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FRP sheet as external reinforcement of RC beams

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Abstract
Age, steel reinforcement corrosion, construction design flaws, higher service load requirements, damage from seismic occurrences, and upgrades to design principles all make it necessary to renovate old reinforced concrete (RC) bridges and buildings. Fiber-reinforced polymers, or FRP, have shown promise as a material for restoring old reinforced concrete buildings. Structures can be strengthened, repaired, or retrofitted to address any kind of deficiency as part of the rehabilitation process. In buildings and bridges, RC rectangular-section beams and girders are the most prevalent shape.

Keywords: Externally joined bending reinforcement FRP composites reinforced concrete beam installed close to the surface

Introduction
Globally, there will inevitably be more infrastructure retrofits. This is caused by the deterioration of the existing infrastructure's structural strength as a result of aging and environmental attacks, the upgrading of different design codes as a result of a better understanding of various design concepts over time, the demand for more load carrying capacity as a result of today's increased service needs, etc. In civil engineering, Fiber Reinforced Polymer (FRP) is a relatively new kind of composite material made of fibers and resins that has shown to be effective and affordable for the creation and maintenance of both new and deteriorating structures.

Need of retrofitting in rc structures
Different varieties of concrete now have strengths between 40 and 70 MPa, up from low values of 15-20 MPa. One application for this is raising the load capacity of existing buildings, such parking garages, which were built to withstand much lower service loads. Repairing damaged concrete structures and seismic retrofitting are two more uses. Concrete structure repair and rehabilitation can be broadly divided into two groups.

- Repair in which damage due to deterioration and cracking is corrected to restore the original structural shape, and
- Repair which is necessary to strengthen the structural capacity of members whose load carrying capacity is either inadequate or whose strength has been severely impaired due to sustained damage.

Degradation of steel reinforcements due to corrosion, cracking of concrete due to weathering, rapidly changing traffic needs (both in terms of intensity and load levels) and recent earthquake damages have necessitated the use of strengthening of basic structural components such as slabs, panels, walls, beams and columns.

Literature Review
Fiber-reinforced polymers (FRPs) are indeed a vital subset of composite materials, widely employed across diverse industries like aerospace, automotive, marine, and construction. Within construction, FRPs offer robust structural solutions. Typically, three primary fibers are utilized: glass, carbon, and aramid. Each fiber type possesses distinct properties suited for various structural requirements. This versatility underscores the widespread adoption of FRPs in modern construction practices.

Suitability of frp for uses in structural engineering
Externally bonded fiber-reinforced polymers (FRPs) offer an effective solution for the rehabilitation of reinforced concrete or masonry structures worldwide. These FRP jackets,

composed of continuous carbon (C), glass (G), or aramid (A) fibers embedded in an epoxy, vinyl ester, or polyester matrix, deliver a compelling combination of attributes. Their high strength-to- weight ratio, corrosion resistance, and ease of handling and installation make them particularly appealing for seismic retrofitting projects. Despite their higher material costs, the superior performance and durability of FRP jackets continue to drive their widespread adoption in construction endeavors seeking enhanced strength or inelastic deformation capacity.

When an FRP specimen is tested in axial tension, the applied force per unit cross-sectional area (Stress) is proportional to the ratio of change in a specimen's length to its original length (Strain). When the applied load is removed, FRP returns to its original shape or length. In other words, FRP responds linear-elastically to axial stress.

Among FRPs high strength properties, the most relevant features include

- Excellent durability and corrosion resistance.
- High strength-to-weight ratio.
- A member composed of FRP can support larger live loads since its dead weight does not contribute significantly to the loads that it must bear.
- Ease of installation.
- Versatility.
- Anti-seismic behavior.

One of the most common uses for FRP involves the repair, rehabilitation and retrofitting of damaged or deteriorating structures as shown in Fig.1.1 (a), (b).

These include structures such as siding/cladding, roofing, flooring and partitions.

Fig 1: A) Application of Externally Bonded FRP Composites. B). Retrofitting Of Column-Beam Joint

Methodology

The inaugural application of FRP strengthening targeted concrete beams, crucial load-bearing structural components engineered to withstand vertical gravity loads alongside horizontal forces from seismic or wind activity. These beams often succumb to structural deficiencies, manifesting in two primary failure modes: flexural and shear failure. By reinforcing these beams with FRP materials, engineers fortify them against such vulnerabilities, enhancing their resilience and longevity in the face of dynamic loading scenarios.

