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REINFORCED CONCRETE BEAM STRENGTHENING USING GLASS FIBRE REINFORCED POLYMER

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Abstract: *Various existing strengthened concrete structures all over the entire world are in critical need of repair and restoration because of decline due to multiple factors like venerable, improper maintenance, corrosion of steel reinforcement, marginal design, poor construction, use of inferior material, design demands due to increased service loads, exposure to harmful environments and damage in case of seismic events like earthquakes and improvement in design guidelines. The present study is based on the experimental study of glass fibre reinforced polymer (GFRP) strengthened reinforced concrete beams. To check the shear reinforcement efficiency of the RC beam, externally use GFRP compounds with epoxy resin adhesive and evaluate the highest performance. The Utility Fiber Reinforced Polymer (FRP) composite is a highly effective technology for repairing and strengthening structures that have become structurally weak during their useful life. FRP composite reinforcement structures offer a convenient and economical alternative to traditional restorative structures and materials. In the predominant study, an experimental investigation was carried out to observe the bending and shear behavior of reinforced concrete (RC) girders through the use of glass fiber reinforced polymer sheets. Beams were strengthened with 1.2 mm Epoxy Bonded Glass Fiber Reinforced Polymer ((GFRP)) lamination using epoxy resins and tested to fail using a symmetrical two-point loading system. Total 9 beams of size 150 mm X 150 mm X 1000mm were casted initially out of which 3 beams were controlled beams and the rest 6 beams were strengthened with different combinations of GFRP laminate such as U-wrap, Bottom Wrap and Side U-wrap.*

Keywords: *Glass fibre reinforced polymer, Fiber reinforced polymer, Strengthening, Reinforced Concrete beam, epoxy.*

I. INTRODUCTION

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There are many existing concrete structures This includes homes, bridge decks, girders, and marine systems that have only deteriorated due to heavy maintenance, poor maintenance, corrosion of metal reinforcement, fringe design, poor construction, poor fabric use, design requirements within multiple service loads, and advertising of harmful environments and damage, in earthquake situations such as earthquakes and improvements in design tips. These degraded systems cannot handle the load for which they are designed. Therefore, maintenance, rehabilitation, and improvement of structures is some of the most important topics in civil engineering areas. Therefore, these forms of structures need complete replacement or strengthening. Instead of replacing systems, a more reliable solution is to completely disassemble the structure and continue reinforcing the damaged structures, which can also increase the shape's sporting load capacity and the shape's durability. Structural reinforcement involves enhancing the ability of structural elements to safely withstand internal forces caused by loads, including bending, shear, axial, and torsion. Certain reinforcement techniques, including section growth, externally linked reinforcement, tension, and additional support, may be used to achieve greater strength and serviceability. Carbon Fiber Reinforced Polymer (CFRP), Glass Fiber Reinforced Polymer (GFRP), and Armid Fiber Reinforced Polymer (AFRP), sheets, strips, and rods are commonly used as reinforcing materials due to their soft weight, excess electricity, and bright corrosion resistance [1].

Glass fibre reinforced polymer (GFRP) Slabs/slabs are widely used to reinforce weakly reinforced concrete (RC) systems. Over the past decades, the adoption of adhesive composites to reinforce existing concrete systems has progressively improved. The behavior of the intersection between GRP and urban reinforcement has been extensively studied, and some studies have been followed by design suggestions for externally realized GRP reinforced concrete systems. In current years, much research is focused on strengthening designed and poorly designed social responsibility structures. Khalifa and Nanni [2]. GFRP significantly increases the bending electricity of the masonry wall. Civilian structural failure indicates a loss of structural integrity due to potential athletic weight loss. In a well-designed device, a local failure should not aim at the immediate or even recent destruction of the entire shape of any load. Parretti and Nanni [3] provided an evaluation of the design to fortify RC participants using near-ground connected FRP (NSM) vehicles. Suleiman et al. [4] conducted empirical and numerical studies to study the applicability of CFRP sheets for periodic reinforcement of RC beams. They developed a limited detailed version by incorporating concrete cracking, the bonding between concrete and metal reinforcement, and the bonding between concrete and carbon fiber reinforced plastic panels. Dias and Barros [5] evaluated the efficacy of shear reinforcement delivered by externally bonded reinforcement (EBR) and NSM CFRP. The effect on the percentage and slope of the slices in terms of NSM shear strengthening performance was investigated. Shear failure in reinforced concrete (RC) girders occurs unexpectedly without warning signals and can lead to disastrous results. RC beams should reach a point of shortcoming due to various reasons, besides design flaws, wear of the shear reinforcement (stirrups), and boom in tie blocks appearing in the structure—effective bonding period, GRP sheet orientation, etc. In contrast, bound probes addressed the reaction of continuous shear reinforced RC beams.

