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Performance Assessment of Glass Fiber Reinforced Concrete Beams

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Abstract:
It is well known fact that plain concrete is brittle in nature; it has low tensile strength and less ductility. Moreover, plain concrete suffers from cracking due to drying shrinkage and various other causes. It has been found that the use of Glass fibers in plain concrete controls shrinkage cracking to a some extent and also improves the tensile properties of concrete. "Glass fiber reinforced concrete (GFRC)", is lightweight but strong. This product is covered by international standards and has been practiced all over the world. Since the fibers cannot rust like steel, there is no need for a protective concrete cover thickness to prevent rusting. The AR Glass fiber when distributed randomly showed better performances in mechanical properties.

In the present investigation, mechanical properties the compressive strength, split tensile strength, and flexural strength concrete containing varying percentages of AR Glass fiber by volume of concrete was studied. It was observed that the use of fibers increases the flexural toughness and the flexural behaviour of the concrete and it varied with the type of fibers used. In this study, mainly AR Glass fiber were randomly dispersed in the matrix of the reinforced concrete beams. The depth of the fiber concrete was varied as up to effective cover of the concrete beam, and up to one-third depth from bottom of the beam with 1.5% GFRC by volume of concrete in the tensile zone. The effect of varying GFRC layer depth was observed. A comparative study on flexural behaviour, ultimate load carrying capacity load-deflection behavior, and cracks pattern and crack widths of Glass fiber reinforced composite beams and the nominal concrete beam under two point loading was carried out.

Keywords:- ***Fiber Reinforced Concrete, Glass Fiber, AR Glass fiber, Load-Deflection behaviour.***

1. INTRODUCTION
1.1 GENERAL

The maintenance, rehabilitation and upgrading of structural members, is one of the most crucial problems in civil engineering applications. Moreover, a large number of structures constructed in the past using the older design codes in different parts of the world are structurally unsafe according to the new design codes. Since replacement of such deficient elements of structures incurs a huge amount of public money and time. Strengthening has become the acceptable way of improving their load carrying capacity and extending their service lives. There has been an exponential rise in the use of concrete with the increase in infrastructural development. With this ever-increasing consumption of concrete, the fundamental natural ingredients which make the concrete, that is, fine and coarse aggregates are depleting at a very fast pace. This necessitates the use of alternate materials which can be added to cement, without lowering its performance. The better idea would be to add ingredients which can improve the performance of the same.

In this regard, several researchers have worked on using materials like rice husk, sugarcane bagasse and so on. In adding a new ingredient to the standard

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ingredients of concrete, one must bear in mind the short term and long term interaction of the ingredient with other elements, the effect on the compressive strength, flexural strength, workability, durability, permeability, tensile strength, bond and homogeneity. The requirements of performance also depend on many other factors like mixing, mixing time, transportation methods, placement, use of admixtures, curing methodologies, climatic factors.

1.2 STRENGTHENING FACTORS:

- The selection of the most suitable method for strengthening requires careful consideration of many factors including the following engineering issues:
- Magnitude of strength increase.
- Effect of changes in relative member stiffness.
- Size of project (methods including unique materials and strategies may be less financially savvy on little undertakings).
- Environmental conditions(methods utilizing glues may be inadmissible for applications in high temperature
- In place concrete strength and substrate integrity (the effectiveness of methods relying on bond to the existing concrete can be significantly limited by low concrete strength).
- Dimensional/clearance constraints (section enlargement might be limited by the degree to which the enlargement can encroach on surrounding clear space).
- Accessibility.
- Operational constraints.
- Availability of materials, equipment, and qualified contractors.
- Construction cost, maintenance cost and life-cycle costs and load testing to verify existing capacity or evaluate new techniques and materials.

1.3 INTRODUCTION OF FIBER REINFORCED CONCRETE (FRC):

Concrete is acknowledged to be a relatively brittle material when subjected to normal stresses and impact loads, where tensile strength is only approximately one tenth of its compressive strength. As a result for these characteristics, concrete member could not support such loads and stresses that usually take place, majority on concrete beams and slabs.

1.4 ADVANTAGES AND LIMITATIONS OF FIBER REINFORCED CONCRETE (FRC):

- Fibers, which are randomly distributed throughout the concrete, can overcome cracks and control shrinkage more effectively. These materials have outstanding combinations of strength and energy absorption capacity. In general, the fiber reinforcement is not a substitution for conventional steel reinforcement. The fibers and steel reinforcement has their own role in concrete technology. Therefore, many applications in which both fibres and continuous reinforcing steel bars can be use together.

