EXPERIMENTAL INVESTIGATION OF RC COLUMNS AND ARCHES REINFORCED WITH GLASS FIBER RENFORCED POLYMER (GFRP)

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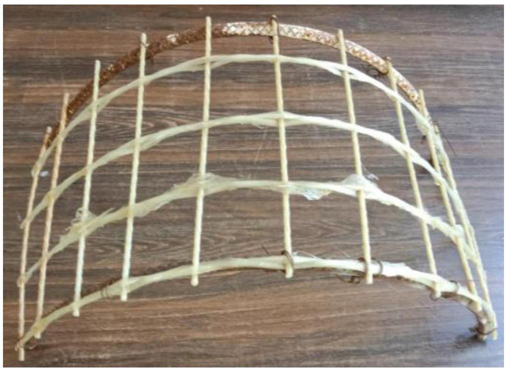
Keywords:
GFRP Rebar, GFRP Mesh, longitudinal member, lateral tie, Column.

Introduction:
The global construction industry is increasingly challenged to meet the demand for sustainable, durable, and cost-effective materials, as conventional steel reinforcement, though widely used in concrete structures, is highly prone to corrosion in aggressive environments such as marine and industrial conditions, leading to higher maintenance, reduced service life, and increased lifecycle costs, thereby necessitating the exploration of alternative materials like Glass Fiber Reinforced Polymer (GFRP), a composite made of high-strength glass fibers embedded in a polymer matrix such as vinyl ester or epoxy resin, which offers advantageous properties including corrosion resistance, lightweight nature, high tensile strength, and non-magnetic characteristics, making it highly suitable for applications in bridge decks, coastal infrastructure, chemical plants, MRI rooms, and electrical installations, while also enabling easier handling, transportation, and installation due to its low weight, contributing significantly to sustainable construction by reducing maintenance needs, extending structural lifespan, and lowering overall costs, although its relatively brittle behavior compared to steel requires careful design considerations, prompting the development of hybrid reinforcement methods and the incorporation of discrete fibers to improve ductility and structural performance, thereby emphasizing the importance of understanding the behavior of GFRP-reinforced concrete elements under various loading conditions to optimize their design, ensure safety, and enhance their effectiveness as a viable alternative to conventional steel reinforcement.



Objectives:

1. Evaluate the performance of reinforced concrete columns with Glass fiber reinforced polymer as longitudinal reinforcement.
2. Evaluate the performance of concrete columns with Glass fiber reinforced polymer mesh as lateral ties.
3. Study the structural behaviour of Arches with Glass fiber reinforced polymer Mesh reinforcement.
4. Evaluate and contrast the strength characteristics of columns and Arches when reinforced with GFRP versus traditional reinforcement.

Methodology:

The experimental methodology of this study focused on the fabrication, curing, and testing of six different groups of short reinforced concrete (RC) columns with varying reinforcement configurations, where unlike curved structural members such as arches that resist loads through horizontal thrust, the columns were designed to carry purely axial compressive loads; all specimens were proportioned with a length-to-lateral dimension ratio less than 12 to ensure short column behaviour and minimize buckling effects, and the longitudinal reinforcement consisted of combinations of Glass Fiber Reinforced Polymer (GFRP) rebars and conventional HYSD steel rebars, while lateral confinement was provided using GFRP mesh and HYSD stirrups arranged in different internal and external configurations to study their effectiveness; the required materials including cement, fine aggregates, coarse aggregates, GFRP rebars, HYSD bars, and GFRP mesh were carefully selected, and a suitable concrete mix design was adopted to achieve the desired strength, after which reinforcement cages were fabricated according to the specified configurations and placed in moulds before casting, ensuring proper compaction to eliminate voids and maintain uniformity; the specimens were demoulded after 24 hours and subjected to standard water curing to attain adequate strength, and upon completion of curing, they were tested under monotonic axial compression using a 60-tonne Universal Testing Machine (UTM), where the load was applied gradually until failure, while deformations were precisely measured using a dial gauge and a digital vernier caliper with a least count of 0.001 mm, along with detailed observations of crack initiation, propagation, and failure patterns, resulting in the generation of load–displacement and stress–strain data for each specimen, which were subsequently analyzed to compare the ultimate load-carrying capacity, stiffness, ductility, and failure modes of different reinforcement configurations, thereby providing valuable insights into the structural performance of GFRP-reinforced columns in comparison with conventional steel-reinforced columns.

Result and Conclusion:

RC short columns are compression members with a low slenderness ratio ($L/D < 12$) and primarily fail due to material strength rather than buckling, carrying high axial loads with minimal lateral deformation and nearly uniform stress distribution; as the load increases, micro-cracks develop followed by spalling of the concrete cover, while the core concrete and reinforcement continue to resist the load with improved confinement provided by transverse reinforcement, and the failure is typically sudden, dominated by concrete crushing and yielding or buckling of reinforcement, making proper detailing essential to ensure ductile behaviour.

