Experimental Investigation on Ductility and Durability Studies of Concrete Incorporated with Fly Ash and Glass Fibre

G. Anantha Rami Reddy, K. Shyam Chamberlin

Abstract: ***Concrete industry is facing the environmental impact, by the emission of CO_2 while cement production. Cement partially replaced with pozzolanic waste material like fly ash reduces the releasing of CO_2. Fly ash is produced from thermal power plants. Due to using of glass fibers to conventional concrete has a huge compressive strength and flexural strength. This research work deals the study of different grades (M30, M40) of GFRC by partial replacement of cement with fly ash. According to mix proportions, standard sizes of specimens are casted in order to find the durability properties, ductility and flexural strength. Durability properties are achieved by testing the specimens for sulphate and also acid attacks. Whereas ductility and flexural strength is obtained from stress-strain curves. And obtained results are compared to conventional concrete. It is been observed from this research is that, ductility, durability and flexural strength is higher for GFRC than conventional concrete.***

Index Terms: ***Glass fiber, fly ash, compressive strength, stress-strain curve, flexural strength.***

I. INTRODUCTION

OPC 53 grade S cement is manufactured as per specification laid down by ministry of railways under IRST40: 1985. It is a very finely ground cement with is high C_3S content designed to develop high early strength required for manufacture of concrete sleeper for Indian Railway. Cementitious materials such as mortars and concretes are utilized for the development of construction material because they're durable, low-cost and have an adequate compressive strength and stiffness for structural use. It cannot be directly used to the structures due to its low ductility and less tensile strength. Fibers prevent micro cracks from widening. The components become ductile and tough due to addition of fibers. Conventional concrete cracks easily. When concrete is reinforced with randomly dispersed fibers, we get favorable behavior for repeated loads. For the fixing of proper reinforcement it is very difficult for the odd shape of structures, it is not commence in the case of fiber reinforced concrete and also the progress of work can be achieved at much faster rate. Generally fly ash has higher impact on the environment because of presence of heavy metals like mercury, cadmium, boron. Our paper deals with effective use of fly ash as a construction material which can be replace up to 40%by weight of cement. We all are aware of the fact that concrete is weak in tension and strong in compression in order to compensate the tension and strong in compression to acquire the high tensile in the concrete. Due to this the reinforcement or fibers are utilized in the process of concreting. For the thin members the fiber reinforced concrete are used to gain the tensile strength. The pozzolanic material having essential with the siliceous and aluminous materials as which reacts with calcium hydroxide in the presence of water at ordinary temperature and liberated in the process of hydration to form compounds as like as possessing cementitious properties. Fly ash is waste material, generated in the thermal power station, when powdered coal is used as fuel. The PPC (Portland Pozzolona Cement) products have the high resistance and with the less heat of hydration to attack the aggressive water than the OPC (Ordinary Portland Cement). Portland cement can be expected in general only at later ages provide the concrete is cured under moist conditions for a sufficient period .In India there is apprehension in the minds of the user to use the Portland pozzolana cement for structural work. If the Portland pozzolana cement is manufactured by using the right type of reactive pozzolanic material, the Portland pozzolanic cement will not be in any way inferior to ordinary Portland cement except for the rate of development of strength up to 7days.

Fly ash contributes the strength of concrete in three ways,

- The amount of water consumed will be automatically reduced with addition of fly ash.
- As fly ash is cementitious material, it can increase the amount of paste generated with which workability can be increased.
- Effective reaction will takes place between fly ash and Cao.

The first two aspects are beneficial to the earlier strength. Thus, the decrease of earlier strength of concrete containing fly ash is attributed to the slow pozzolanic reaction between fly ash and CaO. To evolve the optimum percentage of fly ash that can be added to replace cement in concrete [1]. and the workability conditions of the fly ash are less compared to fresh concrete and the reinforced beams have shown similar behavior as of normal fresh concrete [2] with the addition of glass fibers to the fly ash have shown similar increment of strength when tests were conducted after 28 days according to [3]. To derive the properties of glass fibers reinforced concrete with partial reinforcement of cement and evolve the parameters of that are coinciding with conventional concrete [4] and the strength was

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constantly increasing up to addition of fly ash to a percentage of 30 and been decreasing after that [5].

