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An Experimental Programme on Frc with Opc, Flyash, Ggbs, and Metakaolin

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Abstract *The production of Ordinary Portland Cement (OPC) is increasing year by year world over. Further, the production of every tonne of OPC generates one tonne of green house gases, (CO_2) which results in Global Warming. Usage of OPC is more in construction industry as it is a major ingredient in Concrete. As the usage of Concrete is increasing year by year, more and more is the OPC production and hence the environment is getting polluted; added to this undesirable scenario, the natural resources like lime stone used to manufacture cement and river sand are getting depleted year by year. In order to prevent the usage of large amounts of OPC in Concrete, mineral admixtures like Ground Granulated Blast furnace Slag (GGBS), Fly Ash and Metakaolin which are pozzolanic and cementitious in nature are adopted to replace certain percentages of OPC. Manufactured Sand (M-sand) is adopted to replace river sand. Experimental investigation is conducted on fiber reinforced concrete with steel fibers @1% of weight of binder by casting requisite number of cubes and cylinders of concrete of grade M25; in these mixes OPC is replaced with GGBS, Fly Ash and Metakaolin up to 45%. Mechanical properties are determined by conducting compressive strength and split tensile strength tests; additionally some of the durability properties are established by conducting Water absorption and Sorptivity tests. Test results are comparable between controlled concrete and innovative concrete of present investigation.*

Keywords: *Compressive strength, Fly Ash, GGBS, Metakaolin, split tensile strength, Water absorption and Sorptivity tests.*

I. INTRODUCTION

Concrete plays a vital role in construction industry. Concrete is a mixture of cement, coarse aggregates, fine aggregates and water. Cement is the major ingredient of the concrete compared to all other ingredients, as it has better binding capacity of structure together. However One ton production of cement almost emits same amount of CO_2 into atmosphere. Many modern concrete mixes are modified with addition of admixtures, which improve the microstructure as well as decrease the calcium hydroxide concentration, by consuming it through a pozzolanic reaction. There are different Pozzolanic materials such as Fly Ash, Ground Granulated Blast Furnace Slag (GGBS) and Metakaolin. These mineral admixtures acts as a reactive binder components like Cement [1]. Concrete failure is brittle if once failure is initiated there is a loss of loading capacity which makes its application limited. Fibers are added to control cracking due to plastic and drying shrinkage and to increase the tensile strength, flexural strength.

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Different types of fibers are available with different characteristics of their own. Steel fibers, glass fibers, nylon fibers are some of the fibers used mostly.

A. ***Steel fibres:-***There are several types of steel fibres are available as reinforcement. Some of them are straight, hooked end, crimped steel fibres. The typical diameter ranges from 0.25 to 0.5mm. And fibres are made from mild steel wire of diameter 0.3 to 0.75 mm conforming to IS: 280-2006[2] which are practically used in India. Steel fibers are available in different aspect ratios (l/d) such as 40, 55, 60 and 80. And a certain amount of steel fibre in concrete can increase resistance to cracking and toughness of concrete. Addition of steel fibers increases mechanical properties (flexural and tensile strength) and lowers the workability[3].

B. ***Fly Ash:*** - Fly Ash is a material which is coal combustion product extracted from the flue gases through electrostatic precipitators in dry form. This ash is fine material and has good pozzolanic property. According to IS 456-2000, ASTM C618 fly ash can be used as the additive material. Use of Fly Ash in concrete is desirable because of its benefits such as increased workability reduction of cement consumption and decreased permeability[4]. Thermal cracks and heat of hydration are reduced when Fly Ash is used as replacement to OPC in Concrete. Fly ash adds additional strength to concrete mass as it converts released lime in the hydration of OPC into additional binding material. 10% to 20% replacement of cement with Fly Ash shows good compressive strength for 28 days[5].

C. ***Ground Granulated Blast furnace Slag (GGBS):-*** Ground Granulated Blast furnace Slag is a cementitious material used for the replacement of cement, which is a by-product of iron and steel manufactured blast furnaces. GGBS is obtained by heating of iron ore, limestone and coke in a blast furnace for about 1500 degree Celsius. GGBS consists of alumina, silica and some other oxides. The main constituents of blast furnace slag are CaO, SiO2, Al2O3 and MgO, These minerals are mostly found in most of the cementitious substances. Addition of slag to cement increases the durability properties of concrete and also reduces the porosity of concrete[6] ,Some of the recent studies in various parts of the world have revealed that GGBS can protect the steel reinforcement more efficiently, so that it can resist corrosion, and thus the structure as a whole[1]. A 30 to 40% of replacement of cement by GGBS was found to produce optimum strength of concrete [7].

