Strengthening of Beams and Columns using GFRP Bars

C B Nayak¹, Tade M.K² and Dr. S B Thakare³
¹ Phd Scholar, DYPIET, Pune;
Email: cbnayak@gmail.com
² M.E. Structural Engineering, VPCOE, Baramati;
Email: tademayur1@gmail.com
³ Principal, APCOER, Pune;
Email: prof_sbsthakare@rediffmail.com

Abstract: Nowadays infrastructure development is raising its pace. Many reinforced high concrete and masonry buildings are constructed annually around the globe. There are large numbers of structures which deteriorate or become unsafe to use because of changes in use, changes in loading condition, change in the design configuration, inferior building material used or natural calamities. Thus repairing and retrofitting of these structures for safe usage has a great market. There are several situations in which a civil structure would require strengthening due to lack of strength, stiffness, ductility and durability. Beams, columns may be strengthened in flexure by using GFRP in tension zone. In this present work comparative study will be made with and without GFRP circular bars in a beam and column. An experiment study will be carried out to study the change in the structural behavior of beams & columns with GFRP circular bars of different thickness, varying span to depth ratio.

Keywords: GFRP, epoxy resin, flexural, retrofitting, strengthening.

1. INTRODUCTION

Fibers are the principal constituents in the fiber reinforced composite material. They occupy the largest volume fraction in a composite laminate and share the major portion of the load acting on the composite structure. The effectiveness of fiber reinforcement depends on the type, length, volume fractions and orientation of fibers in the matrix. The most extensively used fibers in composites is those manufactured from E-glass. E-glass is a low alkali borosilicate glass originally developed for electrical insulation applications. It was first produced commercially for composite manufacture in 1940’s, and its use now approaches worldwide. [1]

Many different countries manufacture E-glass and its exact composition varies according to the availability and composition of the local raw materials. E-glass is manufactured as continuous filaments in bundles, strands each containing typically between 200 and 2000 individual filaments of 10-30 µm diameters.[2] These strands may be incorporated into larger bundles called roving and may be processed into a wide variety of mats, clothes, and performs.
and cut into short-fiber formats. Glass filaments have relatively low stiffness but very high tensile strength (3GPa). As their initial very high strength, glass filaments are relatively delicate and may become damaged by abrasion and by attack from moist air. It is always necessary to protect the newly drawn strands with a coating. This is usually applied as a solution or emulsion containing a polymer that coats the fibers and binds the fibers in the strand together, a lubricant to reduce abrasion damage and improve handling, additives to control static electric charges on the filaments, and a coupling agent, usually a silane, that enhances the adhesion of the filaments to the matrix resin and reduces property loss on exposure to wet environments. The main objective of this project is to study the performance and behavior of beams & columns using GFRP circular bars. This study involved experimental works on GFRP circular bars. Circular bars will be embedded grooved in to concrete with the help of Epoxy resins.[3] This gives good improvement in ductility and load carrying capacities of concrete beams & columns. GFRP can be produced with higher strength and higher modulus of elasticity than steel, hence improving the flexural, shear strength, and deflection of structural member. Furthermore, the corrosion resistance characteristic gives more advantage on using GFRP in reinforced concrete where it can be used for structures exposed to corrosive condition. The usage of GFRP as reinforcement is very new and restricted on buildings. The main reason is because the lack of experience in handling this material and cost of using it. [4]

Generally, FRP reinforced concrete members such as beam and column are defined as a concrete structure that is reinforced with FRP. Such reinforcement may come in various types and shapes. But the commonly used materials are the GFRP, CFRP and AFRP in the form of reinforcing bars. Among these reinforcing bars, CFRP is the most expensive compared to the glass or aramid. When cost becomes a major consideration in the construction, GFRP reinforcing bars are more applicable. Many conventional steel reinforced concrete structures faced with the steel corrosion problem due to the exposure to aggressive environments. Instead, it was more critical for the marine structures, foundations and structures constructed in the seasonal countries.[5] Most of them will be exposed to chlorides, sulphate and de-icing salts that will attack the concrete structures. For those reasons, FRP reinforcing bars becomes an alternative to replace the steel reinforcements. Nowadays, internal reinforcing technology with the FRP composites become more popular and many researches being carried out to prove that they are successfully can be used to replace the conventional steel reinforcements.[6]

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1.1 Objectives

- To study behavior of beam with and without GFRP bars.
- Circular GFRP bars with varying diameter. (i.e. 8mm,10mm,12mm)
- Varying span to depth ratio.
2. LITERATURE SURVEY

The evolution of the composite material has replaced most of the conventional material of construction in automobile, aviation industry etc. Fiber reinforced composites have been widely used in hundreds of applications where there was a need for high strength materials. There are thousands of customs formulations which offer FRP a wide variety of tensile strengths and flexural strengths. When compared with traditional materials such as metals, the combination of high strength and lower weight has made FRP an extremely popular choice for improving a product’s design and performance.

