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Shear strengthening of reinforced concrete beams using fibre reinforced polymer composites

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ABSTRACT

Since fiber-reinforced polymer (FRP) composites are superior to traditional steel reinforcements, they are widely used in advanced concrete technology. By using a combination of fibres and FRP strengthening techniques, RC beams can have increased strength and ductility. The kind, arrangement, composition, and strengthening method of the fibres in FRP composites in reinforced concrete beams regulate their total strength. Shear deficient specimens were strengthened by using glass and basalt fibre wrapping. Twelve beams were fabricated and tested under the static and cyclic loads. The main objective of the study is to obtain compressive and flexural behaviour from the shear deficient RC beams. This study evaluates the performance of Reinforced Concrete (RC) beams enhanced in shear using basalt fibre and glass fibre. After curing the beams were wrapped with fibres other than the conventional. All the 12 beams were tested under the same loading condition with the four point loading. The shear deficient RC beams do not have required shear reinforcement and hence they fail by shear first. FRP strengthening in the shear zones can increase the shear strength of the beams and hence these strengthened beams fail in flexure first or sometimes as flexure-shear failure.

Keywords: FRP RC Beams; Retrofitting; Strengthening; Static load; Cyclic Load.

1. INTRODUCTION

A fiber-reinforced polymer is known as a fiber-reinforced polymer (FRP) composite. It stands for a class of materials that are included in the group known as composite materials. By spreading particles of one or more materials into another material, which creates a continuous network around them, composite materials are created. FRP composites are not the same as conventional building materials like aluminium and steel. Iron and aluminium are isotropic, however fiber-reinforced polymer composites are anisotropic. As a result, their qualities are directional, meaning that the direction of the fibre implantation determines the optimal mechanical properties. These materials offer excellent corrosion resistance, a high strength-to-density ratio, and practical electrical, magnetic, and thermal properties. They are brittle, though, and the rate of loading, temperature, and ambient factors can all have an impact on their mechanical characteristics. Fibre reinforcement has two main purposes: it carries the load down the fiber's length and gives the fibre strength and stiffness in one direction. In many structural applications where load-carrying capability is crucial, it takes the place of metallic materials. Because of its mechanical qualities, FRP can be used in engineering applications to make considerable improvements in usefulness, safety, and economy of construction. GFRP (glass fibre reinforced plastic) rebars seem like a good substitute for steel reinforcement in concrete. These rebars work well in applications that require long-term corrosion resistance, low conductivity to electromagnetic and electrical fields, a high strength-to-weight ratio, and other similar qualities [1]. The mechanical and geometrical characteristics of the steel columns (steel type, thickness, and diameter), as well as the strength of the concrete, the fibres' bond strength, and the interaction between the confinement caused by the steel pipes and that caused by the fibres, all affect the strength of the 14 circular columns filled with plain concrete and fibre reinforced concrete [2]. The performance and effectiveness of jacketing with FRP wraps as an alternative to traditional repair techniques for corrosion-damaged reinforced concrete columns were investigated in this research [3]. Field exposure-based durability assessment of FRP column wrap systems. Tests carried out subsequent to field exposure reveal significant differences in the degradation mechanisms and failure types of the two systems under examination [4]. The Shear strengthening of RC deep beams using externally bonded FRP systems. The aim of this research is to strengthen reinforced concrete deep beams against shear by using an externally bonded fiber-reinforced polymer system within the

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beam web [5]. The impact of the 16 FRP wrap on the axial strength of columns made of reinforced concrete. When test results of wrapped circular columns are compared with values computed with A23.3-94 (CSA 1994), it becomes evident that the FRP wrap greatly improves the axial strength of circular columns [6]. The axial compressive behaviour of concrete-filled thin steel tubes can be significantly enhanced by the FRP wrap in terms of both ductility and load carrying capability [7]. The test results have also been compared using two models of stress-strain: a cyclic stress-strain model and a monotonic stress-strain model. These models are based on test databases that contain only a limited number of tests for HSC and are restricted to concrete constrained with a FRP wrap [8]. The performance of "Non-Ductile" specimens that were retrofitted with undamaged specimens that were designed in accordance with Indian Standard [9]. Due to full-section enclosure and confinement of concrete, CFFTs are significantly stronger under concentric loading than their corresponding conventional RC counterparts [10]. The torsional moment at cracking and the ultimate torque capacity can be predicted with a sufficient degree of precision, and the elastic and post-cracking response of FRP strengthened RC beams under torsion may be realistically modelled [11]. When the applied load increases, the strain distribution factor progressively rises. The shear span-to-effective depth ratio is the main determining factor. The strain distribution factor decreases as this ratio rises [12]. The impact loads, the failure mode of reinforcing concrete (RC) beams can transition from brittle shear mode to ductile flexure mode [13]. U-Wrapped beams of the same depth, the whole wrapping scheme performs better in terms of raising the shear strength and dramatically enhancing the ductility of the enhanced RC beams [14]. The shear capacity is increased by shear strengthening with CFRP U-wrapped laminates. Nonetheless, the brittle debonding of the laminates is the primary cause of failure [15]. Better shear strength and ductility are obtained by shear strengthening employing several FRP layers along the shear span, followed by U shape and side schemes [16]. The CFRP-ECC composites increased the shear capacity of the RC beams by values ranging from 61.1% to 160.1%. The combining cutting-edge FRP technologies with ecologically friendly materials like M-sand enhances structural performance and strength while adhering to sustainable construction standards and minimizing the ecological footprint of the sector [17]. The available case studies and analytical techniques, the confinement effects of FRP composites under vertical loading situations were examined while raising the vertical resistance of pile foundations [18]. A study was given on the impact of crushed stone sand, a byproduct of crushed aggregate production – on the mechanical properties of steel-fiber-reinforced concrete. The conclusion was that crushed stone sand might serve as a substitute for natural sand [19]. Four full-scale restrained concrete bridge deck slabs were built, and the punched shear had carrying capacities greater than three times the calculated design load. This study examined the effects of a FRP reinforcing layer on the behavior of concrete bridge deck slabs reinforced with FRP bars [20]. The BFRP composite concrete surface caused the basalt fibers to become debonded from the beam surface without breaking [21].