D. ***Metakaolin:-***Metakaolin is an anhydrous calcined form of mineral kaolinite. Metakaolin is very reactive pozzolana. Kaolin is converted into Metakaolin when it is heated to temperature between 600 to 850°C. Metakaolin particle size is smaller than cement particle size. Optimal performance is achieved by replacing 7% to 15% of the cement in concrete with Metakaolin. The benefits are not fully realized until at least 10% Metakaolin is used [8].

This paper is an experimental investigation on how the strength and durability characteristics vary on replacement of cement with pozzolanic materials in fiber reinforced concrete.

II.MATERIALS

A. Cement

Cement used in this study is ordinary Portland cement of 53 grade confirming to IS: 2269-1987 specifications.

B. Fine aggregates

Manufacturing sand is used instead of river sand in this investigation as fine aggregate which is having specific gravity of 2.6, fineness modulus of 3.10.

C. Coarse aggregates

Crushed angular aggregate used in this study confirming to IS: 383-1970.Which was bought from the quarry nearby and the size of coarse aggregate used is 20 mm which is free from deleterious materials. Coarse aggregate used has specific gravity is 2.64 and bulk density of 1592 kg/mm^3.

D. Flyash

Fly Ash is the mineral admixture used in this study confirming to ASTM C 618-2003.

Properties(As per manufactures certificate)

Color	Dark grey
Bulk density	1042 kg\m^3
Class	F
Specific gravity	2.1

E. GGBS

GGBS is a granular material formed when molten iron blast iron slag is rapidly chilled by immersion in water .GGBS specific gravity is 2.8. (As per manufactures certificate)

Properties of GGBS:

S. No	Property	RESULT
1	color	Off white
2	Specific gravity	2.8
3	Bulk density	1280 kg/m^3
4	Fineness	340m^2/kg

F. Metakaolin

Metakaolin is an anhydrous calcined form of mineral kaolinite. Metakaolin used in this investigation has Specific gravity of Metakaolin is 2.7. (As per manufactures certificate)

Physical properties of Metakaolin:

color	OFF white
Bulk density	365(gm/liter)
moisture	0.27%

G. Fibers

The fibres used are hooked end steel fibres. Which are randomly oriented and having aspect ratio of 40.In this study steel fibres@1% by weight of binder are used in all concrete mixes.

H. Super plasticizer

In order to have additional workability super plasticizer is used. These are used to reduce the water in concrete for same workability. Super plasticizer used in the study is MasterRheobuild920SH. (0.1%) by weight of cement based on Naphthalene formaldehyde polymers with following properties as per IS: 9103-1999[9].

Material used	Specific gravity	Water absorption
Cement	3.15	NIL
Fine aggregate	2.6	2.5%
Coarse aggregate	2.64	1%
Fly ash	2.1	NIL
Metakaolin	2.7	NIL
GGBS	2.8	NIL
Super plasticizer	1.20	NIL

III. EXPERIMENTAL INVESTIGATION

General

Experimental investigation is made by replacing cement with GGBS, Metakaolin and Fly ash in fiber reinforced concrete with 1% steel fibers in varied proportions 15%, 30%, 45%.Mechanical properties compressive strength, Split tensile strength are determined additionally some of the durability properties are established by conducting Water absorption and Sorptivity tests.

TESTS

A. Compressive strength

Cubes of 15 cm X 15 cm X 15 cm are commonly used. These specimens are tested by compression testing machine after 7 days or 28 days curing according to IS 516-1969 [10]. A loading rate of 140 kg/cm2 per minute till the Specimens fails. Load at the failure divided by area of specimen gives the compressive strength of concrete.

B. Slit tensile strength

Size of 150mm diameter and 300mm height cylinder is used to determine the tensile strength and it is the standard method and performed in accordance with IS 5816-1970.