ButjeAlfonsius, et. al\textsuperscript{8} presented the behavior of concrete cylinders wrapped with FRP sheets subjected to a harsh environment such as high temperature, heating and cooling cycles, and prolonged heat temperature. The high temperature was represented by a temperature of +45ºC for 70 days, heating and cooling cycle was represented by a temperature of +23ºC to +45ºC for 33 cycles, and prolonged temperature was represented by a temperature of +45ºC for 70 days.

RatanKharatmol, et. al\textsuperscript{9} presented material with a sufficient aspect ratio [length to thickness] to provide a discernable reinforcing function in one or more directions. FRP composites are different from traditional construction materials such as steel or aluminium. FRP composites are anisotropic [properties apparent in the direction of the applied load] whereas steel or aluminium is isotropic [uniform properties in all directions, independent of applied load]. Therefore, FRP composite properties are directional, meaning that the best mechanical properties are in the direction of the fiber placement. Reinforced concrete buildings may be vulnerable to progressive collapse due to a lack of continuous reinforcement.

Ifeolorun, olofin andRonggui Liu\textsuperscript{10} investigated literature on Carbon fiber Reinforced Polymer [CFRP] cables. The behaviors of built-in structures are very crucial, especially structures with large dimensions and long service, usually involving advanced technology. Hence, there is the need to understand the behavior of carbon fiber reinforced polymer [CFRP] cable which is considered to be a new discovery for making composite materials. This review covers literature on the behavior and strength of CFRP cables in relation to bridges as well as the use of such cables in other civil engineering structures other than bridges. This paper also describes, briefly, some selected projects in which CFRP cables have been used to demonstrate the wide range of the current and potential applications of CFRP cables for Civil Engineering Structure.

Concluding Remark:

Composite materials have a great potentiality of application in structures subjected primarily to compressive loads. Composite materials have attractive aspects like the relatively high compressive strength, good adaptability in fabricating thick composite shells, low weight and corrosion resistance. But, material characterization and failure evaluation of thick composite materials in compression is still an item of research. When reinforced concrete members are strengthened with externally bonded GFRP, the bond between the GFRP and RC substrate significantly affects the members load carrying capacity. The usage of composite materials like GFRP is still not widely recognized. The lack of knowledge of technology using GFRP and the simplicity of it will make some people hesitant to use it.
3. PROBLEM STATEMENT

Recently, civil engineers and construction industry have begun to realize that this material (GFRP) have potential to provide remedies for many problems associated with the deterioration and strengthening of infrastructure. Effective use of glass fiber reinforced polymer could significantly increase the life of structures, minimizing the maintenance requirements. Glass fiber reinforced polymer is type of fiber composite material in which glass fibers constitutes the fiber phase. GFRP materials possess good rigidity, high strength, low density, corrosion resistance, vibration resistance, high ultimate strain, high fatigue resistance, and low thermal conductivity. Glass fiber reinforced polymer is currently used worldwide to retrofit and repair structurally deficient infrastructures such as bridges and buildings. Using GFRP reinforcing bars in new concrete can eliminate potential corrosion problems and substantially increase a member’s structural strength. When reinforced concrete members are strengthened with externally bonded GFRP, the bond between the GFRP and RC substrate significantly affects the members load carrying capacity. The usage of composite materials like GFRP is still not widely recognized. The lack of knowledge of technology using CFRP and the simplicity of it will make some people hesitant to use it.

