STRENGTHENING OF DISTRESSED STRUCTURAL ELEMENT BY USE OF GLASS FIBRE REINFORCED POLYMER

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ABSTRACT

In modern concrete technology, Fibre Reinforced Polymer (FRP) is widely utilized because of its excellent mechanical properties, such as non-conducting, good tensile strength, anti-corrosive , high stiffness etc.,. Reinforced concrete (RC) structural members will gradually lose durability without proper servicing, so these damaged RC structural members need to be repaired and maintained properly, or strengthened. Both the Externally Bonded (EB) and the Near Surface Mounted (NSM) method, both of which use FRP, might be used to reinforce these damaged RC elements. Depending on the FRP used, such as AFRP, CFRP, GFRP, etc., as well as the direction of the FRP, the implementation of FRP to a damaged RC member will result in an increase in strength. The primary objective of this papers is on the application of different FRP types to reinforce distressed RC components by raising their various strength metrics, including axial load carrying capacity, flexural strength, impact load, shear strength, durability and torsional strength. Another major worry in this evaluation is the FRP-enhanced RC member's failure.

1. INTRODUCTION

Traditional techniques including external post-tensioning and steel plate connections are frequently employed to reinforce reinforced concrete beams, slabs, and columns. These techniques have intrinsic flaws, such as difficult application and short durability. For reinforced concrete beams and columns, the connection of FRP plates or thin plates has recently gained a lot of popularity. In reality, the Swiss Federal Material Testing and Research Laboratory reinforced RC beams with CFRP plates using FRP for the first time in the middle of the 1980s.

This chapter is concerned with studying the behavior and strength of RC elements strengthened FRP plates and sheets. Beams strengthened with FRP suffix plate for flexural strength. RC beams wrapping with 'D' and full wrap for shear strength, columns wrap with main fiber horizontal for axial strength and slab wrapped at the soffit for flexural strengthening using FRP wraps. All the discussion are with reference to plain concrete beam and column, which have been the predominant concern of present research.

2. LITERATURE REVIEW CUM. FUNCTIONAL PROPERTIES

2.1. AXIAL LOAD CARRYING CAPACITY OF COMPRESSION MEMBER

Although the improvement in strength is greater in the eccentric loaded column than the concentric loaded column, When wrapped in CFRP, the eccentrically laden column had a more noticeable impact. With more CFRP layers, a column's capacity to support weight rises. The CFRP wrapping also increases the column's ductility.

According to research by **K.P. Jaya et al.**, the weight carrying capability of a column wrapped in 2, 4, or 6 layers of GFRP increases by 8%, 28%, or 32%, respectively, compared to the specimen that isn't wrapped. When compared to unwrapped columns, columns that have been wrapped with CFRP have an average strength gain of 98.3%. Further comparing the improvement in load capacity wrapped in GFRP and CFRP, According to research by K.P. Jaya et al. (2012), while GFRP gains merely 70% with six layers, CFRP gains 98.3% with a single layer.

Rochette et. al. investigation into the compressed rectangular and square column and enclosed with aramid and carbon. The author came to the conclusion that an excessive amount of confinement causes a highly abrupt and devastating event similar to a blast. The confinement effect is inversely correlated with the cross-sectional form for a specific number of wraps.

Chaallal et. al. had used CFRP wrap in an exploratory inquiry. The specimen featured cross sections that were square, rectangular, and round. They discovered that the CFRP wrapping boosts compressive strength more for square or rectangular sections than the circular sections. Additionally, they found that the compressive strength significantly rises as the number of wrapping layers grows. The results also demonstrate that, when compared to controlled specimens, concrete column wrapping could increase strength by up to 90%.