2. MATERIALS AND METHODS

2.1. Ordinary Portland Cement

Ordinary Portland Cement (OPC) 53 grade was mainly used for preparing the specimens. The important properties of cement determined are given in Table 1.

2.2. Aggregate

The river sand confirming to IS: 383 – 1970 (*Reaffirmed 2002*) [22] is used as the fine aggregate and crushed granite stone aggregate of maximum size 20 mm was used as the coarse aggregate. The properties of fine and coarse aggregates are presented in Table 2.

2.3. Steel

The size and diameter of reinforcement was selected with references to IS: 1786 – 2008 [23]. The 8 mm and 12 mm diameter rebars used has been tested for its tensile stress in a universal testing machine. Properties of steel is given in Table 3.

Table 1: Properties of cement.

SL. NO.	TESTS PERFORMED	RESULTS	SL.NO.	TESTS PERFORMED	RESULTS
1	Standard consistency	30 percent	5	Fineness (<90 microns)	5 percent
2	Initial setting time	48 minutes	6	3rd day compressive strength of cement	30.0 N/mm^2
3	Final setting time	310 minutes	7	7th day compressive strength of cement	42.0 N/mm^2
4	Specific gravity	3.14	8	28th day compressive strength of cement	58.5 N/mm^2

Table 2: Properties of fine and coarse aggregate.

SL. NO.	PROPERTY	FINE AGGREGATE	COARSE AGGREGATE
1	Specific gravity	2.67	2.72
2	Fineness modulus	2.62	6.70
3	Water absorption	0.64 percent	0.45 percent
4	Bulk density	1600 Kg/m^3	1600 Kg/m^3

Table 3: Properties of steel bars.

SL. NO.	PROPERTY	STEEL BARS
1	Tensile strength, ultimate	500 MPa
2	Tensile strength, yield	250 MPa
3	Elongation at break	20%
4	Modulus of elasticity	200 GPa
5	Compressive yield strength	152 MPa
6	Bulk modulus	160 GPa
7	Poisson's ratio	0.26
8	Shear modulus	79.3 GPa

Table 4: Properties of fibres.

SL. NO.	TYPES OF FIBRE	TENSILE STRENGTH (MPa)	MODULUS OF ELASTICITY (GPa)
1	Glass fibre	1050–3850	70
2	Basalt fibre	2800–3100	85–87

2.4. Water

Water used in this mixing is to be fresh and free from any organic and harmful solutions which will lead to deterioration in the properties of mortar. Salt water is not to be used. Potable water is fit for use mixing water as well as for curing of beams.

2.5. Concrete

The characteristic compressive strength of concrete used for the study is 30 N/mm^2. The mix ratio adopted is 1:1.48: 2.94: 0.45 (cement: Fine aggregate: Coarse aggregate: Water). The compressive strength of cubes after 28 days water curing was 39.12 N/mm^2.

2.6. Fibre

The fibre choosen frequently controls the properties of composite materials. Carbon, Glass, and Aramid are three major types of fibres which are used in construction. The composite is often named by the reinforcing fibre, for instance, CFRP for Carbon Fibre Reinforced Polymer. The most important properties that differ between the fibre types are stiffness and tensile strain in Table 4.

2.7. Preparation and casting of specimens

The specimens were prepared by casting them in steel moulds. After one day of casting, specimens were demoulded and then immersed in water for curing. After sufficient water curing, the concrete specimens were prepared for FRP wrapping. The following steps were followed for FRP wrapping.

- **Rubbing:** The surfaces of the concrete specimens were rubbed to remove loose and deleterious material with a silicon carbide water-proof paper sheet.
- **Saturant Coating:** The Nitowrap 410 saturant system was made of two parts, resin and hardener. The components were thoroughly hand mixed for 3 minutes before application. Properties of Nitowrap 410 saturant is given in Table 5.

Table 5: Properties of Nitowrap 410 saturant.

COLOUR	PALE YELLOW TO AMBER
Application temperature	15°C–40°C
Viscosity	Thixotropic
Density	1.25–1.28 g/cc
Pot life	2 hours @ 30°C
Full cure	5 days @ 30°C

Table 6: Properties of FRP materials.

PROPERTIES	GFRP	BFRP
	UNIDIRECTIONAL	UNIDIRECTIONAL
Weight of fibre (g/m^2)	920	330
Fibre thickness (mm)	0.90	0.6
Nominal thickness per layer (mm)	1.5	1.0
Fibre tensile strength (N/mm^2)	3400	4840
Tensile modulus (N/mm^2)	73000	86000

- **FRP wrapping:** The first coat of saturant was applied over the primer coat and FRP sheet was confined directly on the surface.