II. LITERATURE SURVEY

Reinforced cement concrete is an incredibly common building material used to construct structural additions such as beams, columns, slabs, etc. One of the primary drawbacks of RCC is its susceptibility to environmental aggression. It can significantly reduce the electricity and life of the structures. The structurally deteriorating RC structures are restored because structural details fail to provide the best electrical and serviceability. Some of these systems are in such dire conditions that they need to be replaced. Two strategies are usually followed to strengthen the beams concerning the preferred electrical reinforcement: bending strengthening or shear strengthening.

Several existed works conducted experimental on the Strengthening of RCC beam using GFRP. Some of the research works are given below.

Radhikesh et al.[2018] The fairing test is based entirely on the empirical research of GFRP (Glass Reinforced Polymer) concrete beams. They studied the behaviour of control and GRP-supported beams under static load. The practical approach of the study facilitates the evaluation of the overall performance of the RC package with GFRP compounds of different styles. To explore the shear strengthening performance of RC beam, externally use GFRP compounds with epoxy resin adhesive and examine the highest overall performance. They determined the increase in sheer energy, hardness, load capacity and flexibility through the application of GFRP compounds. The reinforcement plan should be cost-effective. The validated experimental methods are then used to read the efficacy and efficacy of different reinforcement schemes using an epoxy impregnated GFRP fabric. The range of layers, orientation, and fibre distribution is taken into account. It considering the parameters in all GFRP-reinforced girders, the failure mode was changed from shear to bend failure and confirmed a remarkable improvement in ductile behaviour. The GFRP-reinforced beam indicates an increase in shear capacity, hardness, load capacity and flexibility at 38.41. % and 13. 47% respectively in the beam control assay. Based on empirical research, schemes are recognized that provide optimal development in the overall performance of the beam reinforcement.

Ahima Ashokan et al. [2019] Enhancing RC packets is important to achieve the expected service life of the systems. The life of the RC beam can also be reduced due to improper beam design, entry into chemical retail stores, and many more. Reinforcement of RC girders with sheet metal and FRP is most popular all over the world. Several researchers have tested various FRP compounds in conjunction with aramid, glass, and carbon to reduce the negative aspects of metals, including corrosion, excessive unit weight, and conduction problems. The advantages offered by this fabric are abrasion resistance, high tensile strength, advanced flexibility, lightweight, and the rarity of the extra heavy system in the application. The rafters are reinforced with a distinctive quantity and composition of the fibreglass panels. Four girders are cast and pre-loaded before being coated with GFRP and then checked for final load and bending strength. A study was conducted to investigate residual sports load capacity and beam failure pattern using externally bonded GFRP fiberboard.

R.Murugan et al.[2019]This study demonstrates the bending behaviour of GFRP square concrete girders, slotted bars and sand-drawn reinforcing bars. Girders are cast with popular concrete mix grade M30, with a reinforcement ratio of 0.73%, compared to traditional metal-reinforced girders. A total of 5 rectangular girders, 125mm x 250mm x 3200mm, were cast. The bending test has been converted to a load lower than the stator. The experimental prediction was changed to monitor the maximum load capacity, crack propagation, crack width and beam failure patterns. The results indicate that both types of GRP reinforcements are on par with conventional metallic reinforcements.

