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# AN EXPERIMENTAL STUDY ON STRENGTH PROPERTIES OF CONCRETE BY PARTIAL REPLACEMENT OF CEMENT WITH MEATAKAOLIN AND FINE AGGREGATE WITH COPPER SLAG

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*Abstract*— **The strength of concrete using alternate materials is an important task of researchers. An Experimental work has been made to find the influence of Metakaolin (MK) as partial replacement of Cement and Copper Slag (CS) as partial replacement of fine aggregate on strength properties of concrete. Four concrete mixes were prepared using different proportions of Copper slag ranging from 0 to 100% and Metakaolin 0% to 20%.The effect of Metakaolin and Copper slag on Compressive strength, Split tensile Strength, Modulus of Elasticity and Flexural strength of M30 grade concrete were obtained. The addition of Copper Slag up to 50% as fine aggregate replacement and Metakaolin upto 15% as cement replacement attains strength of concrete comparable with that of the Control concrete. it is observed that at a combination of 15% of Metakaolin and 50% of Copper Slag is maximum strength.**

***KEY WORDS: Copper slag, Metakaolin, Control Concrete***

## I. INTRODUCTION

As rapid developments are taking place in the field of Concrete Technology, many engineers and researcher have been making attempts to improve strength parameter of the Concrete. A number of studies were carried out to investigate the utilization of various materials as partial replacement of Cement in the production of Concrete. Leaving the waste materials to the environment directly can cause environmental problem. These industrial wastes are dumped in the nearby land and the natural fertility of the soil is spoiled.

### A. *Metakaolin*

Researchers have studied on the effect of replacement of Portland cement by Metakaolin (MK) and also on fiber addition on the mechanical and durability properties of ordinary Portland cement concrete.

The T-O clay mineral kaolinate does not contain interlayer water. Dehydroxylated disordered kaolinite shows higher pozzolanic activity than ordered. The dehydroxylation of kaolin to Metakaolin is an endothermic in nature due to the large amount of energy required to remove the chemically bonded hydroxyl ions.

Advantages of Metakaolin:

- Increase in Compressive Strength.
- Make finishing easier.
- Reduce efflorescence.
- Maintain colour.

### B.*Copper Slag*

Copper Slag (CS) is a by-product of copper extraction by smelting. During smelting, impurities become slag which floats on the molten metal Slag that is quenched in water produces angular granules which are disposed of as waste product. In the current investigation the copper slag used was brought from Sterilite Industries India Ltd (Tuticorine,Tamilanadu).

## III.PROPERTIES OF MATERIALS

The materials used in experimental investigation are:

1. 53 grade Ordinary Portland Cement (OPC)
2. Fine Aggregate
3. Coarse Aggregate (Natural aggregate)
4. Potable water
5. Metakaolin and
6. Copper Slag

 

The properties of the materials are presented in following sections.

A. *Cement*

Cement is a fine mineral powder manufactured with very precise process. Cement is the main constituent of Concrete. It's an economical, high-quality construction material used in construction projects worldwide. The cement used throughout the experimental investigation was Ordinary Portland Cement of 53 grade confirming to IS specifications. The results of the tests on cement are shown in Table I.

TABLE I. PROPERTIES OF CEMENT

| S. No | Property | Test Result |
|---|---|---|
| 1. | Normal consistency | 30% |
| 2. | Specific gravity | 3.12 |
| 3. | Fineness of cement | 7.6% |
| 4. | Initial setting time | 90 minutes |
| 5. | Final setting time | 330 minutes |

*B.Aggregates*

Aggregates are the important materials of the concrete. They give body to the concrete, reduce shrinkage and effect economy. The mere fact that the aggregates occupy 70-80% of the volume of the concrete.

*B.1 Fine Aggregate*

The locally available river sand confirming to zone-II of IS 383-1970 has been used as fine aggregate. The various tests conducted on fine aggregate and the results as given in the Table II.

