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RETROFITTING OF CONCRETE SPECIMEN USING GLASS FIBER REINFORCED POLYMER

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Abstract – The experimental investigation is carried out on short column retrofitted with glass fibre reinforced polymer (GFRP). In this experimental study the concrete with target a mean strength of 30 MPa grade is utilized. The specimen of sizes 100 mm X 100 mm x 300 mm and 100 mm x 150 mm x 30 mm with aspect ratio of 1 and 1.5 respectively are used. The specimens were singled and doubly wrapped with glass fibre. Thus the mechanical properties of short column specimen with varying aspect ratio were tested under compression testing machine (CTM). From the test result it is observed that short column specimen with double glass fibre wrapping gives better performance as compare to single wrapped and conventional concrete specimen.

Keywords- Compressive strength, Double wrapping, Glass fibres, Retrofitting, Single wrapping.

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INTRODUCTION

All the residential structures are considered for a certain design life depending on the type of structure. Elements of most of these structural are constructed with RCC. Now a day's various factors such as environmental influences, inadequate design and construction or need for structural up-gradation so as to meet new seismic design requirements because of new design standards, deterioration due to corrosion in steel caused by exposure to an aggressive environment and accident events such as earthquakes, excessive deflections, and poor concrete quality, etc. or sometimes even to solve execution errors caused at the time of construction. For these purposes, various strengthening techniques have been developed to satisfy these strengthening requirements. Retrofitting means action taken to upgrade the seismic performance of an existing structure so that it achieves intended seismic performance level. It includes adding of the members, shear walls, bracing, reducing loads, strengthening of structural elements and increasing ductility of members etc. In this experimental work Glass fibre was used as a retrofitting material. Glass fibers have high strength, considering their relatively low cost. E-glass is the most commonly used glass fibers available in the construction industry. Wherever the conventional methods of strengthening of various element of RCC are not useful, there Fibre Reinforced Polymer (FRP) can be used because of its lower cost of labour and equipments though the constituent of FRP are costlier compared to steel and concrete.

MATERIAL USED

In the concrete mix the materials usually are cement, fine aggregate, coarse aggregate and water. The materials used in this study for concrete mix are:-

A. *Cement*

Cement used throughout the experimental work is ordinary Portland cement 53 grade conforming to IS 269-1967 manufactured by Ultra tech Company. The properties of cement are given in table 1.

TABLE 1. Properties of Cement

Property	Average value	Standard value
Specific gravity	3.11(standard)	3.15
Fineness(%)	3.5	<10%
Consistency (%)	31	-
Initial setting time (min)	75	>30
Final setting time (min)	3509	>600

B. *Coarse Aggregate*

Crushed stone aggregate has been used. It is a locally available with sharp, angular aggregate, with maximum size of aggregate 20 mm. The properties of coarse aggregate are given in table 2.

TABLE 2. Properties of Coarse Aggregate

Sr No	Property	Average value
1	Specific Gravity	2.80
2	Water absorption	1.53%
3	Moisture content	1.92%
4	Type	Crushed
5	Maximum Size	20 mm

C. *Fine Aggregate*

The sand used for the experimental work was locally procured and conformed to grading zone III. Sieve Analysis of the Fine Aggregate was carried out in the laboratory as per IS 383-1970 [11]. While the fine aggregate shall conform to the grading zone III. The properties of fine aggregate are given in table 3.

TABLE 3. Properties of Fine Aggregate

	Property	Average value
1.	Specific Gravity	2.72
2.	Water absorption	3.98%
3.	Moisture content	5.09%
4.	Fineness Modulus	4.87
5.	Type	Natural Sand
6.	Grading Zone	III

D. *Water*

Fresh and clean water is used for casting the specimens in the present work. The water is relatively free from organic matter, silt, oil, sugar, chloride and acidic material etc as per Indian standard.

E. *Primer*

The material and their properties are available from Hindustan Technical Fabrics Limited. Mumbai. The properties of primer are given in table 4.

TABLE 4. Properties of Primer

Composition	Two parts
Type of resin	Epoxy polyamine
Solid by volume	100%
Mixing ratio	1 : 1 base and curing agent
Specific gravity	1.08 kg
Color	Transparent
Pot life	45 min at 21 degree centigrade
Storage	18.24 degree centigrade

F. *Saturant*

A. Epoxy saturant is the name of the saturant. Various properties of saturant are given in table 5.

TABLE 5. Properties of Saturant

Color	**Pale yellow to amber**
Application temperature	15 – 40 degree centigrade
Mixing ratio	1.5 : 1
Viscosity	Thixotropic
Density	1.12 – 1.16 g/cm^3
Pot file	2hrs at 30 degree centigrade
Cure time	5days at 30 degree centigrade
Storage condition	Under normal ware house condition < 35 degree centigrade

E. *Glass Fibre Reinforced Polymer (GFRP)*

GFRP is weaved in fabric form and unidirectional. The properties of GFRP are given in table 6.