However, fibres are not efficient in withstanding the tensile stresses compare to conventional steel reinforcement. But, fibres are more closely spaced than steel reinforcement, which are better in controlling crack and shrinkage. Consequently, conventional steel reinforcement used to increase the load bearing capacity of concrete member; fibres are more effective in crack control.

Due to these differences, there are particular applications that fibres reinforced are advance than conventional steel reinforcement. These include:

- Fibres comprise as ‘primary reinforcement’, in which the conventional steel reinforcement cannot be utilized. The fiber concentrations are comparatively high in thin sheet materials, normally exceeding 5% by volume, acts to

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increase in toughness and strength of mortar or concrete

- Fibres can be components to withstand locally high loads or deformations, which applies to structures like precast piles, precast walls, blast resistant structures or sewer tunnel and linings.

- Applications that control cracks persuaded by temperature and humidity, such as Pavements and slabs, where fibres offered as 'secondary reinforcement'. The uses of steel bars and wire mesh require unnecessary labor and material costs for structure concrete. With replacement of randomly distributed short fibres as an alternative reinforcement, will significant reduce both labor and material costs, greatly increase construction and project time.

1.5 DEFINITION OF GLASS FIBER REINFORCED CONCRETE:

Glass fiber reinforced Concrete is defined as a "Composite material consisting of mixture of cement mortar or concrete and discontinuous, discrete, uniformly dispersed suitable fibers". Continuous meshes, woven fabrics and long wires or rods do not fall into discrete fibers category. Fiber is a small piece of reinforcing material possessing certain characteristic properties like circular or flat. The fiber is often described by a convenient parameter called "Aspect Ratio" the aspect ratio of the fiber is the ratio of its length to its diameter.

GFRC has both good tensile and compressive strength as well as being lightweight with good fire properties and low maintenance.

2. OBJECTIVES OF THE STUDY:

- To study the flexural behaviour of reinforced concrete beams.
- To study the effect of GFRC strengthening on ultimate load carrying capacity and failure pattern of reinforced concrete beams.
- To study the cracks behaviour of reinforced concrete beams.
- To study the effect of GFRC strengthening on the cracks behaviour of reinforced concrete beams.

2.1 PRESENT INVESTIGATION:

- The purpose of this research is to investigate the flexural behaviour and cracks behaviour of the reinforced concrete beams strengthened with Alkali resistant glass fiber chopped strands.

- More particularly, the effect of AR Glass fiber by varying the AR Glass fiber reinforced concrete layer depth in tension zone of the concrete beam on the flexural strength, cracks behaviour and ductility of beams are investigated. Three sets of beams were fabricated and tested up to failure.

In set1 three control beams were fabricated.

- In set2 three beams having AR Glass fiber concrete layer depth up to effective cover in tension zone of the beams from bottom were fabricated.
- In set3 three beams having AR Glass fiber concrete layer depth up to one-third depth in tension zone of the beams from bottom were fabricated.

Determine and compare the mechanical properties, flexural behaviour and cracks behaviour of control beams and AR Glass fiber reinforced concrete beams by conducting tests under two point loading.

3. MATERIAL PROPERTIES

3.1 GENERAL

The properties of the materials used in the experimental work are presented in this chapter. The material specifications for cement, fine aggregate, coarse aggregate and AR Glass fiber are discussed.

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Sieve analysis was done for sand to test their suitability for use in concrete.

3.2 CEMENT

In the present study Ordinary Portland Cement (OPC) 43 grade was used. COROMANDEL brand OPC was used. The specific gravity of cement is given is 3.12

3.3 FINE AGGREGATE

Locally available river sand conforming to grading zone-II as per IS: 383 -1970 was used. The sand was screened at site to remove deleterious material. Sieve analysis was done and the analysis results are given table the specific gravity of sand is 2.65

3.4 COURSE AGGREGATE

In the present study a locally available coarse aggregate (20 mm) from quarry was used. The specific gravity of coarse aggregate is 2.79. Sieve analysis was done and the analysis results are given table the specific gravity of sand is 7.35.

3.5 WATER

Normal tap water available in the concrete laboratory of AITS, fit for drinking, was used to cast concrete samples.

3.6 STEEL

In the present study High-yield strength deformed bars confirming to Fe415 are used having diameters 10mm for main longitudinal bars and 8 mm for stirrups

3.7 AR GLASS FIBER

In the present study AR Glass fiber chopped strands was used. The length of the fiber is 12mm, diameter is 14 microns, aspect ratio is 857 and specific gravity is 2.68.

