EXPERIMENTAL STUDY ON MECHANICAL PROPERTIES OF STEEL FIBER REINFORCED CONCRETE USING M-SAND AND METAKAOLIN

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Abstract

Today, concrete is the most widely used construction material due to its good compressive strength and durability. Plain concrete needs congenial atmosphere by providing moisture for a minimum period of 28 days for good hydration and to attain desired strength. Concrete contains coarse aggregate, fine aggregate, Cement and water. Now a days, there is a scarcity in River Sand. So, most probably M-sand can be used .It is the sand produced from hard granite stone by crushing. The size of M-Sand is less than 4.75 mm. Metakaolin is a dehydroxylated form of clay mineral Kaolinite, which is eco-friendly. It can be used as a replacement of Cement. The particle size of metakaolin is smaller than Cement. Steel fibres are usually used to increase the ductility properties. The aim of the investigation is to evaluate the extent of use of M-Sand in Concrete as partial replacement of fine aggregate and adding Metakaolin as a replacement of Cement to increase the binding property and to increase the ductility properties of the concrete by adding Steel fibers. In this experimental study, Metakaolin is added as 12% replacement of Cement,1.25% of steel fibres are added and M-Sand is varied from 60 to 100% as a replacement of fine aggregate.And compressive strength, split tensile strength, modulus of rupture and flexural behaviour of the concrete with varying quantity of M-Sand is evaluated and compared with the conventional concrete specimens.

Keywords: M-Sand, Metakaolin, Steel fiber, Flexural Strength, Split Tensile Strength, Modulus of Rupture, Ductility.

I. INTRODUCTION

Concrete is the most widely used man made construction material. It is obtained by mixing of cement, water, fine & coarse aggregate in required proportions. The concrete has high compressive strength, but its tensile strength is very low. In situation where tensile stresses are developed, the concrete is strengthened by steel bars forming a composite construction called reinforced cement concrete. The concrete without reinforcement is termed plain cement concrete. The process of pouring concrete is called concreting. The strength, durability and other characteristics of concrete depends on the proportion of mix, the method of compaction and other controls during placing, compaction and curing .Though concrete is a widely accepted building material there is some drawbacks in it. The low tensile strength, low impact strength and brittle nature of concrete make it necessary to be reinforced with steel rods. It was proved that placing the steel reinforcement in the tension zone of concrete will enhance the tensile strength of concrete and prevents flexural (or) bending failure. But later on, as an alternative approach to placing steel reinforcement in the tension zone, it was found that dispersion of fibres in concrete can drastically increase the various strength properties of concrete along with the ductility of concrete. Therefore, various fibres like steel, galvanized iron, polypropylene, glass, carbon, asbestos, jute plastic etc. are used in concrete. The addition of fibres to concrete delays the failure mechanism and induces ductility nature. Such product evolved due to introduction of fibres in concrete is called ‘Fibre Reinforced Concrete (FRC)’.In fibre reinforced concrete, it

S.No.	Description	
1	Specific gravity	50
2	Fineness	49
3	Normal Consistency	47

was found that the strength properties increase with the percentage of fibres. But, higher percentage of addition of fibres, say above 2% possess many difficulties like workability, accelerates stiffening of fresh concrete, causing segregation and pulling out of fibres etc.

II. EXPERIMENTAL PROGRAM

S.No.	**Description**	
1	Specific gravity	2.54
2	Fineness	2%
3	Normal Consistency	28%

Experimental Investigations have been carried out on the specimens to ascertain the workability and strength related properties.

A. *Materials Used*

Cement is defined as the material with adhesive and cohesive properties which make it capable of bonding the constituents of concrete into a compact durable mass. Cement is obtained by grinding the raw materials (calcareous materials like limestone, chalk, marine shell and argillaceous materials containing silica, alumina and iron oxide). The mixture is then burnt in a large rotary kiln at a temperature of 1300°C to 1500°C. The resulting product called clinker is cooled and ground to fine powder called cement. In this project, Ordinary Portland Cement (OPC) 53grade was used.

Aggregate which is passed through 4.75mm IS Sieve and retained on 75 micron IS Sieve is termed as fine aggregate. Fine aggregate is added to concrete to assist workability and to bring uniformity in mixture. Usually,the natural river sand is used as fine aggregate. Ordinary River sand confirming IS 383-1970 is used in this project.

The coarse aggregate for the works should be river gravel or crushed stone. Angular shape aggregate of size 20 mm and below. The aggregate which passes through 75mm sieve and retain on 4.75mm is termed as coarse aggregate. In this project, crushed granular aggregate of 20mm size is used.

B. *M-Sand*

M-Sand is produced from hard granite stone by crushing. The size of M-Sand is less than 4.75 mm. Now a days there is a scarcity in River Sand. So, most probably M-Sand can be used. The manufactured sand is obtained from stone quarries by crushing of stones. Its specific gravity is found to be 2.6. Now a days,the cost of River sand is high and hence there is a demand for M-Sand and its usage.

