Effect of Glass Fibre on FLY - ASH Based Concrete

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Abstract: **Emission of carbon dioxide (CO2) into the environment is main reason for global warming. Among many, cement production is the one of the major reason for global warming. The increase in consumption of concrete increases the utilization of large quantities of energy and decrease the natural resource available. Industrialization leads pollution and disposal of its waste has become a challenging problem. From both these problems, the only possible solution is to replace the ingredients of concrete with industrial by products. Fly-ash based glass fibre concrete is a product being manufactured in this direction and also strength parameters.**

Concrete being brittle is weak in tension. The inclusion of fibres in concrete have significantly improves its Compressive as well as tensile strength. The use of different types of fibres & their orientation in the matrix have shown positive responses among the researchers. Fibre is easy available material. Due to glass fibre reinforced the glass fibre easily surrounded to the cementations medium.

In the present study, the effect of addition of Glass fibre on the blended cement concrete such as fly ash based cement concrete and ordinary Portland cement concrete were studied. In the fly ash based cement concrete, proportion of the element of the binding material was 30% fly ash and 70% cement. Various proportions of glass fibre such 0%, 0.5%, 1%, 1.5%, 2%, 2.5%, and 3% of binding material by weight was chosen to see the effect of glass fibre on both types of cement concrete by determining the mechanical properties such as Compressive strength , split-tensile strength test and flexural strength. The requisite number of standard specimens were tested as per the procedure described in the respective IS codes. The tests were conducted on the specimens after 7 days, 14 days and 28 days curing. It is observed that the blended cement concrete with 1.5% glass fibre seems to be quite promising in enhancing the properties Compared to other cases considered in the study.

Keywords: Carbon dioxide (CO_2), Global Warming, FLY-ASH, Glass fibre, Concrete

I. INTRODUCTION

A. *General* :

In present scenario concrete is one of the most widely used materials in the construction field. Usually, it is associated with ordinary Portland cement which is the main Component for making concrete. Cement offers excellent performance as a binding material in concrete. So the demand for cement rises day by day due to development of infrastructure all over the world. On another hand, cement manufacturing Companies are increases from past decades to till now. Not only consumes the required amount of raw material but also require high energy intensive for producing cement in manufacturing Company.

B. *Environmental Concern*

In our present world cement industries are responsible to second largest producing of co2.it is estimated that about 6%of all co2 emissions because for production of one ton Portland cement emits approximately one ton of co2 into the open atmosphere. In order to protect the environment, the main concern of minimizing of co2 emissions to the atmosphere. This is done by reducing the use of percentage of cement in making of concrete. Yet the use of Portland cement is still unavoidable for the foreseeable future.

To mitigate these environmental problems, our civil engineers were strived to produce many alternatives and more eco-friendly concrete by doing many experiments and test on replacing of different percentage of ingredients with industrial by–products such as Fly-ash, silica fume, granulated blast furnace slag, Rick husk Ash and Me-takaolin. Which possess excellent mechanical properties. For every year million tons of industrial waste is generated which causes environmental pollution if not disposal well.

C. ***FLY ASH*** *Production and its availability*

In the process of electricity generation large quantity of fly ash gets produced and becomes available as a by-product of coal-based power stations. R.E. Davis and his associates at university of California published research details on use of fly ash in cement concrete. This research had laid foundation for its specification, testing & us-ages. Any country's economic & industrial growth depends on the availability of power.

Use of Fly-ash in concrete imparts several environmental benefits and thus it is eco-friendly. It saves the cement requirement for the same strength thus saving of raw materials such as limestone, coal etc. required for manufacture of cement. Manufacture of cement is high-energy intensive industry. In the manufacturing of one ton of cement, about 1 ton of CO is emitted and goes to atmosphere. Less requirement of cement means less emission of result in reduction in greenhouse gas emission.

