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# Mechanical Properties Of Concrete With METAKOALIN As An Admixture And M-Sand as a Replacement For River Sand

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**Abstract - Concrete is probably the most extensively used construction material which governs the total cost of the project, produced from locally available constituents.This paper deals with the addition of optimum quantity ofmetakaolinas an admixture and partial replacement of river sand with manufactured sand in concrete for strength and sustainability.Metakaolin is a cementitious material used as an admixture to produce high strength concrete to modify the properties of concrete inpoor concrete structures (example-seashores) where underground structures suffer severe loss of compressive strength, permeability, durability. The use of manufactured sand as a replacement helps to achieve sustainable development in India. Properties likeworkability, compressive strength and durability of M30 grade mixes are studied byperforming trials, incorporating varying percentages of Metakaolin(0%, 5%, 7.5% and 10% of weight of cement) and M-sand as a replacement with percentage variation as follows- 0%, 30%, 60% and 100% of the weight of ordinary sand.The workability of the concrete is studied based on Slump test and Compaction factor tests. Concrete cubes and cylinders of respective mixes mentioned above are casted based on IS codes, their properties are studied andthe results obtained using the above mentioned proportions werecompared with IS codes for controlled concrete.**

**Keywords - Concrete, Metakaolin, Manufactured sand, Compressive strength,Splitting tensile strength, Sustainability**

## I. INTRODUCTION

The use of supplementary cementitous materials (SCMs) is fundamental in developing low cost construction materials for use in developing countries. By the addition ofpozzolanic materials, various properties of concrete like workability, durability, strength, resistance to cracks and permeability can be improved.Metakaolin is a fine, natural white clay which has high content of silica and hence called'High Reactivity Metakaolin' (HRM). During the cement hydration process, water reacts with Portland cement and forms calcium-silicate hydrate (CSH). The by-product of this reaction is calcium hydroxide (lime). This lime has weak links in concrete, and hence reduces the effect of the CSH. When Metakaolin is added in the hydration process, it reacts with the free lime to form additional CSH material, thereby making the concrete stronger and more durable.

Metakaolin functions by converting an undesirable byproduct of the cement hydration process, calcium hydroxide (Free lime) to various forms of calcium aluminate. These materials can be described as cementitious as they contribute to the strength of the concrete.

Metakaolin reduces the size of pores in cement paste and transforms many finer particles into discontinuous pores, therefore decreasing the permeability of concrete substantially. Metakaolin increases compressive and tensile strengths. It reduces permeability and efflorescence. Also, it reduces heat of hydration leading to better shrinkage and crack control. Hence the use of Metakaolin has wide scope in its use in concrete.

Huge quantity of concrete is consumed by construction industry all over the world. In India, conventional concreteis produced using natural sand from river beds as fine aggregate. This poses an environmental problem and also, the government's restrictions on sand quarrying have resulted in scarcity andsignificant increase in its cost. Excess digging of sandfrom river beds is hazardous to the environment. The deep pits dug into the river bed affect theground water level. Hence there is a need for an alternative to meet the requirement of fine aggregate.

The cheapest and the easiest substitution for natural sand is manufactured sand obtained from limestone quarries, lateriticsand and crushing natural stone quarries. Concrete containing limestone filler asa replacement for natural sand can attain more or less the same compressive strength, tensile strength,permeability, modulus of rupture and lower degree of shrinkage as the control concrete. The resultant concrete is found to have better workability and higher compressive strength.

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### 1.1 SCOPE OF THE VENTURE

Throughout the developing world, river sand and gravel are widely exploited as aggregates for building constructions since sand extracted from river channels requires almost no post processing other than size selection. Sand is a non-renewable resource which would have unimaginable impacts on human, plant and animal life because of its unforeseen effects on the ecosystem when exploited. Realizing this fact, Sustainable Sand Mining Management Guidelines 2016 from Union Ministry of Environment, Forests and Climate Change (MoEF& CC) condemned the use of sand in concretization including its burial under highways despite very high value of minerals found in the sand. In this scenario that prevails today, M-sand poses itself as a powerful alternative for river sand. Manufactured sand has several advantages since it has lesser impurities and good working properties. It has various other pros because it is free from silt and clay particles, and has denser particle packing than natural sand. It also offers higher flexural strength, better abrasion resistance, higher unit weight and lower permeability. Despite these advantages, manufactured sand does not have well-defined directives based on which it can be used. Thus, in this research, the properties of concrete samples containing river sand and m-sand will be studied and the results will be compared with each other, keeping in mind the possible objective of obtaining greater strength properties in samples containing m-sand.