Hence, the strengthening of such beams is needed in flexure or shear or both zones and the use of external FRP strengthening to

Beams may be classified as

- Flexural strengthening
- Shear strengthening
- Flexural strengthening

Flexural strengthening of beams entails the application of FRP composites to their tension zone, typically achieved through epoxy bonding. The orientation of fibers within the FRP aligns parallel to the direction of high tensile stresses, optimizing reinforcement effectiveness. Engineers utilize both prefabricated FRP strips and sheets for this purpose, selecting the appropriate form factor based on project requirements and structural conditions. This strategic application of FRP materials bolsters the beam's capacity to resist bending forces, mitigating the risk of flexural failure and enhancing overall structural performance.

Shear strengthening

Shear failure in reinforced concrete (RC) beams presents distinct characteristics compared to flexural failure. While flexural failure is ductile, shear failure tends to be brittle and can lead to catastrophic consequences. When an RC beam lacks sufficient shear capacity, or when its shear capacity falls short of the flexural capacity post-flexural strengthening, shear strengthening becomes imperative.

Both FRP composite plates and sheets are viable options for reinforcing the shear zone of beams. However, sheets are often favored due to their flexibility, ease of handling, and application. Various FRP bonding schemes can be employed to augment the shear resistance of RC beams. These schemes encompass strategies such as wrapping the beams with FRP sheets in different orientations, applying strips or grids of FRP, or using near-surface-mounted FRP reinforcement techniques. Each bonding scheme is tailored to the specific requirements of the structure and the desired enhancement in shear capacity, offering engineers a range of options to address shear deficiencies effectively. These include:

1. Bonding FRP to the sides of the beam only,
2. Bonding FRP U-jackets covering both the sides and the tension face, and
3. Wrapping FRP around the whole cross section of the beam. FRPs are strong only in the directions of fibers. The fiber directions in FRP composites may be unidirectional, bi-directional or multi-directional. The use of fibers in two directions can be beneficial with respect to shear resistance even if strengthening for reversed loading is not required, except for unlikely case in which one of the fiber directions is exactly parallel to the shear cracks.

Modes of failure of FRP strengthened beams are
Fiber failure in the FRP

Shear failure in fiber-reinforced polymer (FRP) composites arises when the tensile stress within the fibers surpasses their tensile strength. This failure mode is typified by rapid and progressive fiber rupture within the composite, particularly evident in sheet applications. Shear failure tends to be brittle in most cases, highlighting the sudden and catastrophic nature of the failure mechanism.

The orientation of fibers relative to the principal strain in concrete plays a pivotal role in determining the ductility of the composite. Proper alignment of fibers can enhance the composite's ability to absorb energy and deform plastically before failure, thereby promoting ductile behavior. Conversely, misalignment or inadequate bonding may compromise ductility, leading to brittle failure modes. As such, careful consideration of fiber orientation is essential in optimizing the performance and resilience of FRP composites in shear strengthening applications.

Bond failure

Bond failure is governed by the properties of the weaker materials in contact, i.e. concrete and adhesive. When the shear strength of one of these exceeds the force then transfer cannot be ensured anymore and a "slip" is produced. The deboning can take place in the concrete, between the concrete and the adhesive, in the adhesive, between the adhesive and the fibers. The use of sidebonded FRP sheets enhance the shear capacity of the flange beam, but strength of FRP sheets in fullest extent may not be utilized due to the bond failure between the FRP and the concrete. U- jacketing is currently the most popular shear strengthening solution due to its high practicality, but it is limited by end peeling of the U-jacket legs. These drawbacks have opened up a new area of research on development of anchorage system.

Types of FRPs

There are three types of fibers dominate. These are carbon, glass, and aramid fibers and the composite is often named by the reinforcing fiber

Carbon Fiber Reinforced Polymer (CFRP)

Carbon fiber reinforced polymer, is a material consisting of extremely thin fibers about 0.005-0.010 mm in diameter and composed mostly of carbon atoms. The carbon atoms are bonded together in microscopic crystals that are more or less aligned parallel to the long axis of the fiber. The crystal alignment makes the fiber very strong for its size. Several thousand carbon fibers are twisted together to form a yarn, which may be used by itself or woven into a fabric.

Glass Fiber Reinforced Polymer (GFRP)

GFRP is a lightweight, strong material with very many uses, including boats, automobiles, water tanks, roofing, pipes and cladding. The plastic matrix may be epoxy, a thermosetting plastic (Most often polyester or vinyl ester) or thermoplastic. Glass fibers are basically made by mixing silica sand, limestone, folic acid and other minor ingredients. The mix is heated until it melts at about 1260 °C. The molten glass is then allowed to flow through fine holes in a platinum plate.