TABLE 6. Properties of GRPF

Type	E-glass
Fiber orientation	Unidirectional
Young's modulus of elasticity	75,900 N/mm^2
Effective fiber sheet thickness	0.43mm
Density of wrap	900 g/cm^2
Specific gravity of fiber	2.56
Tensile strength in uni-direction	2060MPa

II. EXPERIMENTAL WORK

In order to study the effect of Glass fibre reinforced polymer (GFRP) on structural member, column specimens of 100mm x100 mm x 300 mm & 100 mm x150 mm x 300 mm are used. The concrete is prepared for estimated strength of 30MPa with coarse aggregate of max. size 20 mm, fine aggregate of grading zone III according to IS 383-1970 [6], cement. Water cement ratio of 0.46 is taken. All tests are perform on fresh as well as on harden concretes per IS 10262-2007 [5]. After 1 day, specimens were demoded & then put up for curing at room temperature. Compressive testing is performing on all specimens.

- **Mechanical Testing Procedure**

It is most common to identify the quality of concrete by its compressive strength measured on standard cubes at various curing period on Compression testing machine. The concrete is filled into the Short columns mold in layers approximately 5cm deep and tested up to their failure. The column specimen is of the size 100 mm x100 mm x 300 mm and 100 mm x150 mm x 300 mm. Total 18 specimens are tested in compression testing machine. Two aspect ratios are taken as 1:1 and 1:1.5. In aspect ratio 1:1 (i.e. 1) three control specimens, three with single layer of GFRP and three with double layer of GFRP are tested & with aspect ratio 1:1.5 (i.e. 1.5) three control specimens, three with single layer of GFRP and three with double layer of GRPF are tested.

III. TEST RESULT AND DISCUSSION

The compressive strengths for various specimens are given in table 7 for control (conventional), singly wrapped and doubly wrapped.

TABLE 7 Load Carrying Capacities of Various Layers

Specimen size for	**Load in kN at which specimen fails**					
M30	Control specimen		Single layer		Double layer	
100×100×300	317.8	316.3	458.2		551.8	556.2
	320.6		450.8	452.73	565.7	
	310.5		449.2		551.1	
100×150×300	465.6		648.5		772.4	
	476.2	471.43	645.7	645.6	776.4	784.16
	472.5.		642.6		803.7	

TABLE 8 Strength of column in N/mm²

Grade of concrete	Layers of GFRP	Ultimate compressive strength in N/ mm2.			
		Aspect ratio 1	**% increase in strength**	**Aspect ratio 1.5**	**% increase in strength**
M30	Control specimen	31.63		31.42	
	Single layer	45.27	43.12%	43.04	36.98%
	Double layer	55.62	75.8%	52.27	66.35%

Figure 1 Effect of aspect ratio

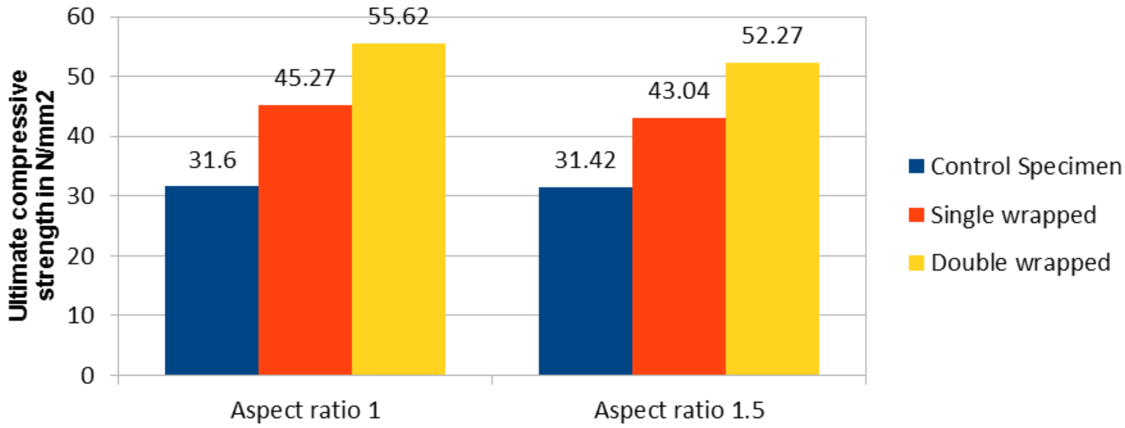
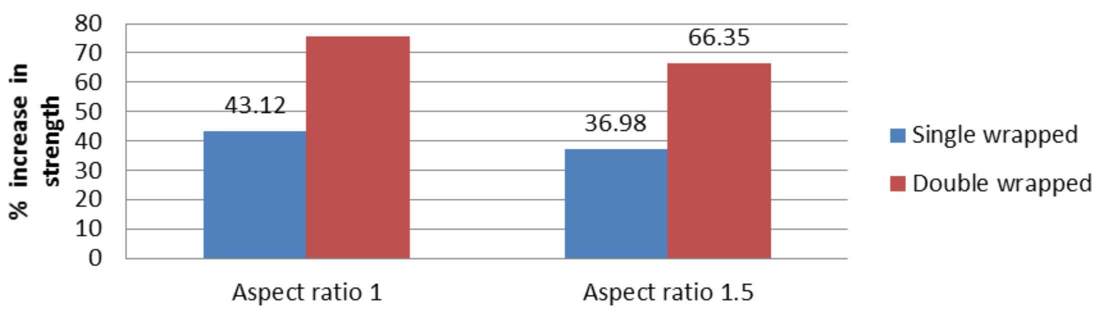


