STRENGTHENING OF REINFORCED CONCRETE BEAMS USING GLASS FIBER REINFORCED POLYMER COMPOSITES

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ABSTRACT:

Concrete is a composite material which is powerless in pressure and is regularly influenced by breaking and scaling which are associated with plastic and solidified states and drying shrinkage. Worldwide a lot of research is right now being led concerning the utilization of fiber overlays and sheets in the repair and fortifying of fortified solid individuals. Fiber-fortified polymer (FRP) application is exceptionally successful approach to repair and fortify structures that have turned out to be basically powerless over their life expectancy. FRP repair systems give a financially suitable other option to customary repair structure and materials .In this paper Experimental investigations done on the behavior of the concrete strengthened using discontinuous blended chopped glass fibers (6mm and 12mm) are carried out with concrete mix different at various percentages (0.25%, 0.50%,0.75%) to the total weight of concrete. Experimental data on load for compression, tensile and flexural tests have been carried out, strength variations and failure modes of each specimen were obtained for age of 7,14 and 28 days.

Keywords: *Compressive Strength Split Tensile Strength, Flexural Strength, Glass Fiber Mix, Fiber Reinforced Polymer*

CHAPTER-I
INTRODUCTION

The glass fiber reinforced polymer composites are advantages in the strengthening done by reduction of magnitude of forces and maximizing the member's resistance the strengthening techniques are carried out by section enlargement, external bonded reinforcement, post-tensioning work, and supplemental supports. In this study external bonded reinforcement used to achieve improved strength and serviceability. The durability studies of the glass fiber reinforced polymers are carried out investigation on glass fiber reinforced concrete moderate deep beam. Finally they reported, addition of glass fiber in moderate deep beam, it improved strength, shear stress and ductility at without using stirrups in deep beam. In this paper, strengthening of reinforced concrete beam is carried outby using glass fiber reinforced polymer composites the reinforced concrete beam in flexure, strengthened with different configuration and different layers of GFRP sheets. Finally the effect on strength and ductility of beam is obtained

Concrete is a rigid material with high compressive strength and weak in tensile strength. Reinforcing bars are used to improve the tensile strength. In addition to that fibers can make the concrete more homogenous and can improve the tensile response, particularly the ductility. The various types of fibers added to concrete are steel, glass, carbon, hemp. Fiber reinforced polymer composite materials have been successfully used in the construction of new structures and in rehabilitation of existing structures. Repair with externally bonded FRP reinforcement is a highly practical strengthening system, because of ease and speed of installation, efficiency of structural repair. Bonding of FRP to concrete is faster and less labor intensive. The most commonly used FRP types are CFRP, GFRP, and AFRP. FRP can apply for strengthening a variety of structural members like beams, columns, slabs and masonry wall. It is used in bridges or expressway piers and chimneys also.

CHAPTER-II
METHODOLOGY

The studies on Effects of Glass Fiber Reinforced Polymer Composites are reported on literature and strengthening is accomplished by either reducing the magnitude of forces or by enhancing the member's resistance. The strengthening techniques are enlarging the section, bonded reinforcement at externally, post-tensioning work, and supplemental supports may be used to achieve improved strength and serviceability. In this study, a comparison has been made between plain concrete and high strength achieved by concrete using glass fiber of two lengths (6 &1 2mm) for M30 grade of concrete. The test (compression test, split tensile test and flexural strength test) is to be done on the concrete with the addition of glass fibers of various percentages (0.25%, 0.50%, and 0.75%) to total weight of the concrete. Mix design of M30 concrete is to be designed as per IS 10262:2009 and to find out the quantities of ingredients.

