ISSN (Online): 0974-5645 Behaviour of RC Columns with GFRP Sheet and

Recycled Aggregate

ISSN (Print): 0974-6846

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Abstract

Background/Objectives: The experimental investigations are carried out to study the behaviour of Glass Fiber Reinforced Polymer (GFRP) sheet not wrapped and wrapped around RC column. Methods/Statistical analysis: Strength of the RC column was assessed by performing compressive and split tensile strength tests at the interval of 7, 14, and 28 days as per code of provision. Findings: In this study, the recycled aggregate has been replaced with the natural aggregate. The replacement percentage was chosen for this study was 10%, 20%, 30%, 40%, and 50%. The compressive strength of partial replacement of recycled coarse aggregates (PRRCA) are found to be higher than the compressive strength of normal concrete. Furthermore, results on load, deflection and failure modes of each of the columns were also obtained. **Applications/Improvements:** Strength of the damanged concrete structures can be improved after wrapping GFRP sheet over the damaged structures.

Keywords: Axial Load, Fiber Reinforced Polymer, Identified Deficiencies, Recycled Coarse Aggregate, Wrapping

1. Introduction

Concrete is obtained by a mixing of cementitious material, water and aggregates, and sometimes admixtures, in required proportions1. In order to conserve the usage of natural resources, the recycled aggregates can be used for making concrete instead of natural aggregate as the replacement materials².

The process of weight reduction only can be achieved primarily by the usage of suited material, optimized design and also it depends upon the manufacturing processes. Material selection process is based on cost of the material, availability and strength of material. The weight reduction achievement aids with adequate improvement of mechanical properties of the expired concrete has made using a glass fiber is a very good replacement material for conventional steel. Today the glass fiber is most popular and also one of the innovative construction material in the civil industry. The glass fiber material have more elastic strain energy capacity and high strength to weight ratio as compared with steel, as a results, the usage of steel in concrete will reduce. Further, it gives more convenience to design for any shape³. Other application has been considered either by making reinforcing bars with continuous glass fibres joined together and impregnated with plastics, or by making similar short, rigid units, impregnated with epoxy, to be dispersed in the concrete during mixing⁴.

GFRP products are more appropriate for structural element designing, demand ing of both high strength to weight ratio and also high corrosion resistance. These GFRP composite materials are thus widely used in several fields ranging from construction industries to aerospace engineering⁵. Around all over the world GFRP waste are expected to increase by 15 % annually. The efforts were made to recycle the GFRP waste powder as an admixture and substitute to fine aggregate in concrete composites and

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GFRP waste as structural reinforcement material in architectural cladding panels, thus, usage of GFRP in concrete gives most environmental sustainability⁶.

The several waste by-products like waste plastics⁷, waste clay bricks⁸, and crushed rock powder⁹, are used as partial replacement of coarse aggregates, granite powder¹⁰ and flyash¹¹ are used as partial replacement of fine aggregate for increasing the strength of the concrete by several studies. This study used replacement of recycled coarse aggregates (PRRCA) for increasing the strength of the concrete.

2. Materials Used

2.1 Cement

Ordinary Portland cement¹² is used in this research. The physical tests like consistency tests, setting tests, soundness tests, etc were carried for OPC and the results are presented in Table 1.

Table 1. Properties of cement				
Tests	Values			
Consistency Test	120			
Setting Time	445Minutes			
Specific Gravity	3.148			
Autoclave And Lechatlier	-0.01 &1			
Fineness Test	2.44gms			

2.2 Fine Aggregate

In this study, sand is used as a fine aggregate, which is confired by fineness modulus (2.78). The specific gravity of sand and water absorption of fine aggregate is 2.66 and 0.917% respectively.



Demolished Concrete Cube

Figure 1. Recycled coarse aggregate.

2.3 Coarse Aggregates

Table 2 represents the properties of coarse aggregates. It was observed from Table 2 that the properties of coarse aggregates were within the permissible limit (as per Indian standards).