II. OBJECTIVES

The main objectives of this experimental investigation are as follows:

1. To study the various properties of fly ash and glass fibers which is used as mineral admixture for partial replacement of cement and as the additional reinforcement.
2. To study the behavior and workability of the concrete when cement is partially replaced with fly ash with percentage (40%) and the glass fibers (0.4%) in concrete.
3. The mechanical properties of concrete such as split tensile, compressive strength, Durability and Ductility.
4. Use of industrial waste in use full manner to reduce the disposal problem in present and future days and significantly reduce the CO_2 emission and also avoid adverse effect environment, provide economic construction material to the construction industry.

III. MATERIALS USED

A. Cement

Commercially available OPC of grade-53 was used. Cement is the most important binding material of cement conforming to IS 12699: 1999 is used in this project work. The properties of cement are tabulated as Table I.

Table I: Properties of Cement

Specific Gravity	3.14
initial setting	80 minutes
Final Setting Time	215 minutes

B. Fine Aggregate

Fine aggregate used for concrete was Krishna river sand. Fine aggregate is the main ingredients of concrete mix for the construction. Fine aggregate are material passing through an IS sieve that is less than 4.75mm beyond which they are known as coarse aggregate. And the properties considered fine aggregates are from Table II. Fine aggregate used in this investigation is confirmed to Zone II of Table IV in IS 383:1970. Table III shows the Zone selection for Fine aggregate.

Table II: Properties of Fine Aggregate

Specific Gravity	2.63
Zone	II
Water Absorption	1.09 %

C. Coarse Aggregate

The coarse aggregate can be formed by the crushing of granite. And having with the maximum size of 20mm and 12.5mm. The properties are shown in Table IV. It was obtained from local surrounding quarry areas of Vijayawada.

Table IV: Properties of Coarse Aggregate

Specific Gravity	2.89
Water Absorption	0.69 %

Table III: Zone selection for Fine aggregate

IS Sieve Size (mm)/micron	Weight retained in gm	Cumulative Weight retained in gm	Cumulative Percentage retained in gm	Percentage passing for				
				Cumulative Percentage Passing in gm	Grading			
					Zone 1	Zone 2	Zone 3	Zone 4
10	0	0	0	100	100	100	100	100
4.75	6	6	0.6	99.4	90-100	90-100	90-100	95-100
2.36	15.5	21.5	2.15	97.85	60-95	75-100	85-100	95-100
1.18	195.5	217	21.7	78.3	30-70	75-90	75-100	90-100
600	203	420	42	58	15-34	35-59	60-79	80-100
300	384	804	80.4	19.6	5--20	8--30	Dec-40	15-50
150	165.5	969.5	96.95	3.05	0-10	0-10	0-10	0-15
Total = 969.5								

D. Glass Fiber

Alkali resistance glass fibers are used in project work. Glass fiber is chemically inorganic fiber and obtained from molten glass of Specific composition. Glass fiber is made up of natural materials such that its produces substances of ecologically pure and not harmful to the community. Glass fiber made up from 200-400mm individual filaments. It is not possible to mix fibers more than 3%. Glass fibers have excellent electronic heat and insulation capacities. The properties of glass fiber are shown in Table V.

Table V: Properties of Glass Fiber

Length	12mm
Diameter meter	0.4 micron
Density	2700 kg/m^3
Specific Gravity	2.68
Modulus of rupture	72Gpa
Tensile strength	1700Mpa

E. Fly ash

Class F fly ash was used in that study and it is collected and the Specific Gravity of fly ash is 2.13 and chemical oxide composition is shown below in Table VI.

Table VI: Chemical Oxide of Fly ash

Chemical	Sio_2	Al_2o_3	Fe_2o_3	Na_2o	Mgo	Cao	So_3
%	61.24	25	8.71	0.09	0.09	4.42	0.49

F. Acid

In order to check the sulphate attack resistance the specimen is placed in acidic solutions such as H_2SO_4,$MgSO_4$ with 5% of concentration in water.