C. *Metakaolin*

Metakaolin is a chemical paste that forms upon thermal treatment of Kaolinite.It is formed upon the thermal treatment in the range of 400 to 500 C,the water is driven away from an amorphous aluminosilicate called Metakaolin.It is white in colour and acts as a pozzolanic material.The reactivity of the Metakaolin may also be affected by grinding to a finer particle size.

D. *Steel Fiber*

Steel fibres are added to increase the ductility properties of concrete. Steel fibres with aspect ratio 40 is used. Aspect ratio is the L/D ratio of the fibres.

Type of steel fiber	**Length of steel fiber (mm)**	**Diameter of steel fiber (mm)**	**Aspect ratio**
Hooked end	40	1	40

III. MIX DESIGN

The concrete mix M30 is designed as per IS10262:1982, IS 456:2000 for the conventional concrete. Mix design are given below in table I.

TABLE I.
MIX PROPORTIONS

Cement	**Fine Aggregate**	**Coarse Aggregate**	**W/C**
1	1.31	2.66	0.45

IV. DETAILS OF CONCRETE SPECIMEN

The concrete specimens for cubes, cylinders and prism have been casted as per the given table II.

TABLE II.
SPECIMEN DESCRIPTION

Description	No. of Specimens					
	Control	M1	M2	M3	M4	M5
Cube	6	6	6	6	6	6
Cylinder	3	3	3	3	3	3
Prism	3	3	3	3	3	3

M1 - 60% M-Sand,12% Metakaolin,1.25% Steel fibres
M2 - 70% M-Sand,12% Metakaolin,1.25% Steel fibres
M3 - 80% M-Sand,12% Metakaolin,1.25% Steel fibres
M4 - 90% M-Sand,12% Metakaolin,1.25% Steel fibres
M5 - 100% M-Sand,12% Metakaolin,1.25% Steel fibres

V. TESTS ON FRESH AND HARDENED CONCRETE

Workability tests such as slump test and compaction factor test were carried out for fresh concrete as per BIS specifications. The obtained slump value for controlled concrete was 100 mm. The obtained compacting factor value for controlled concrete was 0.8.

VI. RESULTS AND DISCUSSIONS

A. Fresh Concrete Tests

The workability tests were carried out for concrete specimens. The slump test and compaction factor tests were carried out. The Slump Cone Test results of workability were listed in table III.

TABLE III.

SLUMP CONE TEST

S.No.	Type of Mix	Slump Value	Workability
1	Control	50	Medium
2	Mix1	49	Medium
3	Mix2	47	Medium
4	Mix3	42	Medium
5	Mix4	38	Medium
6	Mix5	40	Medium

From the values, it is found that the slump value is 50 mm for Control mix, which indicates the medium workability

TABLE IV. COMPACTION FACTOR TEST

S.No.	Type of Mix	Compaction Factor	Workability
1	Control	0.93	Medium
2	Mix1	0.91	Medium
3	Mix2	0.90	Medium
4	Mix3	0.89	Medium
5	Mix4	0.87	Medium
6	Mix5	0.86	Medium

From the values, it is found that the compaction factor value for control mix is 0.93, which indicates medium workability.

B. Hardened Concrete Tests

The compressive strength tests were carried out on every concrete specimens of size 150mmx150mmx150mm and the values were recorded for each control specimens and fiber introduced specimens. The average compressive strength values for each specimens are computed on the BIS standards after 7 and 28 days of curing. The average compressive strength values are given in table II.

TABLE V.COMPRESSIVE STRENGTH OF CUBES AFTER 7 DAYS OF CURING

S.No.	Grade	Description	Average Strength
1.	M30	Control Mix	21.04 MPa
2.		Mix 1	25.18 MPa
3.		Mix 2	26.38 MPa
4.		Mix 3	27.15 MPa
5.		Mix 4	24.35 MPa
6.		Mix 5	21.31 MPa

FIGURE I GRAPHICAL REPRESENTATION OF CUBES AFTER 7 DAYS CURING

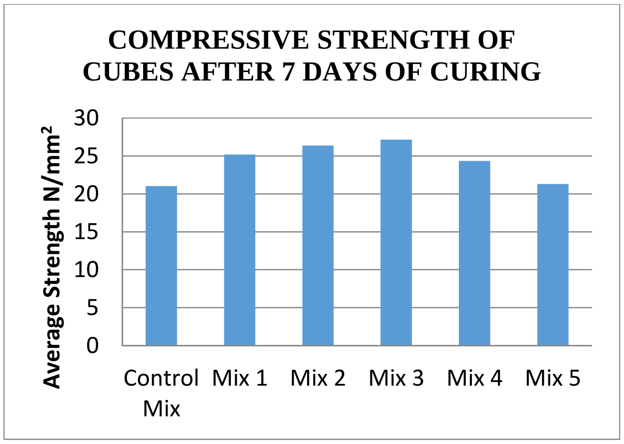


TABLE VI. COMPRESSIVE STRENGTH OF CUBES AFTER 28 DAYS OF CURING

S.No.	Grade	Description	Average Strength
1.	M30	Control Mix	30.79 MPa
2.		Mix 1	33.50 MPa
3.		Mix 2	35.21 MPa
4.		Mix 3	37.75 MPa
5.		Mix 4	35.93 MPa
6.		Mix 5	34.80 MPa

