

# Study on Rectangular Reinforced Concrete Beams with Glass Fibers

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**ABSTRACT:** The effect of glass fibre on flexural strength, split-tensile strength and compressive strength was studied for different fibre content on M-20 grade concrete designed as per IS 10262. The maximum size of aggregates used was 20mm. To study the effect on compressive strength, flexural strength, split-tensile strength 6 cubes, 6 prisms and 6 cylinders were casted and tested. Glass fibre (or glass fibre) is a material consisting of numerous extremely fine fibers of glass. Glassmakers throughout history have experimented with glass fibers, but mass manufacture of glass fiber was only made possible with the invention of finer machine tooling. In 1893, Edward Drummond Libbey exhibited a dress at the World's Columbian Exposition incorporating glass fibers with the diameter and texture of silk fibers. Glass fibers can also occur naturally, as Pele's hair. Glass wool, which is one product called "fiberglass" today, was invented in 1932–1933 by Russell Games Slayter of Owens-Corning, as a material to be used as thermal building insulation. It is marketed under the trade name Fiberglas, which has become a generalized trademark. Glass fiber when used as a thermal insulating material is specially manufactured with a bonding agent to trap many small air cells, resulting in the characteristically air-filled low-density "glass wool" family of products. Glass fiber has roughly comparable mechanical properties to other fibers such as polymers and carbon fiber. Although not as strong or as rigid as carbon fiber, it is much cheaper and significantly less brittle when used in composites. Glass fibers are therefore used as a reinforcing agent for many polymer products; to form a very strong and relatively lightweight fiber-reinforced polymer (FRP) composite material called glass-reinforced plastic (GRP), also popularly known as "fiberglass". This material contains little or no air or gas, is denser, and is a much poorer thermal insulator than is glass wool.

**KEYWORDS:** Compressive Strength, Glass Fibres, Flexural Strength, Split Tensile Strength, Polymer etc.

## I. INTRODUCTION

One of the most important building materials is concrete and its use has been ever increasing in the entire world. The reasons being that it is generally modest and its constituents are effortlessly accessible, and has convenience in extensive variety of common framework works. Anyway concrete has certain inconveniences like fragility and poor protection from split opening and spread. Concrete is weak by nature and have low rigidity and subsequently strands are utilized as a part of some shape to expand its elasticity and reduction the fragile conduct. With time a considerable measure of investigations has been done to upgrade the properties of cement both in new state and in addition solidified state. The essential materials continue as before yet super plasticizers, admixtures, miniaturized scale fillers are likewise being utilized to get the coveted properties like workability, Increment or abatement in setting time and higher compressive quality. Strands which are connected for basic cements are ordered by their material as Steel filaments, Soluble base safe Glass filaments (AR), Manufactured filaments, Carbon, pitch and polyacrylonitrile (Dish) strands. During its whole life span, nearly all engineering structures ranging from residential buildings, an industrial building to power stations and bridges faces degradation or deteriorations. The main causes for those deteriorations are environmental effects including corrosion of steel, gradual loss of strength with ageing, variation in temperature, freeze-thaw cycles, repeated high intensity loading, contact with chemicals and saline water and exposure to ultra-violet radiations. Addition to these environmental effects earthquakes is also a major cause of deterioration of any structure.

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This problem needs development of successful structural retrofit technologies. So it is very important to have a check upon the continuing performance of the civil engineering infrastructures. The structural retrofit problem has two options, repair/retrofit or demolition/reconstruction. Demolition or reconstruction means complete replacement of an existing structure may not be a cost-effective solution and it is likely to become an increasing financial burden if upgrading is a viable alternative. Therefore, repair and rehabilitation of bridges, buildings, and other civil engineering structures is very often chosen over reconstruction for the damage caused due to degradation, aging, lack of maintenance, and severe earthquakes and changes in the current design requirements.

Previously, the retrofitting of reinforced concrete structures, such as columns, beams and other structural elements, was done by removing and replacing the low quality or damaged concrete or/and steel reinforcements with new and stronger material. In any case, with the Introduction of new propelled composite materials, for example, fiber reinforced polymer (FRP) composites, solid individuals would now be able to be effectively and successfully reinforced utilizing remotely fortified FRP composites.