C. Water absorption

Sizes of 100mm×100mm×100mm concrete cubes are used to determine the water absorption.

Specimens are dried at 110°C for 24 hrs after curing for about 28 days. Specimens are placed in container and it was fully immersed in such a way that height of water above the specimen after immersion is 2cm. Weights are noted at different intervals of time.

Mi%=100× (mi-mo)/mo

mi=weight of wet sample at time t

mo=weight of dry sample.

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D. Sorptivity test

To determine the cumulative change in volume of water absorbed per unit area against square root of time as per ASTM C1585. Specimens are made about a Size of 100mm diameter and 50mm depth which were oven dried at 110°C for 24 hrs after curing for about 28 days. Sealant or tape are used to seal the sides of specimens but the suction face and face opposite to are not sealed .it is a placed in a container containing water about 5 to 10mm height of water .

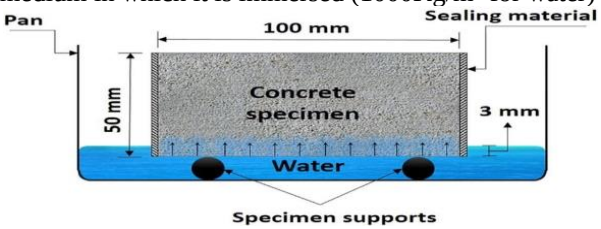
Rate of water absorption =K

K is the slope of $\mathbf{I\ vs\ \sqrt{t}}$

I = W/(A×d)

W= amount of water absorbed in Kg

A=Area of cross section contact with water; d=density of medium in which it is immersed (1000Kg/m^3 for water)



IV. MIX PROPORTIONS

The Concrete mix of M25 grade is designed as per IS 10262-2009[11].The partial replacements of OPC with Mineral Admixtures are done based on weight basis.

Grade	water	cement	Fine aggregate	Coarse aggregate
M25	0.45	1	2.39	3.17

V. CONCRETE MIXES AND TEST RESULTS

C0: OPC 100%+ M-Sand +Coarse aggregate + Fibers (1% of weight of OPC)

C1: OPC 85%+M-Sand+ Coarse aggregate + Fibers (1% of weight of binder) + 5%GGBS +5% Fly ash + 5%Metakaolin

C2: OPC 70%+ M-Sand +Coarse aggregate + Fibers (1% of weight of binder) + 10%GGBS + 10% Fly ash + 10%Metakaolin

C3: OPC 55%+ M-Sand +Coarse aggregate + Fibers (1% of weight of binder) + 15%GGBS +15% Fly ash + 15%Metakaolin

A. Workability

Workability is shown as histograms vide Fig (1) for different mixes. It was observed that workability is decreased as the replacement of OPC is increasing

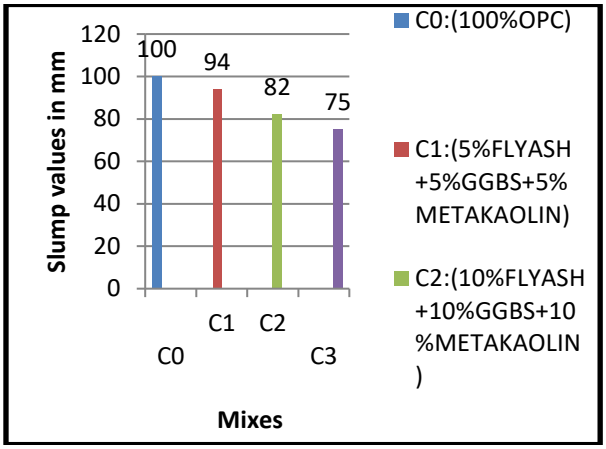


Fig (1): Workability

B. Compressive strength

For all the mixes 7days and 28 days age compressive strength is represented as histograms vide Fig(2) and Fig(3) respectively .Test results indicated that 28 days compressive strength of mixes of 15% and 30% replacement is optimum among all the replacements. It is clearly seen that the 28 days compressive strength of mix in which OPC was replaced by 15% is 22.7% more than that off controlled concrete at 28 days.