D. *Glass Fibre Concrete*

Glass Reinforced Concrete can be define as a Composite material consisting of mixtures of cement, mortar or concrete and discontinuous, discrete, uniformly dis-persed fibres. Continuous meshes, woven fabrics and long wires or rods are not considered to be discrete fibres. In which consists of extremely fine fibres of glass. Generally, they were having the high ratio of surface area to its weight. Thereby which are used as thermal insulators. Also which has more surface area makes it more susceptible to chemical attack. So glass FIBRE is widely used in exterior building faced panels and as architectural precast concrete. Although it possesses very high tensile strength about 1020 to 4080 MPa. Although it is less dense than steel. Also, it is used in making of shapes of front structure of any building.

Fibre reinforced concrete is one which containing fibrous material which im-proves its structural integrity thereby concluding that Fibre reinforced concrete is a Composite material of cement concrete or mortar and discontinues discrete and uniformly dispersed Fibre. All Fibre available in nature is not ineffective and economical. Mostly used Fibres are steel, glass, carbon and natural Fibres.

II. MATERIALS AND METHODOLOGY

A. *Glass Fibre Concrete*

Glass Fibre reinforced concrete or GFRC is a type of Fibre-reinforced concrete. The product is also known as glass Fibre reinforced concrete or GRC in British English. Glass Fibre concretes are mainly used in exterior building facade panels and as architectural precast concrete. Glass Fibre-reinforced concrete consists of high-strength, alkali-resistant glass Fibre embedded in a concrete matrix. In this form, both Fibres and matrix retain their physical and chemical identities, while offering a synergistic combination of properties that cannot be achieved with either of the Components acting alone. In general, Fibres are the principal load-carrying members, while the surrounding matrix keeps them in the desired locations and orientation, acting as a load transfer medium between the Fibres and protecting them from environmental damage.

1. How Glass Fibre Reinforced Concrete Can be Used

GFRC can be used wherever a light, strong, weather resistant, attractive and fire retardant material is required GFRC can be used in manufacturing architectural products such as wall panels, window surrounds, column covers, , brackets, quoins, railings, Pilasters, copings, domes, site furnishings, planters, bollards, urns and tables.

B. Properties of GFRC

Glass Fibre Reinforced Concrete (GFRC) is a cement-based material that is be-coming popular material because of its many advantages over its counterparts. Some of these advantages include easy customization, water resistance, and lightweight. GFRC can also be customized depending on the requirements of the project by modifying the materials used and their corresponding amount.

1. Structural Properties of GFRC

GFRC derives its strength from a high dosage of AR glass fibres and a high dosage of acrylic polymer. While Compressive strength of GFRC can be quite high (due to low water to cement ratios and high cement contents), it is the very high flexural and tensile strengths that make it superior to ordinary concrete. Essentially the high dose of fibres carries the tensile loads and the high polymer content makes the concrete flexible without cracking.

C. *Alkali Resistant Glass Fibres for GFRC*

The glass used in GFRC is of alkali resistant and the alkali resistance of AR glass fibres is a result of adding zirconia (zirconium oxide) to the glasses. The best fibres have zirconia contents of 19% or higher. More the amount of zirconia in glass more will be the alkali resistance. Figure 1 shows the relationship between Zirconia content and the alkali resistance of glass fibres.

D. Materials For Fly-ASH Based Glass Fibre Concrete

In the present glass Fibre concrete preparation Fly-ash is used as a replacement for the cement.

1. FLY-ASH

Fly-ash is obtained from thermal power stations as a fine powder when using pulverized coal or lignite as fuel. So that Fly-ash is also known as ‘‘pulverized fuel ash”. Generally, this is used as pozzolana siliceous or alumina-siliceous in nature. The particles of Fly-ash are in shape of “balls” which are finer than cement particles. Gen-really ranging in size from 2μm to 10μm. Fly-ash is classified into two types namely F-class, C-class. In the present study F-class glass Fibre used.