TABLE II . PROPERTIES OF FINE AGGREGATE

| S. No | Property | Test Result |
|---|---|---|
| 1. | Specific gravity | 2.6 |
| 2. | Fineness modulus | 3.8 |
| 3. | Grading of sand | Zone-II |

*B.2 Coarse Aggregate*

The coarse aggregate used in this investigation is confirmed to IS specifications. In this study, nominal size of 20 mm and 12 mm coarse aggregate were used.

*C.Copper Slag*

The properties of copper slag were shown in Table III.

Table III. Properties of Copper Slag

| S.NO | Property | Value |
|---|---|---|
| 1 | Specific gravity | 3.4 |
| 2 | Fineness modulus | 3.3% |
| 3 | Water absorption | 0.3% |
| 4 | Particle shape | Irregular |
| 5 | Colour | Glassy |
| 6 | Grading | Zone-II |

*D. Metakaolin:*

Metakaolin used in this experimental study is obtained from ASTRRA chemicals, Chennai. Properties of the Metakaolin as given by the supplier are given in the Table IV

Table IV. Properties of Metakaolin

| S.NO | Property | Value |
|---|---|---|
| 1 | Specific Gravity | 2.1 |
| 2 | Density (gm/cm$^3$) | 2.17 |
| 3 | Colour | Half-white |
| 4 | Particle Shape | Spherical |

*E. Water:*

The water used for casting and curing of Concrete test specimens was free of acids, organic matter and impurities which when present can adversely affect the strength of Concrete.

## IV.EXPERIMENTAL WORK

*A.General*

The experimental investigation is carried out to obtain the Compressive Strength of Concrete by partial replacement of Cement with Metakaolin and Fine Aggregate with Copper Slag. In the present investigation Concrete specimens were prepared with 10%, 15%,20% of Metakaolin and 25%, 50%, 75% and 100% Copper Slag.

*B. Concrete mix preparation:*

It can be defined of selecting suitable ingredients of Concrete and determining their relative proportions with the objective of producing Concrete of required strength and durability as economically as possible. The design of Concrete mix is not a simple task on account of widely varying properties of the constituent materials.

*C. Curing Procedure*

After the casting of cubes, cylinders and prisms the specimens are kept at room temperature for one day and the specimens are removed from the moulds after 24 hours of casting of Concrete specimens. Marking has been done on the specimens to identify the casting items. To maintain the constant moisture on the surface of the specimens, they are placed in water tank for curing. All the specimens have been cured for the desired age. Concrete specimens are cured for 3, 7, 28,56 and 90 days. Similarly M30 Concrete cylinder specimens, cubes, prisms were prepared as per the design mix proportion cured under the above mentioned standard conditions for 28 days for testing.

*D. Compressive strength test*

The test was conducted in compression testing machine. The load was applied at the rate approximately 140kg/cm$^2$/min until the failure of the specimen.

## VI.RESULTS AND DISCUSSIONS

The following tests were conducted on M30 grade of concrete by partial replacement of cement with Metakoalin and fine aggregate with copper slag and then results were compared with the controlled concrete.

- Compressive Strength
- Split Tensile Strength
- Flexural Strength
- Modulus of Elasticity