Compressive strength in N/mm²				
Days	C0	C1	C2	C3
`7	26.8	25.48	24	20.19
28	36	44.2	38.04	31.5

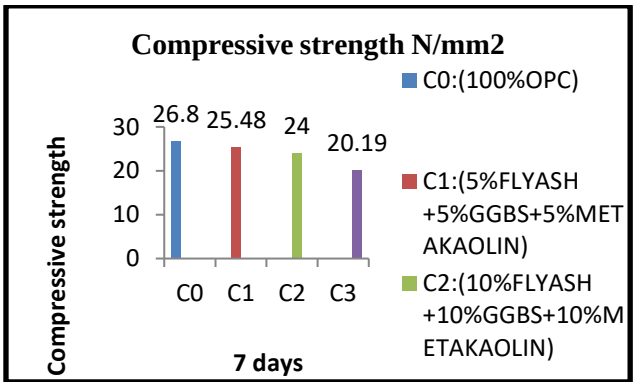


Fig (2):7 days Compressive strength N/mm2

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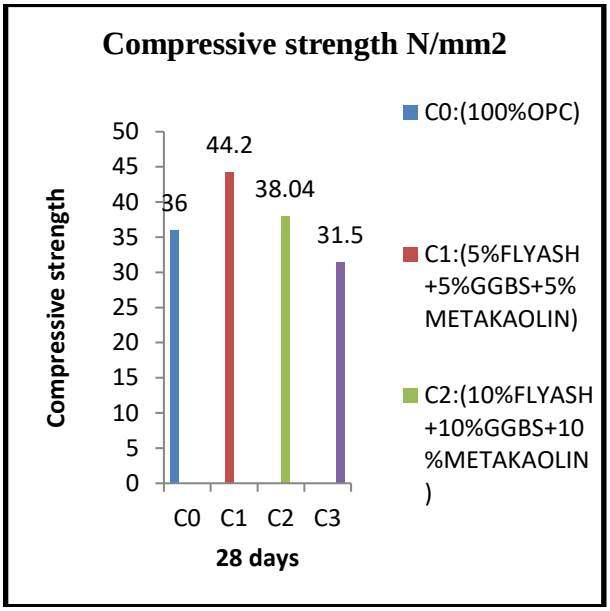
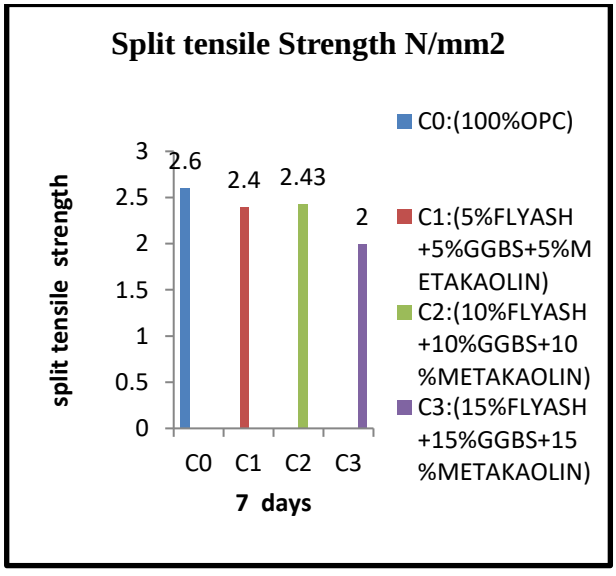


Fig (3): 28 days Compressive strength N/mm2

C. Spilt tensile strength

Split tensile strength values for all the mixes at 7 days and 28 days are represented as histograms vide Fig(4) and Fig(5) respectively . Split tensile strength is observed maximum at 15% replacement of OPC with mineral admixtures.

Split tensile test N/mm^2				
Days	C0	C1	C2	C3
7	2.6	2.4	2.43	2
28	3.57	4.6	3.9	3