## II. EXPERIMENTAL PROGRAM

### 2.1 MATERIALS

### 2.1.1Cement:

The cement used in this experimental study is 43 grades Ordinary Portland Cement. All properties of cement are tested by referring IS 12269-1987 specification of 43 grade Ordinary Portland Cement. The properties of cement are given in **table 1**.

***Table 1****: Properties of cement*

| Sl.No. | Property | Value |
|---|---|---|
| 1 | Specific Gravity | 3.15 |
| 2 | Fineness | 97.50 |
| 3 | Initial setting time | 40 min |
| 4 | Final setting time | 480 min |

### 2.1.2Fine aggregate (M-sand):

Fine aggregate used in this research is M- sand. Fine aggregates are the aggregates whose size is less than 4.75mm.

***Table 2****: Properties of M-sand*

| Sl.No | Property | Value |
|---|---|---|
| 1 | Specific Gravity | 2.65 |
| 2 | Fineness modulus | 5.25 |
| 3 | Water Absorption | 7.0% |
| 4 | Surface texture | smooth |

### 2.1.3Fine aggregate (River sand):

Good quality natural river sand is readily available in many areas and can be easily obtained and processed. Generally they are classified based on size, i.e.; those below 4.75mm are regarded as fine aggregate.

**Table 3**: Properties of River sand

| Sl.No. | Property | Value |
|---|---|---|
| 1 | Specific Gravity | 2.56 |
| 2 | Fineness modulus | 4.55 |
| 3 | Water Absorption | 6.2% |
| 4 | Particle Shape | Smooth |

### 2.1.4 Coarseaggregate:

Coarse aggregate of nominal size 20mm is chosen and tested to determine the different physical properties as per IS 383-1970. Test results conform to the IS 383 (PART III) recommendations.

***Table 4****: Properties of Coarse aggregate*

| Sl.No. | Property | Value |
|---|---|---|
| 1 | Specific Gravity | 2.70 |
| 2 | Fineness modulus | 7.15 |
| 3 | Water Absorption | 8.0% |
| 4 | Particle Shape | Angular |

### 2.1.5 Metakaolin:

Metakaolin is a fine, natural white clay which has high content of silica, and hence called 'High Reactivity Metakaolin' (HRM).

***Table 5:*** *Properties of Metakaolin*

| Description | Property |
|---|---|
| Specific gravity | 2.5 |
| Mean grain size | 2.54 |
| Specific area $cm^2/gm$ | Specific area $cm^2/gm$ |
| **Chemical compositions** | **(%)** |
| Silicon dioxide ($SiO_2$) | 60-65 |
| Aluminium oxide ($Al_2O_3$) | 30-34 |
| Iron oxide ($Fe_2O_3$) | 1.00 |
| Calcium oxide (CaO) | 0.2-0.8 |
| Magnesium oxide (MgO) | 0.2-0.8 |
| Sodium oxide ($Na_2O$) | 0.5-1.2 |
| Potassium oxide ($K_2O$) | 0.5-1.2 |
| Loss on ignition | <1.4 |

## III. EXPERIMENTAL PROCEDURE

### 3.1Mixing of constituent materials:

Cement and Metakaolinwere measured and mixed until a uniform colour was obtained. The blendedmix was spread on already measured fine aggregate placed on an impermeable platform and mixed thoroughlybefore coarse aggregate and water were added.

***Table 6****: Mix proportion*

| Concrete Grade | Cement | Sand | Coarse Aggregate | W/C ratio |
|---|---|---|---|---|
| M30 | 1 | 1.08 | 2.36 | 0.4 |

### 3.2 Casting and curing of specimens:

The sample concrete wascast in well lubricated moulds. After compaction, they were left at room temperature for 24 hours. After 24 hours, they wereimmersed in water curing tanks for specified periods of time. To investigate the effect of inclusion of metakaolin(as an admixture), cubic specimens of side 150 mm and cylindrical specimens having 150mm diameter and 300mm heightwere cast for reference and other mixes having

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variable metakaolin content as an admixture and M-sand content replacing river sand.