G. Mixing, CASTING and CURING

***Mixing*:** In the above mentioned Table VII, the mix proportion in which the fly ash is partial replaced with (OPC) ordinary port land cement by 0% and 40% of grade M30 and M40. Similarly glass fibers are replaced by 0% and 0.4%. In order to improve its workability super plasticizer of 0.8% is used.

Casting: The Concrete cubes casting of 144 cubes of size 150mm each side, cylinder size of 150mm diameter and 300mm high. Reinforced concrete beams of size 2200mm x 150mm x 300mm by using 12mm and 10mm diameter bars with 8mm diameter stirrups is made to check the results of compressive strength, split tensile strength, stress strain curve and flexural behavior for concrete mix. Admixture MYK PC-20 is added at the time of Mixing the concrete to enhance workability and maintain the uniform slump for all the M30 and M40 grade.

***Curing*:** After completed casting of specimens. The curing duration may be varied different type of specimens. For cube specimens 7 days, 28 days, 60 days and 90days, cylinder specimens 7days and 28days is taken for curing period. Beam specimens 28days is taken as curing period.

Table VII: Concrete Mix Proportion

S. No	Material	M30 conventional	M30 Composite	M40 conventional	M40 Composite
1	Cement (kg/m^3)	356	235	400	264
2	Fly ash (kg/m3)	-	156	-	176
3	F. A. (kg/m3)	705	673.0	672	637
4	C. A. (kg/m3)	1278	1220	1272	1205
5	Water (lt/m3)	168	168	160	160
6	Super Plastizer(lt/m3)	2.1	2.1	3.2	3.2
7	Glass Fiber(%)	-	10.8	-	10.8

H. Super Plasticizer

To increase the workability of the glass fiber reinforced concrete mixes, the high range of water reducing proxy MYK PC-20 has been used in this present work.

I. Water

Water is the most important additive to form a molded mix in a concrete .the fresh water available in laboratory are used for concreting mixing and curing both glass fiber reinforced concrete mixes M30 and M40 grades are used in water.

J. Mix Proportion

In this study, control mix proportion M30 and M40 grade was designed according to IS 10262-1982 to the mean target compressive strength 38.69Mpa and 48.59Mpa. Fly ash was used to replace the ordinary Portland cement different levels of 0%, 40% by binder content the alkali resistance glass fibers of 0%and 0.4% by volume of fraction of the concrete walls was used. The mix proportions of M30 and M40 grades are in Table VII.

IV. TEST RESULTS AND DESCRIPTION

A. Compressive Strength Test

M30 Grade: The compressive strength for control mix and composite mix for M30 is shown in Fig. 1.

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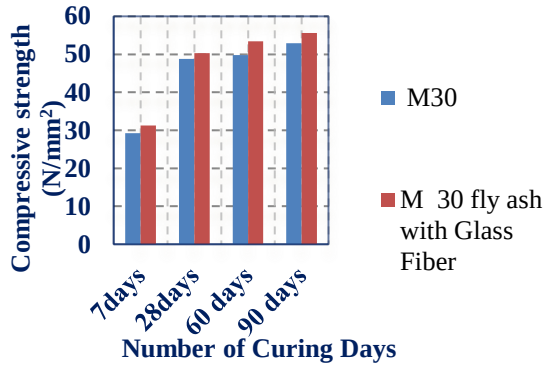

Fig. 1: Compressive strength M30 grade plane and fly ash and glass fiber

M40 grade: The compressive strength for control mix and composite mix for M40 is shown in Fig. 2.

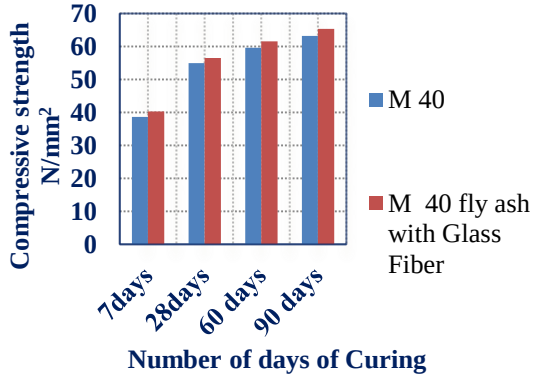

Fig. 2: Compressive Strength M40 Grade plane and Fly ash and Glass fiber

B. Split Tensile Strength

M30 grade: The split tensile strength variation for control mix and composite mix for M30 grade is shown in Fig. 3.