FRP layer was confined around the concrete specimens with an overlap of (¼)th of the perimeter to avoid sliding and debonding of fibres during tests and to ensure the development of full strength. Properties of GFRP and CFRP materials are given in Table 6.

2.8. Experimental investigation

In order to know the mechanical behaviour of FRP confined concrete, concrete specimens were cast and then tested with and without FRP wrapping. The 28 days cured specimens were wrapped with fibre reinforced polymers with single plies. Unidirectional glass and basalt fibre reinforced polymers were used as a component for this study.

3. EXPERIMENTAL RESULTS AND DISCUSSION

Mechanical behaviour of FRP confined concrete specimens were studied with the help of conducting compression and flexural tests. The experimental results show that the specimens confined with carbon fibre reinforced polymer have more strength than the specimens confined with other fibre reinforced polymer in both single and double plies for wrapping after 28 days of curing.

3.1. Compression test on concrete cubes

The test was performed in reference of the IS: 516 - 1959 (Reaffirmed 2004) [24]. A standard size of 150 × 150 × 150 mm plain concrete cubes was used for this experiment. Table 7 presents the compressive strength of FRP confined concrete cubes.

3.2. Compression test on concrete cylinders

The experiment was performed in accordance with IS: 516 - 1959 (Reaffirmed 1999) [24]. A standard test cylinder of 300 mm length and 150 mm diameter plain concrete cylinder was used for this test. Table 8 presents the compressive strength of FRP confined concrete cylinders.

3.3. Flexure test on concrete prisms

The experiment was performed in accordance with IS: 516 - 1959 (Reaffirmed 1999) [24]. A standard size of 100 × 100 × 500 mm simple plain concrete prisms was used for this study. Table 9 presents the flexural strength of FRP confined concrete prisms.

Table 7: Compressive strength of FRP confined concrete cubes.

SPECIMEN DESCRIPTIONS	COMPRESSIVE STRENGTH (N/mm²)
Unconfined concrete cubes	39.12
Unidirectional GFRP confined concrete cubes with fibres perpendicular to loading	51.10
Unidirectional BFRP confined concrete cubes with fibres perpendicular to loading	56.26

Table 8: Compressive strength of FRP confined concrete cylinders.

SPECIMEN DESCRIPTIONS	COMPRESSIVE STRENGTH (N/mm²)
Unconfined concrete cylinders	32.94
Unidirectional GFRP confined concrete cylinders with fibres along the circumference	45.07
Unidirectional BFRP confined concrete cylinders with fibres along the circumference	49.51

Table 9: Flexural strength of FRP confined concrete prisms.

SPECIMEN DESCRIPTIONS	FLEXURAL STRENGTH (N/mm²)
Unconfined concrete prisms	3.26
Unidirectional GFRP confined concrete prisms with fibres along the length	6.77
Unidirectional BFRP confined concrete prisms with fibres along the length	8.31

4. CASTING AND TESTING OF REINFORCED BEAMS

4.1. Design

Beams were designed as per the Indian standard code IS 456 - 2000 [25]. The beams were of 150 × 200 mm cross section with a total length of 1 m as shown in Figure 1. A clear cover of 25 mm was provided in all the sides. Total of 12 beams out of which 6 were designed to fail by shear and 6 were designed to fail by flexure. The reinforcement details were provided so that the beams fail by shear and flexure separately.

4.2. Casting of reinforced beams

Steel moulds were prepared of size 1000 × 150 × 200 mm. required reinforcements were prepared and casting was done. Cover blocks were provided and reinforced was placed after greasing the sides of the mould for better demoulding. Casting of concrete was done and the specimen is surfaced. Demoulding was done after 24 hours and then let to cure for 28 days. Figures 2, 3, 4 and 5 shows the steps in casting of RC beam specimen including placing reinforcement in the mould.

4.3. Wrapping of fibre

After curing the beams were wrapped with fibres other than the conventional beams. The surface was marked and scrapped using sand paper. The epoxy resin along with 10% of hardener was applied thoroughly on the marked areas of the beam. The fibre mat either glass or basalt was placed over the resin coating and again another coating of resin was applied on the fibre mat. It was important to make sure even spread of the resin on the fibres without leaving air voids. It was left for curing for 7 days. Then the specimen was tested using Leaf Spring Testing Machine.

4.4. Testing of specimen

All the 12 beams were tested under the same loading condition with the four-point loading using an I-beam. The instrument used for testing was Leaf Spring Testing Machine. The machine has the loading accuracy of well

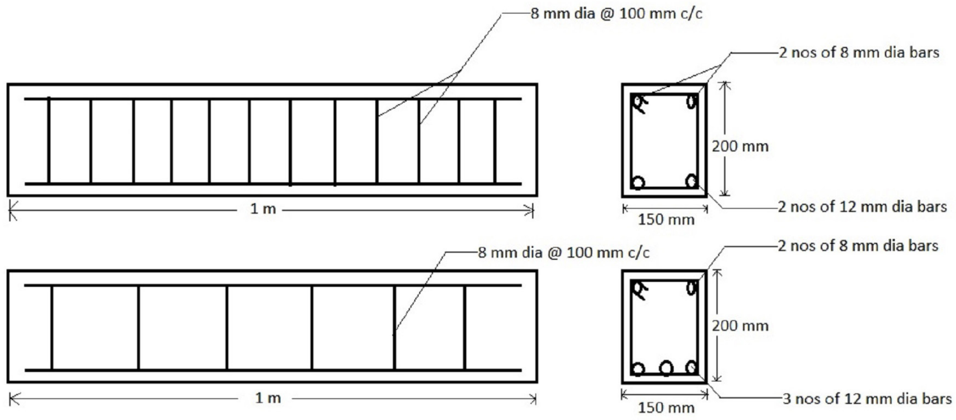

Figure 1: Reinforcement details of flexure deficient beams.