Jun-Hyuk Song et al. [2019] Polyurea coating helps improve the flexibility and strength of structural personnel. Fiber Reinforced Polyurea (FRPU) provides excessive loading potential and is achieved by definitely spraying it on the organ's surface. In contrast to current reinforcement methods, the FRPU cladding approach can prevent the flexibility of concrete beams from deteriorating and peeling off the concrete surface. In this test, 20 concrete girders were admired for their durability and flexibility using polyurea or FRPU reinforcement.) The test variables covered the type of reinforcing fibres, coating thickness, and the weight-to-content ratio of the fibres inside the FRPU. Furthermore, all samples' load capacity and mechanical behaviour were compared according to the content of mineral fibres, ground glass fibres or carbon nanotubes (CNTs). Specimens reinforced with polyurea or FRPU were confirmed to maintain the sport load capacity and bending flexibility at a certain level after the concrete failure of the midsection concern.) Concrete beams eventually failed to break through polyurea or FRPU without disintegrating. Experiments were conducted to demonstrate the effect of reinforcement with FRPU and to determine its superiority

Siew Choo Chin et al.[2020] This article presents the structural behaviour of reinforced concrete (RC) girders with and without openings externally reinforced with bamboo fiberboards (BFRC) in shear and bending, respectively. Mechanical burners comprise the tensile and flexural strengths of the entire BFRC epoxy, polyester and vinyl sheet with 0%, 10%, 20%, 30% and 40% size fiber fractions. A set of fourteen beams was cast to evaluate the structural behaviour of RC beams reinforced with BFRC panels. All packages were tested to failure under the deviation of four factors. The results presented were in terms of load skew behaviour, failure pattern, and crack sampling. The performance of BFRC panels mainly based on epoxy, polyester and vinyl ester in shear reinforcement of slotted RC girders was also evaluated. The results indicated that the slots within the shear region reduced the single beam power of the control beam to approximately 52%-55%—shear reinforcement for slotted RC beams. The use of BFRC sheets mainly based on epoxy showed a significant improvement in restoring structural potentials of the beam up to 32-36% better than non-reinforced beams. Meanwhile, reinforcing

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the RC beams in bending with epoxy-based BFRC plates could recover the true beam capacitance up to 98% of the treated beam. It is made of bamboo fibre reinforced with epoxy, polyester and vinyl resins with a controlled 40% fibre percentage to restore the true potential of the beam by up to 82% Note that BFRC panels should deflect and reduce crack formation away from the reinforced location as well as offer beam ductility.

Nino Spinella [2019] The reaction behaviour of bio-shear reinforced concrete beams has become a subject of much research, and several studies have been presented in the literature. However, various problems, such as FRP deformation in shear failure and the interaction between the internal and external reinforcement, are not fully understood. This article presents an analytical model of the reaction behaviour of shear reinforced concrete beams using FRP. The proposed system is entirely based on the modified pressure field theory and can reproduce the entire load-displacement curve. The stress and strain fields were carefully calculated for each loading step. The effective failure stress of FRP reinforcement was investigated using unusual techniques. Instead, the stress reduction of the stirrups in the presence of the compound external reinforcement was omitted and taken into account, thus evaluating the numerical predictions. The accuracy of the proposed transcript was assessed using a database of 71 FRP-enhanced samples. The results showed that the proposed version produced valid effects, and key parameters' influence on the predictions was highlighted. In addition, obtained a simplified formula for evaluating the cutting energy.

Esmaeel Esmaeeli et al. [2016] This document focuses on the general performance of the proposed scheme for seismic strengthening of weak shear connections of 3D reinforced concrete angle beam-column connections. This technology consists of GRP sheets and a metal cage and no longer requires drilling into existing concrete elements to install GRP panels. Two complete contacts compared to the beam shaft were made without any transverse reinforcement of their common area. One was tested in the build condition, taken as a tampered sample, even when the other was altered for examination after hardening. The seismic behavior of these samples was studied under the imposed cyclic load pattern in conjunction with the axial load of the fixed shaft. Comparing the results of these samples revealed a significant improvement in the seismic response of the reinforced sample. This congruence with the software feasibility of this approach indicates the suitability of the proposed strengthening scheme to practical programs. Finally, the experimentally acquired combined shear electrostatics from the manipulated and conditioned samples is compared with that expected with the help of the bonding and elastic binding model relationships and ACI-318, respectively. This evaluation found a high-quality prediction of joint fracture strength for both built and reinforced specimens.

