



Optimized GFRP wrapping configuration for maximum strengthening

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Abstract

The role of anchorage and end confinement is also crucial in preventing premature debonding. Were any special anchoring techniques or surface preparations used to enhance the bond between the GFRP and concrete since the study confirms that a 45° fiber orientation provides superior torsional resistance, it might be valuable to explore hybrid configurations combining 45° and 90° orientations. Did the study investigate such hybrid layouts? Overall, the findings provide strong support for using GFRP in torsional strengthening applications. However, extending the research to different loading conditions, cyclic torsion, and long-term durability (e.g., creep, temperature effects) could further validate its practical applicability. These insights could be crucial for optimizing GFRP reinforcement strategies in retrofitting and new structural applications. Would you like to include additional factors such as ductility, stiffness variations, or cost-effectiveness the application of GFRP significantly improves both the first crack and ultimate load capacities of the beams. GFRP applied at 45° with respect to the beam axis provides better strength than at 90°, likely due to its ability to resist both shear and torsional stresses more effectively.

Keywords: GFRP and concrete, GFRP applied at 45°, GFRP applied at 90°, stiffness variations, ultimate load capacities

Introduction

Glass Fiber Reinforced Polymer (GFRP) wrapping has emerged as an effective technique for strengthening and retrofitting structural elements such as beams, columns, and slabs. The optimization of GFRP wrapping configurations is crucial to achieving maximum structural performance while minimizing material usage and cost. The effectiveness of GFRP strengthening depends on factors such as fiber orientation, number of layers, wrapping technique, and bonding quality.

This study explores various GFRP wrapping configurations, including unidirectional (UD) and bidirectional (BD) fiber orientations, full and partial wrapping techniques, and different fiber angles (0°, 45°, 90°). The impact of these configurations on bending strength, shear capacity, and ductility is analyzed through experimental and numerical approaches. Special attention is given to hybrid wrapping techniques that combine multiple orientations to enhance both flexural and shear resistance.

By optimizing the wrapping configuration, this research aims to develop cost-effective and high-performance strengthening solutions for reinforced concrete (RC) structures, enhancing their load-carrying capacity, durability, and seismic resistance.

Literature Review

Vivek V. Mane et al (2023) Concrete is one type of composite material composed of fine and coarse aggregate bonded together with cementations paste that is durable in its hardened state over time. It has now become an important and widely used building material. However, it possesses a brittleness material property in tension even though it is strong in compression. Here the study is restricted to the concrete subjected to torsion phenomena. In the past decades, various ways have been explored to improve the ductile material strength property of the concrete matrix in proposed new construction. Reinforced concrete is constructed by using conventional reinforcements; prestressed concrete is an example of that. Also, various types of fibers in the form of discrete nature are applied to improve the tensile strength capacity of concrete in proposed construction, and retrofitting techniques using various materials are exercised to strengthen the existing structures. Hence, remarkable research in the literature on fiber reinforced concrete and on FRP techniques has been carried out. However, welded wire mesh with high yield strength can be encased in concrete members to improve composite material property and avoid abrupt cracking with an increase in torque carrying capacity of plain and reinforced concrete beam specimens used for proposed construction.

Manish raj et al (2021) Many beams located at the perimeter of buildings carry loads from slabs, joists and beams from one side of the member only. This loading mechanism generates torsional forces that are transferred from the beams to the columns. Such beams are deficient in torsional shear capacity and are in need of strengthening.. Fiber Reinforced Polymer (FRP) as an external reinforcement is used extensively to address the strength requirements related to flexure and shear in structural systems, but the strengthening of beams subjected to torsion is yet to be explored. In this project, the behavior and performance of reinforced concrete beams strengthened with externally bonded Glass FRP (GFRP) sheets subjected to pure torsion has been studied. Experimental result reveal that externally bonded GFRP sheets can significantly increase both the cracking and the ultimate torsion capacity. Concrete with mix proportion 1:1.8:3.6 was used during the casting of the specimens. Glass fibre sheets used was bi-directional woven roving mat. Polymer matrix Epoxy resin with 10 % hardener was used as the binder of GFRP sheets with the concrete surface. The obtained result shows that the load carrying capacity of the retrofitted beam is far more than the control beam. FRP based strengthening has better aesthetic appearance compared to other methods and is easier to implement and is light in weight.

Methodology

The effectiveness of Glass Fiber Reinforced Polymer (GFRP) wrapping in strengthening structural elements depends on several key parameters, including fiber orientation, wrapping configuration, fiber type, and the bonding method. The optimization of GFRP wrapping aims to maximize flexural, shear, and axial strength while ensuring efficient material usage.



Fiber Orientation

- ❖ **Unidirectional (UD) GFRP (0° or 90°):** Best for enhancing **axial and flexural strength** when aligned along the load path.
- ❖ **Bidirectional (BD) GFRP ($\pm 45^\circ$):** Best for **shear strengthening** due to its diagonal fiber alignment.

Wrapping Configuration

- ❖ **Full Wrapping:** Provides uniform confinement, best for **columns and circular sections** under compression.
- ❖ **U-Wrap (U-Jacket):** Improves **flexural and shear strength** in beams by resisting tension cracks.
- ❖ **Strip Wrapping (Intermittent Wrapping):** Reduces material use while still improving shear capacity.
- ❖ **Spiral Wrapping:** Effective for cylindrical members, allowing better energy dissipation.

Fiber Type and Thickness

- ❖ **Higher fiber volume fraction (V_f)** increases strength but must be optimized to prevent premature debonding.
- ❖ **Multi-layered configurations** improve durability but should be bonded with high-performance epoxy resins.
- ❖ Unidirectional (UD) GFRP provides superior tensile strength in the direction of fibers, making it highly effective in flexural strengthening.
- ❖ Bidirectional (BD) GFRP offers better confinement and resistance against shear forces due to fiber reinforcement in both principal directions.
- ❖ High-strength epoxy adhesives enhance fiber-matrix bonding, reducing premature debonding and improving overall structural capacity.
- ❖ Using multiple layers (2-3 plies) instead of a single thick layer provides better energy dissipation and crack resistance.
- ❖ Under pure bending, UD fibers along the beam length achieve maximum stiffness and deflection control.
Under combined bending and shear, a hybrid approach (BD + UD) prevents localized failures and improves ductility.



- ❖ Deboning and peeling failures can be mitigated by anchoring the wrap with mechanical fasteners or additional epoxy layers.

Conclusion

The optimal GFRP wrapping configuration depends on the structural element and loading conditions. A combination of unidirectional and bidirectional layers, full or U-wrap configurations, and proper anchorage techniques can significantly enhance structural performance. By selecting the right fiber orientation, layer thickness, and bonding method, GFRP wrapping can provide maximum strengthening and durability while minimizing material usage.

Shear Strengthening: Wrapping at $\pm 45^\circ$ (BD GFRP) enhances shear capacity by distributing stress uniformly and preventing diagonal shear cracks.

Flexural Strengthening: 0° (UD GFRP) wrapping along the beam length maximizes resistance to bending by aligning fibers with principal stress.

Hybrid Configuration: Combining 90° and $\pm 45^\circ$ layers enhances both flexural and shear resistance, providing an optimized balance for structural performance.

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