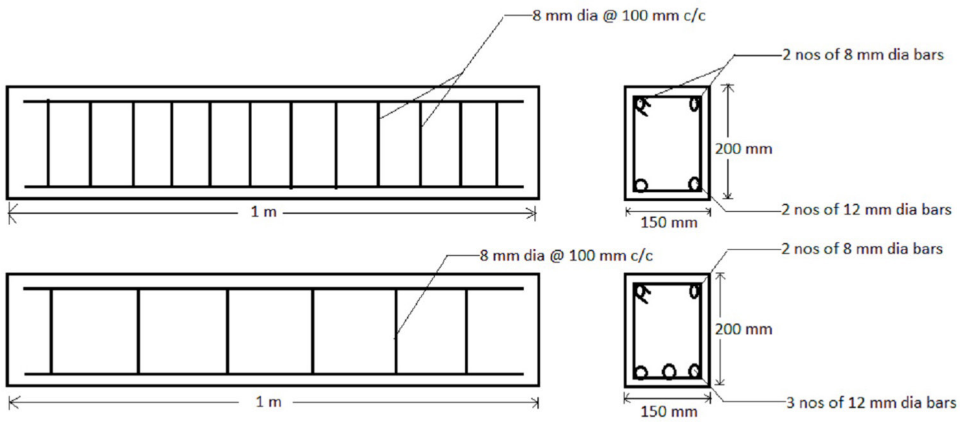

Figure 2: Reinforcement details of shear deficient beams.

Figure 3: Placing of reinforcemet in the mould.

within ±1% in confirmation with IS 1828 (part 2):2002 [26]/BS1610-1:1992 [27]. It is designed as per IS 1135 1995 *(Reaffirmed 2006)* [28] having the maximum capacity of 200KN. The test setup of the different types of reinforced beams are shown in Figures 6, 7 and 8.

Figure 4: Casting of specimen.

Figure 5: Demoulding of specimen.

Figure 6: Test setup of conventional beam.

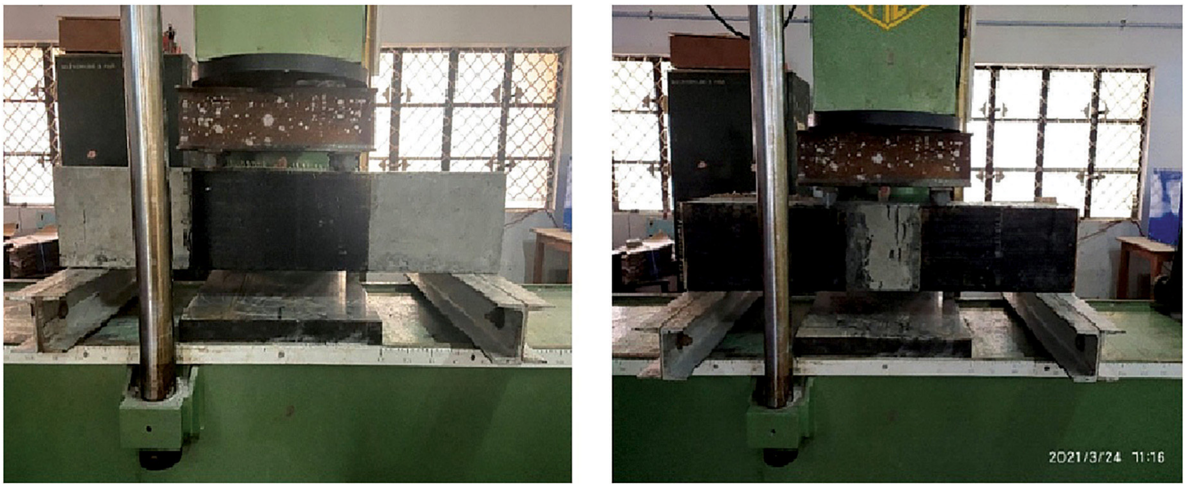

Figure 7: Test setup of basalt fibre wrapped beams.

Figure 8: Test setup of glass fibre wrapped beams.

4.5. Failure modes

The failure modes in the different types of beams are discussed below. The conventional shear deficient RC beams always fail in shear as the flexural strength is high in these beams. While the failure mode in flexure deficient RC beams is flexure as required shear reinforcement is provided in this type of beams. FRP strengthening in deficient beams change the failure mode from shear to flexure and vice versa. Thus the FRP strengthened shear deficient RC beams fail in flexure and the FRP strengthened flexure deficient RC beams fail in shear.

4.5.1. Shear deficient beams

The shear deficient RC beams do not have required shear reinforcement and hence they fail by shear first. FRP strengthening in the shear zones can increase the shear strength of the beams and hence these strengthened beams fail in flexure first or sometimes as flexure-shear failure. Figure 9 shows the shear failure in the shear zones of the conventional shear deficient RC beams.