Figure 1. Fly-Ash

(Material Procured from: Class-F Fly-ash from NTPC, Visakhapatnam)

E. *Glass Fibre*

Glass Fibres are the versatile industrial materials. Glass Fibres are generally derived from silica. And the availability of this material was more. Many different types of Fibres are there such as, steel Fibres, plastic Fibres and glass Fibres. The glass Fibres are hard in nature and they are also dangerous. While cutting, and using these glass Fibres in concrete proper care should be taken. Glass Fibres absorb more water while mixing the concrete. If the content of glass Fibre was increases then the water absorption was also increases. Glass Fibre was also segregating the materials while mixing the concrete. There are so many glass Fibres are there and they have special property individually.

F. *Aggregates*

Aggregates are the important Component in concrete nearly 75 to 80% of volume is occupied. They give rigid skeleton structure to the concrete. Good gradations of aggregates are one of the most important factors for producing workable concrete. Good grading implies that a sample fraction of aggregates in required proportion such that the sample contains minimum voids. Samples of the well graded aggregate containing minimum voids give good bond strength to the concrete.

i) Coarse Aggregate

The properties of the coarse aggregate used in a concrete mixture affect the modulus for a few reasons. One property is the Modulus of Elasticity of the coarse aggregate. A higher aggregate modulus will result in a concrete having a higher modulus. As expected, a lightweight aggregate will have a lower modulus than the mortar paste. In tests, concrete containing a higher percent of coarse aggregate resulted in a higher elastic modulus. The particle shape of the aggregate contributes to the effectiveness of producing a high performance concrete. Crushed rock creates a much better bond between the paste and the aggregate than gravel does. However, the aggregate-mortar bond may be more important in flexure tests than in Compression tests. The gravel performed poorly because of the weak bond between the aggregate and the cement paste. The granite aggregate, on the other hand, gave the worst results because of its mineral Composition.

ii) Fine Aggregate

River sand is used as a fine aggregate. Sand is a naturally occurring granular material Composed of finely divided rock and mineral particles. It is defined by size, being finer than gravel and coarser than silt. Sand can also refer to a textural class of soil or soil type; i.e., a soil containing more than 85 percent sand-sized particles by mass. The fine aggregates utilized were easily accessible from the local market. Fine aggregate can be classified as those particles which roughly pass the 4.75mm IS sieve and significantly retains on the 75micron sieve. Fine Aggregates having specific gravity value of 2.74

G. *Methodology Experimental Program*

The experimental programs consist of following steps:

- To find the properties of all the ingredients of glass Fibre reinforced fly ash based concrete.
- To determine best combination ratios of binder materials of cement and fly ash by prepare a trail mixes of different combinations like 10%, 20%, 30% and 40% of fly ash replaced. Prepare mortar cubes to finalize the optimum percentage of ingredients in binder.
- To finalize the mix proportions of GFC, by designing M30 grade concrete and use binder as 70% and 30% of cement and fly ash combinations and the different percentages of glass Fibers considered as 0.5%, 1%, 1.5%, 2%, 2.5% and 3%. The other mix will be design as without replacement of cement by fly ash and same content of glass Fibers adding to compare results.
- To prepare a cubes, cylinders and prisms to obtained a there mechanical properties such as Compressive strength, spilt tensile and flexural strengths. The specimens were unmolding within 24 hours, its kept in room temperature and placed on curing tank.
- After Completion of curing period of 7 days, 14 days and 28 days the Compressive, spilt tensile and flexural tests are conducted and the results will be analysed.

III. MATERIALS AND METHODOLOGY

A. *General*

Before doing the mix design for a particular grade of concrete, some data about the materials will be require to determining the proportions of the cement, aggregates and water to attain a required strength of the concrete. Those are:

- Grade Designation.
- Type Cement.
- Type and size of the aggregates.
- Maximum water-cement ratio.
- Minimum cement content.
- Workability Exposure conditions (Mild,Moderate,Severe,extreme).
- Test data of materials.(As per specifications in IS383: 1970) like:
  - Specific Gravity.
  - Water absorption.
  - Zone of aggregates etc.