***Table 7:*** *Test Specimen Details*

| Sample | Variation of materials in % to M30 mix | |
|---|---|---|
| | Metakaolin | M-sand |
| CON | 0 | 0 |
| S1 | 5 | 0 |
| S2 | 5 | 30 |
| S3 | 5 | 60 |
| S4 | 5 | 100 |
| S5 | 7.5 | 0 |
| S6 | 7.5 | 30 |
| S7 | 7.5 | 60 |
| S8 | 7.5 | 100 |
| S9 | 10 | 0 |
| S10 | 10 | 30 |
| S11 | 10 | 60 |
| S12 | 10 | 100 |

### 3.3 Compressive strength test:

It is used to determine the compressive strength of concrete. The strength of a concrete specimen depends on cement, aggregate, w/c ratio, curing temperature, age and size of specimen. Cubes of size 150 mm x 150 mm x 150 mm were cast and subjected to curing for 7 days, 14 days and 28 days and then, compressive strength of each cube was determined. The cubes were tested in 2000 kN capacity hydraulic Compression Testing Machine (CTM). The test results are tabulated in **table 8**.

### 3.4 Splittingtensile strength test:

It test is used to determine the tensile strength of concrete. Cylindrical specimens were used in this test. The test was carried out by placing a cylindrical specimen horizontally between the loading surfaces of a compression testing machine and the load was applied until the failure of the cylinder occurred along the vertical diameter. Cylinders ofdiameter 100 mm and length 200 mm were cast and subjected to curing for 7 days, 14 days and 28 days before determining the split tensile strength. The cylinders were tested in 400 kN capacity Universal Testing Machine (UTM).The test results are shown in **table 9**.

## IV. RESULTS AND DISCUSSIONS

### 4.1 Cube compressive strength:

Three cube samples each for various proportions were tested to determine the compressive strengths of cubes after 7 days and 28 days of curing using a 2000kN Compression Testing Machine. The test was conducted as per standards. It is seen that after 28-days of curing, the compressive strength increases with increase in metakaolin and attains a maximum value when the amount of metakaolin is 7.5% of the amount of cement and 60% of ordinary sand is replaced by M-sand. When metakaolin content exceeds 10%, it reduces the water cement ratio and delays the pozzolonic activity. This condition results in the chemical reaction in concrete where excess metakaolinreacts with hydrated calcium hydroxide, thus reducing the compressive strength of concrete. The conclusion is that, the optimum quantity of metakaolin as an admixture and M-sand as replacement was found to be 7.5% and 60% respectively.

***Table 8:*** *Cube compressive strength of Concrete*

| Sample | Compressive Strength (N/mm$^2$) | | |
|---|---|---|---|
| | 7 days | 14 days | 28 days |
| CON | 22.56 | 27.50 | 33.70 |
| S1 | 23.15 | 29.56 | 35.96 |
| S2 | 24.30 | 30.82 | 36.24 |
| S3 | 26.80 | 31.17 | 37.75 |
| S4 | 24.35 | 30.85 | 35.30 |
| S5 | 26.63 | 32.43 | 38.04 |
| S6 | 26.91 | 33.65 | 38.42 |
| S7 | 27.85 | 34.93 | 39.80 |
| S8 | 26.24 | 31.82 | 37.63 |
| S9 | 23.76 | 29.12 | 35.48 |
| S10 | 25.31 | 30.60 | 36.12 |
| S11 | 26.15 | 31.56 | 37.25 |
| S12 | 25.18 | 30.65 | 35.93 |

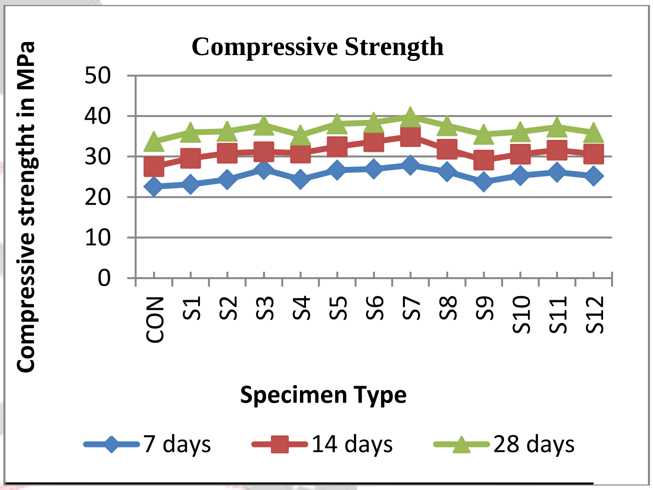


**Figure 1: Variation of Compressive strength for various mix proportions**

### 4.2 Splittingtensile strength:

Three cylindrical samples, each of the mix with various proportions were tested to determine the split tensile strength after 28 days of curing using a 3000kN Compression Testing Machine. The tests were conducted as per standard specifications. The test results are tabulated in **Table 9**. The results show that there is a slight variation in strength among the samples subjected to 7 days,14 days and 28 days of curing.It is seen that after 28-days of curing, the split tensile strength increases with increase in metakaolin and M-sand and attains a maximum value when the percentagesof the two constituents are 7.5 % and 60% respectively. Thus the optimum quantity of metakaolin as an admixture and M-sand as replacement was found to be 7.5% and 60% respectively.**(Refer Table 9)**