Fam A. et, al. presented Experimental results of 3 short beams and 5 short columns composed of rectangular filament wound tube (CFRFT) filled with GFRP concrete. The tube includes fibres with a longitudinal axis orientation of 450 and 900 w.r.t. Additional longitudinal fibers are provided in the flange to improve flexural stiffness. The beam is made up of "partially filled concrete and fully filled tubes, which has a central hole to reduce its own weight using tubes of two different sizes, the impact of the reinforcement ratio was investigated. Concrete-Filled Rectangular Steel Tubes (CFRTSTs) and CFRFTs with comparable reinforcing ratios were tested for flexural behavior. The eccentricity ratio (e/h) of 0, 0.09, 0.18, and 0.24 was investigated for short columns, where (h) is the section depth. To assess the restraining effect, transverse strain is measured across the concentric load column's perimeter. Studies have revealed that CFRST is a workable system that can provide equivalent flexural strength to CFRST and that CFRFT is a feasible system that can do the same. The rolled tube's construction and increasing failure cause the beam to behave somewhat non-linearly. Compression fails despite the internally drilled CFRFT beam's overall strength-to-weight ratio being 77% higher than that of the fully filled beam. The constraining effects of the CFRFT columns can be reduced by enlarging them.

2.2. FLEXURAL STRENGTHENING

In their investigation of reinforced concrete beams, Philip et al. used CFRP, GFRP, and AFRP as externally bonded materials that were adhered to the tension side of the span. Researchers discovered that using FRP plates enhances stiffness by 17% to 99% and increases the flexural strength of strained beams by 40% to 97%.

D. Kachlakev et. al. When researchers reproduced four beams from a current bridge and upgraded them with GFRP and CFRP for their inquiry, They found that the reinforced beam's ability to support static loads rose by almost 150%. According to the analysis, the bridge's retrofitted GFRP and CFRP beams could readily support the bridge's structural requirements, which include a moment of 868 KN-m and static load of 658 KN. They also discovered that the midspan failure under flexural in the GFRP-retrofitted bridge beam was caused by the yielding of the tension failure, which represented a 31% improvement over the control specimen. According to this study, using CFRP rather of GFRP results in higher stiffness and greater durability.

In their study, Ning Zhuang et al. looked at damaged RC beams that had been reinforced with CFRP composites. They had used an aged, distressed animal for their experimental investigation.

In order to perform the flexure test on the beam specimen for the bridge, which had a length of 2300mm and cross section of 200*250mm; four points of load were applied. They came to the conclusion that the best and most effective way to strengthen badly damaged RC beams is to use externally bonded CFRP sheets. According to their research, using CFRP helps the yield increase from 5% to 36%.

According to Jamal A. Abdalla et al., the application of Galvanized Steel Mesh (GSM) and CFRP has their own benefits as well as drawbacks. The major drawbacks is that the bonded beams made of CFRP and GSM lack ductility, so Aluminium Alloys (AA) are used to address this issue. They had conducted an experimental investigation using 6 beams put through a flexure test for this purpose.

The conclusions show an enhancement in ductility and flexural strength. When compared to beams bonded with GSM and CFRP alone, the examined beams of AA with high density steel mesh (SMH) and AA with CFRP exhibited strain capacities that were 4.55 and 6.52 times higher, accordingly. Due to the hybrid GSM and AA laminate used to strengthen the beam, the flexural capacity rises by about 28%.

Mohammed A. Mashrei et. al. analysis using experimentation to compare the ability to enhancement of RC reinforced by groove-bonded CFRP using the EBRIG and EBROG procedures to unreinforced beams. Several methods are used to enhance this 13 RC beam. They found that reinforced RC beams might be able to support higher weight Traditional CFRP strengthening has only enhanced the capacity to handle loads by 16.2% with a single layer application and by 77.5% with two layers of wrapping. EBROG and EBRIG have improved the capacity to carry loads by 62% and 95%, accordingly, by placing a single longitudinal layer of CFRP sheet on grooves.

Lamanna et. al. examined the practise of fastening fibre-reinforced polymer (FRP) reinforcing strips to concrete constructions, which needs a lot of time and labour that is only somewhat experienced. They suggested an alternative method: employing a commercially available powder-actuated fastening mechanism to attach FRP strips to concrete. Predrilling, several fastener lengths and layouts, and three different strip moduli's effects were investigated. Three of the reinforced beams with mechanically fastened FRP strips demonstrated strengthening on par with the reinforced beams with bonded FRP strips.

Sharif et. al. As part of the inquiry on the repair of RC reinforced concrete beams, the structure was initially loaded with epoxy resin-bonded glass fibre reinforced plastic panels. In order to fix the RC beams with plates and attach them to the beam ceiling, they were loaded to 85% of their maximum bending capacity. To assess the failure brought on by the significant concentration of peeling stress in the board's reduction zone, the thickness of the board was adjusted. To stop the aforementioned failures and guarantee ductility, several repair and anchoring techniques were used. The load-deflection curve acts as a representation of the repaired beam, and several failure modes are investigated.

