.59
5	10%+50%	520 540 530	23.11 24.00 23.56	23.55

Compressive strength test results (28 DAYS)

SL NO	% OF MK +RS REPLACEMENT	FAILURE LOAD (KN)	COMPRESSIVE STRENGTH 28 DAYS (N/mm^2)	AVG COMP. STRENGTH (N/mm^2)
1	0%	560 580 590	24.89 25.78 26.22	25.63
2	2.5%+50%	650 620 640	28.89 27.56 28.44	28.29
3	5%+50%	770 760 790	34.22 33.78 35.11	34.37
4	7.5%+50%	720 730 700	32.00 32.44 31.11	31.85
5	10%+50%	570 590 600	25.33 26.22 26.67	26.07



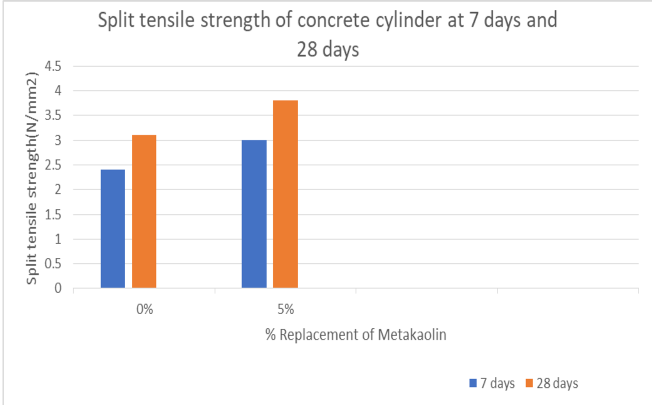


Fig 2: FAILURE OF CUBES UNDER LOADING

Fig 3: FAILURE OF CYLINDER UNDER LOADING

3.2 Split tensile strength test results (7 DAYS)

SL NO	% OF MK +RS REPLACEMENT	FAILURE LOAD (KN)	SPLIT TENSILE STRENGTH (N/mm²)	AVG SPLIT TENSILE STRENGTH (N/mm²)
1	0%	170 160 180	2.40 2.26 2.54	2.4
2	5%+50%	210 230 200	2.97 3.25 2.82	3.01

Split tensile strength test results (28 days)

SL NO	% OF MK +RS REPLACEMENT	FAILURE LOAD (KN)	SPLIT TENSILE STRENGTH (N/mm²)	AVG SPLIT TENSILE STRENGTH (N/mm²)
1	0%	230 210 220	3.25 2.97 3.11	3.11
2	5%+50%	260 270 280	3.67 3.81 3.96	3.81

3.3 Shear strength test results (7 DAYS)

SL NO	% OF MIX	FAILURE LOAD (KN)	SHEAR STRENGTH (N/mm²)	AVG SHEAR STRENGTH (N/mm²)
1	0%	150 170 160	16.67 18.89 17.78	17.78
2	5%+50%	180 190 200	20.00 21.11 22.22	21.11

Shear strength test results (28 DAYS)

SL NO	% OF MIX	FAILURE LOAD (KN)	SHEAR STRENGTH (N/mm²)	AVG SHEAR STRENGTH (N/mm²)
1	0%	250 240 230	27.78 26.67 25.56	26.67
2	5%+50%	290 280 300	32.22 31.11 33.33	32.22