III. OBJECTIVES OF THE WORK

1. Calculate the effectiveness of GFRP technology in reinforced concrete (RC) girders.
2. Study of the maximum bearing capacity of samples reinforced with the glass fiber reinforced polymer (GFRP) coating technology.
3. Measure the efficiency of Glass Fiber Reinforced Polymer (GFRP) fabrics in terms of utilizing the strength and deformation ability of FRP.
4. Evaluation of the results obtained from RC beam displacement and reinforcement of RC beams with different combinations of glass fiber reinforced polymer (GFRP)).

IV. MATERIALS USED

a) Cement

Ordinary Portland Cement (OPC) 43, Wonder Cement grade conforming to IS: 8112-1989 has been used in recent experimental work. Examined for physical housing as per Indian Standards. The properties of ordinary Portland cement are presented in Table 1

Table.1 Portland cement

S.No	Description of test	Results obtained	Requirement of IS: 8112-1989
1	Initial Setting Time	153 minutes	Min. 30 minutes
2	Final Setting Time	243 minutes	Max.600 minutes
3	Specific Gravity	3.125	3.15

b) Coarse Aggregate

Coarse aggregates collected from quarries and approved aggregates range from 10mm to 20mm and have a sufficient gravity of 2.87 coarse mixes. Assessments are completed in the coarse mix according to IS 2386-1963.

c) Fine Aggregate

It uses river sand passing through a 4.75 mm sieve and has a specific gravity of

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2.66. The sector for the classification of high-quality mixtures is the second area. Physical housing with excellent aggregates is specified according to IS 383-1970.

d) Water

Water is available on campus as per the water needs of concrete and treatment as per IS: 456-2000.

e) Glass Fiber Reinforced Polymer (GFRP)

The uni-directional glass-fiber-reinforced polymer (GFRP) strips of 1.2 mm thickness were used to strengthen the RC beams, as shown in Figure.1. Adhesives have been used to make certain distinct bonds between concrete and layers. Laminate Houses of Glass Fiber Reinforced Polymer (GFRP) made by the manufacturer in Pondicherry Muthirapalayam, Tamil Nadu, India.

Fig.1 (GFRP) laminate of thickness 1.2 mm for strengthening of beams

f) Epoxy Resin

Epoxy resins are low molecular weight primary polymers that can be processed into various positions. A thermosetting polymer is formed by reacting an epoxy "resin" with a polyamine "solid.".

g) Reinforcement

The longitudinal reinforcements used were 10 mm diameter HYSD Fe 415 rods and eight mm diameter rods as suspension rods. In addition, stirrups were fabricated with 6 mm diameter Fe 250 medium metal rods.

h) Mix proportion of concrete

Concrete mix dosage of grade M 30 was achieved according to Indian Standard 10262: 1982 and Indian Standard 10262: 2009. Based on the effects of the parts, the concrete mix design was converted to finishing. The ratio of water to cement adopted in the design of the mixture becomes 0: 45. The mixing ratio of M30 concrete used in the recent examination is presented in Table 1.

Table.2 Mix proportion of M30 Concrete

Content	Quantity		
Cement	406.9kg/m^3		
Water	175 kg/m^3		
Fine aggregate	618.716 kg/m^3		
Coarse aggregate	1151.7 kg/m^3	20 mm	692.12 kg/m^3
		10 mm	459.6 kg/m^3
w/c ratio	0.43		

i) Casting of Cubes

For concrete cube compression tests, cubes of size 150 mm x 150 mm x 150 mm were used. The cubes were tested at 7 and 28 days of curing using a compression testing machine.

