International Journal of Enhanced Research in Science, Technology & Engineering
ISSN: 2319-7463, Vol. 12 Issue 6, June-2023, Impact Factor: 7.957

Effect of strengthening Schemes on Concrete Beams and Columns retrofitted with GFRP

Mr. Om Ramesh Kale

ABSTRACT

The research work described focuses on the use of Glass Fiber Reinforced Polymers (GFRP) for strengthening Reinforced Cement Concrete (RCC) structures. The need for strengthening arises due to factors such as insufficient capacity, corrosion of internal reinforcing steel, changes in use, poor initial design, and more stringent design codes. The objective is to improve the function and lifespan of the structures using GFRP materials.

GFRP offers several advantages over conventional reinforcement materials, including high strength, stiffness, corrosion resistance, ease of installation, simple repair methods, excellent durability, long service life, minimum maintenance, and lower life cycle costs.

The experimental program consists of testing RCC beams and columns strengthened with GFRP sheets. For the beams, a symmetrical two-point concentrated loading system is used, and three sets of beams are tested: control beams, single-layered GFRP (S1) beams, and double-layer GFRP (S2) beams. The tests involve measuring load, deflection, and failure modes of the beams to investigate the effect of the number of GFRP layers and their orientation on load carrying capacity and failure mode.

For the columns, axial compression tests are conducted using Universal Testing Machine (UTM). Three sets of columns are tested: control columns, columns reinforced with single layers of GFRP sheets, and columns reinforced with double layers of GFRP sheets. The aim is to enhance the ductility and compressive strength of the columns. The interaction curve of wrapped RCC columns with GFRP is also studied, focusing on the compressive control region.

The research work includes both experimental and analytical studies to understand the behavior of RCC beams and columns reinforced with GFRP sheets. The keywords associated with this research include FRP, GFRP, load, deflection, RCC beam, RCC column, and axial compressive strength. Overall, the research aims to provide insights into the strengthened behavior of RCC beams and columns using GFRP sheets, contributing to the knowledge and understanding of GFRP strengthening techniques for concrete structures.

Experimental investigations on the flexural behavior of RCC beams strengthened using glass fiber reinforced polymer (GFRP) sheets were carried out. Externally reinforced concrete beams with GFRP sheets were tested to failure using a symmetrical two-point concentrated loading system. The test program consisted of casting and testing of 3 beams. All 3 beams having a size of 2300 mm x 150 mm x 230 mm using M20 grade of concrete and Fe 500 grade steel. The first set of 1beams was control beams, the second set of1 beams was single-layered GFRP (S1) beams and the third set of 1beams was double-layer G FRP(S2) beams. Experimental data on load, deflection and failure modes of each of the beams were obtained. The effect of the number of GFRP layers and their orientation on the ultimate load carrying capacity and failure mode of the beams has been investigated.

The other test program consisted of casting and testing of 3 numbers of RCC columns. All columns had a size of 700 mm x 150 mm x150 mm using M20 grade of concrete and Fe 500 grade steel. Among the 3 columns, the first 1 set was control columns, the second 1 set were columns reinforced with single layers of GFRP sheets and the remaining 1sets were column reinforces with double layer GFRPs sheets. Axial compression test will be carried out on all 3 columns using Universal Testing Machine (UTM) of 100 tons capacity. RCC columns with GFRP showed increases in ductility and compressive strength of column. Since then, almost all RCC columns were affected by axial force and moment bending. Studies of the interaction curve of wrapped RCC columns with GFRP showed enhancement of just compressive control region in interaction Curve with no effect on tension control region of RCC Columns from the wrapping of column with G FRP. This research work is also focused on enhancing the axial compressive strength of RCC reinforced by the GFRP system that oriented in the direction of the applied axial load.

This research work investigates the behavior of RCC Beam and Column (structural members) reinforced with GFRP sheets. It includes an experimental programmer on representative samples and analytical studies to predict the

strengthened behavior of RCC Beam and Column.

MATERIAL

The preparation of RCC beams and columns involves the use of various materials, including cement, coarse aggregates, fine aggregates, water, steel reinforcement, and composite materials such as GFRP for strengthening purposes.

Cement: Cement is a binding agent that is mixed with water to form a paste, which binds the aggregates together and provides strength and durability to the concrete.

Coarse Aggregates: Coarse aggregates, such as crushed st1 or gravel, are used in concrete to provide bulk and strength. They occupy a significant volume in the concrete mixture.

Fine Aggregates: Fine aggregates, typically sand, are used to fill the spaces between the coarse aggregates, improving the workability of the concrete mixture and providing a smooth surface finish.

Water: Water is mixed with cement to initiate the chemical reaction called hydration, which causes the cement to harden and bind the aggregates together. The water-to-cement ratio affects the strength and workability of the concrete.