***B.** Design Procedure*

The Bureau of Indian Standards recommended a set of procedure for design of concrete mix mainly based on the work done in national laboratories. The mix design procedure as per the Indian standard recommended method of Concrete Mix Design (IS 10262: 2009) as follows:

1. Target mean strength:

The target mean strength at 28 days is given by:

$$F_{ck} = f_{ck} + (t \times S)$$

Here,

F_{ck} = Target mean Compressive strength after 28 days f_{ck} = Characteristic Compressive strength after 28days

t = Risk factor

S = Standard deviation

Here, Risk factor (t) is taken as 1.65 as per the IS 456:2000 Clause9.2.2. TheStandard deviation values (s) are different for the different grades of concrete and those values are as shown in following table as per IS 10262:2009 in table 1.

Table 1. Assumed Standard Deviation (IS10262:2009)

Grade of Concrete	Standard Deviation
M30	6.0
M35	
M40	
M45	

2. Water - Cement Ratio (W/C):

Various parameters like types of cement, aggregate, maximum size of aggregate, surface texture of aggregate etc. are influencing the strength of concrete, when W/C ratio remain constant, hence it is desirable to establish a relation between concrete strength and free water cement ratio with materials and conditions to be used actually at site.

W/C can be select based on experience or by conducting the workability tests and the selected water – cement ratio should satisfy the maximum w/c ratio value with exposure conditions in IS 456:2000 Table 5.

C. *Cement Content*

By using the Water – Cement (W/C) ratio and Water content, Cement content can be calculated:

$$Cement\ Content = \frac{Water\ Content}{(\frac{W}{C})Ratio}\ Kg$$

The cement content should be greater than the minimum cement content with respect to exposure condition which was mentioned in the IS456: 2000 Table 2

Table 2 Minimum Cement Contents for different exposure Condition

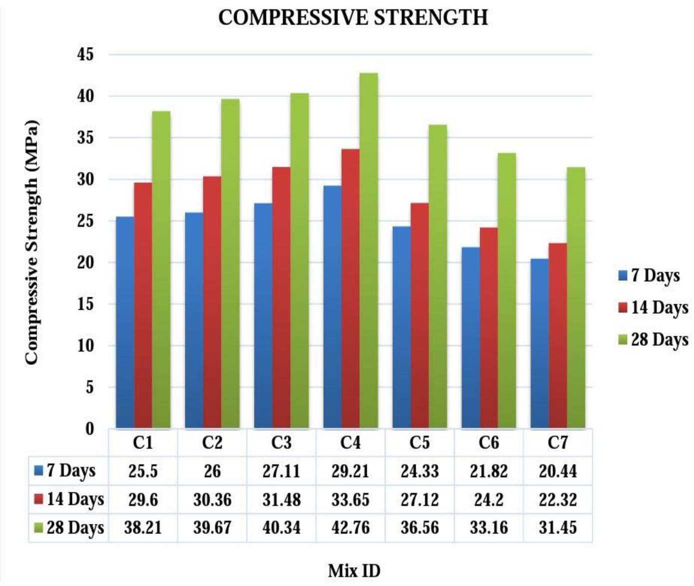
Exposure Conditions	Minimum Cement Content (Kg per cum) (Plain concrete)	Minimum Cement Content (Kg per cum) (Reinforced Concrete)
Mild	220	300
moderate	240	300
severe	250	320
Very severe	260	340
extreme	280	360