FIGURE II. GRAPHICAL REPRESENTATION OF CUBES AFTER 28 DAYS CURING

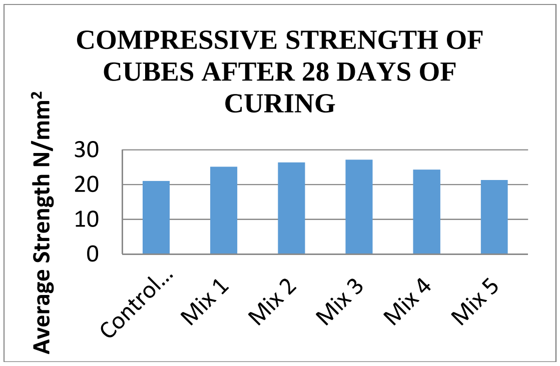


TABLE VII. SPLIT TENSILE STRENGTH OF CYLINDERS AFTER 28 DAYS OF CURING

S.No.	Grade	Description	Average Strength
1.	M30	Control Mix	1.43 MPa
2.		Mix 1	1.88 MPa
3.		Mix 2	2.08 MPa
4.		Mix 3	2.36 MPa
5.		Mix 4	1.80 MPa
6.		Mix 5	1.65 MPa

FIGURE III. GRAPHICAL REPRESENTATION OF CYLINDERS AFTER 28 DAYS CURING

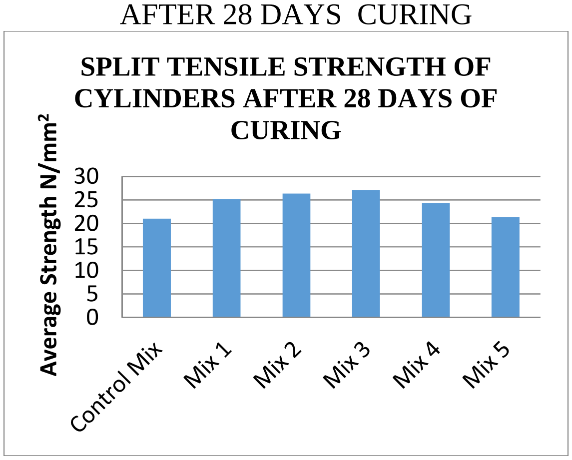
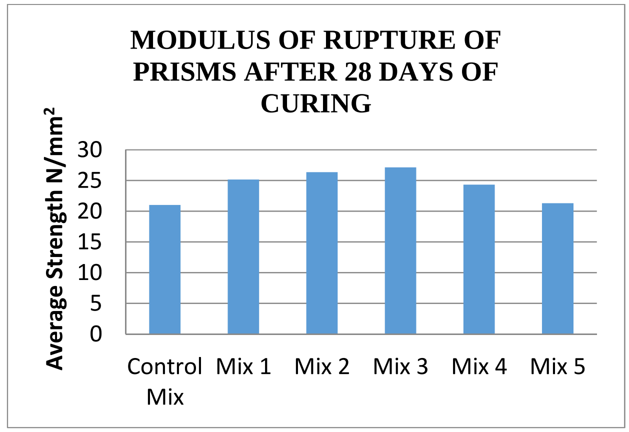


TABLE VI MODULUS OF RUPTURE OF PRISMS AFTER 28 DAYS OF CURING

S.No.	Grade	Description	Average Strength
1.	M30	Control Mix	4.46 MPa
2.		Mix 1	6.33 MPa
3.		Mix 2	7.50 MPa
4.		Mix 3	8.41 MPa
5.		Mix 4	5.91 MPa
6.		Mix 5	5.25 MPa

FIGURE IV. GRAPHICAL REPRESENTATION OF PRISMS AFTER 28 DAYS CURING



VII. CONCLUSION I

Based on the experimental studies,the following results are made.

