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Art-of-review on CFRP Wrapping to Strengthen Compressive and Flexural Behavior of Concrete

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ABSTRACT

Strengthening of reinforced concrete structures is given top priority in construction sector across the world. Ageing and load pattern changes will affect the stability of structure may be reduced. In this case, Fibre-Reinforced Polymer (FRP) materials are recognized as vital constituents to solve stability issues of the modern concrete structures. The purpose of present constructive studies of various techniques for FRP retrofit concrete structures because, the FRP material has improves the structural performance in terms of stability, stiffness, strength and durability such that the Fibre-Reinforced Polymers wrapping is one of the techniques to regain the strength of a concrete structures. By various researchers the different wrappings techniques are used to regain the strength and also enhanced the durability of the structure. This paper focuses mainly on various wrapping techniques of FRP sheets for external strengthening of RC structures such as reinforced circular columns, square beams, columns and column-beam joints.

1. INTRODUCTION

FRP is a material composite that is combined with two different materials namely strengthening fiber and polymer matrix. This Sophisticated composite material used extendedly at aviation, navy & car ventures amid from previous couple of decades (1960 onwards) because of their great designing parameters are high stiffness and strength, less density, high fatigue and damping continuance, low thermal conditions and so forth. Structural specialists and therefore the housing industry have started to comprehend the composites as capability of reinforcing materials for several issues identified with the disintegration of infrastructures.

Presently multi day's numerous nations, repair and retrofitting of existing structures have turned into a noteworthy piece of the development movement. The recovery of solid structures is twisting up continuously on account of the need to keep up and upgrade the immense manufactured condition obtained from the twentieth century. Over the latest two decades, there has been an extending energy for using FRP composites to restore and strengthen reinforced structures. The external wrapping of FRP sheets/fabrics is a standout amongst the best procedure. ACI Committee-503 guidelines have different recommendations of FRPC materials included for selection of polymer adhesives (Resigns) for concrete [1]. Rebar's and structural shapes are first applications by using composites. Afterwards, FRPC laminates are used for bridge girders to strengthening of concrete by bonding them to the tension side face of girder [2]. Carbon Fiber / Aramid or Kevlar Fiber/ Basalt Fiber & Glass Fiber are using to increase or to regain the strength of concrete structures.

2. STRUCTURAL ELEMENTS REPAIR AND REHABILITATION

The dominant a part of restoration works contains rehabilitation of previously damaged structures damaged because of seismic activity and nature calamities. Strengthening of concrete structures is additionally needed because of a result by degradation issues which are arising from improper design methodologies, questionable quality of construction. Due to these circumstances the structural rehabilitation has received abundant attention over the past 20 years in the construction sector. For these recent attentions on FRP composites researchers tends to had given, experimental and analytical analysis that had demonstrated that the utilization of this composite materials for rehabilitation of old structural elements is more cost-effective and needs less efforts and duration than the standard construction techniques. So, by means of cost it is most effective than any other rehabilitation technique that is standard throughout the years. Composite materials were initially used for flexural strengthening of RC bridges and also reinforcement of RC columns and brick walls against at the time of seismic activity.

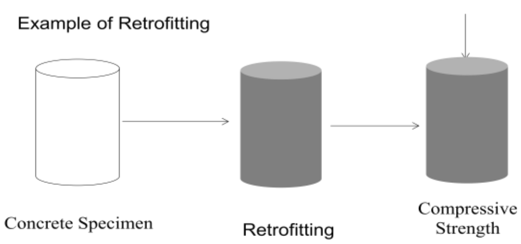


Figure 1. Retrofitting of concrete specimens

Table 1. Properties-fiber reinforced polymer composites [1]

Item	Carbon ®Ber				Aramid ®Ber		Glass ®Ber	
	Polyacrylic Nitril Carbon		Pitch-Carbon		Kevlar 49 @Twaron	TechNora	E-glass	Alkali-resistant glass
	High strength	High-Young's modulus	Ordinary	High-Young's modulus				
Tensile strength (Mpa)	3430	2450±3920	764 ±980	2,940±3,430	2,744	3,430	3430±3528	1,764 ±3430
Young's modulus (GPa)	196±235	343±637	37±39	392±784	127	72.5	72.5±73.5	68.6 ±74.5
Elongation (%)	1.3±1.8	0.4±0.8	2.1±2.5	0.4 ±1.5	2.3	4.6	4.8	2±3
Density (Gm/cm^3)	1.7±1.8	1.8±2.0	1.6 ±1.7	1.9±2.1	1.45	1.39	2.6	2.27
Diameter (mm)	5± 8		9±18		12			8±12