Materials:

Concrete is a construction material composed of Portland cement and water combined with sand, gravel, crushed stone, or other inert material such as expanded slag or vermiculite. The cement and water form a paste which hardens by chemical reaction into a strong, stone-like mass. The inert materials are called aggregates, and for economy no more cement paste is used than is necessary to coat all the aggregate surfaces and fill all the voids. Too much water, however, produces a concrete that is more porous and weaker. The quality of the paste formed by the cement and water largely determines the character of the concrete. Proportioning of the ingredients of concrete is referred to as designing the mixture, and for most structural work the concrete is designed to give compressive strengths of 15 to 35 MPa

Reinforcement Materials (Glass Fibers):

Normally, fiber is a material made into a long filament with a diameter generally in the order of 10 tm. The aspect ratio of length and diameter can be ranging from thousand to infinity. The functions of the fibers are to carry the load and provide strength, thermal stability, stiffness, and other structural properties in the FRP. Glass fibers are also available as thin sheets, called mats. A mat which is made by both long continuous and short fibers (e.g., discontinuous fibers with a length between 25 and 50 mm) arranged in random and bonded together. The width of such mats is variable between 5 cm and 2 m, their density being roughly 0.5 kg/m^2 These are fibers commonly used in the naval and industrial fields to produce composites of mediumhigh performance. Their peculiar characteristic is their high strength

Typical properties	density (g/cm^3)	young's modulus(Gpa)	Tensile strength(Gpa)	tensile Elongation
High strength	1.8	230	2.48	1.1
high modulus	1.9	370	1.79	0.5
ultra high modulus	20-2.1	520-620	1.03-1.31	0.2

Fiber Reinforced Polymer (FRP):

Fiber reinforced polymer (FRP) is a composite material made by combining two or more materials to give a new combination of properties. However, FRP is different from other composites in that its constituent materials are different at the molecular level and are mechanically separable. The mechanical and physical properties of FRP are controlled by its constituent properties and by structural configurations at micro level. Therefore, the design and analysis of any FRP structural member requires a good knowledge of the material properties, which are dependent on the manufacturing process and the properties of constituent materials.

Epoxy Resin:

Epoxy resins are relatively low molecular weight pre- polymers capable of being processed under a variety of conditions. The main advantages are that they can be partially cured and stored in that state and they exhibit low shrinkage during curing. Viscosity of conventional epoxy resins is higher and they are more expensive compared to polyester resins.

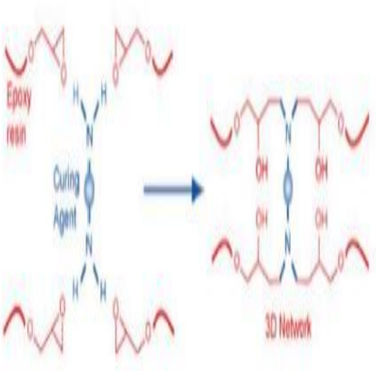


Figure: Curing of epoxy resin with primary amines

Beam Design and Testing Procedure:

A total of 29 RC beams were cast to investigate the shear strengthening using Sprayed GFRP under quasi-static loading. These beams contained flexural reinforcement, but none or less than the required stirrups. The total length of these beams was 1 m, and they were tested over an 800 mm span.

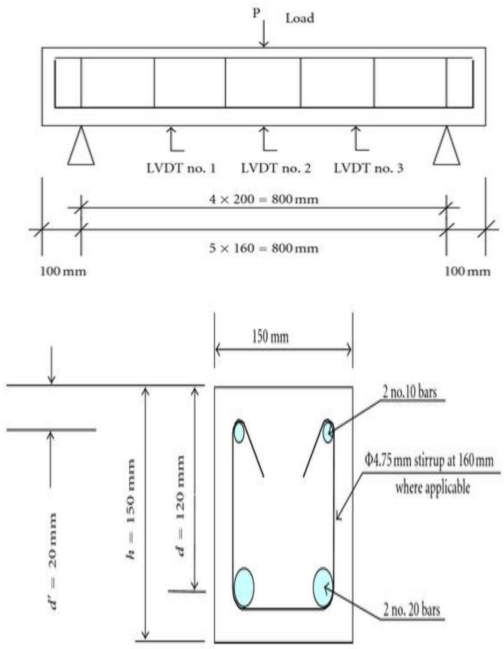


Figure 3.1 Load configuration and cross-sectional details of RC beams

Table 3.1 Properties of RC beams		
Width of compression face of member	150	mm
Overall depth of beam	150	mm
Distance from extreme compression fiber to centroid of tension reinforcement	120	mm
Distance from extreme compression fiber to centroid of compression reinforcement	20	mm
Specified compressive strength of concrete	44	MPa
Specified yield strength of tension reinforcement	440	MPa
Specified yield strength of compression reinforcement	474	MPa
Specified yield strength of shear reinforcement	600	MPa
Area of tension reinforcement	600	mm^2
Area of compression reinforcement	200	mm^2

