# Mechanical and Durability Properties of Fibre Reinforced Concrete made with OPC, GGBS and Metakaolin

**N. Sanjeev, T. Sampath Kumar Reddy**

***Abstract:*** ***Concrete is a globally utilized material in the construction field. In the last few decades, Concrete consumption has become multifold and usage has enhanced in massive scale due to the rapid growth of infra sector. Generally, Concrete consists of cement, aggregate, and water; these ingredients become more expensive day by day and additionally hard to please and is increasing widely. During the process of making Ordinary Portland Cement(OPC) produces a large amount of greenhouse gases and the environment being polluted. To minimize the cement utilization and environmental issues is essential to switch the cement by another alternate materials such as pozzolanas. The various number of pozzolanic materials comes from industrial wastes are Ground Granulated Blast furnace Slag (GGBS), Fly Ash (FA), Silica Fume (SF), Metakaolin (MK) etc are utilized in concrete. Similarly, the availability of river sand is getting drained furthermore it turns out troublesome. In order to avoid this problem river sand is alter by Manufactured Sand (M Sand). An attempt is made in the present investigation to study on properties of fiber reinforced concrete ( steel fibers @ 1% of binder) of M40 grade made with OPC, GGBS, MK and manufactured sand. In this study, OPC is replaced by GGBS and MK in different proportions. By casting requisite number of cubes, cylinders then Mechanical properties are determined such as Compressive strength, Split tensile strength tests and durability properties are determined by conducting Water absorption and Sorptivity tests. Test results are compared between controlled concrete and innovative concrete of M40 grade.It is observed that 30%(15%GGBS,15%MK) replacement is optimum for strength and durability criteria.***

***Keywords:*** ***Compressive strength, GGBS, MK, OPC, Split tensile strength, steel fibers, Sorptivity, Water absorption.***

## I. INTRODUCTION

Concrete is one of the most extensively utilized construction material in the world and about 6 billion tons of concrete is consumed by the construction industry every year. At present preparing of concrete is to increase both strength and durability properties to meet the demands of modern construction. Concrete is manufactured by mixing the cement, aggregates and water in required proportions. During cement manufacturing process it emits large amount of $CO_2$ and environment is polluted. To overcome this problem cement is replaced by pozzalonic materials conforming to Ground Granulated Blast furnace Slag (GGBS), Fly Ash (FA), Metakaolin (MK) etc are used to some extent. These mineral admixtures acts as reactive binder components like cement.Natural sand is mainly obtained by excavation from riverbeds .

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The availability of Natural sand is getting drained furthermore it turns out troublesome. Because of that Natural sand is completely alter by Manufactured sand (M-sand) in concrete. It not only enhancing the performance of concrete but also of their economic and environmental advantage [1][2]. Generally Concrete is weak in tension and brittle in nature. Fibers are added to control cracking and also to increase the tensile strength, flexural strength. Based on the availability we use different type of fibers like Steel fibers , Glass fibers , Nylon fibers etc., with different aspect ratio. In the present study hooked end steel fibers are used. The past researches have shown that GGBS,MK can be replaced up to 30%.However,it gives optimum results in strength [3][4]. The slump value decreases gradually by increase in Metakaolin content[5]. By adding of 1% fibers in concrete makes reduce crack formation and enhancing strength, durability properties [6]. An attempt is made in present investigation to study on properties of fiber reinforced concrete of M40 grade made with OPC, GGBS,MK and manufactured sand of different proportions.

## II. MATERIALS

The materials utilized in the present investigation are Cement, Fine Aggregate(FA), Coarse Aggregate(CA), GGBS, MK, water, fibers, super plasticizer. The materials used for casting were discussed below .

### A. Ordinary Portland Cement (OPC):

For all mixes 53 grade of OPC (PENNA CEMENT) conforming to IS:12269-1987 (specifications for 53 grade)[7] is used. The Specific Gravity (SG) of OPC is 3.15.

### B. Fine Aggregates (FA):

M-sand was used in place of Natural sand conforming to zone II conforming to IS 383:1970 [8]. It was collected from RANK Ready Mix Concrete Private Limited, Hyderabad, India. The Specific gravity ,water absorption and Fineness modulus was observed to be 2.6, 2.5% and 3.10 respectively. The conducted tests were conforming to IS 2386:1963 [9] .

### C. Coarse aggregates (CA):

In this investigation locally available crushed angular aggregates with grain size of 20 mm down grade were used conforming to IS 383:1970. The Specific gravity, water absorption and Bulk density was observed to be 2.64 ,1% and 1592 Kg/m$^3$ respectively. The conducted tests were conforming to IS 2386:1963 [9].