Figure 10 shows the flexure failure in the BFRP strengthened shear deficient RC beams. Figure 11 shows the flexure failure in the GFRP strengthened shear deficient RC beams.

5. RESULTS AND DISCUSSION

5.1. Shear deficient beams

The results of the four-point loading in shear deficient beams are discussed in this chapter and the results are further compared and analysed. Different loading conditions such as static and cyclic loading are discussed and compared.

Figure 9: Failure of conventional shear deficient RC beams.

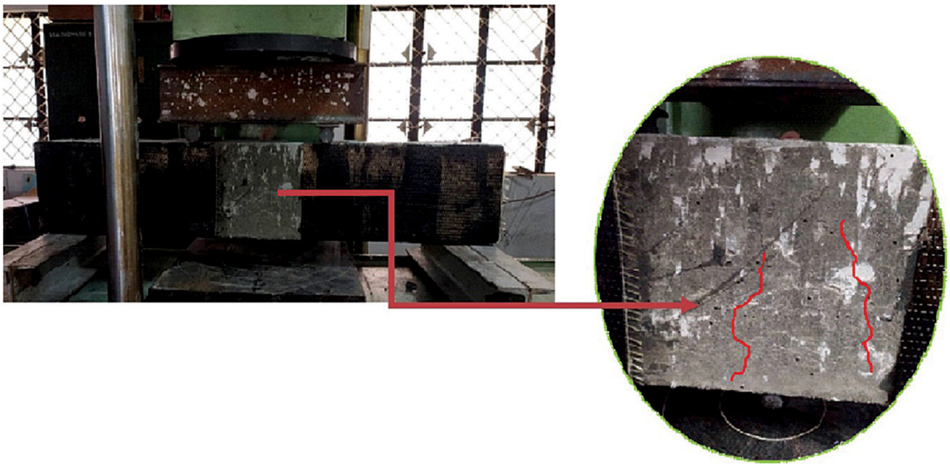

Figure 10: Failure of BFRP strengthened shear deficient RC beams.

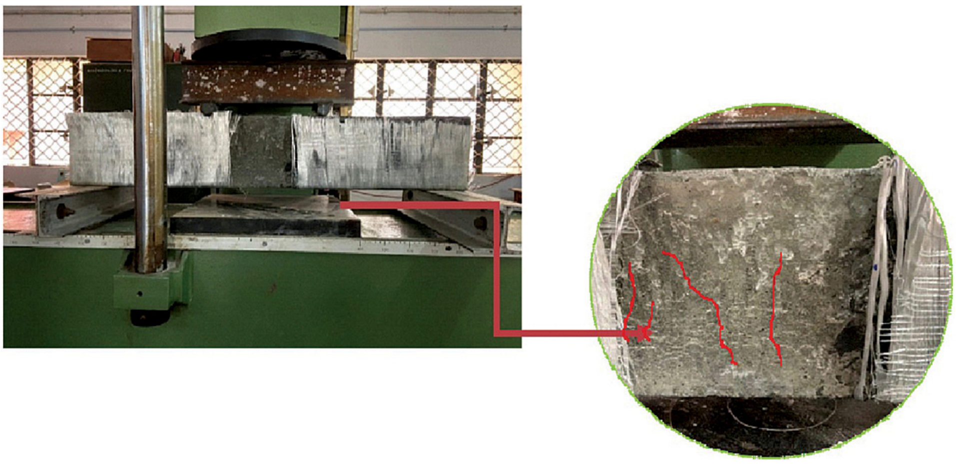

Figure 11: Failure of GFRP strengthened shear deficient RC beams.

5.1.1. Static loading

A static loading is applied as two-point loading on the beams until failure load. The results of the static loading in shear deficient RC beams are given in the Table 10 and Figure 12 shows the comparisons of specimens.

Numerous techniques have been investigated for FRP strip shear strengthening. Nonetheless, a few of these techniques have gained widespread acceptance and been included in rules. The shear strength of rectangular beams can be increased via side bonding, U jacketing, and wrapping techniques.

Four-point loading was applied to a total of six beams during testing. Figure 13 shows the load vs. displacement curve for static loading in RC beams with shear deficiencies.

Chart shown that basalt fibre strengthened RC beams performed better than glass fibre strengthened RC beams. 15% of strength was increased when we use basalt fibre and 9% of strength was increased when we use glass fibre.

The load displacement curve for the shear deficient RC beams under static loading is given in the Figure 13.

Table 10: Results of the static loading in shear deficient RC beams.

TYPE OF CONFINEMENT	ULTIMATE LOAD IN kN
Unconfined RC beam	105
Strengthened by basalt fibre mat in the ends of the RC beam	120.3
Strengthened by glass fibre mat in the ends of the RC beam	114.02

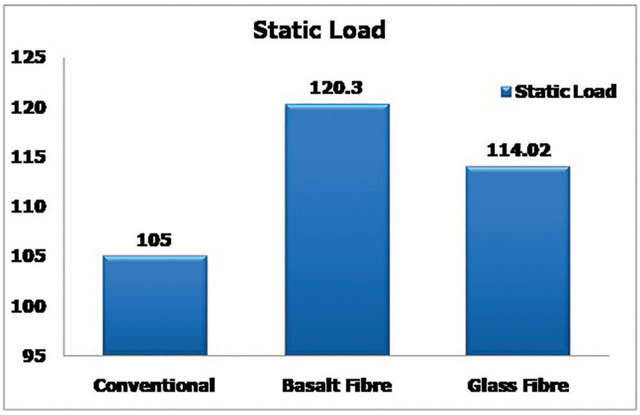

Figure 12: Ultimate load of conventional, basalt fibre and glass fibre under static loading.