4. EXPERIMENTAL PROGRAMME

4.1 COMPRESSIVE STRENGTH TEST:

Compressive strength of a concrete is a measure of its ability to resist static load, which tends to crush it. Most common test on hardened concrete is compressive strength test. It is because the test is easy to perform. Furthermore, many desirable characteristic of concrete are qualitatively related to its strength and the importance of the compressive strength of concrete in structural design. The compressive strength gives a good and clear indication that how the strength is affected with the increase of fiber volume dosage rate in the test specimens.

4.2 INDIRECT TENSILE STRENGTH TEST:

Tensile strength of a concrete is a measure of its ability to resist forces, which stretch or bend it. Unlike steel, the concrete is sufficient in strength only in one direction. The tensile strength of concrete is approximately one-tenth of the compressive strength and it is not generally used in the design of concrete structure. Nevertheless, it is an important property in many applications. Addition of fiber is one of the primary reasons to increase the tensile strength.

4.3 FLEXURAL STRENGTH TEST:

Flexural strength of a concrete is a measure of its ability to resist bending. Flexural strength can be expressed in terms of ‘modulus of rupture’. Concrete specimens for flexural strength were cross sectional area of 100mm width with 100mm depth and length of 500mm concrete beam. The specimen is subjected to bending, using four point loading until it fails.

FIG 4.1. GFRC Mixing

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FIG 4.2. Beams formwork

5. RESULTS AND DISCUSSIONS

5.1 GENERAL

Experimental studies have been undertaken to evaluate the mechanical properties of the concrete and mainly describes the experimental results of 3 sets of beams (weak in flexure). Their behaviour through the static test to failure is described using recorded data on deflection behaviour and the ultimate load carrying capacity. The crack pattern and the mode of failure of each beam are also described in this chapter.

5.2 COMPRESSIVE STRENGTH

The 150 x 150 x 150 mm cubes were tested for compression test under uniaxial compression after 28 days period of normal water curing.

Table 5.1 Compressive strength of Control concrete (CC) & GFRC

Percentage of AR Glass fiber by volume of concrete.	Compressive Strength (N/mm2) (7 days)	Compressive Strength (N/mm2) (28 days)	Percentage of increase in 28 days compressive strength
Control concrete	18.20	26.85	0.00
0.5	19.10	28.30	5.40
1.0	19.85	28.32	5.47
1.5	20.12	29.24	8.90

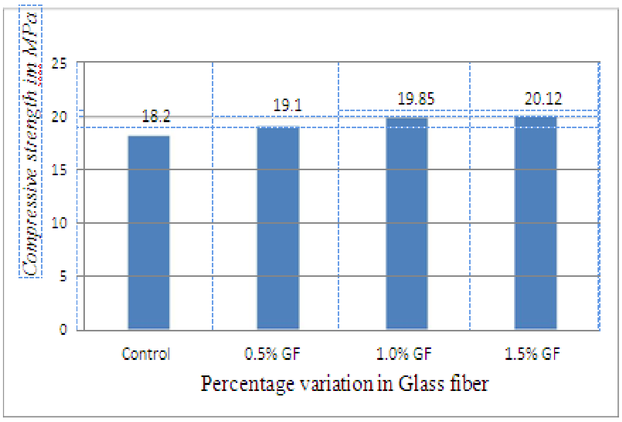

Fig.5.1 Comparison of 7 Days compressive strength between CC vs. GFRC

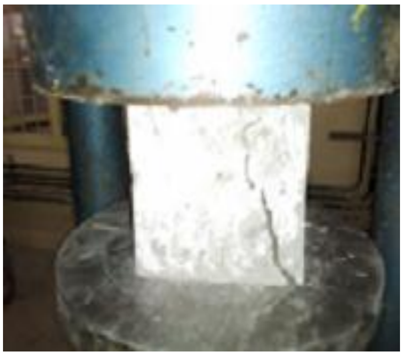

Fig 5.2 Concrete cube specimens testing for compressive strength

The above results showing that with the increase in percentage of glass fiber by volume of concrete will also increasing the compressive strength of concrete. The increase in percentage of compressive strength for 0.5% GF is 5.40%, for 1.0% GF is 5.47%, and for 1.5% GF is 8.90%. The results presented in table-6.1 indicate no significant changes in the compressive strength of concrete in both 7 and 28 days. As is well known, fibers cannot take compressive loads, this was expected.

5.3 SPLIT TENSILE STRENGTH:

Test Results of 150mm diameter and 300mm height cylinders were tested for splitting tensile strength for M20 grade of concrete with percentage variation in glass fibers as shown in Table 6.2 below.

