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# Experimental Study on the Mechanical Properties of Concrete Replacing Cement and Natural Sand with Metakaolin and ROBO Sand

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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, 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. Now-a-day's availability of natural sand is constraint, so alternative material called ROBO Sand is using in concrete mix; it has similar properties as Natural Sand. In this present investigation partial replacement of cement with metakaolin at 0%, 5%, 10%, 15% and 20% and replacing natural sand with 50% ROBO sand. The mechanical properties of concrete i.e. compressive strength, split tensile strength and flexural strength are studied of concrete made with replacement of MK-RS and results are compared with conventional concrete. In this work totally six mixes are prepared with $M_{40}$ grade concrete mix and average of three specimens were tested for 7 days, 28 days and 90 days for each mix.*

***KEYWORDS:*** *Cement, Metakaloin, Robo sand.*



## I. 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 characteristic of concrete depends upon the properties of constituent of material and their combined action.

. 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.

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 these alternative materials i.e. Metakaloin and RoboSand will become more viable.

## II. EXPERIMENTAL PROGRAMME

*1) CEMENT*

The physical properties of the cement used in present investigation i.e. Ordinary Portland cement of 43-Grade (JP cement) confirming to IS 8112: 1989.

***Table 1 Physical Properties of Cement***

| S.NO | Properties | Test Values | Standard Values (IS) |
|---|---|---|---|
| 1 | Specific gravity | 3.14 | |
| 2 | Fineness (%) | 2.6 | < 10 |
| 3 | Initial setting time (min) | 92 | >30 |
| 4 | Final setting time(min) | 186 | <600 |

2) FINE AGGREGATE

Locally available river sand was used as a Fine aggregate. The sieve analysis and Physical properties of Fine aggregate are discussed below.

***Table 2 Physical Properties of Fine aggregate***

| S.NO | Property | Requirement as per IS: 383 | Observed Value |
|---|---|---|---|
| 1 | Water absorption (%) | 2 | 0.80 |
| 2 | Fineness Modulus | 2-3.5 | 3.3 |
| 3 | Specific gravity | 2.6-2.7 | 2.61 |
| 4 | Moisture content (%) | - | 0.40 |

*3) Robo Sand*

ROBO Sand is collected from locally available 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.

***Table 3 Physical Properties of Robo sand***

| S.No | Property | IS Standard value per IS: 383 | Observed Value |
|---|---|---|---|
| 1 | Water absorption (%) | - | 1.5 |
| 2 | Fineness Modulus | 2-3.5 | 3.32 |
| 3 | Specific gravity | 2.6-2.7 | 2.61 |
| 4 | Moisture content (%) | - | 0.9 |

*4) Coarse Aggregate*

Locally available crushed sand stone 20mm and 10mm sizes have been used as Coarse aggregate. The results of sieve analysis and physical properties of the coarse aggregate of 20mm and 10mm sizes have been shown in table4

***Table 4 Physical Properties of Coarse aggregate***

| S.NO | Property | Requirement as per IS: 383-**1970** | Observed Value |
|---|---|---|---|
| 1 | Water absorption (%) | - | 1.76 |
| 2 | Fineness Modulus | 5.5-8 | 6.1 |
| 3 | Specific gravity | 2.6-2.8 | 2.65 |
| 4 | Moisture content (%) | - | 2 |

5) WATER

The water should be free from organic impurities. The potable water is generally considered satisfactory for the concrete as per clause 5.4 of IS: 456-2000. Tap water available in the laboratory was used for making concrete and curing of the concrete specimens.

6) CONCRETE MIX DESIGN

Concrete Mix Design of Grade $M_{40}$have been done as per of the recommended guidelines of IS: 10262-2009. The weight ratio of mix proportion is **1: 1.73: 2.86** keeping water cement ratio as 0.38. it was Proposed to investigate the properties of concrete, cast with partial replacement of cement with 0%, 5%, 10%,15% and 20% of Metakaolin and 50% Natural sand is replaced by ROBO Sand throught the work in all mixes.

***Table 5 Materials requiredPer $m^3$ of Concrete***

| S. NO | % of Metakaloin | MK(kg/$m^3$) | Cement | Natural sand | Robo sand | Coarse Aggregate 10mm | Coarse Aggregate 20mm |
|---|---|---|---|---|---|---|---|
| 1 | Control Mix | 0 | 400 | 690 | - | 571 | 571 |
| 2 | 0% MK(M1) | 0 | 400 | 345 | 345 | 571 | 571 |
| 3 | 5%MK(M2) | 20 | 380 | 345 | 345 | 571 | 571 |
| 4 | 10%MK (M2) | 41 | 360 | 345 | 345 | 571 | 571 |
| 5 | 15%MK (M3) | 60 | 340 | 345 | 345 | 571 | 571 |
| 6 | 20%MK (M4) | 80 | 320 | 345 | 345 | 571 | 571 |

## III. TEST RESULTS

A. Compressive Strength

The cube specimens were tested at the age of 7 days, 28 days and 90 days in Compression Testing Machine (CTM) after drying at room temperature according to IS: 516-1959. The load was applied without impacts and jerks and uniformly @ 140 N/cm$^2$ /minute. The failure load taken by the each specimen was recorded. The compressive strength was calculated dividing the failure load by cross sectional area of the cube.