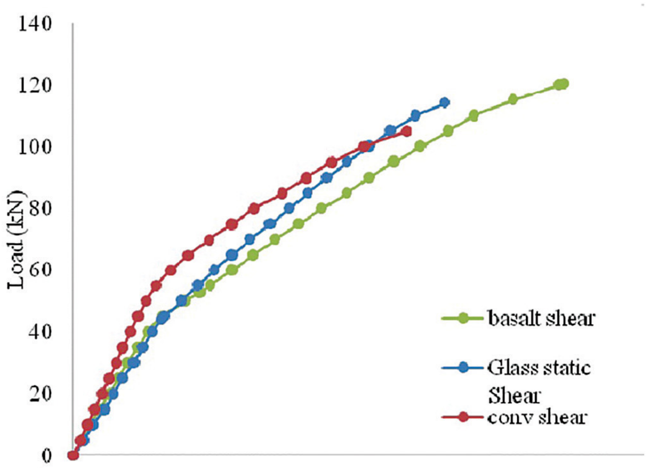

Figure 13: Load vs displacement curve of static loading in shear deficient RC beams.

5.1.2. Cyclic loading

A cyclic loading is applied as two-point loading with positive cycles of repetitive loading on the beams. The ultimate loads taken by the shear deficient RC beams under cyclic loading is given in the Table 11.

Ultimate Load of Conventional, basalt fibre and glass fibre under Cyclic Loading is shown in Figure 14.

Chart shown that basalt fibre strengthened RC beams performed better than glass fibre strengthened RC beams under cyclic loading. 13% of strength was increased when we use basalt fibre and 4% of strength was increased when we use glass fibre.

The results of the cyclic loading in shear deficient RC beams are given in the Table 12, 13, 14.

Figure 19 shows the load displacement curve of the shear deficient RC beams under cyclic loading.

5.1.2.1. Effect of FRP wrapping

To increase the strength of the shear deficient beams, different FRP wrappings are provided. The strength of FRP wrapping has influenced the shear deficient RC beams in a significant manner. The test results show that the basalt fibre wrapped RC beams performed better than the unconfined RC beams. The ultimate load taken by

Table 11: Ultimate strength of shear deficient RC beams under cyclic loading.

TYPE OF CONFINEMENT	ULTIMATE STRENGTH IN kN
Unconfined RC beam	91.25
Strengthened by basalt fibre mat in the ends of the RC beam	103.45
Strengthened by glass fibre mat in the ends of the RC beam	95.07

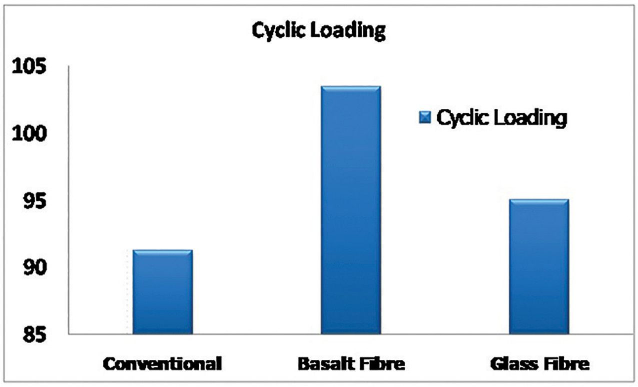

Figure 14: Ultimate load of conventional, basalt fibre and glass fibre under static loading.

Table 12: Results of the cyclic loading in conventional shear deficient RC beam.

CYCLE NUMBER	PEAK LOAD	STIFFNESS	STIFFNESS DEGRADATION	ENERGY DISSIPATION	CUMULATIVE ENERGY DISSIPATION
	kN	kN/mm	kN/mm	kN-mm	kN-mm
1	10	35.71		0.12	0.12
2	20	35.71	0.00%	0.37	0.5
3	30	35.71	0.00%	1.16	1.66
4	40	35.36	1.82%	4.65	6.31
5	50	33.33	6.67%	16.06	22.37
6	60	30.76	13.85%	19.95	42.32
7	70	28.57	20.00%	43.48	85.81
8	80	26.66	25.33%	52	137.81
9	91.25	25.56	28.41%	126.21	264.01

Table 13: Results of the cyclic loading in BFRP strengthened shear deficient RC beam.

CYCLE NUMBER	PEAK LOAD	STIFFNESS	STIFFNESS DEGRADATION	ENERGY DISSIPATION	CUMULATIVE ENERGY DISSIPATION
	kN	kN/mm	kN/mm	kN-mm	kN-mm
1	10	50		0.05	0.05
2	20	50	0.00%	0.42	0.47
3	30	50	0.00%	1.08	1.56
4	40	50	0.00%	2.65	4.21
5	50	49.51	0.99%	9.81	14.02
6	60	44.44	11.11%	18.15	32.17
7	70	37.23	25.53%	24.23	56.41
8	80	31.87	36.25%	50.8	107.21
9	90	27.86	44.27%	61.65	168.86
10	103.45	24.54	50.9%	114.72	283.58

Table 14: Results of the cyclic loading in GFRP strengthened shear deficient RC beam.