3. FRP STRENGTHENED CONCRETE BEAMS

To increase in stiffness and strength for FRPC plate provided to a couple of components in tension and placed perpendicular to cracks tends [3-4]. The Glass fiber RC polymer composite (GFRP) gives almost 40 % strength improvement is feasible for RC beams, whereas around 200 % strength upgrade is accomplished with (CFRPC) [5]. CFRP plates which are externally bonded can be efficiently used to strengthen RC beams. In between FRP layers delamination is observed [6]. Perfect bonding between reinforcement and concrete-FRPC laminate is observed [7]. Considering the tension in between concrete and FRPC to examine functionality criteria [8]. It was examined that the repairing of bond failure zone to concrete confinement, leads to significant strength gain under flexural stiffness by cyclic loading [9]. Textile reinforced concrete (TRC) performs all around contrasted and CFRP and has subjectively comparative consequences for the general conduct of the repaired beams [10]. U-jacketing is reduced the shear failure of beams and tensile strains in stirrups [11].

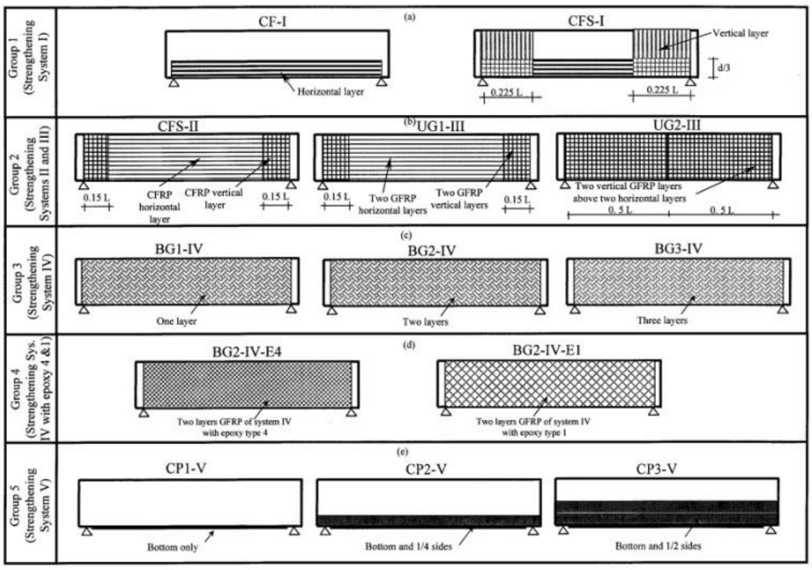


Figure 2. Arrangements of strengthening of tested beams [4]

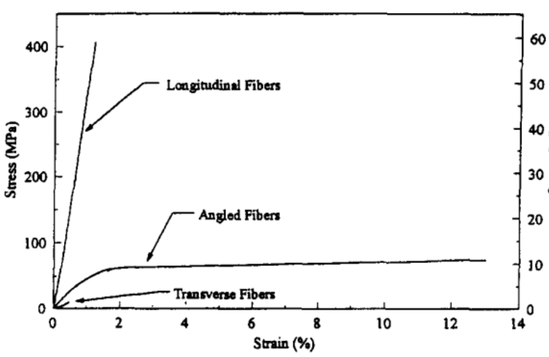


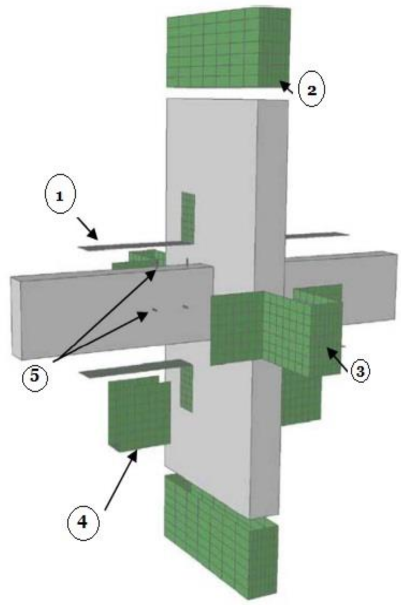
Figure 3. Typical FRP stress strain relationship for various fiber [3]

4. FRP STRENGTHENED CONCRETE COLUMNS

The ductility nature of concrete elements significantly improves the strength by confined wrapping [12]. Shape, size and length of the concrete elements were effect the behaviour of FRP confinement it is very effective when those corners radii would be round edged [13]. Bonding of both concrete and composite will be considerable change by adhesive nature of bonding agent [14]. Ductility of column elements of the structure improved [15]. Uniform stresses around the circular concrete of small-scale square concrete column [16]. Initial later stresses take time to start the intense internal cracking of confined concrete [17]. The hoop direction of fibers increased the stability for columns with a moderate to low slenderness ratio of (l < 40) [18]. Sustainable stress is formed at columns when subjected to eccentric axial loads [19]. For cyclic loading significant variation is seemed in the behaviour of FRP confined concrete when bars are unstable [20]. The FRP confined concrete repaired for corrosion damaged it not only give the strength and ductility it also slows down the percentage rate of the corrosion reactivity [21]. Orientations of fiber fabric wrapping with angles 45°, 0°, 90° and the variations in the layers count would be result the strength [22]. Natural-flax fabric reinforced epoxy polymer material increases in peak load and fracture energy by 6-layer and it is 374 % and 4660 % and also S.E.M analysis show perfect bonding between materials [23]. Elevated temperatures should result the stress parameters in between FRP and concrete [24]. Round edged concrete members will help to decreases the stresses at the corners [25].