4. MATERIALS USED AND METHODOLOGY

4.1 Materials Used

- 53-grade cement: The cement used in the experimentation was Ordinary Portland Cement 53 grade, satisfying the requirements of IS: 12269-1987 specifications.
- Fine Aggregates: Locally available sands was collected from the river bed and used as fine aggregate. The sands used was with fineness modulus 2.96 and conformed to grading zone-III as per IS: 383-1970 specification.
- Coarse Aggregates: The crushed stone aggregate was collected from the local quarry. The coarse aggregates used in the experimentation were 10mm and down size aggregate and tested as per IS: 383-1970 and 2386-1963 (I, II and III) specifications. The aggregates used were having fineness modulus 1.9.
- Water: Ordinary potable water free from organic content, turbidity and salts was used for mixing and for curing throughout the investigation.
- Mix proportion: Mix design was done according to IS: 10262-2007 specification. Mix design for M20 grade concrete is used.

4.2 Methodology

Casting: Rectangular cross section of six beam specimens of dimension (150x230x700) & tor steel was used (at top 2 bars of 10mm and bottom 2 bars of 12mm and stirrups 6mm @ 150mm c/c) and casted as per mix design of M20 and was done under universal testing & same batch was casted for 6 column specimens of dimensions (150x200x300) & tor steel was used (4 bars of 12mm and stirrups of 6mm @ 150mm c/c) tested under compression testing machine.
Test Setup:

A) Conventional Beam Testing

Testing of three numbers of specimens was done under universal testing machine at three point loading. The distance between rollers at the bottom were kept at 600mm. The cracks of specimen were observed during loading at the time of failure.

B) Conventional Column Test

Three numbers of specimens tested under compressive testing machine. The cracks of specimen were observed during loading at the time of failure.

C) Beam Testing After Strengthening

Beams were strengthened by making grooved into beams at bottom side of size 20mm X 20mm. After that grooves were cleaned and primer was applied on concrete surfaces. The base and hardener of primer were mixed together in bucket with proportion of 100:13 as per the guidelines. After 24 hours application of the primer the base and hardener of epoxy saturator was mixes in proportion 100:35 and applied on application area. Various sizes (i.e. 8mm, 10mm, 12mm) of GFRP bars placed into grooves and after that they were fixed with epoxy resins for 24 hours. After that specimen were tested under Universal Testing Machine as shown in below figures.

D) Column Testing After Strengthening

Same procedure was followed as per beams. It was tested under Compression Testing Machine.
5. RESULTS

The performance of GFRP retrofitted concrete beams& columns were analyzed based on the comparison with the conventional beams & columns. In order to indicate the results of analysis clearly, graphs, tables and figures were used. Finally, the results from Six beams & columns were compared in term of ultimate load, deflection, cracking pattern, and mode of failure.

Table 1 Before Strengthening of Beams & Columns

| Sr. No. | Size      | Ultimate Load (KN) | Deflection (mm) | Load at first crack (KN) | Flexural/compressive Strength (N/mm²)28 days |
|---------|-----------|--------------------|-----------------|--------------------------|---------------------------------------------|
| B1      | 150X 230X 700 | 82                 | 3.01            | 32                       | 9.30                                        |
| B2      | 86        | 3.78               | 35              |                          | 9.75                                        |
| B3      | 80        | 2.80               | 38              |                          | 9.07                                        |
| C1      | 150X 200X 300 | 744                | 0.72            | 320                      | 24.8                                        |
| C2      | 642       | 0.81               | 260             |                          | 21.4                                        |
| C3      | 681       | 0.78               | 305             |                          | 22.7                                        |

Fig 5. Filling of Epoxy resin
| Sr. No. | Size          | Ultimate Load (KN) | Deflection (mm) | Load at first crack (KN) | Flexural/compressive Strength (N/mm²) 28 days |
|--------|---------------|---------------------|-----------------|--------------------------|------------------------------------------|
| B4     | 150X23 0X700  | 106.4               | 2.80            | 35                       | 12.06                                    |
| B5     | 150X20 0X300  | 800.36              | 0.68            | 380                      | 26.67                                    |
| C4     | 150X20 0X300  | 834.22              | 0.72            | 355                      | 27.80                                    |

6. CONCLUSION

As per tests it was observed that beams before strengthening failed in flexure and after strengthening failed in shear. It was seen that flexural strength was increased by 30.33%. As per tests it was observed that compressive strength of column increased by 20.76%. There are design codes by institutions such as the American Concrete Institute; there remains some hesitation among the engineering community about implementing these alternative materials. In part, this is due to the lack of standardization and the proprietary nature of the fibre and resin combinations on the market.

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