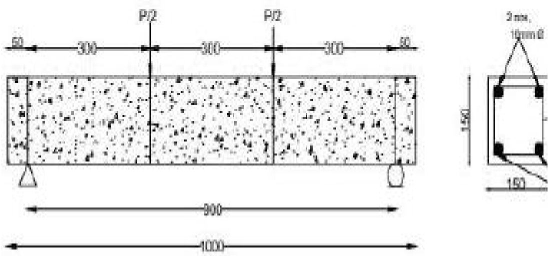

Fig.2 Loading Diagram and Reinforcement detailing of the beam

The parameters influence the overall deformation of the specimens and included different:

1) Stirrup strength;

2) shear reinforcement ratio;

3) Type of flexural reinforcement, and

4) Type of GFRP.

Fiber-reinforced polymer (FRP) is a good reinforcing material. FRP has been widely used within study programs. FRPs consist of high-energy fibers embedded in a resin matrix. The fibers are stronger than steel in the longitudinal path and usually have a weak lateral orientation. In general, FRP does not indicate tensile behavior, and thus, the stress and deformation behavior can be considered linear elasticity to failure. GFRP (glass fiber reinforced polymer) is used in the panels. GFRP has a high strength-to-weight ratio. GFRP is not affected by the use of acid rain, salts, and peak chemicals. GFRP is an engineered fabric consisting of polyester or epoxy resin reinforced with glass fibers. In previous research, FRP modification was able to reduce the variance inherent in URM. On this note, 1 sample was changed to buffered unreinforced, and six samples, with specified reinforcement configurations, were reinforced by a layer of GFRP using epoxy resin with a mixture of 1:10 hardener per lot. The material properties of GFRP and epoxy resin are given in Table 3 and Table 4. Figure 3 shows the enhancement of the RC package. For each sample, three samples were immunized with GRP

Table.3 Material properties of GFRP

Material	Tensile strength (MPa)	Young's modulus (GPa)	Tensile modulus (GPa)	Bending strength (MPa)	Bending modulus (GPa)	Compressive strength (MPa)	Ultimate Elongation (%)
GFRP	2400	70	7800	204	6770	900	2

Table.4 Material properties of Epoxy

Material	Tensile Strength (MPa)	Tensile shear bond strength (MPa)	Compressive Strength (MPa)	Compressive shear bond strength (MPa)	Compressive elasticity modulus (MPa)
Epoxy	20	9.6	50	21	1.5

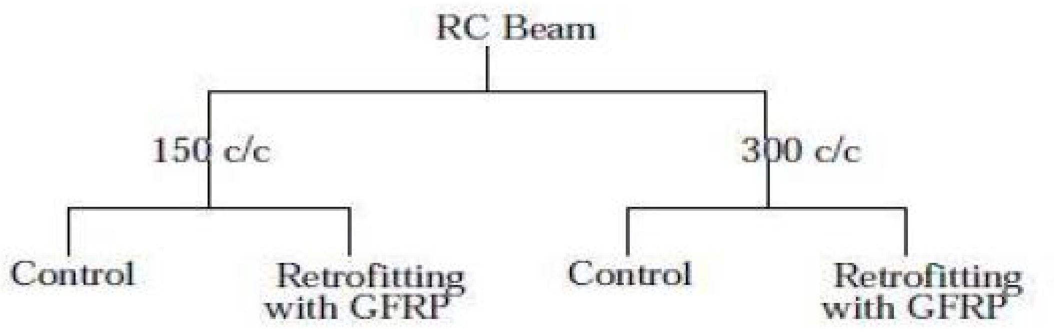

Fig.3 Labelling details with respect to strengthening pattern

V. RESULT AND FINDINGS

This experimental program investigates the efficiency and effectiveness of the GFRP strengthening technique to improve the flexural performance of the controlled beam. Twelve RC beams were tested for center-point loading. Different strengthening configurations have been used. Properties of constituents of the RC beam were determined experimentally. For the casting of concrete beams, the compressive design strength of Cube after 7days is for various specimen no, respectively c1=44.43Mpa, c2=42.2Mpa, and c3=44.43Mpa. Tests were carried out on rectangular reinforced concrete beams with different patterns and types of GFRP sheets. All beams have the same overall cross-sectional dimensions, internal longitudinal reinforcement and stirrup arrangements. The overall length of beam is 1000mm, the width of the beam is 150mm and the cross-section of the beam is 100mm.The length of main bar is 10mm.the value of shear reinforcement is 6mm.The total number of shear bars are used is 6 with 150mm spacing.