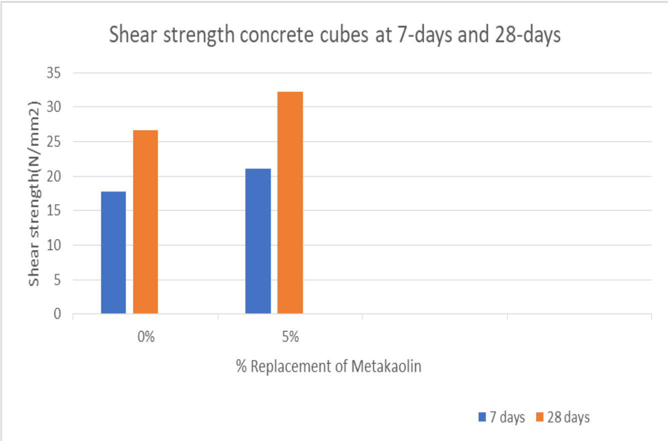


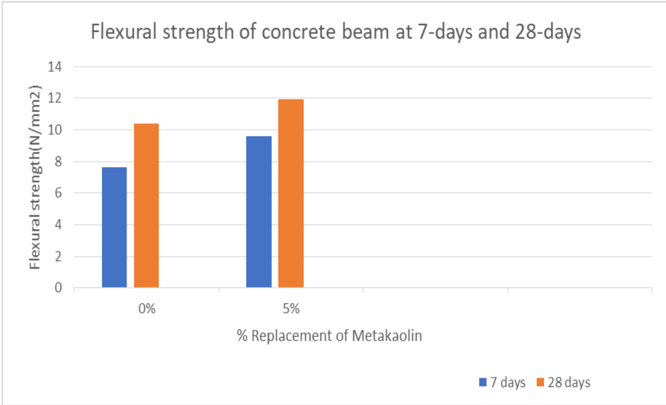
Fig 4: FAILURE OF SHEAR UNDER LOADING

3.4 Flexural strength test results (7 DAYS)

SL NO	% OF MIX	FAILURE LOAD (KN)	FLEXURAL STRENGTH (N/mm^2)	AVG FLEXURE STRENGTH(N/mm^2)
1	0%	2000 1900	7.85 7.46	7.65
2	5%+50%	2400 2500	9.42 9.82	9.62

Flexural strength test results (28 DAYS)

SL NO	% OF MIX	FAILURE LOAD (KN)	FLEXURAL STRENGTH (N/mm^2)	AVG FLEXURE STRENGH (N/mm^2)
1	0%	2600 2700	10.20 10.59	10.39
2	5%+50%	3000 3100	11.77 12.16	11.96



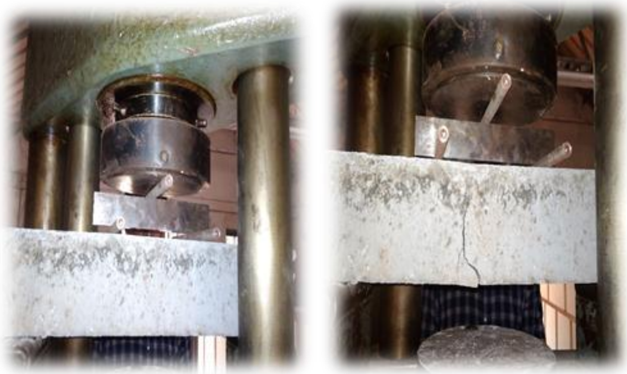


Fig 5: FAILURE OF BEAM UNDER LOADING

4. CONCLUSIONS

1. The compressive strength of conventional concrete cubes is 21.04 Mpa at 7 days, whereas compressive strength of partially replaced cement by an amount of 5% MK and FA by 50% of RS at 7 days found be 30.67 Mpa. Also it is found that the compressive strength of partially replaced concrete cubes have 31.39% higher strength than the conventional concrete respectively.
2. The compressive strength of conventional concrete cubes is 25.63 Mpa at 28 days ,whereas compressive strength of partially replaced cement by an amount of 5% MK and FA by 50% of RS at 28 days found be 34.37 Mpa .Also it is found that the compressive strength of partially replaced concrete cubes have 25.42% higher strength than the conventional concrete respectively .
3. The split tensile strength of conventional concrete cylinder is 2.40 Mpa at 7 days, whereas split tensile strength of partially replaced cement by an amount of 5% MK and FA by 50% of RS at 7days found be 3.01 Mpa .Also it is found that the split tensile strength of partially replaced concrete have 20.26% higher strength than the conventional concrete respectively.
4. The split tensile strength of conventional concrete cylinder is 3.11 Mpa at 28 days, whereas split tensile strength of partially replaced cement by an

amount of 5% MK and FA by 50% of RS at 28days found be 3.81 Mpa .Also it is found that the split tensile strength of partially replaced concrete have 18.37% higher strength than the conventional concrete respectively.

5. The shear strength of conventional concrete cube is 17.78 Mpa at 7 days, whereas shear strength of partially replaced cement by an amount of 5% MK and FA by 50% of RS at 7days found be 21.11 Mpa .Also it is found that the shear strength of partially replaced concrete have 15.77% higher strength than the conventional concrete respectively .
6. The shear strength of conventional concrete cube is 26.67 Mpa at 28 days, whereas shear strength of partially replaced cement by an amount of 5% MK and FA by 50% of RS at 28 days found be 32.22 Mpa .Also it is found that the split tensile strength of partially replaced concrete have 17.22% higher strength than the conventional concrete respectively.
7. The flexural strength of conventional concrete beam is 7.65 Mpa at 7 days, whereas flexural strength of partially replaced cement by an amount of 5% MK and FA by 50% of RS at 7days found be 9.62 Mpa .Also it is found that the bending flexural strength of partially replaced concrete have 20.47% higher strength than the conventional concrete respectively.
8. The flexural strength of conventional concrete beam is 10.39 Mpa at 28 day, whereas flexural strength of partially replaced cement by an amount of 5% MK and FA by 50% of RS at 28days found be 11.96 Mpa .Also it is found that the flexural bending strength of partially replaced concrete have 13.12% higher strength than the conventional concrete respectively.

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