Steel Reinforcement: Steel reinforcement, in the form of bars or mesh, is embedded within the concrete to provide tensile strength. The steel reinforcement resists the tension forces that the concrete al1 may not be able to withstand.

Composite Materials (GFRP): Glass Fiber Reinforced Polymers (GFRP) are composite materials that consist of a matrix of polymer reinforced with glass fibers. GFRP sheets or strips are used for strengthening RCC beams and columns to enhance their load-carrying capacity, stiffness, and ductility.

The combination of these materials, along with proper design and construction techniques, results in the formation of reinforced concrete structures such as beams and columns. Each material plays a crucial role in ensuring the strength, durability, and performance of the RCC elements.

Limitations of Study

The following are the limitations of the present study

- Main limitation of externally strengthening of structures with composite materials is the risk of fire, vandalism, damage, unless the strengthening is protected
- Lack of experience seen in the wrapping techniques and lack of qualified staff
- Design consultants, contactors and clients have limited experience on
- GFRPwrapping techniques
- Composites of different kind are required for various RCC structural comp1nts
- Low ductility value and fickle plastic behavior
- High cost due to GFRP sheets

Benefits of the Study

- The techniques of GFRP wrapping is recognised as an effective and convenient method of repair and rehabilitation of RCC Structural comp1nts
- Strengthening of RCC structures using GFRP has been shown as an excellent way of improving the function as well as the life span
- The benefits of GFRP are high strength, stiffness, corrosion resistance, ease of installation, simple repair methods, excellent durability, minimum maintenance andlower life cycle costs
- Low weight of GFRP fiber, facilitates handling without the use of any equipments
- The other benefits of GFRP are high strength to weight to ratio, resistance to electro-chemical corrosion, larger creep strain and good fatigue strain
- GFRP wrapping increases load carrying capacity, improves the shear strength and ductility and fulfills certain serviceability requirements of the RCC structural comp1nts
- Application of GFRP overlays is 1 of the simple methods for wrapping the existing RCC structures

METHODOLOGY

The methodology for the research on the **"Effect of strengthening Schemes on Concrete Beams And Columns retrofitted with GFRP"** can be summarized as follows:

- Literature Review: Conduct a comprehensive literature review on RCC beams and RCC columns strengthened with GFRP sheets by referring to various journals and conference proceedings.
- Collection of Materials: Study the characteristics and properties of fine aggregates, coarse aggregates, steel, water, and composite materials used in RCC beams and columns.
- Casting of RCC Beams and Columns: Cast three RCC beam specimens with dimensions of 200 mm x 150 mm x 20 mm. Divide the beams into three groups: control beams, single-wrapped GFRP beams, and double-wrapped GFRP beams. Cast three RCC short columns with dimensions of 700 mm x 150 mm x 150 mm. Divide the columns into three groups: control columns, columns wrapped with a single layer of GFRP sheets, and columns wrapped with double layers of GFRP sheets.
- GFRP Wrapping Techniques: Apply GFRP sheets using appropriate wrapping techniques around the RCC beams and columns according to their designated groups. Experimental Program: Perform a two-point load test on the RCC beams using a loading frame with a capacity of 40 tonnes. Conduct an axial compressive test on the RCC columns using a 100-tonnes universal testing machine.
- Analysis and Discussion: Analyze and discuss the experimental test results, focusing on the load carrying capacity, flexural strength, axial compressive strength, and deflection of the GFRP-wrapped RCC beams and columns.
- Conclusions: Draw conclusions based on the evaluation of the experimental results, summarizing the performance of the GFRP-wrapped beams and columns in terms of load capacity, strength, and deflection.
  It is important to note that the specific details of the experimental setup, testing procedures, and data analysis techniques may vary depending on the specific research objectives and available resources.

CONCLUSIONS

Conclusions of RCC Beam

Load at initial cracks was further increased by strengthening the beam at the soffit as well as on the two sides of the beam up to neutral axis from the soffit.

When the beam is not strengthen, it failed in flexure but after strengthening the beam in flexure, then flexure-shear failure of the beam takes place which is more dangerous than the flexure failure of the beam as it does not give much warning before failure. Hence, it is recommended to check the shear strength of the beam and carry out shear strengthening along with flexural strengthening if required.

Flexural strengthening up to the neutral axis of the beam increases the ultimate load carrying capacity, but the cracks developed were not visible up to a higher load. Due to invisibility of the initial cracks, it gives less warning compared to the beams strengthen only at the soffit of the beam.

Strengthening up to neutral axis of the beam provided increase in the ultimate load carrying capacity of the beam. The initial cracks in the strengthen beams S1 and S2 appeared at a higher load compared to the control beam. Following strengthening of the beam, the initial cracks appeared at the flexural z1 of the beam and the cracks widened towards the neutral axis with increase in the load. The final failure is a flexural failure which indicates increase in the shear strength of the beam by GFRP.