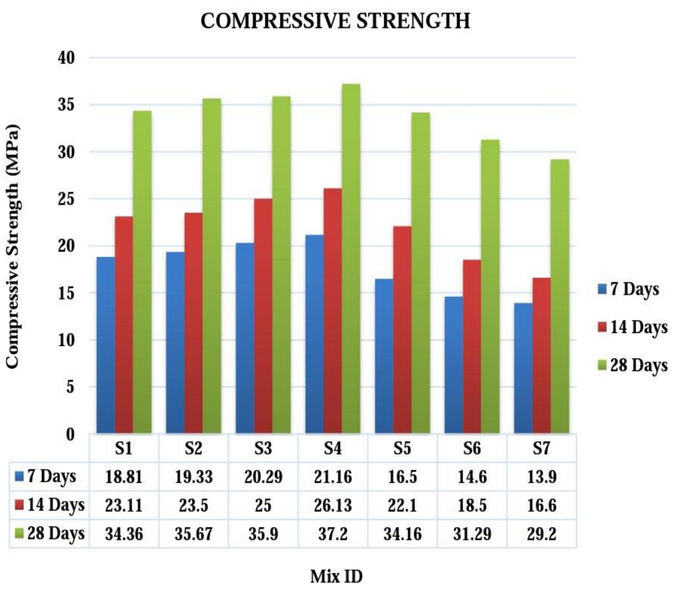
IV. RESULTS AND DISCUSSION

The study was done on the effect of glass Fibre on conventional and Fly ash based concrete. The following are the results obtained from the experiments i.e. from Compression strength test, split tensile strength test and flexural strength test. These tests are done on the normal concrete, 30% of cement replaced with fly ash concrete by adding 0.5%, 1%, 1.5%, 2%, 2.5%, and 3% of glass Fibre (GF) by the weight of binder.

A. *Compressive Strength*

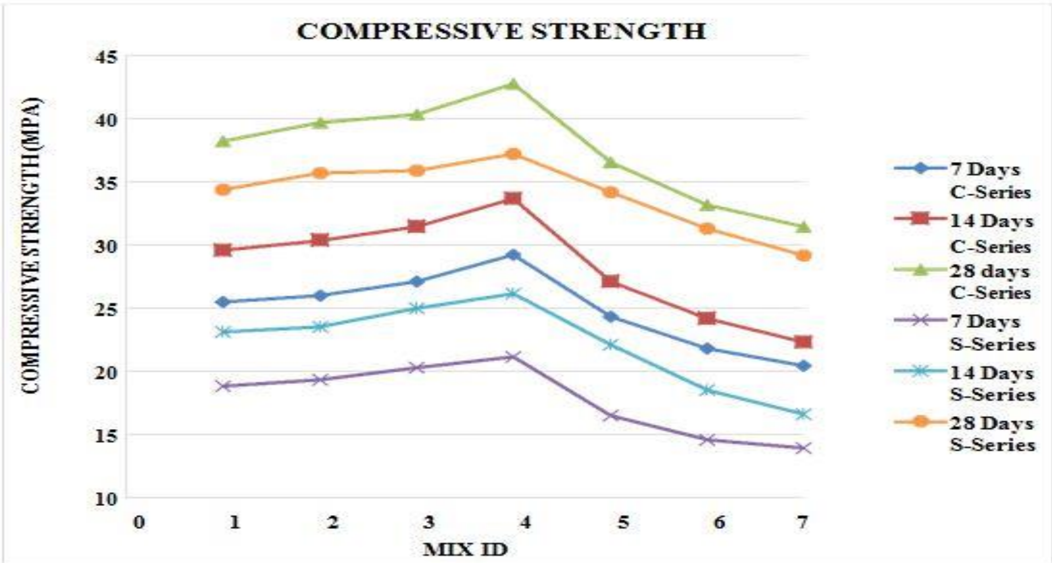
The Graph 6.1 represents the average Compressive strength results of C-Series having 0%, 0.5%, 1%,1.5%, 2%, 2.5%, and 3% of glass fibre on conventional concrete at the ages of 7, 14, and 28 days respectively. In C-series, the Compressive strength value increases with increasing of days. In these results C4 mix (1.5% Of G.F) gives high Compressive strength value of 42.76 MPa at the age of 28 days C7 mix (3.0% Of G.F)gives low Compressive strength value of 31.45 MPa. In 28 days, the results are increased with increasing of glass fibre continues up to 1.5% then decreased up to 3%





Graph 1. Compressive strength results of c-series and s-series

The Graph 5.2 represents the average Compressive strength results of S-Series having 0%, 0.5%, 1%,1.5%, 2%, 2.5%, and 3% of glass fibre on Fly ash based concrete at the ages of 7, 14, and 28 days respectively. In S-series, the Compressive strength value increases with increasing of days. In these results S4 mix (1.5% Of Glass Fibre) gives high Compressive strength value of 37.2 MPa at the age of 28 days S7 mix (3.0% Of Glass Fibre) gives low Compressive strength value of 29.2 MPa, In 28 days. The Compressive strength results are increased with increasing of glass fibre continues up to 1.5% then it decreases gradually till 3.0%

