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Experimental Investigation on the Properties of Concrete by using Metakoalin as an Admixture and M-Sand as Replacement for Sand

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Abstract: Concrete is probably the most extensively used construction material in the world. In all construction works, concrete is an important and costly issue, which governs the total cost of the project.Concrete can generally be produced of locally available constituents. Metakaolin is a cementitious material used as admixture to produce high strength concrete. In the case where inadequate or poor concrete structures like seashore, underground structures suffer severe loss of compressive strength and permeability related durability,use of metakaolin proves very useful to modify the properties of concrete. This paper also puts forward the application of manufacture sand as replacement of ordinary river sand as an attempt towards sustainable development in India. The present paper deals with the study of properties namely workability, compressive strength and durability of M30 grade mixes incorporating different percentages of high reactivity metakaolin by weight of cement and M-sand by weight of ordinary sand .In this work various trials having varying percentage of Metakaolin as 0%,5%,7.5% and 10% by weight of cement and M-sand as replacement of ordinary sand by 0%,30%,60% and 100% to the weight of ordinary sand. Concrete cubes and cylinders of respective mixes mentioned above are casted based on IS codal provision and properties of the same are studied. The workability of the concrete is also studied based on Slump test and Compaction factor tests.This paper also deals with the work to determine optimum quantity of metakaolin to be added as an admixture and optimum replacement quantity of river sand with manufacture sand in concrete to have a dual advantage of strength aspect and sustainability.The results obtained by using above mentioned proportions will be compared with I.S codes for controlled concrete.

Keywords: Concrete, Metakaolin, Manufacture sand, Compressive strength,Splitting tensile strength, Sustainability

1. Introduction:

The use of supplementary cementitous materials (SCMs) is fundamental in developing low cost construction materials for use in developing countries. By addition of some pozzolanic materials, the various properties of concrete like workability, durability, strength, resistance to cracks and permeability can be improved.. Metakaolin is a fine, natural white clay which contains the highest content of siliceous, so called as 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 the formation of calcium hydroxide (lime). This lime has weak link 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 water permeability and efflorescence. Also it reduces heat of hydration leading to better shrinkage and crack control. So use of Metakaolin has wide scope in its use in concrete.

The huge quantity of concrete is consumed by construction industry all over the world. In India, the conventional concrete is produced using natural sand from river beds as fine aggregate. Decreasing natural resources poses the environmental problem and hence government restriction on sand quarrying resulted in scarcity and significant increase in its cost. Normally particles are not present in river sand up to required quantity. Digging sand, from river bed in excess quantity is hazardous to environment. The deep pits dug in the river bed, affects the ground water level. In order to fulfill the requirement of fine aggregate, some alternative material must be found.

The cheapest and the easiest way of getting substitute for natural sand is obtained from limestone quarries, lateritic sand and crushing natural stone quarries is known as manufactured sand. Concrete made with limestone filler as replacement of natural sand in concrete can attain more or less same compressive strength, tensile strength, permeability, modulus of rupture and lower degree of shrinkage as the control concrete (1). Concrete using various combinations of lateritic sand and quarry dust as complete replacement for conventional river sand. The result is found better workability and high compressive strength.

2. Experimental program:

2.1 Materials:

2.1.1 Cement:

The cement used in this experimental study is 43 grade 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

2.1.2 Fine 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

2.1.3 Fine aggregate (River sand):

Good quality natural river sand is readily available in many areas and may be easily obtained and processed.Generally fines are classified based on size, i.e.; below 4.75mm
is 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 Coarse aggregate:

Coarse aggregate of nominal size of 20mm is chosen and tests 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 contains the highest content of siliceous, so called as High Reactivity Metakaolin(HRM).

Table 5: Properties of Metakaolin

Specific gravity	2.5
Mean grain size (μm)	2.54
Specific area cm^2/gm	Specific area cm^2/gm
Chemical compositions	(%)
Silicon dioxide (SiO2)	60-65
Aluminium oxide (Al2O3)	30-34
Iron oxide (Fe2O3)	1.00
Calcium oxide (CaO)	0.2-0.8
Magnesium oxide (MgO)	0.2-0.8
Sodium oxide (Na2O)	0.5-1.2
Potassium oxide (K2O)	0.5-1.2
Loss on ignition	<1.4

3. Experimental procedure:

3.1Mixing of constituent materials:

The cement and Metakaolin were measured and mixed together until a uniform colour was obtained. The blended mix was spread on already measured fine aggregate placed on an impermeable platform and mixed thoroughly before the 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

3.2Casting and curing of specimens:

The specimens were cast in well lubricated moulds. Concrete were placed on the mould and compacted thereafter and they were left at room temperature for 24hrs before being transferred into the curing tank. After 24 hours, they were immersed in water curing tanks until their testing ages. To investigate the effect of inclusion of metakaolin (as an admixture to weight of cement), 150 mm cube specimens, 150 mm diameter and 300 mm height cylinder specimens were cast for referral and other mixes having 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:

The compression test is used to determine the strength of concrete. The strength of a concrete specimen depends upon cement, aggregate, w/c ratio, curing temperature, and age and size of specimen. Cubes of size 150 mm x 150 mm x 1050 mm were cast for finding 7 days, 14 days and 28 days compressive strength. The cubes were tested in 2000 kN capacity hydraulic Compression Testing Machine (CTM). For each mix proportions cubes were tested to find the compressive strength of concrete for 7 days, 14 days and 28 days. The test results are tabulated in table 8.