The parameters needed for calculating the load-carrying capacity of the beam shown in Figure are tabulated in Since not enough shear reinforcement was provided, the maximum strength of the beam would be governed by the shear strength of concrete as well as the shear strength provided by the steel stirrups where applicable. Calculations show that if resistance factors are not considered, the capacity of this beam under quasi-static loading is 131 kN if enough reinforcement is provided for shear. At this point, tension reinforcement would start yielding. It is also worth noting that the beam was designed to produce a typical shear failure mode since not enough stirrups were provided and the shear strength of the concrete was far below the flexural strength of the beam. The RC beam with no stirrups and with stirrups (Φ4.75 at 160 mm) is predicted to have a capacity of about 80 kN and 100.2 kN, respectively.

Control Beams with No GFRP: Six beams were tested under quasi-static loading without the GFRP coating. Results are reported here and will be used later as bench marks for comparison. One beam (beam C-NS in was tested under quasi-static loading with no stirrups and no GFRP. The result of this test is shown in Figure A typical shear failure was observed in this beam with a crack of about 45°.

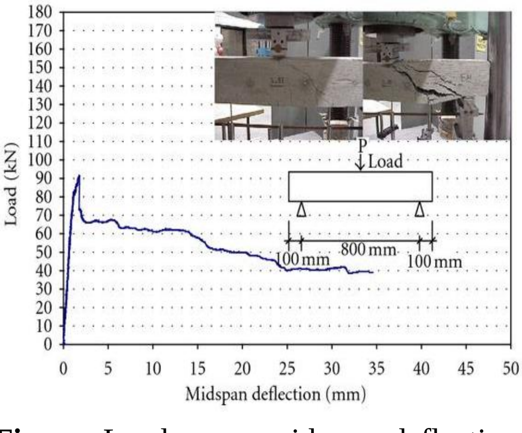


Figure: Load versus mid span deflection of control RC beam C-S-1.

Beams with No Mechanical Fasteners: Nine beams were tested with Sprayed GFRP applied to their lateral sides and no mechanical fasteners were used. The purpose of these tests was to find the best type of concrete surface to create a stronger GFRP-concrete bond. Three different techniques were employed as follows(1)The concrete surface was sandblasted and then washed by a high-pressure washer.

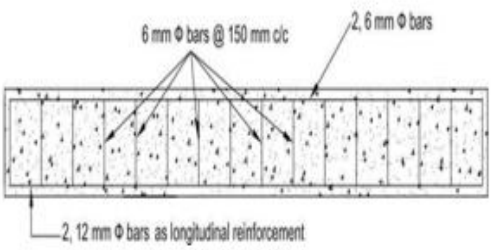
Figure: Surface preparation using pneumatic concrete chisel

The Experimental study: Consists of casting reinforced concrete (RC) beams In-SET I three beams were casted weak in flexure, out of which one is controlled beam and other two beams were strengthened using continuous glass fiber reinforced polymer (GFRP) sheets as weak in flexure. The strengthening of the beams is done with varying configuration and layers of GFRP sheets. Experimental data on ultimate load, deflection and failure modes of each of the beams were obtained. The dimensions of all the specimens are identical. The cross sectional dimensions of the beams are 250 mm by 200 mm and length is 2300 mm. In SET I beams 2, 12 mm φ bars are provided as the main longitudinal reinforcement and 6 mm φ bars as stirrups at a spacing of 75 mm center.