5. FRP SYSTEM FOR BEAM COLUMN JOINTS

Being lacking of stiffness in between beam –column joints it imperils the integrity of whole structure. Repairs with FRP will improve the stiffness and strength of joints that should be achieved by the brittle mode of failure to ductile [26]. Non ductile beam-column joint of composite laminate system evidenced the effective upgrade of shear capability [27]. With the employment of touch of composites Specimens, reinforced exploitation of CFRPs show stiffer behaviour than GFRP, Energy dissipation capability is inflated [28]. Seismic execution of the reinforced beam-column joints in terms of their physical phenomenon response, stiffness, and energy dissipation capability is assessed [29]. Considerable improve in the lateral strength moreover ductility by adding CFRP composites to the non-seismic specimen [30]. Shear and ductility of beam-column connections would be effectively responded by impact ply angle under combined axial cyclic loading [31]. Premature delimitation of FRP bonding area in between FRP and concrete is reduced by anchorage system [32]. Alternative modelling for the assessment of seismic retrofitting of joints are to be analysed by STM model [33]. Concrete surface grooving is the method to enhance the bonding of externally reinforced FRP technique [34]. To improve the seismic performance and to retrieve the column beam failure mode the effective method is to implementing wrapping technique of FRP at potential hinge region [35].



Note: ① One layer of CFRP/GFRP L wrap at each corner. ② One layer of GFRP sheet around the column. ③ One layer of GFRP/CFRP sheet along beam axis. ④ One layer of GFRP U wrap. ⑤ Tyfo fiber anchors.

Figure 4. Typical rehabilitation of T-Beam [32]

Table 2. Overview on existing studies by different authors

S.No	Researcher	Wrapping Material	Loading Type	Result
1	Norris et al. [3]	CFRP sheets	Monotonic static loading	Obtained different strengths on different orientations
2	Buyle-Bodin et al. [6]	CFRP plates	Monotonically in four-point bending	De- lamination decreased by the thickness of layers
3	Yang et al. [8]	CFRP plates	Monotonic static loading	Concrete cover separation failure mode in FRP strengthened RC beams
4	Contamine et al. [10]	(TRC)& CFRP	Static load test	Both materials shows similar behaviour
5	Nguyen-Minh and Rovňák [11]	GFF & CFF	Concentrated loads	Brittleness reduced at shear failure mode of beams
6	Saatcioglu and Grira [12]	3 layers CFRP	Compression	Capable of sustaining axial strains in excess of 0.5 %
7	Yan [23]	(FFRP)	Uniaxial compression	Increases the fracture energy by 6-layer of FFRP
8	Soman et al. [25]	Glass Fiber	Concentric Uniaxial compression	Rounding the corners effected the load-carrying capacity of rectangular columns
9	Mukherjee and Joshi [28]	GFRP,CFRP sheets& CFRP	Axial load	Increase in its yield load and initial stiffness
10	Le-Trung et al. [30]	CFRP	Lateral cyclic loading	Seismic performance improved by fiber direction inclined at 45°

6. CONCLUSIONS

Use of FRP in civil construction both in retrofitting and repair has been checked. This study represents the experimental results from concrete structures such as reinforced circular columns, square beams, columns and column-beam joints. External strengthening by composite materials through confinement can upgrade remarkably by both strength and strain ductility subjected to cyclic loading. The strength of the existing concrete members is depended on many factors that to be fabric size, shape, and also the type and condition of the structure.

(1) For RC Beams wrapping or retrofitting with CFRP, GFRP sheets and laminates are strengthened the structure by taking different load conditions, when compared to normal RC Beams FRP Beams are tends to brittle failure due to sudden breakup of FRP sheets at ultimate load.

(2) For RC beams more than 70 % increase in the Torsional capacity of concrete beams by FRP wrapping.

(3) For Columns strength and deformation capacity under eccentric axial loads is improved, increases pressure, leads internal cracking on the axial stress develops in concrete.

(4) FRP jacketing increases the axial load capacity and also the ultimate concrete compressive strain. Round corners enhance the load-carrying capacity of the rectangular columns.

(5) For T-Beams by using Carbon Fiber Reinforced Plastic sheet orientation at an angle of 45° under lateral cyclic loading condition improves the seismic performance.

There are a few gaps which should be addressed. Experimental, analytical examinations are required to understand the behaviour of joints at beam-column from torsion, ductility. For durability point various temperature condition tests is required to break down the execution of concrete structures.

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