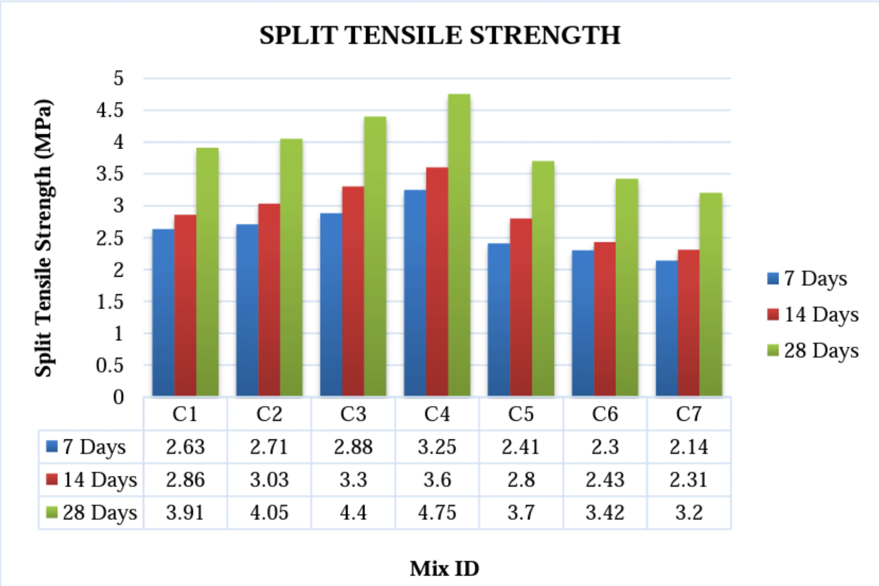


Graph 2. Compressive strength values of C-Series and S-Series

The Figure 6.3 represents the average Compressive strength results of C-Series and S-Series having 0%, 0.5%, 1%,1.5%, 2%, 2.5%, and 3% of glass fibre on conventional and Fly ash based concrete at the ages of 7, 14, and 28 days respectively. In C & S-series, the Compressive strength value increases with increasing of days. In these results C4 mix (1.5% Of Glass Fibre) gives high Compressive strength value of 42.76 MPa at the age of 28 days The Compressive strength results are increased with increasing of glass fibre continue up to 1.5% then it decreases gradually till 3.0%. Fly ash based concrete having lower Compressive strengths when compared to conventional concrete. It was observed it has low Compressive strengths at early ages.