**Table 9:** Split tensile strength of Concrete

| Sample | Split Tensile Strength (N/mm$^2$) | | |
|---|---|---|---|
| | 7 days | 14 days | 28 days |
| CON | 3.29 | 3.78 | 4.17 |
| S1 | 3.41 | 3.87 | 4.22 |

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| | | | |
|---|---|---|---|
| S2 | 3.54 | 3.93 | 4.31 |
| S3 | 3.66 | 4.05 | 4.38 |
| S4 | 3.46 | 3.83 | 4.25 |
| S5 | 3.76 | 4.08 | 4.42 |
| S6 | 3.82 | 4.15 | 4.68 |
| S7 | 3.95 | 4.23 | 4.85 |
| S8 | 3.74 | 3.98 | 4.58 |
| S9 | 3.48 | 3.87 | 4.23 |
| S10 | 3.56 | 3.96 | 4.37 |
| S11 | 3.67 | 4.02 | 4.52 |
| S12 | 3.45 | 3.92 | 4.31 |

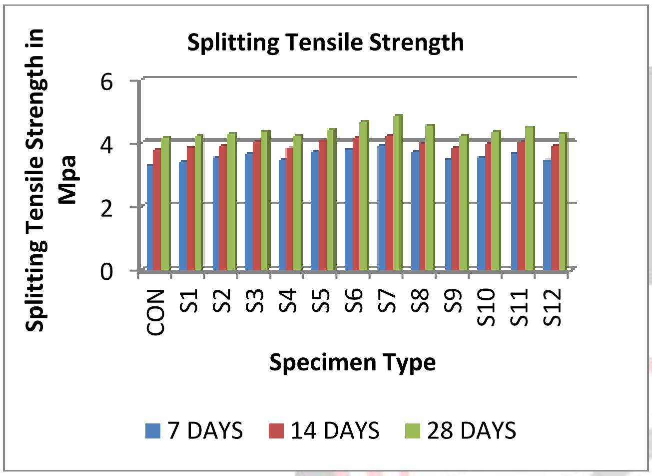


**Figure 2: Variation of Splitting tensile strength for various mix proportions**

From Figure 1 and Figure 2, it is clear that the compressive and splitting tensile strength is maximum for the specimen S7 which contains 7.5% metakaolin and 60% of river sand replaced by M-sand. The maximum value of compressive strength and splitting tensile strength was found to be 39.80 MPa and 4.85 MPa respectively, that is, the partial replacement of river sand and simultaneous inclusion of metakaolin as an admixture increases the values of compressive strength and splitting tensile strength by 6 MPa and 0.68 MPa respectively.

## V. CONCLUSIONS

From the investigation on the effect of addition of Metakaolin as admixture in cement concrete and replacement of river sand with M-sand, the following conclusions can be drawn

- After 28 days of curing, the compressive strength and splitting tensile strength showed an increase up to the optimum quantity of metakaolin and M-sand inclusion. Once this specified proportion is exceeded, the strength of concrete declines.
- The optimum dose of Metakaolin and M-sand is found to be 7.5% and 60% (by weight) respectively at7, 14 and 28 days of curing.
- The highest increase in compressive strength upon the above said modifications was found to be 17.8% over that of conventional concrete specimens.
- The highest increase in splitting tensile strength upon the above said modifications was found to be 16.3% over that of conventional concrete specimens.
- The results encourage the use of Metakaolin, as apozzolanic material for producing high strength concrete.
- Replacement of river sand with M-sand serves as an invaluable means to protect environmental resources, which result in sustainable development as well as economic balance.
- The fineness of Metakaolin and M-sand contributes higher bonding between cement and aggregates, thereby producing quality concrete.
- The use of Metakaolin in concrete can compensate for environmental, technical and economic issues.
- The inclusion of Metakaolin as an admixture results in the early strength development of concrete.
- The increase in Metakaolin and M-sand in optimum proportions improves the compressive strength and split tensile strength.
- The use of Metakaolin and M-sand provides a dual advantage with Metakaolin contributing to strength and M-sand contributing to sustainability.

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