Test Procedure: The specimens were tested using loading frame(two point loading system).The specimen was placed over the two steel rollers bearing leaving 150 mm from the ends of the beam. The remaining 2000 mm was divided into three equal parts of 667 mm .Two point loading arrangement are done and .Loading was done by hydraulic jack of capacity 100 KN. Three number of dial gauges were used for recording the deflection of the beams. One dial gauge was placed just below the center of the beam and the remaining two dial gauges were placed just below the point loads to measure deflections.

Flexural strengthening of beam: The beams were tested for their ultimate strengths. In SET I three beams (F1, F2 and F3) weak in flexure are tested. The beam F1 is taken as controlled beam. It has less load carrying capacity when compared to that of the externally strengthened beams using GFRP sheets. In SET I beams F2 is strengthened only at the soffit of the beam and F3 is strengthened up to the neutral axis of the beam along with the soffit of the beam.

Testing of Specimens: The GFRP strengthened beam and the control beams were tested to find out their ultimate load carrying capacity. It was found that the control beams F1 is failed in flexure and showing that the beams were deficient in flexure In SET I beam F2 failed due to fracture of GFRP sheet in two pieces and then flexural-shear failure of the beam took place. Beam F3 failed due to delamination of the GFRP sheet after that fracture of GFRP sheet took place and then flexural-shear failure of the beam. In SET I beams F2 and F3, GFRP rupture and flexural-shear kind of failure was prominent when strengthening was done using both the wrapping schemes.



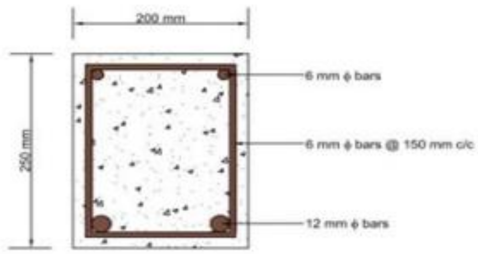


Figure: Reinforcement for set-1 beams

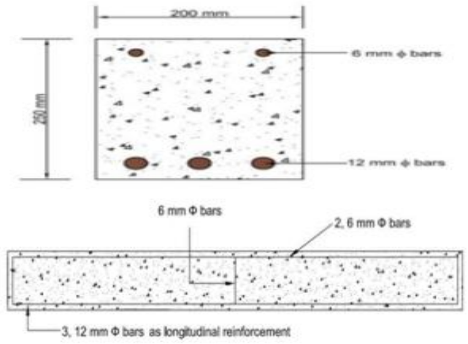


Figure: Reinforcement details for set 2 beams

Figure: Beam test setup under quasi-static loading

Strengthening of Beams:

Before bonding the composite fabric onto the concrete surface, the required region of concrete surface was made rough using a coarse sand paper texture and cleaned with an air blower to remove all dirt and debris. Once the surface was prepared to the required standard, the epoxy resin was mixed in accordance with manufacturer's instructions. Mixing was carried out in a plastic container (Araldite LY 556 – 100 parts by weight and Hardener HY 951 – 8 parts by weight) and was continued until the mixture was in uniform color. When this was completed and the fabrics had been cut to size, the epoxy resin was applied to the concrete surface. The composite fabric was then placed on top of epoxy resin coating and the resin was squeezed through the roving of the fabric with the roller. Air bubbles entrapped at the epoxy/concrete or epoxy/fabric interface were to be eliminated. Then the second layer of the epoxy resin was applied and GFRP sheet was then placed on top of epoxy resin coating and the resin was squeezed through the roving of the fabric with the roller and the above process was repeated. During hardening of the epoxy, a constant uniform pressure was applied on the composite fabric surface in order to extrude the excess epoxy resin and to ensure good contact between the epoxy, the concrete and the fabric.

Figure: Application of epoxy and hardener on beam

Figure: Roller used for removal of air bubbles

The testing procedure for the entire specimen was same. After the curing period of 28 days was over, the beam as washed and its surface was cleaned for clear visibility of cracks. The most commonly used load arrangement for testing of beams will consist of two-point loading. This has the advantage of a substantial region of nearly uniform moment coupled with very small shears, enabling the bending capacity of the central portion to be assessed. If the shear capacity of the member is to be assessed, the load will normally be concentrated at a suitable shorter distance from a support.