CYCLE NUMBER	PEAK LOAD	STIFFNESS	STIFFNESS DEGRADATION	ENERGY DISSIPATION	CUMULATIVE ENERGY DISSIPATION
	kN	kN/mm	kN/mm	kN-mm	kN-mm
1	10	43.48		0.12	0.12
2	20	40	8.00%	0.75	0.87
3	30	40	8.00%	1.16	2.03
4	40	38.83	10.68%	2.25	4.28
5	50	32.05	26.28%	8.81	13.1
6	60	27.27	37.27%	23.02	36.13
7	70	25	42.50%	32.37	68.5
8	80	23.18	46.67%	50.3	118.8
9	90	21.95	49.51%	92.81	211.61
10	95.07	21.04	51.59%	125.67	337.28

the FRP wrapped or strengthened RC beams was greater than the unconfined shear deficient RC beams. Among the FRP wrapped RC beams, basalt fibre wrapped RC shear deficient beams showed greater strength than glass fibre wrapped RC shear deficient beams.

5.2. Comparison of load and displacement

The load and displacement of all the RC beams under static loading are compared and discussed. The peak loads of basalt fibre strengthened RC beams both shear and flexure deficient are found to be high comparatively to that of glass fibre strengthened RC beams. However, results showed that FRP strengthening has increased the load carrying capacity of the conventional RC beams. Figures 15, 16, 17 and 18 show the load displacement curve of various RC beams.

5.3. Comparison of stiffness

The stiffness of the RC beams are compared and discussed. Results showed that stiffness reduces with the increase in the load and number of cycles. Stiffness of the beams gradually reduces when the load is applied. The stiffness reduction was found to be more than 50% in the strengthened beams. Figure 19 shows the stiffness curve of various RC beams.

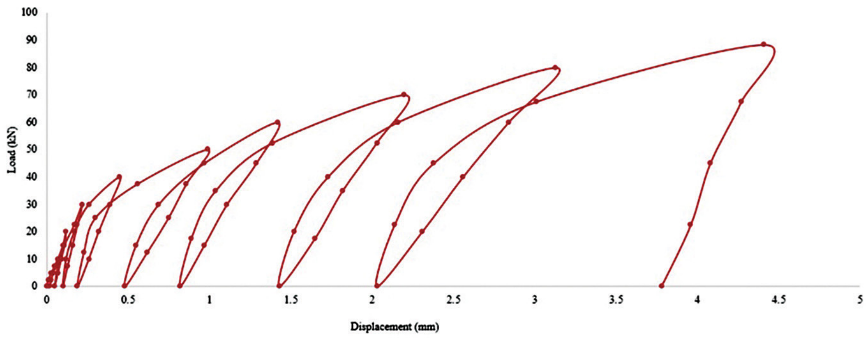

Figure 15: Load vs displacement curve of cyclic loading in shear deficient conventional RC beam.

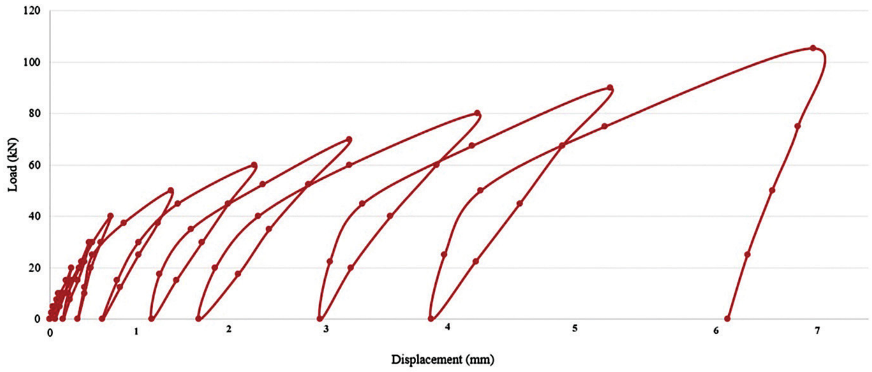

Figure 16: Load vs displacement curve of cyclic loading in shear deficient BFRP strengthened RC beam.

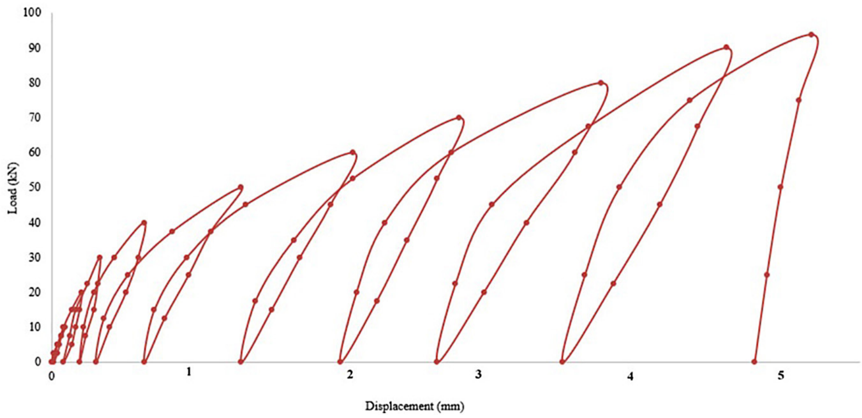

Figure 17: Load vs displacement curve of cyclic loading in shear deficient GFRP strengthened RC beam.