3.4 Splitting tensile strength test:

The splitting tensile strength 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 along the vertical diameter. Cylinders of size 100 mm diameter and 200 mm long were cast for finding 7 days, 14 days and 28 days split tensile strength. The cylinders were tested in 400 kN capacity Universal Testing Machine (UTM).The test results are shown in table 9.

4. Results and discussions:

4.1Fresh concrete properties:

The required quantities of all the ingredients were taken by weigh batching with appropriate coarse aggregate fractions and mineral admixtures. The workability of the concrete was studied by conducting slump and flow tests as per the standard procedure. All the mix proportions were prepared with same water-cement ratio and tested for workability, strength and durability properties of HPC mixes. The inclusion of metakaolin and replacement with M-sand had a significant role in the workability of concrete with a w/c of 0.4.

4.1 Cube compressive strength:

Three cube samples each for various proportions were tested to determine the 7 days and 28 days compressive strength using a 2000 kN Compression Testing Machine. The compressive strength test on cubes is conducted as per standards. It is seen that 28-days compressive strength increases with increase in metakaolin up to 7.5 % and upto 60% replacement of M-Sand. After 10%, Metakaolin reduces the water cement ratio and delay the pozzolonic activity.The additions over 10% cause the concrete to have excess of high reactivity metakaolin to react with the hydrated calcium hydroxide and thus reduce the compressive strength of the concrete.It is observed that all variation of metakaolin percentage (0%,5%,7.5% and 10%) with 60% replacement of M-sand, the compressive strength reaches the maximum value. However 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

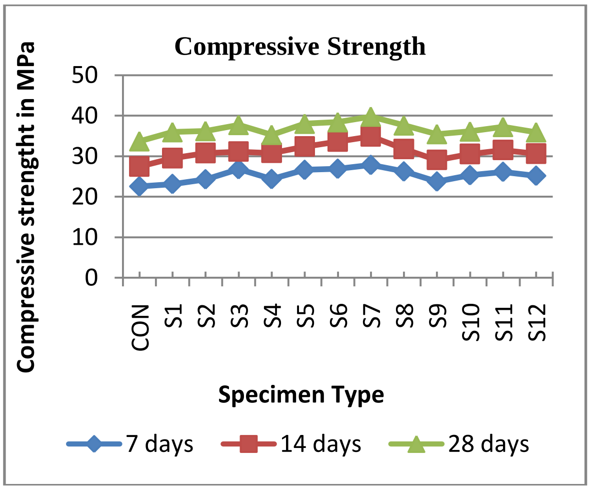

Figure 1: Variation of Compressive strength for various mix proportions

4.2 Splitting tensile strength:

Three cylinder samples each of the mix with various proportions were tested to determine the split tensile strength after 28 days 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 between 7 days, 14 days and 28 days.It is seen that 28-days split tensile strength increases with increase in metakaolin up to 7.5 % and upto 60% replacement of M-Sand. It is observed that all variation of metakaolin percentage (0%,5%,7.5% and 10%) with 60% replacement of M-sand, the split tensile strength reaches the maximum value. However 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
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

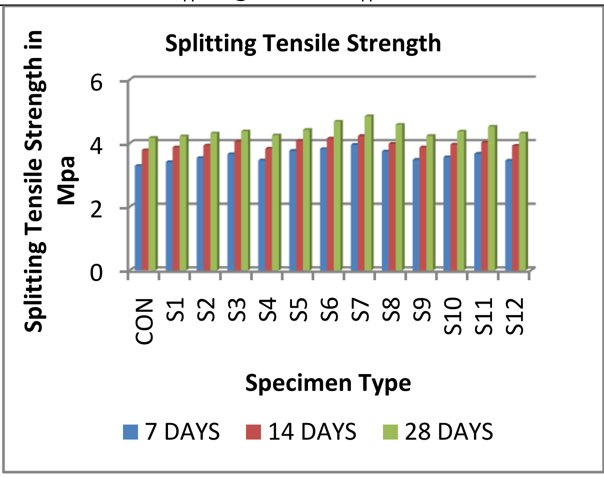

Figure 2: Variation of Splitting tensile strength for various mix proportions

From Figure 1 and Figure 2, it is clear that the compressive and splitting tensile strength is maximum for specimen S7(7.5% Metakaolin and 60% replacement of river sand with M-sand). At the optimum content, the maximum value of compressive strength and splitting tensile strength was found to be 39.80 MPa and 4.85 MPa respectively.

5. Conclusions:

From the present 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

- The results encourage the use of Metakaolin, as pozzolanic 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 for future as well as economical balance.
- The fineness of Metakaolin and M-sand contributes high bond development between the cement and aggregates and thereby capable of 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 up to 60% by weight of river sand improves the compressive strength, Split Tensile Strength upto 7.5%.
- The optimum dose of Metakaolin to be included and M-sand as replacement of river sand is found to be 7.5% and 60% (by weight) respectively at 7,14 and 28 days of compressive strength as well as split tensile strength.
- The 28 day compressive and splitting tensile strength was found to increase up to the optimum content and thereafter it declines.
- The use of Metakaolin and M-sand provide a dual advantage with Metakaolin contributing to strength and M-sand contributing to sustainability.

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