Table 2. Properties of coarse aggregate				
Materials	Coarse Aggregate			
Bulk Density	3.495			
Specific Gravity	2.65			
Water Absorption	0.4			
Impact test	7.1			
Sieve Analysis for Coarse Aggregate	7.5			

2.4 Recycled Coarse Aggregate

Two grades of recycled coarse aggregates were selected for this study (Figure 1). From the Figure 1, it may be observed that grade 1 is obtained if the recycled coarse aggregate were retained on 10 mm size sieve and grade 2 aggregates is obtained if aggregates were retained on 25 mm sieve size. The general properties of recycled coarse aggregate used in this study are presented in Table 3.

Table 3. Properties of recycled coarse aggregate				
Materials	Coarse Aggregate			
Specific gravity	2.3			
Absorption value	4.5%			
Bulk density	1322.59 Kg/m³			
Moisture content	4.46%			
Impact test value	12%			
Crushing value	36.5%			



Recycled Aggregate



Figure 2. GFRP woven roving sheets.

2.5 Glass Fiber Reinforcement Polymer (GFRP)

In this study, Class E, GFRP is used for increasing the strength of the concrete (Figure 2). The properties of GFRP is presented in Table 4. Regardless of the number of the GFRP layers, the warppling is done over the concrete memebrs as one single unit¹³.

Table 4. Properties of GFRP				
Technical data	GFRP			
Thickness	2 mm			
Poisson ratio	0.65			
Elastic modulus	73000 N/mm2			
Tensile strength	3400 N/mm2			
Sheet weight	880 g/m2			
Density	2.6 g/cm3			
Matrix type	woven rovings			

3. Results and Discussion

The recycled aggregate has been replaced partially with the natural aggregate at various proportions viz., 10%, 20%, 30%, 40%, and 50%. The load is applied parallel to the axis of concrete member for both RCA concrete and concrete wrapped with GFRP.

3.1 Mixing Proprotions of Replacement Material in Concrete

The mix proportion of replacement material (including water, cement, fine aggregate, coarse aggregate and percentage of RCA) in concrete is presented in Table 5.

3.2 Test Specimens

The details of test specimens for doing compressive, split tensile strength tests are presented in Table 6.

3.3 Compressive Strength

Compressive strength of concrete can be defined as the measured maximum resistance per unit area of a concrete againt axial loading. Figure 3 indicates the failure of concrete cubes when compression load is applied. The compression test is carried out according to determine the characteristic strength of the concrete. The reported compressive strength is presented in Table 7 and it is the average of 3 measurements tested at the age of 7, 14 and 28 days.

3.4 Split Tensile Strength

The split cylinder test is performed to find the tensile strength of a cylindrical concrete specimen. Figure 4 indicates the split tensile failure of cylinder. The cylindri-

Table 5. Mix proportion of replacement material in concrete								
Water		Cement Fi		Fine Aggregate		Coarse Aggregate		
186 litre	es	465 Kg/m3	6	601.75 Kg/m3		601.75 Kg/m3 1092.4 Kg/m3		
0.4		1		1.294		2.349		
Mix Design	n for M30 Co	ntrol Concrete =	: 1 : 1.3 : 2.4					
		Fine	Coarse	Coarse				
Water	Cement	Aggregate	Aggregate	10% RCA	20% RCA	30% RCA	40% RCA	50% RCA
186 litres	465 kg/m ³	601.75 kg/m³	1092.4 kg/m³	109.24 kg/m ³	218.4 kg/m ³	327.7 kg/m ³	436.9 kg/m ³	546.2 kg/m ³
0.4	1	1.294	2.349	0.2349	0.4698	0.7047	0.939	1.173

Table 6. Details of the test specimens							
Shape & size of column in 'mm'	Specimens Name	Number of columns	Cross Section of specimens	Reinforcement Details			
Circular 150x 900	RCC NW RCC FW01 RCC FW02	1 1 1		6 nos 12mm diameter bars and two legged 8mm lateral ties at 150mm c/c			
Square 150x 150x 900	RCC NW RCC FW01 RCC FW02	1 1 1		4 nos 12mm diameter bars and two legged 8mm lateral ties at 150mm c/c			
Rectangular 120x 180x 900	RCC NW	1		4 nos 12mm diameter bars and two legged 8mm lateral ties at 120mm c/c			



Figure 3. Failure of concrete cube during compression load.



Figure 4. Split tensile failure of cylinder.