## II. LITERATURE REVIEW

Use of fibers in a brittle is not a new concept, the Egyptians used animal hairs, straw to reinforce mud bricks and walls in houses, around 1500 B.C. (Balaguru et al, 1992). Ronald F. Zollo presented a report on fiber reinforced concrete in which he had mentioned about 30 years of development and research in this filed. In the report it is claimed that the work on FRC started around 1960. Since then a lot of work has been done on FRC using different methods of production as well as different types of fiber, size of fiber, orientation and distribution. American Concrete Institute (ACI) Committee 544 divided FRC broadly into four categories based on fiber material type. SFRC, steel fiber FRC; GFRC, glass fiber FRC; SNFRC, synthetic fiber FRC including carbon fibers; and NFRC, for natural fiber FRC. The idea of fiber support has been produced in current times and weak cement based brittle matrix was strengthened with asbestos filaments when in around 1900 the alleged Hatschek innovation was created for creation of plates for material, funnels, and so forth. Later, glass fibers were proposed for fortification of concrete glue and mortar by Biryukovichs. The Ordinary E-glass fibers are not durable and resistant in highly alkaline Portland cement paste.-Majumdar and Ryder invented Alkali Resistant glass fibers by adding Zircon oxide ( $ZrO_2$ ). Romualdi and his co-authors published important influences of the use of steel fiber in concrete which lead the development of steel fiber reinforced cements (SFRC). Over the last 40 years a lot has been done to develop the cement based matrices. The fundamental reason for short scattered filaments is to control the break.

Carbon fiber reinforced mortar (CFRM) and carbon fiber reinforced cement (CFRC) are composites that have high flexural quality and durability and low drying shrinkage, notwithstanding this they have great electrical properties, for example, voltage-touchy impact. Ease pitch carbon filaments is satisfactory for scaffolds, other structural designing structures furthermore for cladding for structures, Kucharska and Brandt. In the districts with Corrosive impact of marine climate and solid winds (e.g. in Japan) CFRC is utilized as a part of scaffold auxiliary components for preferred toughness over it would be conceivable utilizing steel filaments. Fiber-reinforced polymer (FRP) bars can be used to replace steel reinforcement conventional steel has the inherent problem of corrosion as a result of which it undergoes expansion and concrete cracking may occur; therefore FRP rebar may be used as an alternate. The use of these fibers excludes the problem of corrosion and increases the ductility of the FRP-reinforced concrete beams but the load deflection was found to be higher. (Mohamed S. Issa, Ibrahim M. Metwally, Sherif M. Elzeiny 2010).

SIFCON (slurry penetrated fiber cement) is an in number composite in which a high volume of steel filaments is utilized by unique innovation. Strands are preplaced in a mold and the fiber framework got is invaded by cement slurry. Fiber volume may achieve 8–12%, occasionally Significantly higher, and filaments 100–200 mm long may be utilized. The concrete slurry is loaded with fine sand, small scale total and exceptional added substances like fly-ash and silica fumes. The high smoothness (low consistency) of the slurry is vital for satisfactory infiltration of the thick fiber frameworks in a mold. High-quality and resistance against nearby effects and infiltration of shots describe the components made with SIFCON. At the point when rather than single filaments the woven or plaited mats are utilized, then the name SIMCON (slurry penetrated mat cement) is utilized. The fundamental uses of both materials are overwhelming obligation asphalts, nonconcrete to terrorist shields, dividers in bank treasuries, and so forth.

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Externally bonded, FRP sheets are currently being studied and applied around the world for the repair and strengthening of structural concrete members. Strengthening with Fiber Reinforced Polymers (FRP) composite materials in the form of external reinforcement is of great interest to the civil engineering community. FRP composite materials are of great interest to the civil engineering community because of their superior properties such as high stiffness and strength as well as ease of installation when compared to other repair materials. Also, the non-corrosive and nonmagnetic nature of the materials along with its resistance to chemicals made FRP an excellent option for external reinforcement. opening and proliferation. Basic groups of fibers applied for structural concretes and classified according to their material are Brandt:Steel fibers of different shapes and dimensions, also microfibers;Glass fibers, in cement matrices used only as alkali-resistant (AR) fibers;Synthetic fibers made with different materials: polypropylene, polyethylene and polyolefin, polyvinyl alcohol (PVA), etc.Carbon, pitch and polyacrylonitrile (PAN) fibers.