**D. GGBS:**

In the present work GGBS is procured from Lafarge RMC Plant located in Hyderabad, India. According to ASTM C989-06 GGBS is used as mineral admixture in concrete.

**Table-I**: Physical properties of GGBS (As per manufactures certificate):

| S. No | Property | RESULT |
|---|---|---|
| 1 | Appearance | Off white |
| 2 | Specific Gravity | 2.8 |
| 3 | Bulk density | 1280 kg/$m^3$ |
| 4 | Fineness | 340$m^2$/kg |

**E. Metakaolin:**

MK is refined from clay of kaolin by heating of 650$^0$C-900$^0$C. It is not a by product of industrial waste. MK is reacts with calcium hydroxide to produce additional cementing compounds, the material is responsible for holding of concrete.In this the specific gravity of Metakaolin is 2.7 and colour is off white(As per manufactures certificate).

**F. Water:**

potable water is used which is easily available in the lab premises for blending of **C**oncrete ingredients and curing of concrete specimens .The $p^H \geq 7$ .

**G. Fibers:** In this investigation hooked end steel fibers are used with aspect ratio of 40. Steel fibers added @ 1% by weight of binder in all concrete mixes. Fibers are used to reduce the cracks and increase the strength. Fiber are conforming to IS: 280-2006 [10].

**H. Super plasticizer:**

Master Rheobuild 920SH was used as super plasticizer. The purpose of super plasticizer to enhancen the workability properties of concrete and reduce the water content . The properties of super plasticizer are State – liquid, colour - dark brown, density-1.2, chemical name – naphthalene formaldehyde polymers and $P^H$ – 8.40. By recomendations of IS 9103-1999 [11] Super plasticizer usage up to 2% of binder . However, In the present study used super plasticizer @ 1% of binder.

## III. ZEXPERIMENTAL INVESTIGATION\

### A. General

The experimental investigation was done by casting 3 samples(each sample consists of 3) of cubes of size 15cm ,9 samples of cylinders of size 15cm diameter × 30cm height. The specimens are cured in water for 7&28days to study mechanical properties such as compressive strength, split tensile strength and durability properties such as water absorption and sorpitivity tests of M40 grade Concrete. In the present study, steel fibers @ 1% by weight of binder are used in every mix and Cement is replacd with GGBS , Metakaolin of various proportions like 20% (10% GGBS , 10% MK), 30% (15% GGBS , 15% MK), 40% (20%GGBS,20%MK) by weight.

**B. Compressive Strength test**:

In this investigation Each mix three samples cubes of size 15cm are casted , kept with water curing for 7 & 28days .The test was conducted in compliance with IS:516-1969 ( Method of test for strength of concrete). Testing was done by compression testing machine of capacity 2000 KN .

Compressive Strength C = L/A

Where, L = failure load (KN)

A = Area of Cross section in $mm^2$

**C. Split Tensile strength :**

The test was conducted in compliance with with IS 5816:1970.

Split tensile strength (fs) = $2P/\pi DL$

Where fs is splitting strength (MPa), P is the load (KN), L is length in mm , D is diameter (mm).

**D. Sorptivity Test**

Sorptivity measures the rate of penetration of water into the pores in concrete by capillary suction. The objective of this test to determine sorptivity of fibre reinforced concrete grade of M40 as per ASTM C1585.The test was conducted by casting 100mm diameter and 50mm depth. After curing 28 days , the specimens are oven dried at 110$^0$c for 24 hours. The sides of concrete specimen typically coverd with sealant or electrician tape while the suction face and opposite face were kept unsealed . The sample is immersed in water at a depth of 5 to10mm. Then record the initial mass of the specimen and time of start . The procedure is repeated at various timings .

The rate of sorptivity (K) is the slope of I vs $\sqrt{t}$ graph .

$$I = W/(A \times d)$$

Where W= The amount of water absorbed in kg,

A = Area of the specimen that is in contact with water $m^2$,

d = density of the medium in which specimen was immersed (1000kg/$m^3$in case medium is water).

**E. Water Absorption Test**

The aim of the test is to determine the total water absorption of fibre reinforced concrete of grade M40 .By casting Concrete cube specimens of size 10cm. The specimens are cured with water for 28 days , After the curing period is completed the specimens are kept in oven dried @ 110$^0$c for 24 hours. The specimens are completely immersed in a water up to a depth of 120mm in container. Record the initial mass of the specimen and time of start . The procedure is repeated at various timings.

The quantity of water absorbed with respect to the dry sample

$$M_i\% = 100 \times (m_i - m_o)/ m_o;$$

where

$m_i$ = weight of the wet sample @ time t;

$m_o$= weight of dry sample.