***Table 6 Compressive Strength in Mpa***

| | 7 DAYS | 28 DAYS | 90 DAYS |
|---|---|---|---|
| Control MIX | 35.17 | 50.25 | 55.275 |
| 0%MK | 36.21 | 51.64 | 56.804 |
| 5%MK | 37.34 | 53.59 | 58.949 |
| 10%MK | 39.78 | 56.16 | 61.776 |
| 15%MK | 34.82 | 49.14 | 54.054 |
| 20%MK | 31.42 | 48.67 | 53.537 |

B. Split Tensile test

The cylindrical specimen were tested at the age of 7 days , 28 days and 90 days in Compression testing Machine (CTM) after drying at room temperature according to IS: 516-1959 to find the split tensile strength of concrete.

***Table 7 Slit Tensile Strength in Mpa***

| | 7 DAYS | 28 DAYS | 90 DAYS |
|---|---|---|---|
| Control MIX | 3.48 | 3.62 | 3.67 |
| 0%MK | 3.53 | 3.74 | 3.82 |
| 5%MK | 3.55 | 3.78 | 3.87 |
| 10%MK | 4.13 | 4.23 | 4.41 |
| 15%MK | 3.33 | 3.6 | 3.63 |
| 20%MK | 3.21 | 3.53 | 3.59 |

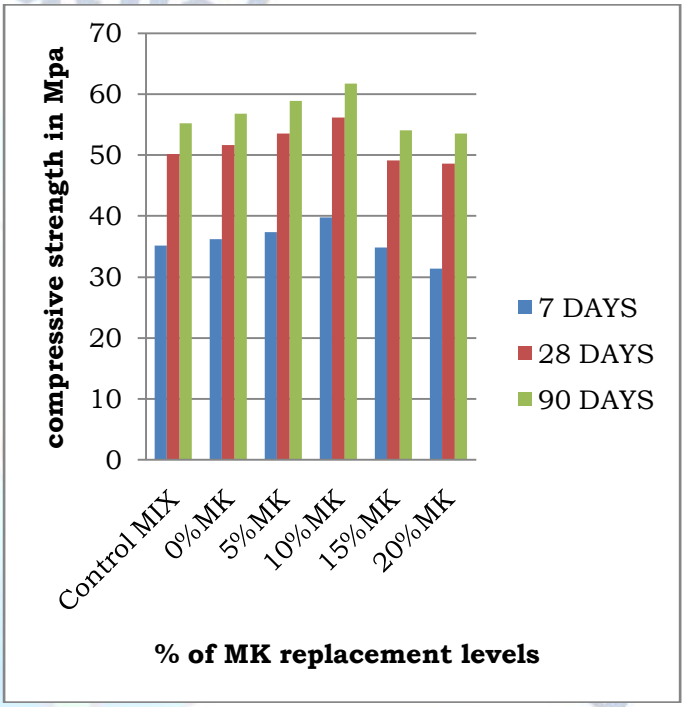
C. Flexural Strength

The bed of the testing machine shall be provided with two steel rollers, 38 mm in diameter, on which the specimen is to be supported, and these rollers shall be so mounted that the distance from centre to centre is 60 cm for 15.0 cm specimens or 40 cm for 10.0 cm specimens. The load shall be applied through two similar rollers mounted at the third points of the supporting span that is, spaced at 20 or 13.3 cm centre to centre. The load shall be divided equally between the two loading rollers, and all rollers shall be mounted in such a manner that the load is applied axially and without subjecting the specimen to any torsional stresses or restraints.