CHAPTER-IV
RESULTS

Plastics, rubber fibers, paints and lacquers are all degraded in sunlight by basically the same free radical mechanism. Similarly, prolonged exposure of GRP under natural weathering which includes moisture, temperature ultraviolet radiation etc. will result in degradation of the material. The mechanical properties of a composite depend on the properties of their components namely the fibers and matrix plus the quality of fiber matrix interface. It was difficult to have uniform composition of glass fiber and resin through-out the material, especially, by hand lay-up process. Therefore, the experimental results show scattering due to the non-uniform composition of GRP produced by hand layup process

The standard GRP specimens were tested after they were exposed to outdoor weathering. The effect on the GRP's tensile strength (Mpa =145 psi), after exposing in the natural environment Minimum of three specimens was tested at each interval and the average results were plotted as It is interesting to note that as the exposure time increases an overall slow decrease in tensile strength of GRP was observed the beams

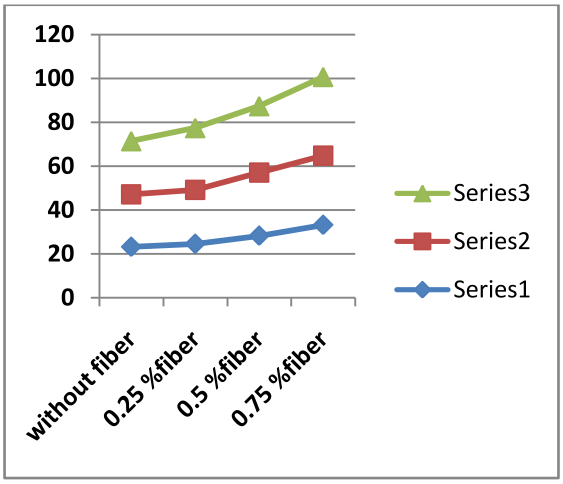
Compressive Strength:

Compressive strength is the capacity of a material or the ability of a structure to withstand load tending to reduce size .For compression test cube specimen of concrete and 150 mm x 150 mm were used respectively. Totally 21 cubes were cast for determination of compressive strength. After 24 hours the mould were demoded and subjected to water curing. Before testing the cubes were dried for 2 hours. All the cubes were tested in saturated conditions after wiping out surface moisture. The load was applied without shock and increased continuously until the resistance of the specimen to the increasing load breaks down and no greater load can be sustained. The maximum load applied to the specimen was then recorded; three cubes each were tested at the age 7 days, 14 days and 28 days of curing for concrete compression testing.

7 Days Test Results (In N/mm^2)

Table 4.1 Compressive strength of concrete (N/mm^2)

without fiber	0.25 %fiber	0.5 %fiber	0.75 %fiber
23.2	24.57	28.27	33.21
24	24.674	28.893	31.625
24.24	28.18	30.25	35.89



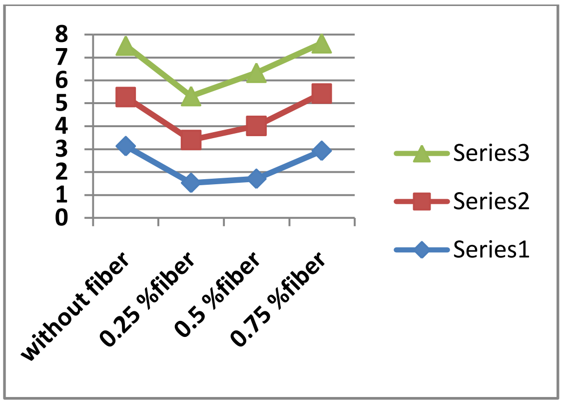
Graph4.1: Compressive strength of concrete

Split tensile strength of concrete:

Concrete may be subjected to tension in very rare cases and is never designed to resist direct tension. However, the load at which cracking would occur is important and needs to be determined. Split Tensile strength of concrete is usually found by testing concrete cubes mould of size 150 mm x 300mm. The tensile strength of concrete as compared to its compressive strength is very low and is found to be only 10-15 % of the compressive strength. There are various factors which influence the tensile strength of concrete like aggregates, age, curing, airentrainment and method of test.