*A.Compressive Strength*

The results of the Cube Compressive Strength of M30 is shown in Table V

Table V Cube Compressive Strength of Concrete for Different Mixes

| **Concrete Mix** | **Compressive Strength of Concrete (MPa)** | | | | |
|---|---|---|---|---|---|
| | **3 Days** | **7 Days** | **28 Days** | **56 Days** | **90 Days** |
| Control Concrete | 17.0 | 25.2 | 38.5 | 39.7 | 42.3 |
| MK0%+CS25% | 18.3 | 26.0 | 39.7 | 40.1 | 42.7 |
| MK0%+CS50% | 18.9 | 27.9 | 39.9 | 41.1 | 42.5 |
| MK0%+CS75% | 18.0 | 25.6 | 38.2 | 39.4 | 41.1 |
| MK0%+CS100% | 16.3 | 23.7 | 34.0 | 35.9 | 36.3 |
| MK10%+CS25% | 20.4 | 30.2 | 39.6 | 40.0 | 42.9 |
| MK10%+CS50% | 21.1 | 31.6 | 42.4 | 43.3 | 44.0 |
| MK10%+CS75% | 19.7 | 28.6 | 41.2 | 42.2 | 44.5 |
| MK10%+CS100% | 18.2 | 27.6 | 37.6 | 39.7 | 41.9 |
| MK15%+CS25% | 22.4 | 32.0 | 41.8 | 42.7 | 44.6 |
| MK15%+CS50% | 25.3 | 33.3 | 46.5 | 47.8 | 48.1 |
| MK15%+CS75% | 21.6 | 31.1 | 44.1 | 45.5 | 46.1 |
| MK15%+CS100% | 19.6 | 29.9 | 40.5 | 41.2 | 43.3 |
| MK20%+CS25% | 20.6 | 28.6 | 39.2 | 40.7 | 42.4 |
| MK20%+CS50% | 20.9 | 30.0 | 41.2 | 42.5 | 44.5 |
| MK20%+CS75% | 18.7 | 27.7 | 39.5 | 42.2 | 43.4 |
| MK20%+CS100% | 17.6 | 26.2 | 35.4 | 39.2 | 40.7 |

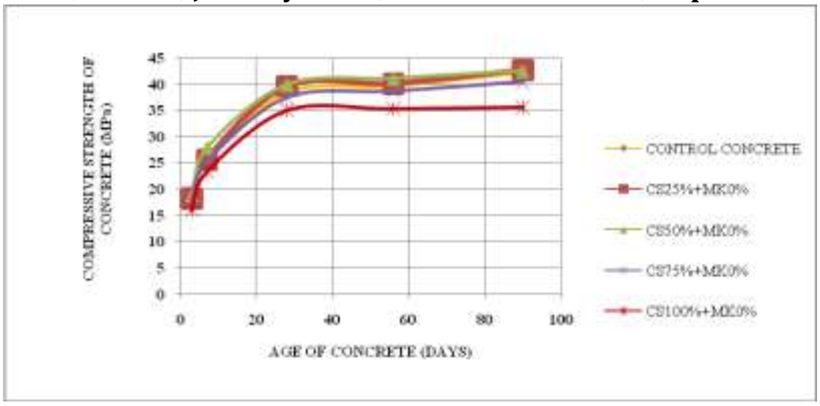


*Fig 1 Variation of Cube Compressive Strength of Concrete with Varying Percentages of Copper Slag*

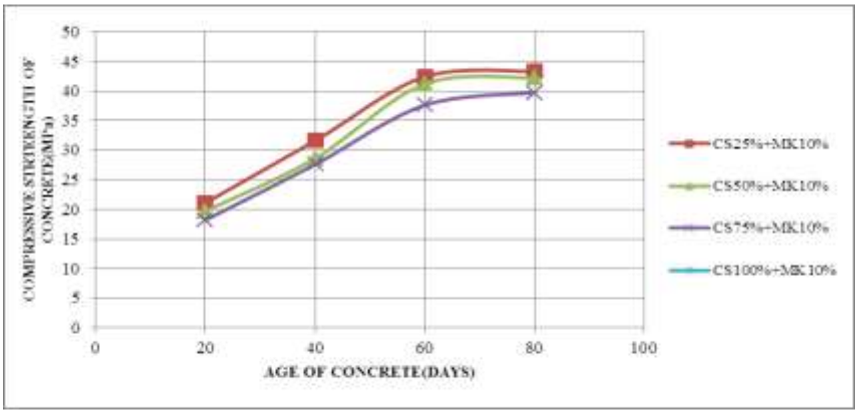


*Fig 2 Variation of Cube Compressive Strength of Concrete at 10% Metakaolin and at Varying Percentages of Copper Slag*

