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# Mechanical and Durability Properties of Fly Ash and GGBS Based Fiber Reinforced Concrete

**N. Sanjeev, K. Harish Kumar**

***Abstract:*** ***Concrete is one of the most commonly and widely adopted material for construction. Cement is used as primary binder material to produce Concrete. However, every tonne of Cement production releases one tonne of greenhouse gases which results in global warming; due to continuous and ever increased usage of Cement and natural sand are causing uncontrollable global warming and depletion of natural resources respectively year by year. This tendency needs to be retarded if not arrested, by developing a comprehensive approach to use more and more pozzolanic mineral admixtures and manufactured sand (M-Sand) in Concrete. In this study on fiber reinforced concrete (with steel fiber @ 1% of binder), Ordinary Portland Cement (OPC) is replaced up to 50% with Fly Ash and Ground Granulated Blast-Furnace slag (GGBS) for M30 grade of Concrete. Mechanical properties like compressive strength and split tensile strength at 7 days and 28day age are tested. Additionally, durability tests like water absorption and sorptivity tests are conducted after 28days of curing. The test results indicated that workability was increased and there was no significant improvement in durability properties on increasing the percentage of OPC replacement. However, 30% of OPC replacement is found to be optimum for strength criteria***

***Keywords: Concrete, Fly Ash, GGBS, Steel fiber, M-Sand, Compressive Strength, Sorptivity and Water Absorption***

## I. INTRODUCTION

Concrete is one of the most commonly adopted material for construction. Durability, potential to sustain extreme weather conditions and ability to be moulded in to any shape made this material widely acceptable. Concrete comprise of cement, fine aggregate, coarse aggregate and water. Though cement generally comprises 12% of Concrete mass [1], about 250 million tons of cement produced in India yearly. Which in turn produces 220 million tons of $CO_2$ approximately which cause environmental pollution and global warming. To overcome this, comprehensive approach is to be developed to use more and more pozzolanic mineral admixtures in Concrete. Most of the pozzolanic mineral admixtures are by-products and their usage in concrete could decrease consumption of cement in construction.

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Hence this could reduce environmental pollution and global warming to large extent. On the other hand, it became necessary to replace natural sand in Concrete by alternate material without compromising on the quality of Concrete as the available sources of natural sand are getting depleted and transportation of good quality sand from long distances may increase cost of construction. The past researches have shown that Fly Ash, Ground Granulated Blast-Furnace Slag (GGBS) could give better result on replacing Ordinary Portland Cement (OPC) [1]. And further, natural sand can be replaced completely by manufactured sand (M-Sand) in Concrete [1] to get same results as natural sand. Steel Fibers are generally added to improve cracking resistance due to plastic and drying shrinkage. Addition of Steel Fibers increases mechanical properties like compressive strength, split tensile strength and flexural strength [2].

The objective of the present study is to determine mechanical and durability properties of M30 grade Steel Fiber reinforced Concrete on replacing OPC with Fly Ash, GGBS and natural sand by M- Sand.

## II. MATERIALS USED:

In the present investigation materials used are OPC, Fine aggregate (M-Sand), Coarse aggregate, Steel fiber, Fly Ash, GGBS, Superplasticizer and Water.

The properties of material used are discussed below:

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

In this study Ordinary Portland cement of 53 grade was used conforming to IS 12269:1987. The properties of the cement are specific gravity (sp. Gravity) 3.15, normal consistency-32%, Compressive Strength - 3, 7, 28 days are 25.3MPa, 36.8MPa, 53MPa respectively, initial setting time 65mins and final setting time 270min.

### *B. Fine Aggregate*:

Locally available M sand was used as fine aggregate conforming to zone II IS 383:1970. The specific gravity and water absorption were tested conforming to IS 2386:1963. The test result of specific gravity is 2.6. The water absorption of M sand is 2.5%

### *C. Coarse Aggregate*:

Locally available Crushed angular aggregate of size 20mm were used conforming to IS 383:1970. The physical properties like specific gravity and water absorption were tested conforming to IS 2386:1963. The test result of specific gravity of coarse aggregate is 2.64. The water absorption of coarse aggregate is 0.5%.

***D. Water:***

the water used is potable water which is easily available near the lab premises for mixing Concrete ingredients and for curing the Concrete specimens.