Table 7. Compressive strength of concrete cube						
Sample 0% 10% 20% 30% 40% 50%					50%	
7 days cube strength (MPa)	25.62	24.17	26.93	25.696	30.63	26.277
14 days cube strength (MPa)	26.26	27.5	29.89	26.83	31.56	27.58
28 days cube strength (MPa)	38.76	39.36	43.913	40.50	45.03	41.58

Table 8. Splitting tensile strength of cylinder for						
various proportions						
Sample 0% 10% 20% 30% 40% 50%						50%
28days cylinder strength (MPa)	4.00	3.69	4.00	3.66	4.10	3.89

cal specimen is placed with its axis horizontally and it's subjected to a line load along the length of the specimen. The results for various combinations against the 28 days curing period is presented in Table 8.

3.5 Fabrication of Specimens

The fiber sheets, precisely cut to fit each specimen, were then applied using a wet-lay-up process. Pressure was applied on FRP surface with a foam roller in order to remove all voids. Once confined, the specimens were allowed to cure for at least another 3 days before testing^{14,15}. The columns after curing and Columns over lapping with GFRP is shown in Figure 5 and Figure 6 respectively. Further, the test setup is represented in Figure 7.



Figure 5. Columns after Curing.



Figure 6. Columns over lapping with GFRP.



Figure 7. Test setup.

The load carrying capacities of the single layer wrapped and double layer wrapped RC columns were obtained and compared to the corresponding without wrapped columns (Table 9). The failure mode observed in wrapped RC columns is shown in Figure 8.

3.6 Stress-Strain Curves from Experimental Results

The axial stress and strain observed for circular column, square column and rectangular column is shown in Figure 9, Figure 10 and Figure 11 respectively.



Figure 8. Failure modes.

Table 9.	Comparison of Ultimate Load for single layer wrapped and double layer wrapped RC columns with
unwrappe	ed columns

Shape of column	Specimens Name	Ultimate load Pu (KN)	% increase in Pu compared without confined column
Square	RCC NW	139	0.0
	RCC FW01	164	18.0
	RCC FW02	187	34.5
Rectangular	RCC NW	133	0.0
	RCC FW01	156	17.3
	RCC FW02	178	33.8
Circular	RCC NW	147	0.0
	RCC FW01	183	24.5
	RCC FW02	214	45.6

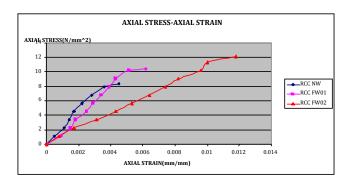


Figure 9. Axial stress-strain relationship for circular column.

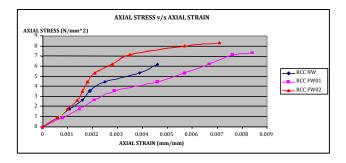


Figure 10. Axial stress-strain relationship for square column.

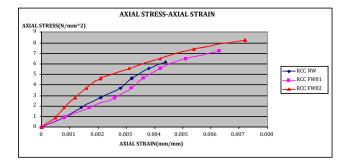


Figure 11. Axial stress-strain relationship for rectangular column.

The study was concluded from Figure 9, Figure 10, Figure 11 that the compressive strength of Partial Replacement of Recycled Coarse Aggregate (PRRCA) is found to be higher than the compressive strength of normal concrete.

4. Conclusion

The experimental investigations are carried out to study the behaviour of GFRP sheet not wrapped and wrapped around RC column. Strength of the RC column was assessed by performing compressive and split tensile strength tests at the interval of 7, 14, and 28 days as per code of provision. The following conclusions were drawn.

- a. The compressive and split tensile strength of concrete containing 40% PRRCA has similar to the strength of normal concrete.
- b. Percentage increase in ultimate load for square column is 18 % and 34.5 % for single and double layer wrapping respectively, when compared to without confined concrete column.
- c. Percentage increase in ultimate load for rectangular column is 17.3 % and 33.8 % for single and double layer wrapping respectively, when compared to without confined concrete column.
- d. Percentage increase in ultimate load for circular column is 24.5 % and 45.6 % for single and double layer wrapping respectively, when compared to without confined concrete column.
- e. For square and rectangular columns with double layer wrapping, stress-strain response is improved considerably than circular columns with double layer wrapping.

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