Fig(4): 7days split tensile strength N/mm2

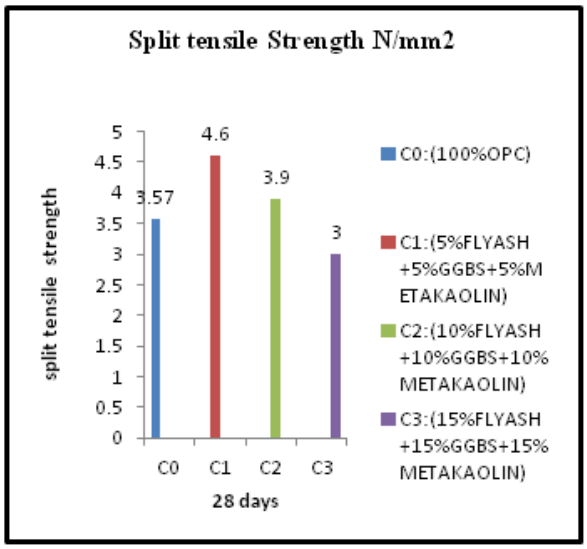


Fig (5): 28 days split tensile strength N/mm2

D. Sorptivity

Sorptivity values for all mixes are represented graphically as shown in Fig (6).Sorptivity values are found to be decreased as the percentage replacement of cement is increased.

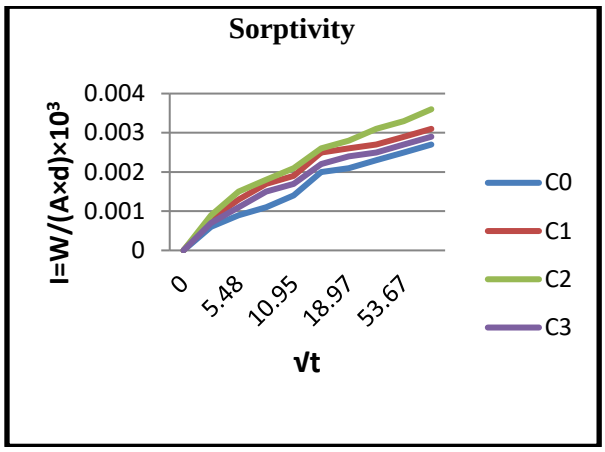


Fig (6):Sorptivity

E. Water Absorption

Water absorption test results for all mixes are represented graphically as shown in Fig (7). It was observed that water absorption was found decreased as the percentage replacement of cement increased.

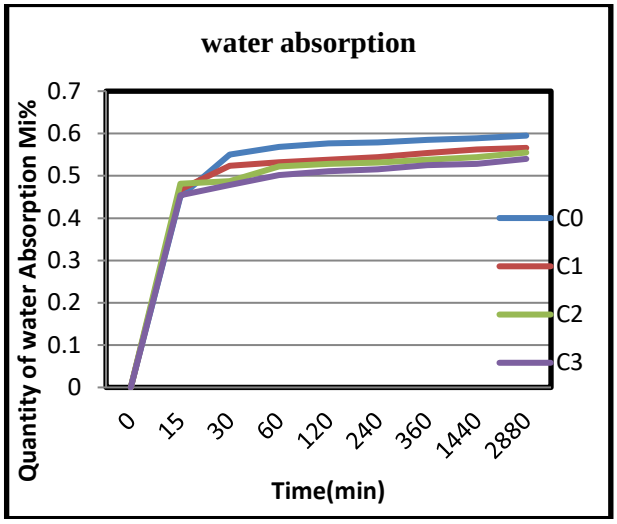


Fig (7): Water Absorption

VI. CONCLUSIONS

From this Experimental investigation the following conclusion are made

1. The workability of the Concrete was decreased from 100mm to 75mm when 45% of Cement was replaced by Fly Ash, Metakaolin and GGBS.
2. Maximum Compressive strength were attained at 15% replacement of cement by Fly Ash, Metakaolin and GGBS ,28 days compressive strength is 23% more than that off controlled concrete.
3. For 15%and 30% replacements the compressive strengths are more than the target mean strengths and for 45% replacement compressive strength is almost equal to target mean strength.
4. Split tensile strength was observed to be maximum when Cement was replaced by the Mineral Admixtures to an extent of 15%.
5. In the present Study there was significant improvement in the durability properties like water absorption and Sorptivity.

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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. 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.

Katta.Manoj, Completed engineering in Chaithanya Bharathi institute of echnology Obtained CGPA -7.2 Btech project is "Estimation of Temperature ,Humidity, Rainfall for next 70 years using Artificial neural networks". Presently pursuing masters in Structural engineering at Gokaraju Rangaraju institute of Engineering and Technology keenly interested to conduct experimental investigation on concrete made with different mineral admixtures.