Based on the experimental results, the following conclusions have been drawn

- The pattern of the graphs indicates an increase in stiffness of the beamsdue to the bonding of GFRP mat as compared to the control beam
- Effective procedure of wrapping enhances the strength considerably
- Retrofitting for shear may enhance the ductility to a considerable extent due to the additional confinement effect
- Mode of failure observed significantly was de-bonding of GFRP sheet
- Diagonal cracks were observed at the support of the beam showing the failure inthe shear
- De-bonding of GFRP mat of the specimen S-1 causes failure sound and thesame was observed
- Cracks widened at the ultimate load of 7.7 kN for S-1
- The mid span deflections at a service load of 6.84 kN (CB) for S-1 reduced by 26.59 %

- The ultimate load is increased by 15.44 % on beams strengthened with single layer of GFRP mat (S-1)
- Results obtained from previous work (Syed Ibrahim et al. 2015), showed the maximum mid span deflection for single layer GFRP laminated beam as 15.4 % and 27.5 % for double layer beam

Conclusions of RCC Column

The analysis of the experimental results obtained in this study, have provided some important findings. The compressive loading test results of the columns indicate increase in the load carrying capacity of the columns by the wrapping columns with GFRP. An important advantage was achieved that GFRP wrapping enhanced the performance of the columns by postponing the rupture of the concrete and reinforcement. It increased the column ductility. Increase in the number of the GFRP layers led to increase in load and the performance of the columns.

It was revealed that in columns with a large eccentricity, which means with a large bending moment, the wrapping of GFRP mats produced higher load and ductility than that in control columns. It was also obtained from this study that the eccentricity of loading reduces the load carrying capacity and performance of the columns. Finally, it was proven that wrapping RCC columns with GFRP enhanced the performance of the columns. Wrapping with a minimum of two-layers would be suggested to achieve significant results.

Based on experimental results, the following conclusions have been made

The effective procedure for GFRP wrapping of columns is increased compressive strength in single and double layered GFRP columns compared with control columns

Peak deflection and Strain values for single layered and double layered GFRP columns were reduced as compared to control column Stress values were increased in single and double layered GFRP wrapped columns as compared to control columns

Average peak deflection for control column is calculated as 7. mm. Peakdeflection for single and double layered GFRP wrapped column were calculated as 5.8 mm and 4.87 mm

REFERENCES

[1]. Ahir, MD, Perikh, KB & Jhummarwala, RA 2016, ‘Strengthening of RC square column with GFRP sheet with different configuration’, International Journal of Engineering Science and Computing, vol. 6, no. 7, pp. 85-90

[2]. Alexandre, L, Carlos Alexandre, S & Eduardo de Miranda, B 2015, in proceedings of conference on Civil Engineering Program, September - 15, Mechanical Properties of Glass Fiber Reinforced Polymers Members for Structural Applications, Brazil

[3]. Al-Sulaimani, GJ, Sharif, A, Basunbul, IA, Baluch, MH & Ghaleb, BN 1994, ‘Shear repair for reinforced concrete by Fiberglass plate bonding’, ACI Structural Journal, vol. 2, no. 91, pp. 458-464

[4]. Athira, MA, Meera, CM & Sreepriya, M 2016, ‘Experimental Study on RC Columns Wrapped With Hybrid FRP Sheets’, International Journal of Innovative Research in Science, vol. 5, no. 8, pp. 54 – 60

[5]. Chen, JF & Teng, JG 200, ‘Shear capacity of FRP strengthened RC beams FRP debonding’, Articles in construction and building materials, vol. 1, pp. 1-4

[6]. Cui, C & Sheikh, SA 2010, ‘Experimental Study of Normal and High Strength Concrete Confined With Fiber Reinforced Polymers’, Journal of Composites for Construction ASCE, vol. 1, no. 12, pp. 55-561

[7]. Deepak, K & Govind, R 2015, ‘Use of GFRP (Glass Fiber Reinforced Polymer) for Strengthening of Reinforced Concrete Beam’, International Journal of Civil Engineering, vol. 1 no. 5, pp. 58 – 61

[8]. Jagannathan, S, Suguna, K & Raghunath, PN 2010, ‘Confined High Strength Concrete Columns: An Experimental Study’, American Journal of Engineering and Applied Sciences, vol. 1, no. , pp. 1 – 1

[9]. Lau, KT & Zhou, LM 2001, ‘The mechanical behaviour of composite-wrapped concrete cylinders subjected to uniaxial compression load’, Journal of Composite Structures, vol. , no. 52, pp. 189-198

[10]. Khalifa, A, William Gold, Antonio, N & Abdel, A 1998, ‘Contribution of externally bonded FRP to shear capacity of RC Flexural Members’, ASCE Journal of Composites for Construction, vol. 2, no. 4, pp. 195 – 20