**F. Mix proportion**

The design procedure for concrete mix of M40 grade as per IS 10262-2009. In the present study the obtained mix proportion of cement , Fine aggregate(M-sand) ,Coarse aggregate is 1 :1 .98:2.79 with water binder ratio 0.40.

**G. Concrete mixes**

**M0:** OPC 100% + Fine aggregate (M-sand) + Coarse aggregate + Steel Fibers (1% of weight of binder)

**M1:** OPC 80% + Fine aggregate (M-sand) + Coarse aggregate + Steel Fibers (1% of weight of binder) + 10%GGBS + 10%Metakaolin

**M2:** OPC 70% + Fine aggregate (M-sand) + Coarse aggregate + Steel Fibers (1% of weight of binder) + 15%GGBS +15%Metakaolin

**M3:** OPC 60% + Fine aggregate (M-sand) + Coarse aggregate + Steel Fibers (1% of weight of binder) + 20%GGBS +20%Metakaolin

## IV. TEST RESULTS

### A. Workability

The workability test results is shown as histogram vide Fig (1) and values in Table(2). From this test results , it observed that workability is Gradually decreased as replacement of OPC with GGBS and Metakaolin increases.

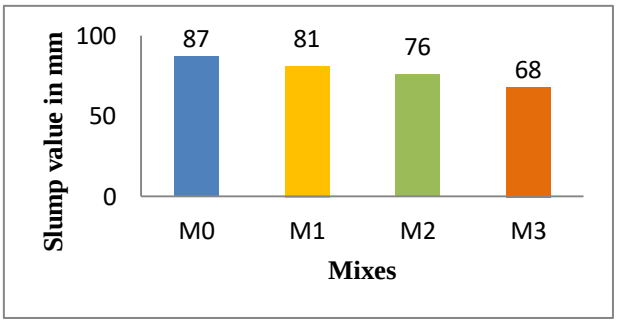



**Fig (1).** workability of concrete mixes M0,M1,M2,M3

**Table II** :Slump values of Concrete mixes M0,M1,M2,M3

| MIX | Slump Value (mm) |
|---|---|
| MO | 87 |
| M1 | 81 |
| M2 | 76 |
| M3 | 68 |

### B. Compressive Strength test

For all the mixes 7& 28 days compressive strength is shown as histogram vide Fig ( 2 )and values in Table III Test results indicated that 30% replacement of OPC is optimum among all the replacements. The compressive strengths for 30% replacement of OPC is 39.72 N/mm$^2$ and 57.26 N/mm$^2$ for 7 & 28 days respectively .

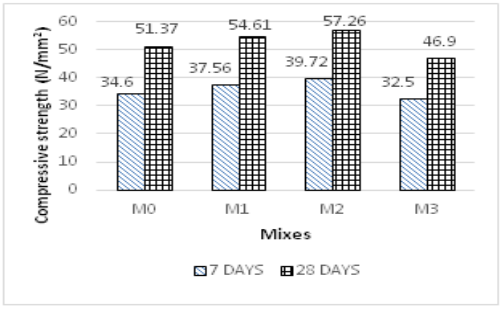


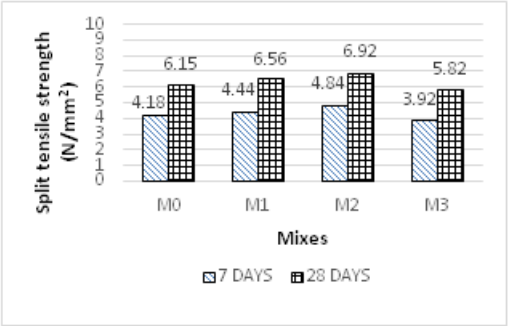

**Fig (2). 7 &28 days compressive strength of concrete of mixes M0, M1, M2 , M3**

**Table III**: compressive strength of concrete of mixes M0, M1, M2 , M3 for 7 &28 days.

| MIX | Compressive Strength in N/mm$^2$ | |
|---|---|---|
| | 7 days | 28 days |
| M0 | 34.6 | 51.37 |
| M1 | 37.56 | 54.61 |
| M2 | 39.72 | 57.26 |
| M3 | 32.5 | 46.9 |

### C . Split tensile strength

For all the mixes 7& 28 days split tensile strength is shown as histogram vide Fig ( 3 ).Test results indicated that 30% replacement of OPC is optimum among all the replacements. The compressive strengths for 30% replacement of OPC is 4.84 N/mm$^2$ and 6.92N/mm$^2$ for 7 & 28 days respectively .