5.4. Comparison energy dissipation

The energy dissipation of the test specimens is discussed. The energy dissipation increases with increase in number of cycles. Energy dissipation depends on stiffness of the beams. Stiffness degradation increases with the increase in cumulative energy dissipation. Figure 20 shows the energy dissipation curve.

6. FINAL CONCLUSION

Twelve RC beams of different reinforcement details were casted and tested to study their behaviour under static and cyclic loading. Results indicate that basalt fibre strengthened RC beams performed better than glass fibre strengthened RC beams. The peak loads of basalt fibre strengthened RC beams as both shear and flexure deficient are found to be high comparatively to that of glass fibre strengthened RC beams. However, both the FRP strengthened RC beams performed better than conventional RC beams. The ultimate load from the cyclic loading is less than that from static loading due to fatigue in the specimen caused by the cyclic loading.

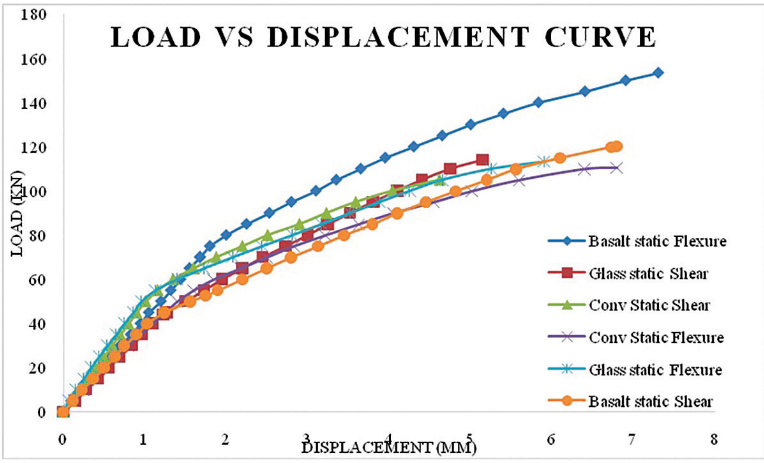

Figure 18: Load vs displacement curve.

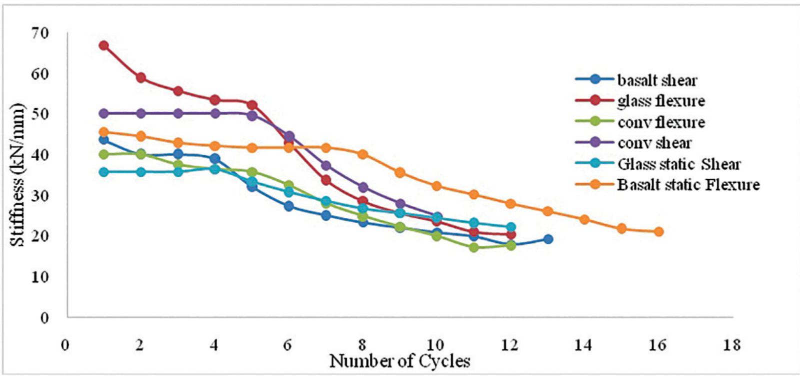

Figure 19: Stiffness curve.

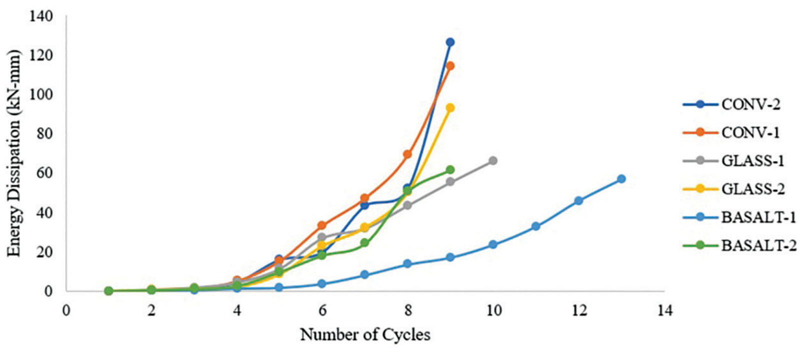

Figure 20: Energy dissipation curve.

Stiffness was found to decrease with the increase in the load and number of cycles. The stiffness reduction was found to be more than 50% in the strengthened beams. Stiffness degradation increases with the increase in displacement and cumulative energy dissipation. FRP strengthening in deficient beams change the failure mode from shear to flexure and vice versa**.**

7. FUTURE STUDY

FRP constructions still have a position in the building industry, despite the fact that they have had tremendous success in the repair and rehabilitation space over the past few decades. This will be feasible if officially enforceable design guidelines are put in place and the whole life cost of FRP is considered. The largest obstacles to the wider application of FRP in civil engineering include access to legal design regulations, FRP structures, lack of ductility, inadequate understanding of structural engineers, lack of simplified FRP design books, and fire and durability endurance.

- In our study, static and cyclic loading were done. In the future, impact loading tests can also be performed.
- Modelling will be performed for this study.
- By using various fibres for wrapping and finding out the behaviour of various fibres.

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