2.3. SHEAR STRENGTHENING

A.Bukhari et. al. has examined through experimentation how much the usage of CFRP boosts shear strength. In their study, they investigated seven continuous beams with rectangular cross sections, one of which was a control specimen and the other six were covered in CFRP. They determine that using CFRP significantly increases shear strength, and they also determine that 45 degrees is the ideal angle at which to install FRP in order to achieve the greatest increase in shear resistance.

Thanasis C. Triantafillou his research tries to provide an analytical framework that adheres to the code. This study also demonstrates the FRP orientation. Testing of 11 beams reinforced with CFRP is part of the experimental analysis, and the analytical portion of the investigation is concerned with creating a model that could illustrate the role of FRP in beam shear capacity. According to the According to the study's findings, this FRP reinforcement technique is very effective. To maximise the FRP's efficiency, it should be oriented closer to the diagonal crack's perpendicular.

Haya H. Mhanna et. al. had carried out an experimentation in which a distressed RC beam with a shear resistance deficiency was strengthened using CFRP sheets that were externally bonded and wrapped in full wrapping and U-wrapping , respectively. In this inquiry, a T-beam is analysed, and two distinct T-beam specimens are also made. In the first, the entire depth of the beam is strengthened, whereas in the second, the height of the web is strengthened (WBR1). The study found that the fully wrapped WBR1 and WBR2 shear strengths increased by 69.28% and 201.63%, respectively, while the shear strength of the beam enhanced with U-wrapped CFRP increased by 114.82% in comparison to the control specimen. According to this research, full wrapping would also provide the RC beam more ductility than U-wrapping.

D Kachlakev et. al. had created a copy of an existing beam to conduct an experimental inquiry. According to the study, adding GFRP (Glass Fibre Reinforced Polymer) for shear can make up for the lacking of stirrups, which causes the RC beam to fail by steel yielding (under reinforced section) at the mid span. The greatest ultimate deflections permitted for the control beam are increased by 200% by using GFRP. A significant diagonal crack causes the control beam to fail, and it is shear insufficient.

2.4. TORSIONAL STRENGTHENING

A.Ghobarah et. al. After conducting an experimental investigation on torsion strengthening, 8 rectangular cross-sectional beams with GFRP and CFRP wraps along with three controlled specimens with varied configurations were cast. In this analysis, the RC beam is subjected to pure tension, angle of the beam's twist, the torsional capacity and strain are all noted. The controlled specimen's torsional capacity increases by roughly 72%. This study suggests, after a number of investigations, that the whole wrapped design is superior to employing merely strips. It also suggests that the best FRP angle is 450 degrees since it increases the RC beam's ductility and torsional strength.

Vishnu H. Jariwala et. al. performed an experimental research. For this, 14 beams were cast for the analysis, GFRP wrapping was employed for reinforcement, and a combined bending and torsion test was performed. The usage of GFRP strengthening also increases ductility. Their findings indicate that the RC beam's torsional strength increases, and the study also reveals that the angle of twist increases at the time of the first crack. Remember that the diagonal strips have a greater effect on torsion resistance than the vertical strips.

Punam Patil et. al. their research aims to assess and compare the efficacy of variously configured epoxy-bonded GFRP and CFRP. For this experiment, 30 rectangular cross section beams were used in total. Depending on the slenderness ratio, the debonding of FRP or crushing causes failure of CFRP-enhanced RC beams. The study's findings show that CFRP has a longer fatigue life than GFRP, that CFRP has stronger torsion resistance than GFRP, and that in an alkaline environment, CFRP is more durable than GFRP.

Shraddha B. Tibhe et. al. conducted research to ascertain how RC beams were reinforced with GFRP and CFRP behave in a torsional manner. For this analysis, 39 rectangular specimens were cast, of which 18 were wrapped in CFRP, 18 in GFRP, and 3 were control specimens. When compared to control samples, they found that specimens wrapped in CFRP and GFRP had higher torsional moment capacities by 60.47% and 47.46%, respectively. According to studies, the minimum and maximum increases in torsional capacity wrapped with CFRP are additionally 40.2% and 101.8%, respectively. The GFRP's torsional capacity increased by 8.76% and 83.49%, respectively, which are the biggest and lowest improvements. Angle of twist, ductility, and torsional resistance all improve.