Steel fibers are most important for structural concrete. Studies also reveal that hooks at the end of the steel fibers, shape, size etc. may improve the fiber matrix bond and also the efficiency may be increased. It has also been observed that due to the presence of fibers large cracks are replaced with dense system of micro-cracks. Opening, propagation of micro cracks are controlled by fine fibers as they are densely dispersed in cement matrix. Longer fibers 50 or 80 mm can increase the final strength of FRC and may help in controlling large cracks. The under load behavior of a SFRC is completely modified with the increase of fiber volume and efficiency.

Not only steel fibers PVA fibers either monofilament or fibrillated polypropylene size varying 10 mm to 80 mm diameter varying 0.5 mm to 1.5 mm are used in high volumes (0.5-2%),it can increase the impact and fatigue strength as well as the strength and toughness of the structural concrete elements. Polypropylene fibers are low modulus and can serve two different purposes depending on the amount used in concrete. On the off case that utilized as a part of little sum (up to 1.0 kg/m<sup>3</sup>) it can control the shrinkage splitting of solid in couple of first hours of setting. During that period, the Young's modulus of cement is like that of the strands, Ramakrishna etc al. The polypropylene fibers can also serve in case of high temperature and fire and as such are used in concrete walls of apartment building, what happens is that these fibers melt and channels are created which helps in releasing the internal pressure there by delaying the destruction of concrete.

### III. METHODOLOGY

Nine numbers of beams were made to carry out experimental study. As described earlier out of nine beams, one beam was designated as controlled beam and other all beams had strengthened with the use of GFRP. There were four series, in series -1, two nos of beams are completely wrapped, one with unidirectional and another one with Bidirectional GFRP sheets. Series -2 consists of two beams were wrapped with sheet having thickness of 10cm GFRP sheets, again same unidirectional and bidirectional way. In series-3 two beams were wrapped with smaller thickness GFRP sheets, having thickness of 5cm. and in series -4 beams were wrapped at an angle of 45 degrees having thickness of 5cm GFRP sheets.

**Table 1: The characteristics of the specimen**

Specimen	Configurations	No of Layers	Concrete cube compressive strength ( N/mm <sup>2</sup> )	Flexural Strength Of Concrete Prism (N/mm <sup>2</sup> )	Split Tensile Strength of Concrete Cylinder (N/mm <sup>2</sup> )
Beam No 1	Control beam	None	27.11	6	2.96
Beam No 2	Uni-GFRP Continuous fully Wrap	2	31	5.83	2.68

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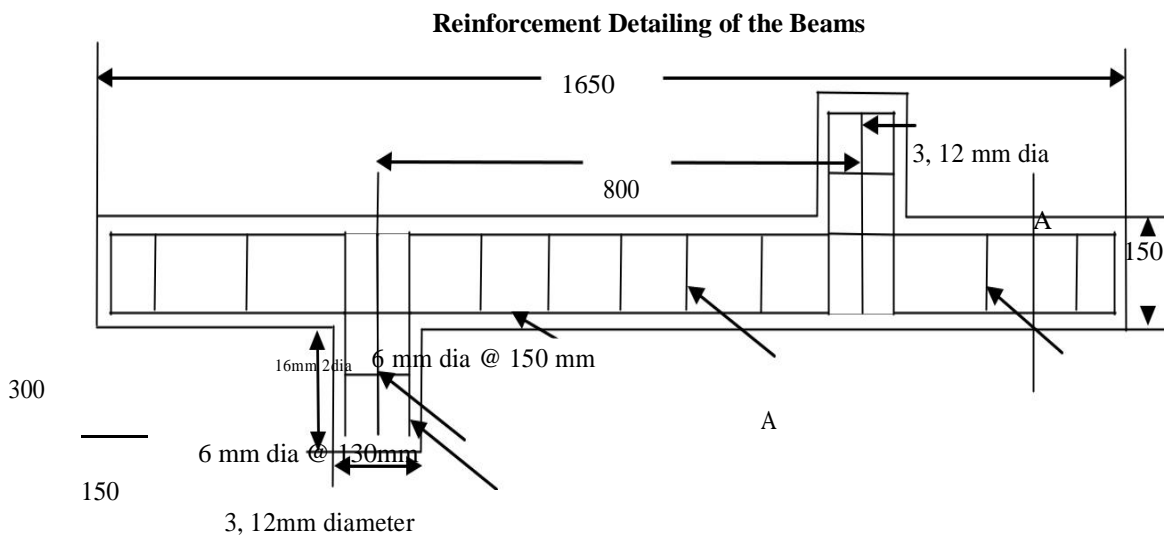
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Beam No 3	Bi-GFRP Continuous fully wrap	2	29.34	6.3	3.15
Beam No 4	10cm Uni-GFRP strips wrap	2	30.25	5.65	3.34
Beam No 5	10cm Bi-GFRP strips wrap	2	28.53	6	2.76
Beam No 6	5cm Uni-GFRP strips wrap	2	25.78	5.7	2.87
Beam No 7	5cm Bi-GFRP strips wrap	2	27.36	5.87	2.4
Beam No 8	5cm Uni-GFRP strips wrap(450)	2	30	6.1	2.76
Beam No 9	5cm Bi-GFRP strips wrap(450)	2	31.5	6.54	3.32