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Table 5.2 Split tensile strength of Control concrete (CC) & GFRC

Percentage of AR Glass fiber by Volume of concrete.	Split tensile Strength (N/mm2) (7 days)	Split tensile Strength (N/mm2) (28 days)	Percentage of increase in 28 days Split tensile strength
Control concrete	2.02	3.16	0.00
0.5	2.52	3.95	25.00
1.0	2.80	4.83	52.84
1.5	3.14	5.46	72.78

Fig 5.3 Concrete cylinder specimens testing for Split tensile strength

5.4. FLEXURAL STRENGTH:

Test results of concrete specimens for cross sectional area of 100mm width with 100mm depth and length of 500mm concrete beams were tested for flexural strength for M20 grade of concrete with percentage variation in glass fibers as shown in Table 6.3 below.

Table 5.3 Flexural strength of Control concrete (CC) & GFRC

Percentage of AR Glass fiber by volume of concrete.	Flexural Strength (N/mm2) (28 days)	Percentage of increase in Flexural strength
Control concrete	3.82	0.00
0.5	4.45	16.49
1.0	5.64	47.64
1.5	7.15	87.17

5.5 Cracking and mode of failure:

All of the beams tested failed in flexure with crushing of concrete in the compression zone at the failure stage after the development of flexural cracks. The failure mode and crack pattern of the beams tested are presented

5.4. Details of cracks for all beams

Sr. No.	Type of Beam	Beam designation	Total Number of Cracks	Crack width for larger crack in (mm)
1	SET I	CB1	15	4
		CB2	16	5.3
		CB3	13	3.8
2	SET II	GF1-I	11	2.5
		GF1-II	12	2.8
		GF1-III	10	3.6
3	SET III	GF2-I	10	2.6
		GF2-II	8	1.9
		GF2-III	9	2.3

6. CONCLUSION

GENERAL

In this experimental investigation Strength properties of concrete, ultimate load carrying capacity, load-deflection behavior, cracks pattern and number of cracks of the reinforced concrete beams strengthened with GFRC are studied. Three SET's of beams were casted and tested. From the test results and calculated strength values, the following conclusions were made.

CONCLUSION

A) Effect of AR Glass fiber on bleeding of AR Glass fiber concrete On the basis of the experimental study it was concluded that addition of glass fiber in concrete gives a reduction in bleeding. A reduction in bleeding improves the surface integrity of concrete, improves its homogeneity and reduces the probability of cracks occurring where there is some restraint to settlement.

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B) Comparison of strength properties of ordinary concrete and AR Glass fiber concrete mixes It was observed that by increasing the percentage of AR Glass fiber by volume of concrete is not showing much variation in the compressive strength of concrete, the increase in percentage of compressive strength for 0.5% GF is 5.40%, for 1.0% GF is 5.47%, and for 1.5% GF is 8.90%. It was showing very good variation on split tensile strength, the increase in percentage of split tensile strength for 0.5% GF is 25.00%, for 1.0% GF is 52.84%, and for 1.5% GF is 72.78% as well as flexural strength, the increase in percentage of flexural strength for 0.5% GF is 16.49%, for 1.0% GF is 47.64%, and for 1.5% GF is 87.17% of concrete.

C)Ultimate load carrying capacity of control beams (SET I) and GFRC beams (SET II & SET III) From the results it was observed that the ultimate load carrying capacity of the GFRC beams are more than that of the control beams. Ultimate load carrying capacity of SET II Beams than of SET I Beams are increasing 72kN to 84kN, 68kN to 94kN, 75kN to 86kN. Ultimate load carrying capacity of SET III Beams than of SET I Beams are increasing 72kN to 90kN, 68kN to 102kN, 75kN to 98kN. And also it was observed that ultimate load carrying capacity is increasing with the increase of GFRC layer depth from bottom of the beam. Ultimate load carrying capacity of SET III beams are more than that of SET I & SET II beams.

D)Load-Deflection behaviour and number of cracks behavior of control beams (SET I) and GFRC beams (SET II & SET III) From the results it was observed that the deflections of the GFRC beams are more than that of the control beams and number of cracks are less than the control beams. And also it was observed that deflections are increasing with the increase of GFRC layer depth from bottom of the beam and cracks are reducing. Therefore, 20-30% of the cracks for SET II Beams and 30-50% of the cracks for SET III Beams are reducing when compared with the SET I Beams.

So, finally from the above results with the increase of GFRC layer depth in RC beams will showing very good results compared with the control beams.

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