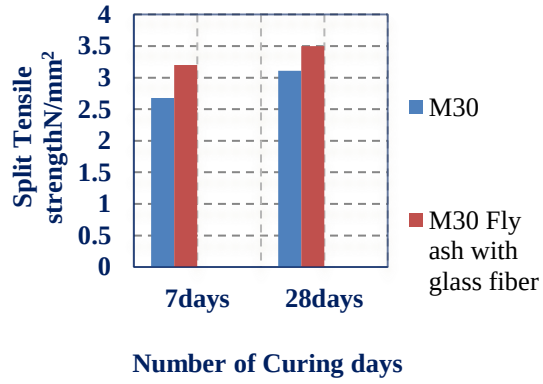

Fig. 3: Split strength M30 grade plane and fly ash and glass fiber

M40 grade: The split tensile strength for control mix and composite mix for M40 grade is shown in Fig.4.

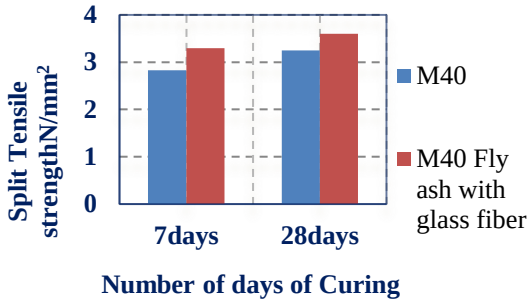

Fig. 4: Split Tensile Strength M40 Grade plane and Fly ash and Glass fiber

C. Stress-Strain Curve

Control Mix: Stress - Strain curve for control mix M30 and M40 grade is shown in Fig. 5.

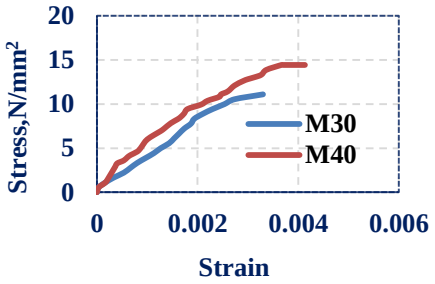

Fig. 5: Stress-Strain curve of M30 and M40 grade control mix

Composite mix: Stress - Strain curve for composite mix M30 and M40 grade is shown in Fig. 6.

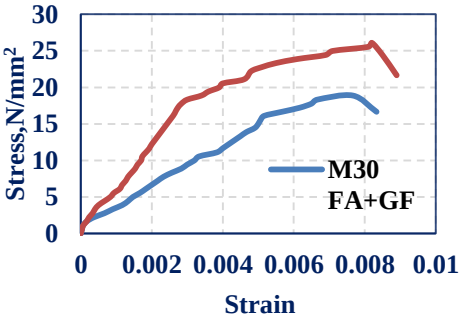

Fig. 6: Stress-Strain Curve of M30 and M40 grade composite mix

D. Flexural Strength Test

The optimum strength, 40% of cement was replaced with fly ash. The beams which were casted are of size 2200mm×150mm×300mm. And tested by using 4-point loading test as loading frame in laboratory. The strength values obtained for conventional and replacement specimens are tabulated and comparison is shown in graphical representation. The beam detailing is shown in Fig. 7. The loading setup is shown in Fig. 8. The cracking patterns on the tested specimens were shown in the Fig. 9 from this flexural strength the load Vs deflection curves are obtained for each specimen, those curves were shown in the Fig. 10. to Fig. 15.