### REINFORCEMENT

HYSD (High yielding strength deformed bars) of 16mm dia, 10mm dia are used to strengthen longitudinal reinforcement and 6mm dia HYSD bars are used as stirrups. For finding a tensile strength three specimen of each bar are used. After doing all the calculations found tensile strength of each bars are( $f_y$ ) of bars of 16mm  $\phi$  bars is 494 N/mm<sup>2</sup>, 12mm  $\phi$  bars is 578N/mm<sup>2</sup>, 10mm  $\phi$  bars is 429 N/mm<sup>2</sup>, 8mm  $\phi$  bars is 523 N/mm<sup>2</sup> and of 6mm  $\phi$  bars is 250N/mm<sup>2</sup>.



Top view of Torsional Beam

For conducting experiment, nine reinforced concrete Torsion beam specimen of size as Shown in the fig (Length of main beam ( $L$ ) = 1.65m, Effective length ( $l_{eff}$ ) = 1.6m. Breadth of main beam ( $B$ ) = 0.15m, Depth of main beam ( $D$ ) = 0.25m, Length of cantilever part ( $l$ ) = 0.3m, Width of cantilever part = 0.15m, Depth of cantilever part = 0.25m, Distance of cantilever part from end of the beam = 0.35m) and all having the same reinforcement detailing are cast. The mix proportion is 0.5: 1:1.8:3.6 for water, cement, fine aggregate and coarse aggregate is taken. The mixing is done by

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using concrete mixture. The beams were cured for 28 days. For each beam three cubes, two cylinders and two prisms were casted to determine the compressive strength of concrete for 28 days.

### Form Work



Img: Steel frame used for casting beam



img: Reinforcement cage

### Mixing Of Concrete

Mixing of concrete is done thoroughly with the help of machine mixer so that a uniform quality of concrete was obtained.

### Compaction

Compaction is done with the help of needle vibrator in all the specimens. And care is taken to avoid displacement of the reinforcement cage inside the form work. Then the surface of the concrete is levelled and smoothed by metal trowel and wooden float.

### Curing Of Concrete

Curing is done to prevent the loss of water which is essential for the process of hydration and hence for hardening. It also prevents the exposure of concrete to a hot atmosphere and to drying winds which may lead to quick drying out of moisture in the concrete and thereby subject it to contraction stresses at a stage when the concrete would not be strong enough to resist them. Here curing is to be done by spraying water on the jute bags spread over the surface for a period of 7 days.

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## IV. EXPERIMENTAL RESULTS

All the experimental results of beams with different types of configurations and orientation of GFRP, their behaviour throughout the test is described using recorded data on torsional behaviour and the ultimate load carrying capacity. The crack patterns and the mode of failure of each beam are also described in this chapter. All the beams are tested for their ultimate strengths. Beam No-1 is taken as the control beam. It is observed that the control beam had less load carrying capacity and high deflection values compared to that of the externally strengthened Beams using GFRP sheets. All the eight beams except the control beam are strengthened with GFRP sheets in different patterns. In series -1, two nos of beams are completely wrapped, one with unidirectional and another one with Bidirectional GFRP sheets. Series -2 consists of two beams were wrapped with sheet having thickness of 10cm GFRP sheets, again same unidirectional and bidirectional way. In series-3 two beams were wrapped with smaller thickness GFRP sheets, having thickness of 5cm. and in series -4 beams were wrapped at an angle of 45 degrees having thickness of 5cm GFRP sheets.