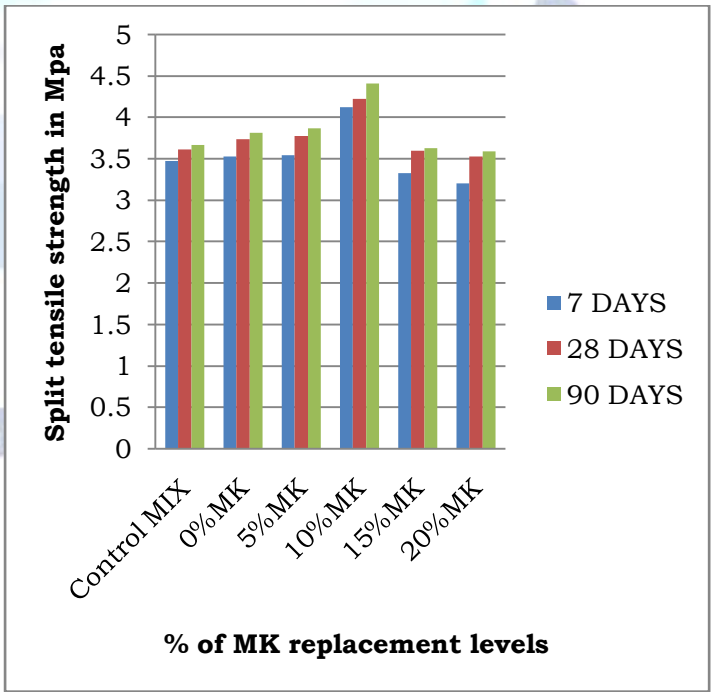
***Table 8 Flexural Strength in Mpa***

| | 7 DAYS | 28 DAYS | 90 DAYS |
|---|---|---|---|
| Control MIX | 2.12 | 2.47 | 2.51 |
| 0%MK | 2.17 | 2.49 | 2.54 |
| 5%MK | 2.19 | 2.55 | 2.58 |
| 10%MK | 2.21 | 2.65 | 2.75 |
| 15%MK | 2.05 | 2.48 | 2.53 |
| 20%MK | 1.18 | 1.33 | 1.46 |

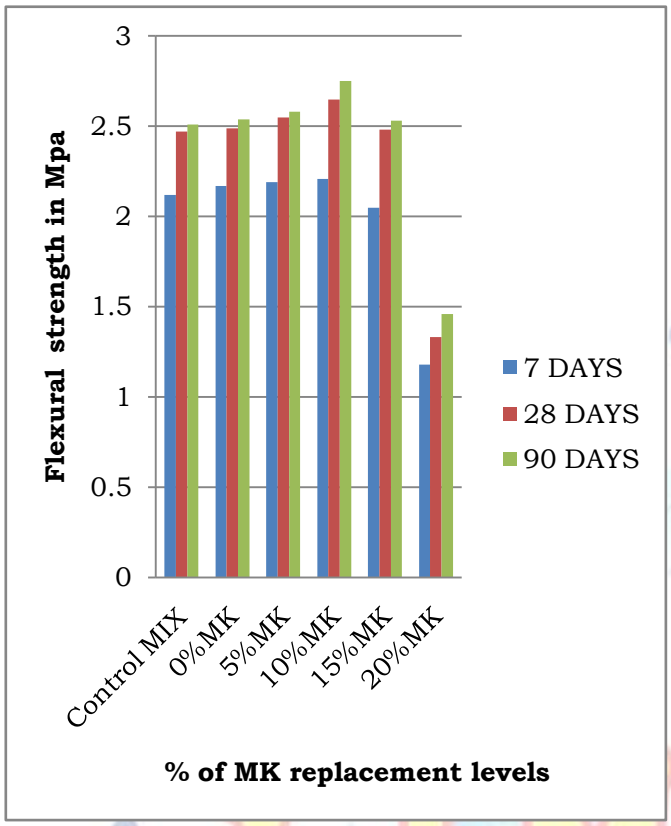
## IV. GRAPHS AND DICUSSIONS




***Graph for table 6***




***Graph for table 7***




***Graph for table 8***

## V. CONCLUSION

*1) Compressive strength*

From the test results it has been observed that the compressive strength of $M_{40}$ grade concrete attaining 4.14% of target strength for control mix concrete and strength going to be increased gradually at 0%, 5% and 10%, replacement of Metakaolin and natural sand with 50% ROBO sand are 2.95%, 6.17%, 13.11%, as compared to control mix at 7 days strength. At 28 days 2.76%, 6.64% and 11.76%, as compared control mix concrete and at 90 days 2.8%, 6.62% and 9.75%, as compared to control mix concrete. At 10% replacement of Metakaolin strength observed to be maximum and after strength is decreasing.

*2) Split Tensile strength*

From the test results it has been observed that the split tensile strength of $M_{40}$ strength going to be increased gradually at 0%, 5% and 10%, replacement of Metakaolin and natural sand with 50% ROBO sand are 1.43%, 2.01%, 6.2%, as compared to control mix at 7 days strength. At 28 days 3.33%, 4.41% and 11.68%, as compared control mix concrete and at 90 days 4.08%, 4.41% and 16.85%, as compared to control mix concrete. At 10% replacement of Metakaolin strength observed to be maximum and after strength is decreasing.

*3) Flexural strength*

From the test results it has been observed that the Flexural strength of $M_{40}$ grade concrete at 7 days initially decreased at 0% replacement of MK and after strength increased up to 10% replacement are 2.35%, 4.24% and after strength decreased gradually. at 28 days strengths are 3.2% and 7.2% at 5% and 10% replacement of MK after strength is decreasing. Similarly at 90 days 1.19% and 9.56% at 5% and 10% replacement of MK after strength is decreasing.

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