The glass strands are cooled, gathered and wound. The fibers are drawn to increase the directional strength. The fibers are then woven into various forms for use in composites.

Aramid Fiber Reinforced Polymers (AFRP)

Aramid, derived from "aromatic polyamide," encompasses a group of high-performance synthetic fibers renowned for their exceptional strength and heat resistance. Prominent examples include Kevlar, Nomex, and Technora. Aramid fibers are typically produced through a chemical reaction involving an amine group and a carboxylic acid halide group, commonly facilitated in a liquid concentration of sulfuric acid. This process results in the formation of crystallized fibers, which are subsequently spun into larger threads for weaving into ropes or fabrics. The resultant aramid materials exhibit remarkable tensile strength, lightweight properties, and resistance to abrasion, making them indispensable in a myriad of applications ranging from ballistic protection to aerospace engineering.

Properties of CFRP

- Carbon fiber reinforced polymer (CFRP) is alkali resistant.
- Carbon fiber reinforced polymers (CFRP) are resistant to corrosion; hence they are used for corrosion control and rehabilitation of reinforced concrete structures.
- Carbon fiber reinforced polymer composite has low thermal conductivity.
- CFRP composites have high strength to weight ratio and hence it eliminates requirements of heavy construction equipment and supporting structures.
- CFRP composites are available in rolls of very long length. Therefore, they need very few joints, avoiding laps and splices, and its transportation is also very easy.
- CFRP composites have a short curing time. Therefore, the application takes a shorter time. This reduces the project duration and down time of the structure to a great extent.
- Application of CFRP composites does not require bulky and dusty materials in a large quantity; therefore, the site remains tidier.
- CFRP composites possess high ultimate strain; therefore, they offer ductility to the structure and they are suitable for earthquake resistant applications.
- CFRP composites have high fatigue resistance. So they do not degrade, which easily alleviates the requirement of frequent maintenance.
- CFRP composites are bad conductor of electricity and are non-magnetic.

Conclusion

The present experimental study is done on the behavior of reinforced concrete beams strengthened by CFRP sheets. Five reinforced concrete (RC) beams having same reinforcement detailing are casted and tested. From the test results, the following conclusions are drawn:

The ultimate load-carrying capacity of all the strengthened beams exceeded that of the Control Beam (CB). However, initial flexural cracks tended to emerge at higher loads in the strengthened beams. Among the various strengthening configurations tested, the U-wrap configuration proved to be more effective than the side-wrap configuration, demonstrating superior performance in enhancing load-carrying capacity.

Interestingly, the beam strengthened with a sustained load (SB-3) exhibited a lower ultimate load-carrying capacity compared to the beam strengthened under normal conditions (SB-1). This suggests that the sustained loading during the strengthening process may have affected the structural behavior or performance of SB-3, resulting in a reduced ultimate capacity. Further analysis may be needed to understand the underlying factors contributing to this discrepancy and to optimize the strengthening methodology for sustained load applications.

It shows that act load carrying capacity on site will be little bit lower as compare to laboratory results.

References

1. Lee J, Fenves GL. Plastic-damage model for cyclic loading of concrete structures. J Eng Mech. 1998;124(8):892-900.

2. Chen GM, Chen JF, Teng JG. On the finite element modelling of RC beams shear-strengthened with FRP. Constr Build Mater. 2012;32:13-26.
3. Bousselham A, Chaallal O. Effect of transverse steel and shear span on the performance of RC beams strengthened in shear with CFRP. Compos Part B Eng. 2006;37(1):37-46.
4. Comité Euro-International du Béton. CEB-FIP Model Code 1990: Design Code. London, UK: Thomas Telford; c1993.
5. Chen GM, Teng JG, Chen JF, Rosenboom OA. Interaction between steel stirrups and shear-strengthening FRP strips in RC beams. J Compos Constr. 2010;14(5):498-509.
6. Lu XZ, Chen JF, Ye LP, Teng JG, Rotter JM. RC beams shear-strengthened with FRP: stress distributions in the FRP reinforcement. Constr Build Mater. 2009;23(4):1544-1554.
7. Chen JF, Teng JG. Shear capacity of fiber-reinforced polymer-strengthened reinforced concrete beams: fiber reinforced polymer rupture. J Struct Eng. 2003;129(5):615-625.
8. Chen G. Behaviour and Strength of RC Beams Shear-Strengthened with Externally Bonded FRP Reinforcement. The Hong Kong Polytechnic University; c2010.
9. Mofidi A, Chaallal O. Shear strengthening of RC beams with EB FRP: influencing factors and conceptual debonding model. J Compos Constr. 2010;15(1):62-74.