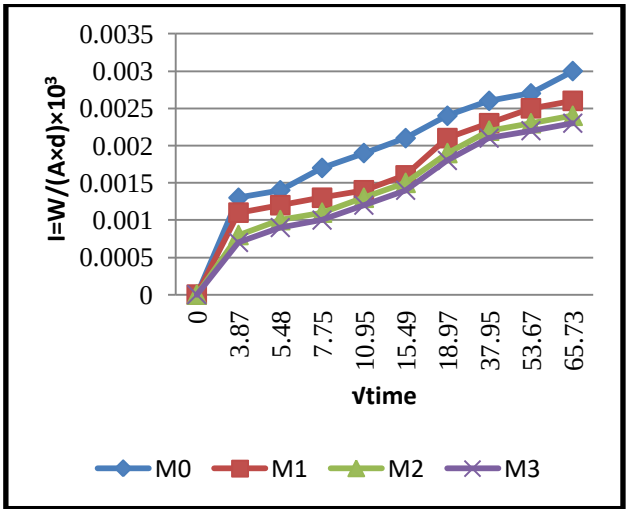

**Fig(3). 7 &28 day split tensile strength of concrete of mixes M0,M1, M2 , M3**

**Table IV** :Split tensile strength of concrete of mixes M0, M1, M2 , M3 for 7 &28 days.

| MIX | Split tensile Strength in N/mm$^2$ | |
|---|---|---|
| | 7 days | 28 days |
| M0 | 4.18 | 6.15 |
| M1 | 4.44 | 6.56 |
| M2 | 4.84 | 6.92 |
| M3 | 3.92 | 5.82 |

### D. Sorptivity test

Sorptivity values for all mixes are shown as graphycally vide Fig (4). It was observed that rate of water absorption is observed gradually decreased as the percentage replacement of cement is increased




**Fig(4). Sorptivity of various mixes M0, M1, M2 , M3**

## E. Water absorption test

Water absorption test results for all mixes are represented graphically as shown in fig (5). It was indicated that water absorption is decreased with increasing percentages of cement replacement with GGBS and MK .

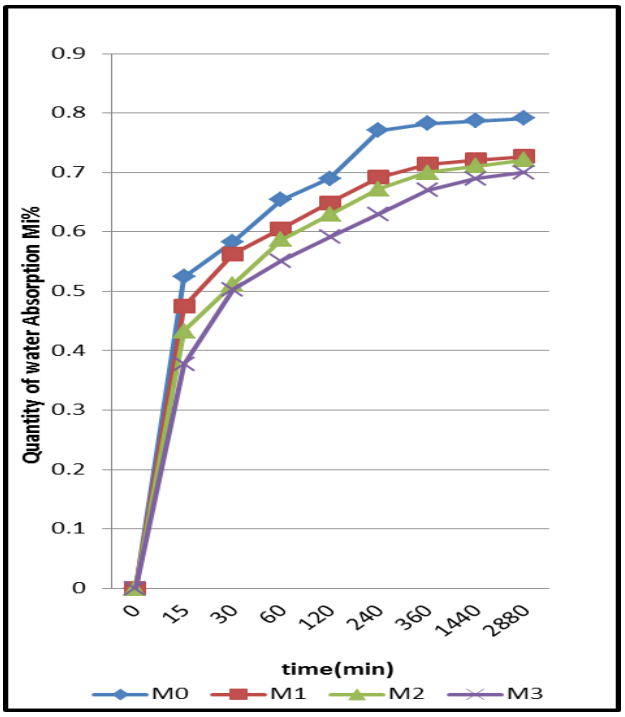



**Fig (5). Water absorption of various mixes M0, M1, M2 , M3**

## V. CONCLUSIONS

From this Experimental investigation the following conclusion are made

1. The workability of the Concrete was decreased from 87mm to 68mm , when the mix contains 100% OPC to 60% OPC.
2. The compressive strength was to be maximum when Cement was replaced by at an extent of 30% ( Mix -M2). It was observed by 14.8% and 10.5% more than that of the controlled concrete (Mix-M0) for 7 and 28 days respectively.
3. The split tensile strength was observed to be maximum when Cement was replaced by the MK and GGBS to an extent of 30% (Mix-M2).It was shows 15.78% and 12.52% more than the controlled concrete (Mix-M0) at 7, 28 days respectively.
4. There was significant improvement in the durability properties like water absorption and Sorptivity when GGBS and MK percentage increses in the concrete @20% to 40% respectively.
5. Based on the test results we concluded that the Mix M2 consists of 15% GGBS and 15% Metakaolin is better to use in construction industry.

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**Dr.N.Sanjeev**,He got his first degree from NIT Warangal in 1983.He completed his PhD from Andhra University, Visakhapatnam. He Joined government of India through UPSC engineering services (so called IES)-1983 batch and was engineer in charge for the construction of longest runway in Asia near Chennai.

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