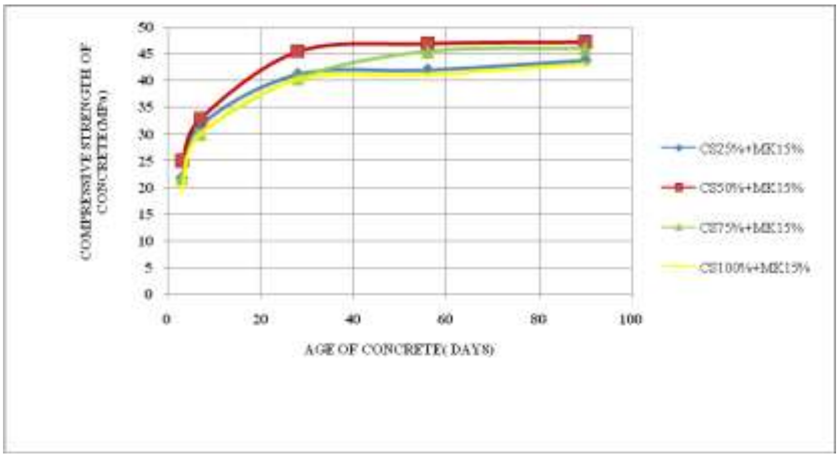


*Fig 3 Variation of Cube Compressive Strength of Concrete at 15% Metakaolin and at Varying Percentages of Copper Slag*

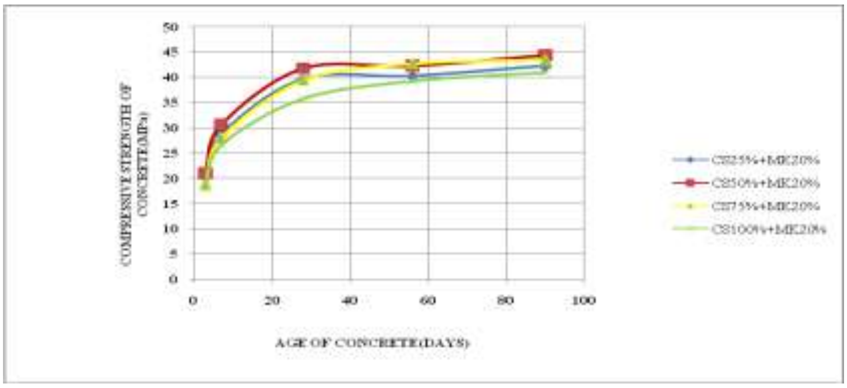


*Fig 4 Variation of Cube Compressive Strength of Concrete at 20% Metakaolin with Varying Percentages of Copper Slag*

B. *Split tensile Strength*

The results of split tensile strength is shown in Table VI

Table VI. Split Tensile Strength of Concrete For Different Mixes

| Concrete Mix | Metakaolin (%) | Copper Slag (%) | Split Tensile Strength(MPa) |
|---|---|---|---|
| Control Concrete | 0 | 0 | 3.7 |
| MK0%+CS25% | 0 | 25 | 3.8 |
| MK0%+CS50% | 0 | 50 | 3.9 |
| MK0%+CS75% | 0 | 75 | 3.6 |
| MK0%+CS100% | 0 | 100 | 2.5 |
| MK10%+CS25% | 10 | 25 | 3.8 |
| MK10%+CS50% | 10 | 50 | 4.1 |
| MK10%+CS75% | 10 | 75 | 3.7 |
| MK10%+CS100% | 10 | 100 | 2.8 |
| MK15%+CS25% | 15 | 25 | 3.9 |
| MK15%+CS50% | 15 | 50 | 4.4 |
| MK15%+CS75% | 15 | 75 | 3.8 |
| MK15%+CS100% | 15 | 100 | 2.7 |
| MK20%+CS25% | 20 | 25 | 3.3 |
| MK20%+CS50% | 20 | 50 | 3.6 |
| MK20%+CS75% | 20 | 75 | 3.1 |
| MK20%+CS100% | 20 | 100 | 2.3 |