- The material properties were found out by conducting various laboratory tests and the end results are within the limits.
- The mix containing the content about 12% Metakaolin,80% M-Sand and 1.25% addition of Steel fibres is found to have better workability than all other mixes due to low water absorption property.
- The maximum compressive strength of Concrete is found as 27.15 N/mm^2 and 37.75 N/mm^2 for 7th and 28th day respectively is obtained for the concrete containing 12% Metakaolin and 80% of M-Sand with 1.25% of addition of Steel fibres.
- The maximum split tensile strength of Concrete is found as 2.36 N/mm^2 for 28th day is obtained for the concrete containing 12% Metakaolin and 80% of M-Sand with 1.25% of addition of Steel fibres.
- The maximum flexural strength of Concrete is found as 8.41 N/mm^2 for 28th day is obtained for the concrete containing 12% Metakaolin and 80% of M-Sand with 1.25% of addition of Steel fibres.
- The replacement of fine aggregate by M-Sand after 80% i.e 90% & 100% decreases the strength compared to the values obtained in 80%

VIII. C ASTING OF BEAMS FOR THE OPTIMUM PERCENTAGE CONCLUDED BY THE RESULTS FROM CUBES,CYLINDERS AND PRISMS

The beams are designed using Limit state method for M25 grade Concrete and Fe415 HYSD Steel bars. The size of the beam specimen is 1000mmX150mmX250mm reinforced with 2 Nos of 10 mm dia bars in tensile zone,2 Nos of 8mm dia bars in Compression Zone and 6mm dia 2 legged stirrups at 150mm spacing c/c are provided. The effective depth of beam is calculated as 200mm by taking 25mm clear cover for Beams

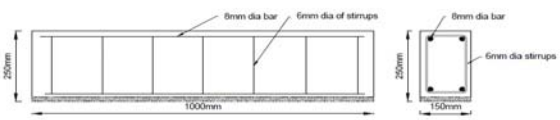


FIGURE V REINFORCEMENT DETAILS OF THE BEAM

IX.LOAD CARRYING CAPACITY OF THE BEAM

Specimen Description	Ultimate Load(KN)	Initial Crack Load(KN)
Control Beam	136	65
Beam with 12% MK, 80% M-Sand &1.25% steel fibres	160	80

X **CONCLUSION II**

Based on the experimental study, the following conclusions are made,

The use of M-Sand,Metakaolin and steel fibres for strengthening of RC beams has been studied from the journals for initiating the work. The preliminary investigations were done for basic ingredients of concrete. From the material property results mix proportions arrived for controlled concrete of M30.The results were obtained for the flexural strength of concrete. The ultimate load carrying capacity of controlled concrete beam is found as 115KN. The ultimate load carrying capacity of RC beam with M-Sand, MK and Steel fibres of aspect ratio 40 is found as 130 KN.

REFERENCES

1. Dr. Adanagouda, Veena.S, 2011, 'Experimental Investigation Of Strength Characteristics Of Metakoalin Waste High Performance Concrete With Steel And Polypropylene', Asian Journal of Civil Engineering (Building and Housing) vol. 13, no. 1 (2012), pp 29-42.
2. Han Aylie, Antonius and Aldyan, Okiyarta.W 2015, 'Experimental Investigation Of Steel Fiber Reinforced Concrete Using Metakaolin', International Journal of Scientific & Engineering Research, Volume 6, Issue 11, ISSN 2229-5518.
3. IS 10262-2009 Guidelines for Indian Standard Concrete Mix Proportioning,
4. IS 456:2000 Code of practice for Plain and Reinforced Concrete.
5. Jaishankar.P, Vayugundlachenchu Rao, 2012, 'Experimental Study On Strength Of Concrete Using Metakaolin & M-Sand', Journal of Advanced & Applied Sciences (JAAS), pp 20-29.
6. Mani Kandhan.K.U, 2015, 'Use Of M-Sand In High Strength And High Performance Concrete', The Open Civil Engineering Journal, 3, pp 34-40
7. Sai.A.V.S, 2012, 'A Study On Strength Of Concrete With Partial Replacement Of Cement With Metakaolin', International Journal of Innovative Research in Science, Engineering and Technology, Vol. 5, Issue 8.
8. Shende A.M, 2012, 'Experimental Study On Steel Fiber Reinforced Concrete', International Journal For Technological Research In Engineering Volume 2, Issue 7, ISSN : 2347 – 4718
9. Vinod B Shikhare, 2013, 'Effect Of Different Types Of Steel Fibers With Metakaolin And Flyash For High Strength Concrete', Volume 2, Issue 5.
10. Yogesh Suryawanshi.R, 2015, 'Experimental Study On Compressive Strength Of Concrete By Using Metakaolin', International Journal of Application or Innovation in Engineering & Management, Volume 5, Issue 5, ISSN 2319 – 4847
11. Yogeswari.R, Geetha.G, 2016, 'Effect Of Replacement Of River Sand By M-Sand In High Strength Concrete', International Research Journal of Engineering and Technology (IRJET) ISSN: 2395 -0056 Volume: 03 Issue: 04.