***E. Fly Ash:***

Type -Class F, colour– dark grey, bulk density - 1042kg/m$^3$, fineness 336m$^2$/kg and sp. gravity - 2.1.

***F. GGBS:***

colour-off white, bulk density-1281kg/m$^3$, sp. gravity -2.81, fineness-342m$^2$/kg

***G. Steel Fiber***:

The fibers used are hooked end steel fibers of aspect ratio 40. And are randomly oriented and uniformly distributed. In this study 1% of steel fibers are used in all Concrete mixes.

***H. Super Plasticizer:***

Master Rheobuild 920SH was used as super plasticizer. State – liquid, colour - dark brown, density-1.2, chemical name – naphthalene formaldehyde polymers and P$^H$ – 8.40.

## III. EXPERIMENTAL INVESTIGATION

***A. General***

In this experimental investigation, Compressive strength and split tensile strength at 7 days and 28 days age were tested to study mechanical properties whereas water absorption and sorptivity tests were conducted at 28 days age to study durability properties of M 30 grade fiber reinforced Concrete. In this study replacement of OPC was varied at 30%, 40% and 50% by both fly ash and GGBS together. And hooked end steel fibers @ 1% by weight of binder were used in all the mixes. The following are the tests conducted to study mechanical and durability properties of all the mixes.

***B. Compression Test***

The compression test is conducted on cubes in accordance with IS 516-1969. 3 samples are tested for 7 days and 28days age.

***C. Split Tensile Test***

It is the standard test to determine tensile strength of Concrete in indirect way, this test was performed on cylindrical specimens in accordance with IS 5816-1970.3 samples were tested at each 7 days and 28 days age.

***D. Sorptivity test***

This aim of this test is to determine sorptivity of M30 grade fiber reinforced Concrete as per ASTM C1585. Sorptivity is the cumulative change in volume of water absorbed per unit area against the square root of time. This test was conducted on 100mm diameter and 50mm depth cylindrical specimen asper ASTM C 1585. After 28 days of curing, the specimens were oven dried at 110$^o$ C for 24hrs [3]. The side faces of the specimens were sealed with Electricians tape or sealant whereas Suction face and the opposite face to it was kept unsealed. The cylindrical specimens were arranged as shown Figure (1). The mass of specimens was recorded at programmed intervals. Sorptivity is the slope of I vs √t graph. where I represent the gain of mass per unit area over the density of water and t represents the time elapsed.

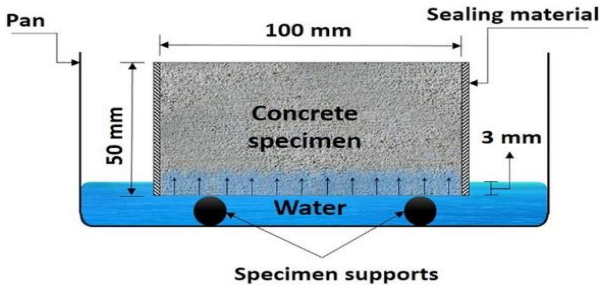


**Fig (1)**

I= $(W_t - W_0)/ (A \times d)$: where $W_t$ = weight of the specimen at time t, $W_0$ = initial weight of specimen, A= area of suction face of the specimen and d= density of the medium in which specimen was immersed (1000 kg/m$^3$ in case medium is water)

***E. Water Absorption***

the objective of this test is to determine the water absorption rate of the fiber reinforced Concrete of M 30 grade. the specimens of size 10cm x 10cmx 10cm were oven dried at 110$^o$ C for 24hrs after 28 days of curing [4]. And then specimens were placed in a container and it was filled with water until the water level reach 2 cm height above the specimen. Then record the weight of the specimen at programmed intervals until the weight difference between two successive 24hr interval measurements is less than 1%. And hence, the water absorption rate is established.

Quantity of water absorbed

$M_i\% = 100 \times (m_i - m_o)/m_o$; where $m_i$ = weight of the specimen at time t; $m_o$= weight of dry specimen

***F. Concrete Mixes***

mix proportion of cement, fine aggregate and coarse aggregate for the present study designed as per IS 10262-2009 is 1:2.17:3. With a binder ratio of 0.43.

M1: 100% OPC + Fine Aggregate (M sand) + Coarse Aggregate + Steel fibers @ 1% by weight of OPC.