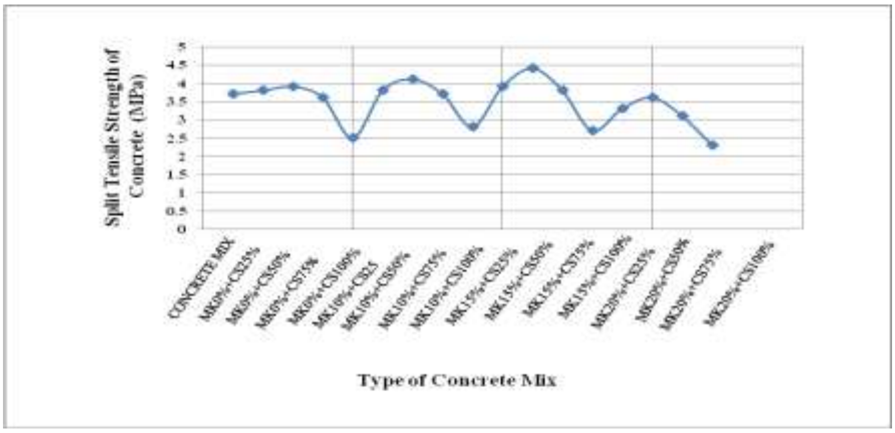


*Fig 5 Variation of Split Tensile Strength of Concrete with Varying Percentages of Metakaolin and Copper Slag*

 

C. *Flexural Strength*

The results of Flexural Strength of concrete is shown in Table VII.

Table VII Flexural Strength of Concrete for Different Mixes

| Concrete Mix | Metakaolin (%) | Copper Slag (%) | Flexural Strength(MPa) |
|---|---|---|---|
| Control Concrete | 0 | 0 | 5.81 |
| MK0% +CS 25% | 0 | 25 | 6.3 |
| MK0% +CS50% | 0 | 50 | 6.7 |
| MK0% +CS75% | 0 | 75 | 6.1 |
| MK0% +CS100% | 0 | 100 | 5.8 |
| MK10% +CS25% | 10 | 25 | 6.5 |
| MK10% CS50% | 10 | 50 | 7.0 |
| MK10% CS75% | 10 | 75 | 6.4 |
| MK10% CS100% | 10 | 100 | 6.0 |
| MK15% CS25% | 15 | 25 | 6.8 |
| MK15%+ CS50% | 15 | 50 | 7.5 |
| MK15%+ CS75% | 15 | 75 | 6.6 |
| MK15%+ CS100% | 15 | 100 | 6.2 |
| MK20%+ CS25% | 20 | 25 | 6.5 |
| MK20%+ CS50% | 20 | 50 | 7.1 |
| MK20%+ CS75% | 20 | 75 | 6.2 |
| MK20%+ CS100% | 20 | 100 | 6.1 |

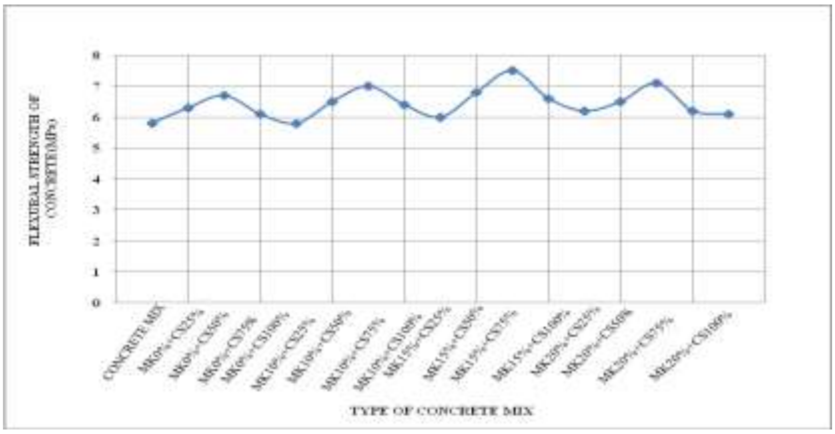


*Fig 6 Variation of Flexural Strength of Concrete with Varying Percentages of Metakaolin and Copper Slag*

D. *Modulus of Elasticity*

The results of Modulus of Elasticity are shown in the Table VIII.