Table.5 Compressive Strength of Cube after 7days

S.NO	SPECIMEN NO.	COMPRESSI STRENGTI
1.	C 1	44.43Mpa
2.	C 2	42.2Mpa
3.	C 3	44.43Mpa

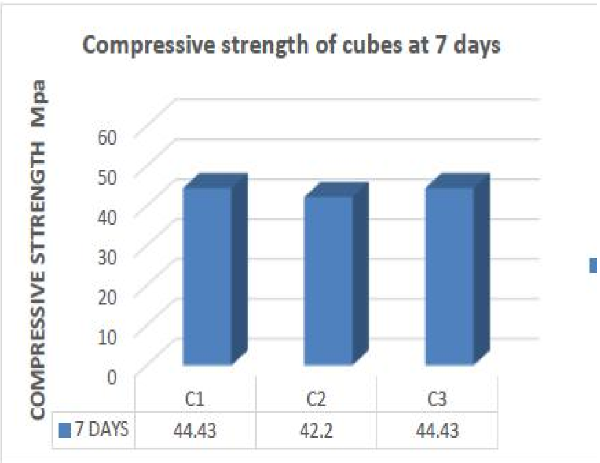

Fig.4 Compressive Strength of Cube at 7 days

Table.6 The compressive strength of cubes for 28-day strength shown in table

S.NO	SPECIMEN NO.	COMPRESSIVE STRENGTH
1.	C 1	53.33 Mpa
2.	C 2	48.8 Mpa
3.	C 3	53.33 Mpa

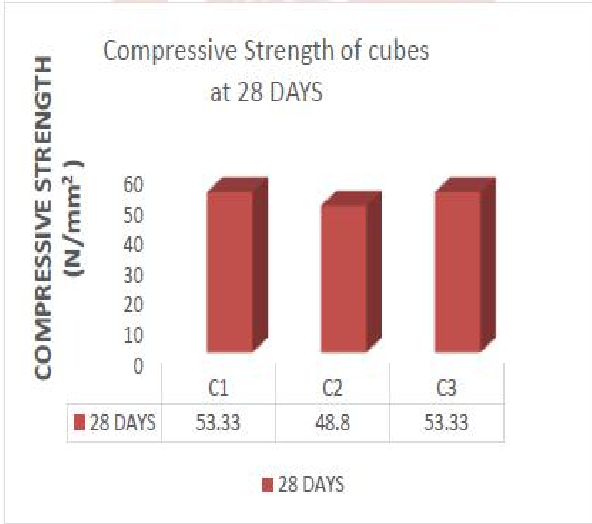

Fig.5 compressive strength of cubes for 28-day

VI. CONCLUSION

The flexural performance of an RC beam with unique reinforcement patterns was studied using GFRP, under the control of central factor loading. The panels are reinforced with patterns. This empirical review demonstrates Glass Fiber Reinforced Polymers (GFRP) as a new generation of reinforcements for non-reinforced brick systems. The brittle behavior of the RC beam is increased while its deformation capacity is strengthened. The experimental conducted on compressive strength of cubes for 7 days and 28 days.

The following conclusions are drawn:

- The yield load and cracks in reinforced girder have higher load as compared to controlled beams.

- The deflection of the beam is reduced due to the U-wrap approach of glass fiber reinforced polymer (GFRP) on the beam compared to the treated beam.
- From previous research, thousands concluded that the energy within the beam is enhanced in a similar way to loading by thirteen% by supplying glass fiber reinforced polymer (GFRP) in the shear region (SFB) and electricity is increased with a 23% boost.
- The beam by providing Glass Fiber Reinforced Polymer (GFRP) in the soles of the beam, in addition to achieving 41% strength, the beam is reinforced with a U-casing (UB) throughout the beam span.

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