3. RESULTS

3.1. Failures Pattern from CASE STUDIES

S. No.	Reference	Technique of Strengthening	Type of FRPused	Location ofFRP	Modes of Failure
1	Sabau et. al.(2018)	NSM	CFRP	Side NSMstrips	Crushing of concrete caused by an intermediate fissure brought on by debonding
2	Sabau et. al.(2018)	NSM	CFRP	Bottom NSM strips	concrete cover separation
3	Teng et. al.(2006)	NSM	CFRP	NSM strips are accessible at mid span only	separation of concrete from concrete cover
4	Teng et. al.(2006)	NSM	CFRP	NSM bottom strips along 97% of beam	Concrete crushing and cover separation
5	Hawouldeh et. al. (2006)	EB	CFRP	Along soffit of the beam	Debonding of FRP from the surface of the RC member and steel yielding
6	Hawouldeh et. al. (2006)	EB	GFRP	Along soffit	Locally debonding and concrete crushing
7	Hawouldeh et. al. (2006)	EB	Hybrid	One layer of GFRP and one layer of CFRP	Concrete crushing and flexural crack and locally debonding
8	Attari et. al.(2014)	EB	CFRP	Parallel to theaxis	Concrete crushing with FRP rupture
9	Ebead and Saeed (2017)	EB	Hybrid	Pultruded CFRP and GFRP plate	Steel yielding with debonding
10	Ary and Kang (2012)	EB	CFRP	Fully wrapped strips which is located at a distance equal to half of depth	Rupture in FRP strips

11	Ary and Kang (2012)	EB	CFRP	U-wrapped strips which is located at a distance equal to half of depth	Debonding
12	Castilo et. al.(2019)	EB	CFRP	U-wrapped strips with straight CFRP anchor	FRP rupture along with concrete crushing
13	Adhikary and Mutsuyoshi (2004)	EB	CFRP	Two vertical sides wrapped with single layer of FRP which are spaced at a distance equal to half of depth	Cover Separation along with FRP rupture in horizontal direction

Table-3 Shows location of FRP and different failure modes.

3.2. FAILURE OF FRP-STRENGTHENED REINFORCED CONCRETE BEAM

Since GCamata et al. (2004) outlined the many failure points from which an RC beam covered in FRP would fail, the failure would come from the weak links. Depending on the weak point in the system, one of three things would happen: the FRP would debond from the surface of the RC member, the steel would yield, or the concrete would crush.Failure of RC reinforced happens for a variety of reasons, including FRP debonding, concrete crushing, primary reinforcement yielding, etc.

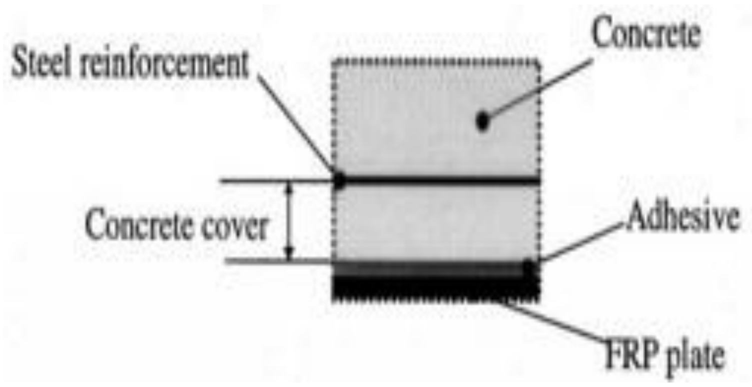

Fig.1. Failure Zones in FRP-strengthened RC member. Camata et. al. (2004).

4. CONCLUDING REMARKS

This chapter is all about the work done by various researches done on Retrofitting of distressed structural element (i.e., flexural strengthening, shear strengthening, torsional strengthening, axial load carrying capacity of column).

All the research shows that the strengthening of distressed structural element is most efficiently done by the use of FRP.

The research work also shows that the by use of FRP the strength of the concrete increases tremendously even most of the time the strength after retrofitting exceeds the actual strength or characteristic strength of the concrete.

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