Table: 4.2 Split tensile strength of concrete (N/mm^2)

without fiber	0.25 %fiber	0.5 %fiber	0.75 %fiber
3.124	1.5214	1.70	2.92
2.15	1.87	2.31	2.502
2.24	1.92	2.3204	2.193



Graph 4.2 Split tensile strength of concrete

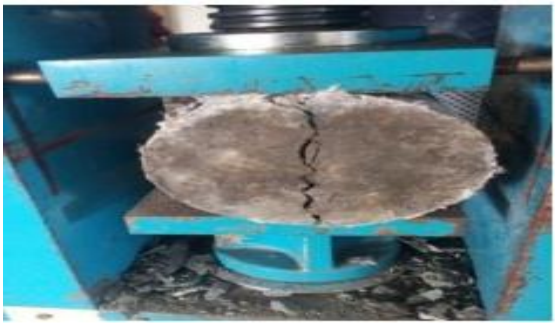


Figure: Split tensile test

Specimen preparation:

Formwork making use of plywood was prepared for the beam as per the required size. A total of 6 beams were cast wherein 2 were controlled specimens and 2 were subjected to U-wrapping and other 2 specimens were subjected to complete wrapping. Each of the specimens were singly reinforced and under reinforced section. Without delay after the beam cast, the beams were covered with plastic sheet to minimize the evaporation of water from the surface of the beam specimen. After 24 hours, the sides of the formwork were removed and the beams were lowered into a curing tank for 28 days, after which the beams were left alone until the time of test. Before testing, beams were whitewashed and then the surface was rubbed with sand paper. Linear variable displacement transducer (LVDT) was connected midspan of the beam to measure deflection. Crack widths were measured using a hand- held microscope with an optical magnification of 40X and a sensitivity of 0.01mm

Flexural strength test:

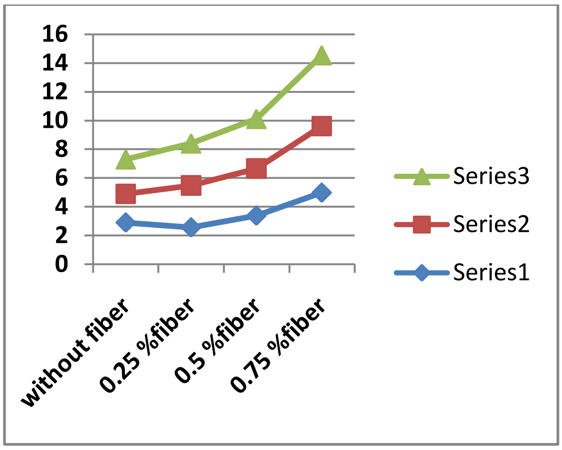
Flexural strength is also a measure of the tensile strength of concrete. In practical concrete may not be subjected to direct tension but it is subjected to flexure in many cases particularly in beams which is a flexural member. Flexural strength is also referred to as modulus of rupture.

Figure: Flexural strength test

Flexural strength of concrete is usually found by testing plain concrete prisms of size 500 mm x 100x 100mm were casting using M30 grade concrete. Specimens with Conventional Concrete and glass fiber concrete of different percentage were casted. After 24 hours, the specimens were removed from the mould and subjected to water curing for various days. After curing, the specimens were tested for flexural strength

Table 4.3 Flexural strength of concrete (N/mm^2)

without fiber	0.25 %fiber	0.5 %fiber	0.75 %fiber
2.9	2.56	3.38	4.98
2.0	2.92	3.28	4.62
2.4	2.93	3.455	4.944