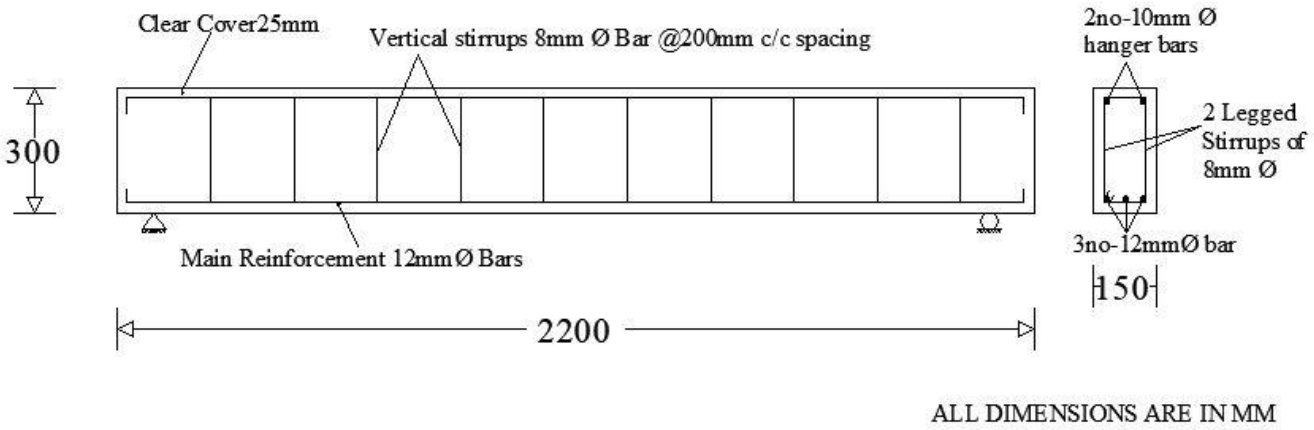

Fig. 7: Detailing of Beam

Fig. 8: Beam Setup

Fig. 9: Cracking pattern on the tested specimen

E. Flexural Strength Test

Composite mix: Flexural Strength of Beam with Composite mix Concrete (M30 and M40) is shown in Fig. 9.

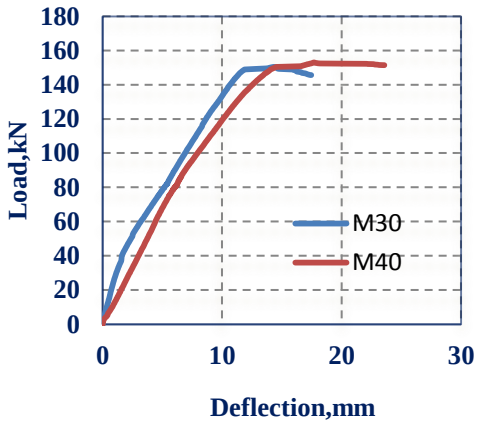

Fig. 10: Flexural strength of beam with Composite mix M30 and M40 grade of concrete

Control mix: Flexural Strength of Beam with Control mix Concrete (M30 and M40) is shown in Fig. 10.

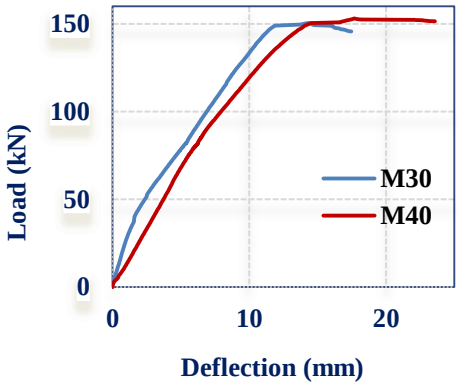

Fig. 11 : Flexural strength of beam with Control mix M30 and M40 grade of concrete

F. Durability Studies with H_2SO_4 AND $MgSO_4$

Concrete cubes of specimen size of 150mm each side were cast for durability studies for M30 and M40 grade concrete 5% H_2SO_4 and $MgSO_4$ concentration for 60days curing 5% H_2SO_4 and $MgSO_4$ concentration for 30days were considered for durability studies M30 and M40 grade consists of two trails 0% and 40% and hence M30 and M40

grade contain 24 cubes placed in individual drums for each solution. Normality of the solution was checked for every day. The compressive strength of the cubes exposed to H_2SO_4 and $MgSO_4$ are tested for compressive strength and results were presented from in Fig. 11-15.