B. *Split Tensile Strength*

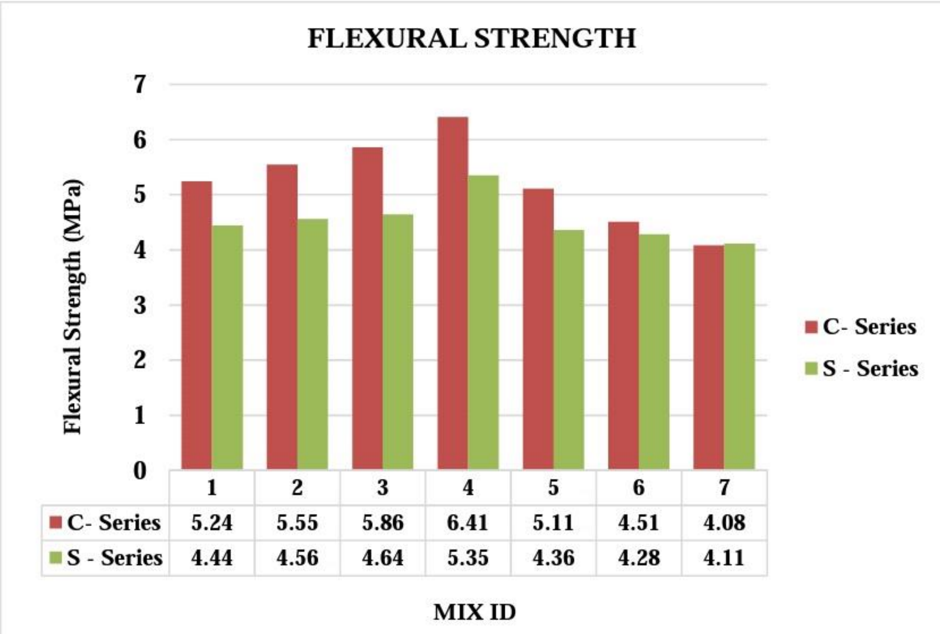
The Graph 6.4 represents the average Split tensile strength results of C-Series having 0%, 0.5%, 1%,1.5%, 2%, 2.5%, and 3% of glass fibre on conventional concrete at the ages of 7, 14, and 28 days respectively. In C-series, the Split tensile strength value increases with increasing of days. In these results C4 mix (1.5% Of Glass Fibre) gives high Split tensile strength value of 4.75 MPa at the age of 28 days C7 mix (3.0% Of Glass Fibre) gives low Split tensile strength value of 3.2 MPa. In 28 days, The Split tensile strength results are increased with increasing of glass fibre continues up to 1.5% then it decreases gradually till 3.0%



	C1	C2	C3	C4	C5	C6	C7
7 Days	2.63	2.71	2.88	3.25	2.41	2.3	2.14
14 Days	2.86	3.03	3.3	3.6	2.8	2.43	2.31
28 Days	3.91	4.05	4.4	4.75	3.7	3.42	3.2

Graph 3. Split Tensile Strength Result of C-Series

C. *Flexural Strength*



	1	2	3	4	5	6	7
C- Series	5.24	5.55	5.86	6.41	5.11	4.51	4.08
S - Series	4.44	4.56	4.64	5.35	4.36	4.28	4.11

Graph 4. Flexural Strength Result of C-Series and S- Series

The above figure represents the average Flexural strength results of C-Series & S-Series having 0%, 0.5%, 1%,1.5%, 2%, 2.5%, and 3% of glass fibre on conventional and Fly ash based concrete at 28 days. In C & S-series, the Flexural strength value increases with increasing of days. In C-Series C4 mix (1.5% Of Glass Fibre) gives high Flexural strength value of 6.41 MPa at the age of 28 days. In S-Series S4 mix (1.5% Of Glass Fibre) gives high Flexural strength value of 5.35 MPa at the age of 28 days The Flexural strength results are increased with increasing of glass fibre continue up to 1.5% then it decreases gradually till 3.0%.

D. *Cost Analysis*

In this paper we replacing cement with supplementary compendious material are fly ash and glass fibre. For this analysis designed a concrete mix for $1m^3$ volume of concrete for M30 grade.

1. Concrete mix design for M30 grade concrete

Cement used = OPC 53 grade
Specific gravity of cement = 3.15
Specific gravity of fine aggregate = 2.69
Specific gravity of coarse aggregate= 2.74
Conforming to grading of zone –II of table 4 of IS 383-1970
The design mix calculation is done based on **IS CODE 10262-2009**

a) **Target characteristic compressive strength:**

$f_t = f_{ck} + 1.65*S$

S is standard deviation taken from **table 1** of IS **CODE 10262-2009**

S = 5 for M40 grade concrete

f_{ck} = characteristic compressive strength

= 30 + (1.65 * 6)

= 38.25 N/mm^2

b) **Selection of water / cement ratio:**

W/C = 0.45

= 0.45 adopted

c) Water content:

Maximum water content is = 186 liters (25 to 50 mm slump) For 20mm size aggregate

For 100mm slump = 186 + 6/100*186

= 197 liters

d) Cement content:

W/C = 0.45

197/C = 0.45

C = 438 kgs

Hence ok 438 < 450 maximum cement content

e) Coarse and fine aggregate:

From **table 3** of **IS CODE 10262-2009**

Coarse aggregate corresponding to 20 mm size which passing through 20mm size sieve. Fine aggregate is taken from zone 2

W/C value is taken 0.45 = 0.62 i.e., 0.45 = 0.62

Volume coarse aggregate = 0.62 * 0.9 = 0.56

Volume coarse aggregate = 1 – 0.56 = 0.44

2. Mix calculation:

Cement = 437 kg

Water = 197 kg

Fine aggregate =673 m^3

Coarse aggregate = 1146.2 m^3

3. Estimation of cost for conventional mix:

Table 3: Estimation of cost for conventional mix

Materials	Calculated quantity(kg)	rate per kg in Rs.	Cost in Rs.
Cement	437	6	2622
Coarse aggregate	1146	.85	974
Fine aggregate	673	1.2	807.6
Water	197	0.2	39.4
		Total cost	**4443**

The estimated cost for 1 cum concrete for conventional mix is sum off rupees is **4443/-.**

The values for material are taken based on present market rates.

4. Estimation of cost for supplementary materials in concrete mix:

The supplementary cementious materials fly ash and glass fibre are partially replaced in cement. For composition **C70F30GF1.5** which showed better compressive strength at28 days. For this mix cost estimation is done by taking the present market rate. The cost estimation table as below:

Table 4 Estimation of cost for supplementary materials to concrete mix in partial replacement of cement for C70G1.5F30

Materials	Calculated quantity (kg)	rate per kg in Rs.	Cost in Rs.
Cement	303	6	1818
Glass fibre	6.5	60	390
Fly ash	131	1.2	157
Coarse aggregate	1146	0.85	974
Fine aggregate	673	1.2	807
Water	197	0.2	39
		TOTAL	**4185**

The cost for supplementary cementious materials which replaced in cement with composition of C70GF1.5F30 is sum of rupees **4185/-.** On comparing conventional concrete mix with cement replaced mix shows better values with difference of price **258**/- per 1 cum of concrete.
So replacement of cement with supplementary materials can allow for proportion **C70GF1.5F30**

5. **Estimation of cost for supplementary materials in concrete mix:**

The supplementary cementious materials and glass fibre are partially replaced in cement . For composition **C100GF1.5** which showed better compressive strength at28 days. For this mix cost estimation is done by taking the present market rate. The cost estimation table as below

Table 5 Estimation of cost for supplementary materials to concrete mix in partial replacement of cement for C100GF1.5

Materials	**Calculated quantity(kg)**	**rate per kg in Rs.**	**Cost in Rs.**
Cement	303	6	1818
Glass fibre	6.5	60	390
Coarse aggregate	1146	0.85	974
Fine aggregate	673	1.2	807
Water	197	0.2	39
		TOTAL	**4028**

The cost for supplementary cementious materials which replaced in cement with composition of C100GF1.5 is sum of rupees **4028/-.**
On comparing conventional concrete mix with cement replaced mix shows better values with difference of price **415**/- per 1 cum of concrete.
So replacement of cement with supplementary materials can allow for proportion **C100GF1.5**

V. CONCLUSION

Based on experimental work reported in this study, the following results were developed.

- The Compressive strength of Conventional concrete are observed to attain maximum strength at 28 days when compared to Fly ash based concrete.
- Fly ash concrete gives very lower strengths at early ages when compared to conventional concrete.
- Maximum Compressive strengths, split tensile strength and flexural strengths attained with 1.5% glass Fibre at 28 days of both type of concrete respectively.
- Mechanical properties of Compressive strength split tensile strength and flexural strength results increased with increasing of age of concrete. These results were increased with increasing of glass fibre content up to 1.5% then decreasing gradually above 1.5% till 3.0%
- In Compressive strengths, Fly ash based concrete attains 80-85% of strength gain Compared to conventional concrete.
- In Split tensile strength, Fly ash based concrete attains 85-90% of strength gain Compared to conventional concrete.
- In Flexural strength, Fly ash based concrete attains 85-95% of strength gain Compared to conventional concrete.

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