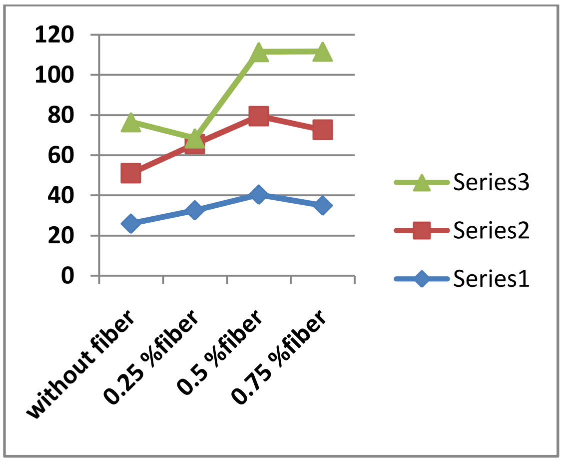


Graph 4.3 Flexural strength of concrete

14 Days Test Results (In N/mm^2)

Table: 4.4 Compressive strength of Concrete 14 days (N/mm^2)

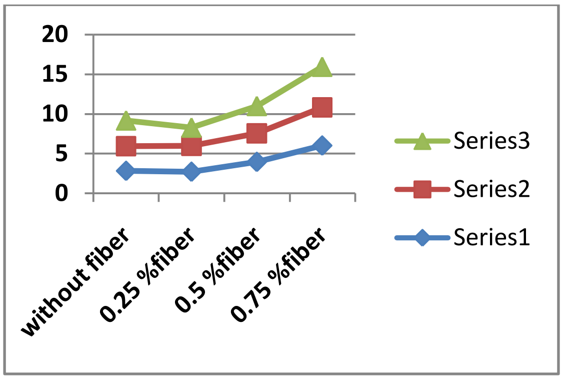
without fiber	0.25 %fiber	0.5 %fiber	0.75 %fiber
25.9	32.56	40.38	34.98
25.12	32.92	39.0	37.62
25.44	2.93	32.0	39



Graph 4.4 Compressive strength of Concrete 14 days

14 Days Split Tensile Strength of Concrete

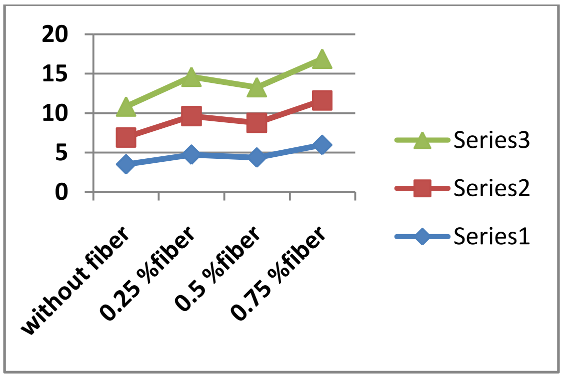
without fiber	0.25 %fiber	0.5 %fiber	0.75 %fiber
2.83	2.72	3.96	6.0236
3.10	3.25	3.6	4.802
3.26	2.321	3.45	5.129



Graph: 4.5 split tensile strength of concrete

Table: 4.6: 14 Days Flexural Strength of Concrete (N/mm^2):

without fiber	0.25 %fiber	0.5 %fiber	0.75 %fiber
3.5	4.72	4.36	5.95
3.42	4.9	4.41	5.66
3.9	4.97	4.5	5.27



Graph: 4.7 14 Days Flexural Strength of Concrete

28 Days Test Results (N/mm^2)

Table 4.8 Compressive Strength of Concrete

without fiber	0.25 %fiber	0.5 %fiber	0.75 %fiber
3.5	32	38	48.39
3.42	31.8	37.96	46
3.9	32	41.25	43