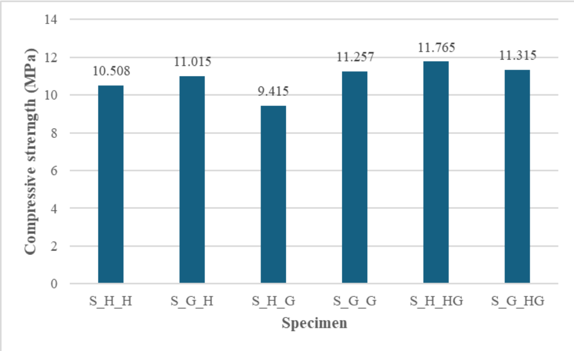


Figure 2: Average compressive strength of column

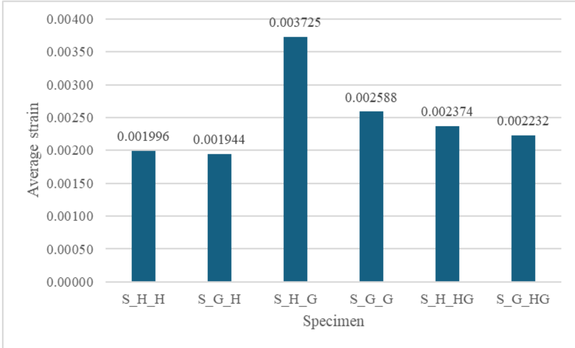


Figure 3:Average Strain of Column

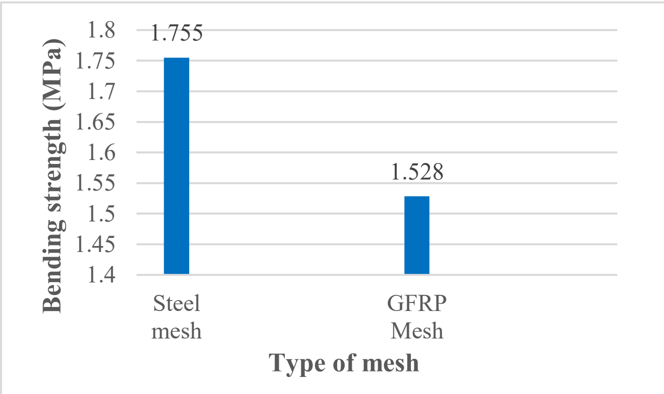


Figure 4:Bending strength of arch

The graph presents a comparative evaluation of the bending performance of specimens reinforced with steel mesh and GFRP mesh. It indicates that specimens with steel mesh exhibit superior bending resistance compared to those reinforced with GFRP mesh, highlighting the influence of mesh type on flexural behaviour.

In conclusion

1. RC columns reinforced with GFRP rebars as longitudinal reinforcement exhibited slightly higher compressive strength compared to conventional HYSD steel rebars. An average increase of about 4% in compressive strength was observed, indicating that GFRP rebars can effectively replace steel rebars in compression members under axial loading.
2. Replacement of conventional HYSD stirrups with GFRP mesh alone as lateral confinement did not result in a significant increase in load-carrying capacity. However, it improved deformability and strain capacity, indicating enhanced ductile behaviour.
3. Columns reinforced with a combination of GFRP mesh and HYSD stirrups used externally at larger spacing showed a notable improvement in compressive strength. The maximum enhancement of compressive strength (up to 19%) was observed in specimens with GFRP longitudinal reinforcement combined with effective lateral confinement.

4. The highest load-carrying capacity among all column specimens was observed in columns reinforced with GFRP rebars as longitudinal reinforcement and a combination of GFRP mesh and HYSD bars as lateral confinement, demonstrating the effectiveness of hybrid confinement systems.
5. Strain measurements revealed that specimens with GFRP mesh as lateral reinforcement exhibited higher strain values, indicating improved ductility and energy absorption capacity compared to specimens with conventional steel stirrups.
6. In the case of RC arches, specimens reinforced with steel mesh exhibited higher average bending strength compared to GFRP mesh-reinforced arches. Steel mesh arches showed approximately 15% higher bending strength than GFRP mesh arches.
7. Despite lower bending strength, GFRP mesh-reinforced arches demonstrated significantly higher displacement capacity, indicating good flexibility and crack distribution. All arch specimens failed predominantly by crown cracking, confirming flexural failure as the governing mechanism.

References:

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Future Scope:

The future scope of this project includes:

1. Long-term performance studies considering creep, shrinkage, fatigue and durability of GFRP-reinforced RC members under aggressive environmental conditions.
2. Investigation of different grades, surface treatments, and configurations of GFRP bars and meshes to improve bond behaviour and structural efficiency.
3. Analytical and numerical modelling using finite element analysis to predict the behaviour of GFRP-reinforced RC members under various loading conditions.
4. Study of seismic performance and cyclic loading behaviour of GFRP-reinforced RC columns to assess their suitability for earthquake-resistant structures.
5. Optimization of hybrid reinforcement systems combining steel and GFRP to achieve improved strength, ductility, and cost-effectiveness.