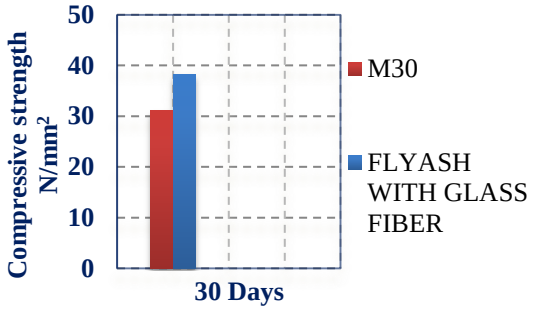

Fig. 12: Compressive Strength of M30 Grade plane and Fly ash and Glass fiber with Sulphate Attack

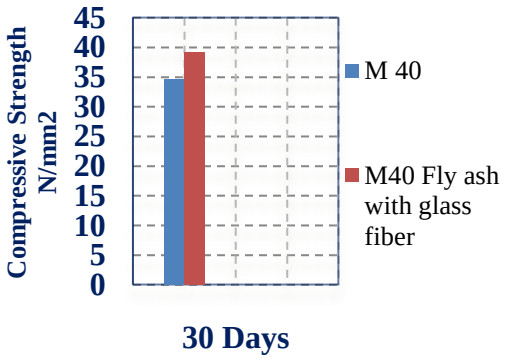

Fig. 13: Compressive Strength M40 Grade plane and Fly ash and Glass fiber With Sulphate Attack

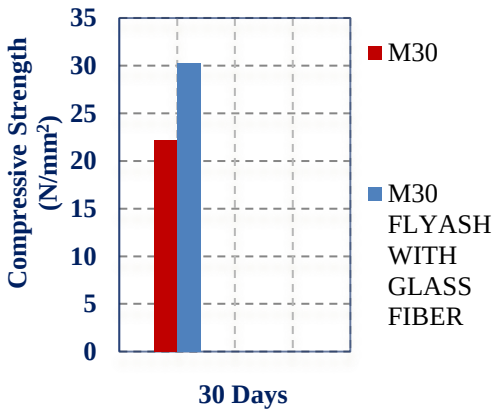

Fig. 14: Compressive Strength M30 Grade plane and Fly ash and Glass fiber With Acid Attack

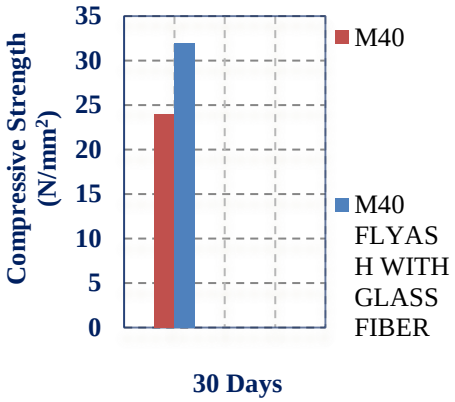

Fig. 15: Compressive Strength M40 Grade plane and Fly ash and Glass fiber With Acid Attack

V. CONCLUSION

The following conclusions were obtained by the addition of glass fiber and fly ash as the replacement of cement.

- The addition of glass fiber and fly ash has improved the compressive strength, split tensile strength and flexural strength of concrete.
- The slump value of the concrete mix by adding Fly ash and Glass fiber is 73mm.
- For the mix of Fly ash (40%), Glass fiber (0.5%) and Cement (60%), there obtained a low workability.
- The addition of 0.8% of admixture is used to increase its workability.
- The compressive and Split tensile strength of M30 and M40 conventional concrete were less when compare to composite concrete.
- When compared with Composite mix, the stress-strain values of Control mix were high.
- With the replacement of cement with Fly ash and Glass fiber, the load carrying capacity of beam increases.
- When the cubes of Composite mix (M30 & M40) treated with $MgSO_4$, the compressive strength value increase when compared with the cubes of control mix (M30 & M40) due to Sulphate attack.
- In case of H_2SO_4, the compressive strength for the composite mix of M30 & M40 was increased when compared with control mix.

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