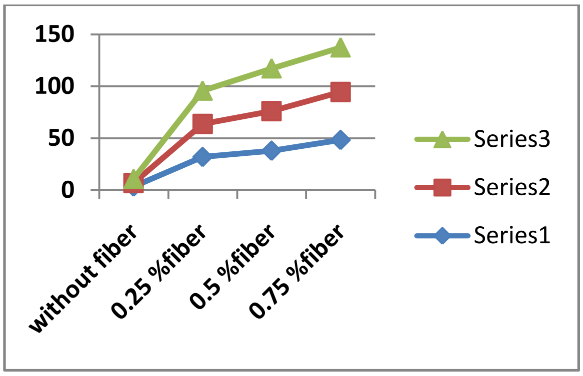
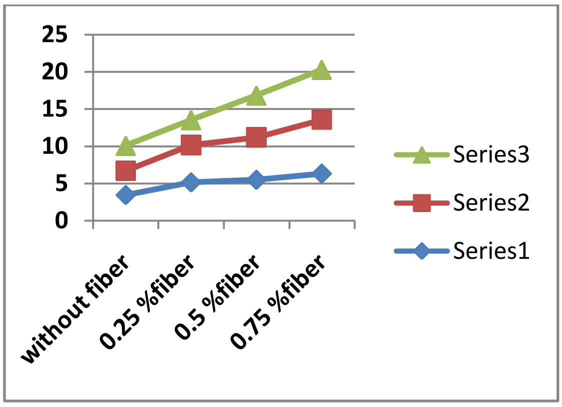


Figure: 4.8 compressive strength of concrete

Table.4.9. Split Tensile Strength of Concrete

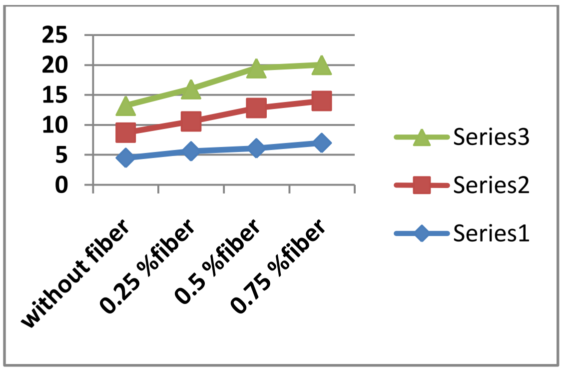
without fiber	0.25 %fiber	0.5 %fiber	0.75 %fiber
3.42	5.13	5.48	6.32
3.29	5.03	5.71	7.24
3.37	3.37	5.63	6.72



Graph 4.9 Split Tensile Strength of Concrete

Table.4.10. Flexural Strength of Concrete

without fiber	0.25 %fiber	0.5 %fiber	0.75 %fiber
4.52	5.61	6.11	7.01
4.2	4.961	6.72	6.99
4.5	5.41	6.645	6.024



Graph: 4.10. Flexural strength of concrete

Behavior study includes the 7, 14 and 28 day strength of concrete with maximum nominal size of aggregates 20mm.This days compressive, tensile and flexural strength was also plotted by taking the average of this three values overall an increase in the various strength was observed with addition of fibers We can observe a quite gradual increase in strength as the percentages of fibers has been increased. The maximum optimum strength is at 0.5%. We can observe an initial decrease at 0.25% and gradual increase in strength as the percentages of fibers has been increased. The maximum optimum strength is at 0.75%. Whereas by using single fiber it gives max strength at 1%. Here we can observe a quite gradual increase in strength as the percentages of fibers has been increased. The maximum optimum strength is at 0.75%. Whereas by using single fiber addition it gives max strength at 1%.

CONCLUSION

The following conclusions are made from the experimental study of addition of glass fibers of two lengths with same diameter and properties into the concrete mix. In this study of addition of combinational glass fibers greater strength and stiffness than the conventional concrete and also possesses good binding and strength to weight ratio. The compressive strength of concrete are increased with the addition of glass fibers to 0.50% by weight of concrete and further any addition of the glass fiber shows in decreases compressive strength (it is been evaluated by studying research paper and journals on this addition).

- Split tensile strength tends to improve for Material Concrete compared to plain concrete.
- Flexural strength shows tremendous increases from 0.5 to 0.75 % in Material Concrete compared to plain concrete. Whereas by using single fiber addition it gives max strength at 1%.
- Optimum combination of is 0 .75% is obtained as higher properties.
- The overall performance of glass fiber concrete increased strength compared to plain concrete.

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