### Torsional Moment and Angle of Twist Analysis

Here the angle of twist of each beam is analysed. Angle of twist of each beam is compared with the angle of twist of control beam. Also the torsional behaviour is compared between different wrapping schemes having the same reinforcement. Same type of load arrangement was done for all the beams. All the beams were strengthened by application of GFRP in two layers over the beams. It was noted that the behaviour of the beams strengthen with GFRP sheets are better than the control beams. The deflections are lower when beam was wrapped externally with GFRP sheets. The use of GFRP sheet had effect in delaying the growth of crack formation. When all the wrapping schemes are considered it was found that the Beam-2 with GFRP sheet fully wrapped over full a length of 0.65m in the middle part had a better resistant to torsional behaviour ascompared to the others strengthened beams with GFRP.

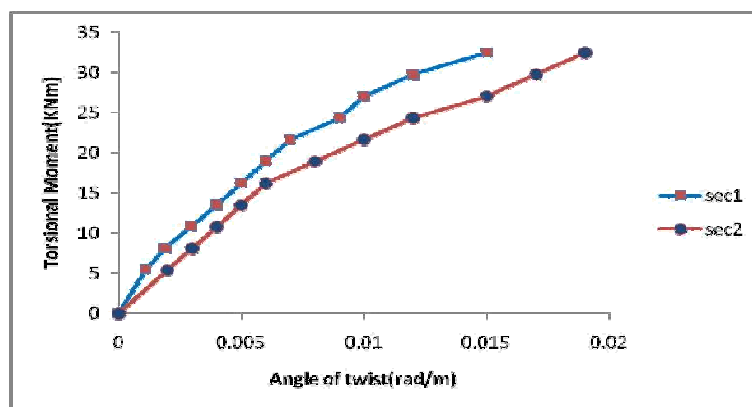


Fig. Torsional Moment vs. Angle of Twist Curve for Control Beam-1

Beam 1 is taken as the control beam which is weak in torsion. In beam1 no strengthening is done. Load was applied on the two moment arm of the beams which is 0.27m away from the main beam and at each increment of the load, deflection at 1/3, 1/2 and 2/3 is taken with the help of dial gauges. Using this load and deflection data, the corresponding torsion moment and the twisting angle were calculated and the above graph was plotted.

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## V. CONCLUSION

The present experimental study is made on the torsional behaviour of rectangular RC beams strengthened by uni-directional and bi-directional GFRP fabrics. Nine rectangular RC beams having same reinforcement detailing and designed to fail in torsion and are cast and tested till collapse.

1. The ultimate load carrying capacity of all the strengthen beams were enhanced as compared to the Control Beam.
2. Torsional reinforced concrete beams strengthened with GFRP sheets exhibited significant increase in their cracking and ultimate strength as well as ultimate twist deformations.
3. Initial cracks appear for higher loads in case of strengthened beams.
4. The load carrying capacity of the strengthened Beam fully wrapped with unidirectional fiber was found to be maximum of all the beams. The increase in load carrying capacity is 88.46% compared to control beam.
5. Both fully wrapped beams Beam had partially collapsed without achieving the ultimate load. The failure occurred in the unstrengthened part of the specimens.
6. Beam was giving the best results in terms of load carrying capacity and angle of twist respectively. And both are having same wrapping pattern of GFRP which is bonded in the torsion part at an angle  $45^0$  with the main beam.
7. Less cracks appeared on the beams strengthened with bidirectional fabrics compare to unidirectional fabrics. This may be due to availability of fiber on diagonal compression Side causing less stress in concrete face in bidirectional fabrics.
8. Test result reveals that strengthening using bidirectional GFRP sheets had not enhanced the ultimate strength but had increased the ductility of the beam.
9. The angle of twist obtained using ANSYS matches the experimental results for lower Range of load value for the beam which are wrapped with GFRP in  $90^0$  angles with main beam. For higher loads there is a deviation with experimental results for these beams.
10. The experimental results obtained for beams wrapped with GFRP at an angle  $45^0$  with axis of the beam are in good agreement with ANSYS results.

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