M2: 70% OPC + 15% Fly Ash + 15% GGBS + Fine Aggregate (M sand) + Coarse Aggregate + Steel fibers @ 1% by weight of binder.

M3: 60% OPC + 20% Fly Ash + 20% GGBS + Fine Aggregate (M sand) + Coarse Aggregate + Steel fibers @ 1% by weight of binder.

M4: 50% OPC + 25% Fly Ash + 25% GGBS + Fine Aggregate (M sand) + Coarse Aggregate + Steel fibers @ 1 % by weight of binder.

## IV. TEST RESULTS

***A. Workability***

The workability for different mixes is shown Fig 2. From this Figure it is observed that workability is increased as the replacement of OPC is increased.

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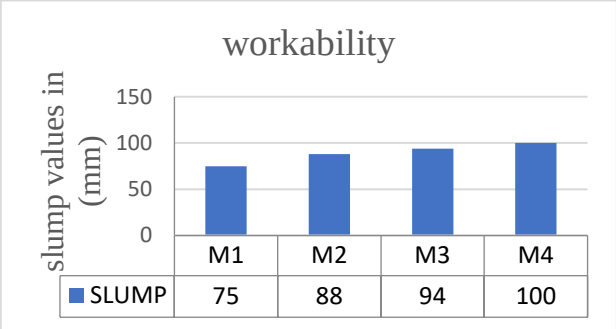


**Fig (2)**

### *B. Compressive Strength*

The Compressive strength values for all the mixes at 7 days and 28days age are shown graphically in Fig 3. It is observed that 30% replacement is optimum among all the replacements.

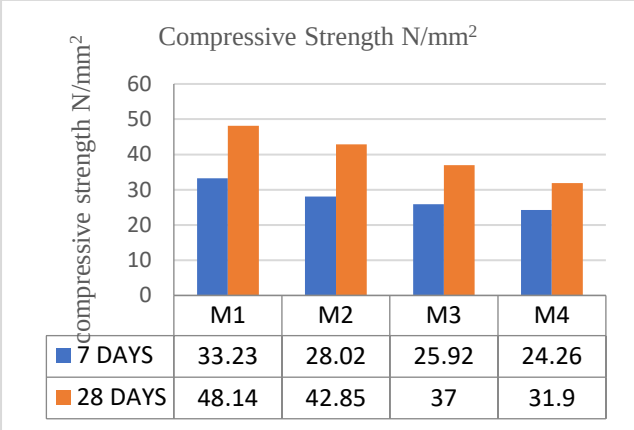


**Fig (3)**

### C. Spilt Tensile Strength

Split tensile strength values for all the mixes at 7 days and 28 days are shown graphically in Fig 4. It is observed that 30% replacement is optimum among all the replacements.

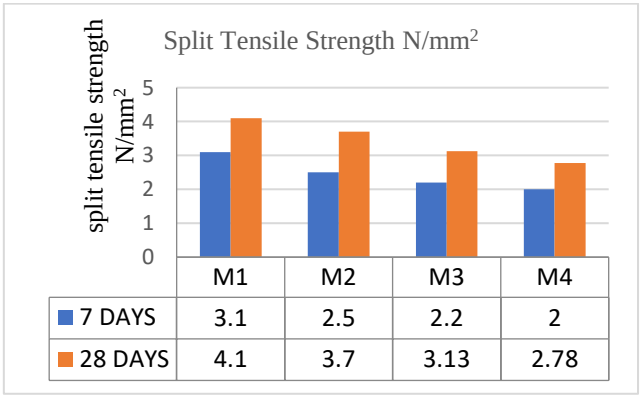


**Fig (4)**

### *D. Sorptivity*

Sorptivity for all mixes are obtained from the graph shown below in Fig 5. It was found that sorptivity of the concrete is increased with increasing percentages of OPC replacement.