Figure 2 % Increase in Strength



For single layer specimens, the maximum percentage increase in strength achieved for square specimens (aspect ratio 1) and rectangular specimens (aspect ratio 1.5) with respect to control specimens were 43.12% and 75.8% respectively.
Similarly for double layer specimens, the maximum percentage increase in strength achieved for square specimens (aspect ratio 1) and rectangular specimens (aspect ratio 1.5) with respect to control specimens were 36.98% and 66.35% respectively.

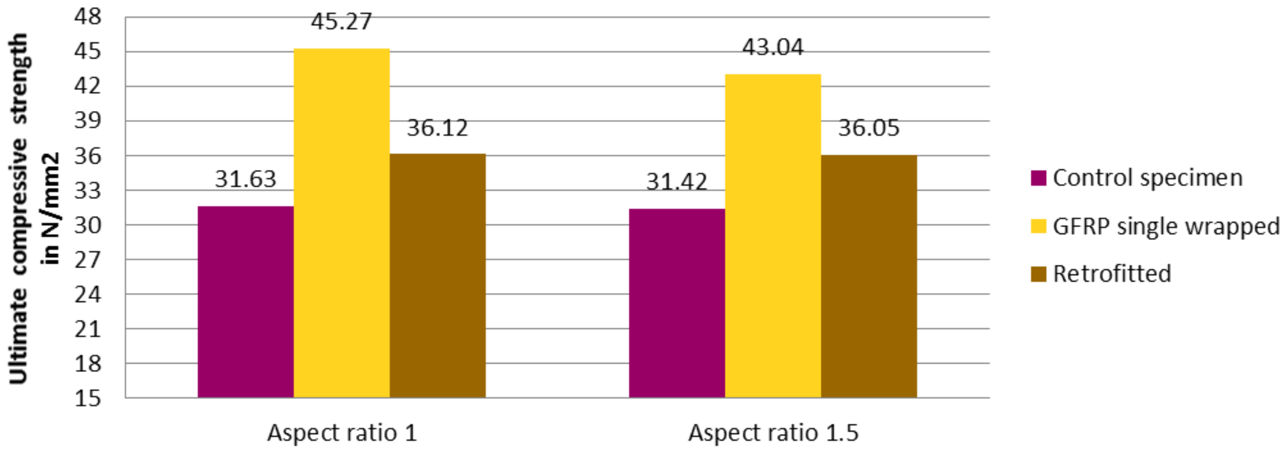
TABLE 9. Load Carrying Capacities of Retrofitted Specimen

Specimen size for	Load in kN at which specimen fails					
M30	Control specimen		GFRP single wrap specimen		Retrofitted specimen	
100×100×300	317.8	316.3	458.2		370.4	361.23
	320.6		450.8	452.73	352.6	
	310.5		449.2		360.7	
100×150×300	465.6	471.43	648.5	645.6	548.6	
	476.2		645.7		541.8	540.8
	472.5.		642.6		532.0	

TABLE 10. Strength of Retrofitted Column in N/mm^2

		Ultimate compressive strength in N/mm2.	
Grade of concrete	Layers of GFRP	Aspect ratio 1	Aspect ratio 1.5
M30	Control specimen	31.63	31.42
	GFRP single wrap specimen	45.27	43.04
	Retrofitted specimen	36.12	36.05

Figure 3 Effect on damaged concrete column by GFRP wrap & by retrofitting.



From above figure, retrofitted specimens are more effective than control specimen and less effective than GFRP wrap specimens. Also it can be seen that the GFRP retrofitting is more effective for aspect ratio 1 than aspect ratio 1.5.

IV .CONCLUSION

1. The experimental results clearly conclude that GFRP wrapping can enhance the strength of concrete columns under axial loading.
2. Confinement by GFRP enhances the performance of rectangular concrete columns. GFRP wrapping is more effective for aspect ratio 1 than aspect ratio 1.5, i.e. for M30 grade of concrete, percentage increased in strength are 43.12% and 36.98% respectively for column with single layer of GFRP
3. As the aspect ratio increases from 1 to 1.5, the strength gain in confined concrete columns decreases.
4. Compressive Strength of the Concrete Columns increases with increase in the number of layer of GFRP. For M30 grade of concrete, percentage increase in strength from single layer to double layer of GFRP are 22.86% and 21.44% for aspect ratio 1 and 1.5 respectively.
5. It is concluded that the retrofitting columns will have significantly better performance compared with the unwrapped columns, i.e. for M30 grade, retrofitted specimens have taken 14.19% and 14.73% more load than control specimens for aspect ratio 1and 1.5 respectively.

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