Table VIII. Modulus of Elasticity of Concrete for Different Mixes

| Concrete Mix | Metakaolin (%) | Copper Slag (%) | Modulus of Elasticity (GPa) |
|---|---|---|---|
| Control Concrete | 0 | 0 | 27.5 |
| MK0% +CS 25% | 0 | 25 | 28.1 |
| MK0% +CS50% | 0 | 50 | 28.6 |
| MK0% +CS75% | 0 | 75 | 28.1 |
| MK0% +CS100% | 0 | 100 | 27.3 |
| MK10% +CS25% | 10 | 25 | 28.5 |
| MK10% CS50% | 10 | 50 | 28.1 |
| MK10% CS75% | 10 | 75 | 28.6 |
| MK10% CS100% | 10 | 100 | 28.0 |
| MK15% CS25% | 15 | 25 | 29.4 |
| MK15%+ CS50% | 15 | 50 | 30.0 |
| MK15%+ CS75% | 15 | 75 | 28.6 |
| MK15%+ CS100% | 15 | 100 | 27.0 |

| | | | |
|---|---|---|---|
| MK20%+ CS25% | 20 | 25 | 27.5 |
| MK20%+ CS50% | 20 | 50 | 27.5 |
| MK20%+ CS75% | 20 | 75 | 27.8 |
| MK20%+ CS100% | 20 | 100 | 26.1 |

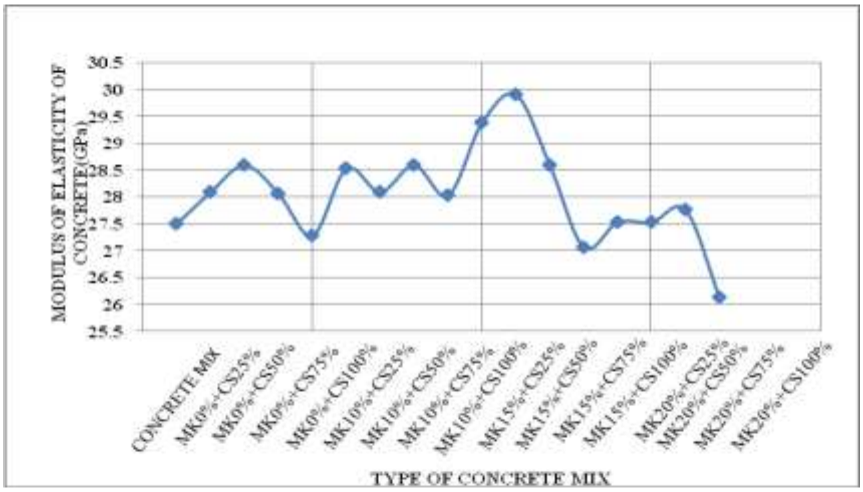


*Fig 7 Variation of Modulus of Elasticity of Concrete with Varying Percentages of Metakaolin and Copper Slag*

## VII.CONCLUSIONS

Based on the results of experimental investigation, it can be concluded that,

- The Compressive Strength decreases as the Copper Slag content is increased by more than 50%.
- From the test results, an increase of 19.6% in Cube Compressive Strength at 28 days is observed with 15% Metakaolin and 50% Copper Slag.
- Split Tensile Strength of 4.1 MPa is obtained in case of 15% MK and 50% Copper Slag compared to control Concrete (3.7 MPa). There is an increase of 18% in Split Tensile Strength compared to Control Concrete
- The increase of 29.1% in Flexural Strength compared to control Concrete is obtained with 15% MK and 50% Copper Slag.
- An increase of 8.7% in Modulus of Elasticity in case of 15% Metakaolin and 50% Copper Slag compared to Controlled Concrete.
- Finally, it can be concluded that the optimum percentage of Metakaolin and Copper Slag are 15% and 50% respectively, can be used for preparation of structural concrete.

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