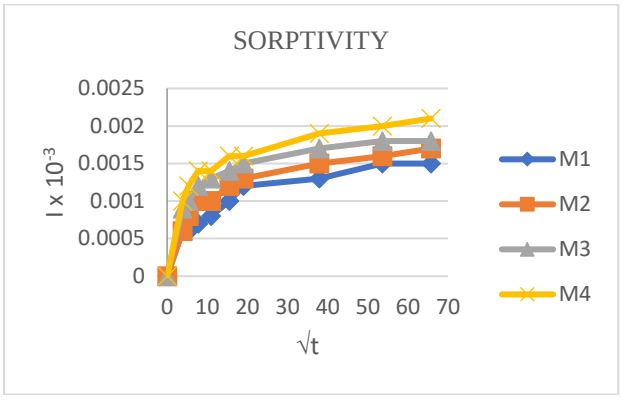


**Fig (5)**

### *F. Water Absorption*

Results for water absorption test for all mixes are represented graphically in Fig 6. It was found that water absorption rate is increased with increasing percentages of OPC replacement.

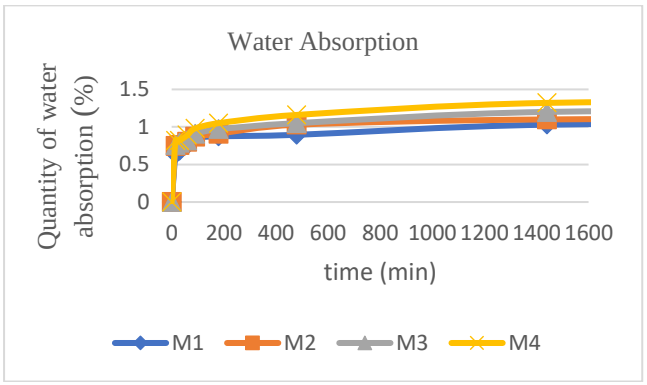


**Fig (6)**

## V. CONCLUSIONS

Based on the experimental investigation, the following conclusion are made

A. The workability of the Concrete was increased from 75mm to 100mm when the 50% of OPC was replaced by Fly Ash and GGBS together.

B. 30% replacement of OPC was found to be optimum. Since, 28-day Compressive Strength was about 13% more than the target mean strength. However, for 40% replacement 28day compressive strength is reaching the target mean strength.

C. The 28 day Split Tensile Strength was observed to be maximum for 30% replacement of OPC with Fly Ash and GGBS when compared to other replacements.

D. It was observed that there was no significant improvement in durability properties on replacing OPC with Fly Ash and GGBS together.

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3. V Seshasayee, B H Bharatkumar and P Gajalakshmi (2016) "Influence of Fly Ash on durability and performance of concrete", International journal of earth sciences and engineering, Vol 09, PP 341-346
4. S.S.Saravanan and Dr. P. Jagadeesh, (2016) "Effect of manufactured sand on durability characteristics of concrete", Applied Science innovations pvt. Ltd., india, Carbon- Science and Technology, pp 70-81

List of codes

1. IS-456:2000, 4th revision for plain and reinforced concrete.
2. IS 10262: 2009.for concrete mix design,
3. IS 12269- 1987: specifications of 53 grade OPC
4. IS 383-1970 for coarse and fine aggregate from natural sources for concrete
5. IS 2386-1963: methods of testing aggregates for concrete
6. IS 516-1959: methods of test for strength of concrete.
7. ASTM C1585 for measurement of absorption (sorptivity) of water by hydraulic cement concretes.
8. ASTM C642 -13 for density, absorption, and voids in hardened concrete


## AUTHOR'S PROFILE

Dr. N. Sanjeev, He got his first degree from NIT Warangal in 1983
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. After 21 years' service retired from government service Served private and corporate construction industries for 6 years up to level of vice president. completed his PHD from Andhra university. And PHD thesis was on structural appraisal of reinforced cement concrete with high volume fly ash concrete. Worked as professor in KLU for 2 years and presently professor in civil engineering in Gokaraju Rangaraju institute of Engineering and Technology since November 2014.

K. Harish Kumar, Completed Civil Engineering at Institute of Aeronautical Engineering college (IARE), Dundigal, Hyderabad in 2017.
B tech project was on "Effect of organic admixtures on compressive strength of concrete under elevated temperatures". presently pursuing Masters in Structural Engineering at Gokaraju Rangaraju institute of Engineering and Technology (GRIET), participated in some of the major conferences conducted by institute of engineers (India) and also participated in workshops like Modern developments in concrete and building technology keenly interested to conduct experimental investigation on mechanical properties and some durability properties of fiber reinforced concrete made with different mineral admixtures. under the guidance of Dr n sanjeev