STRENGTHENING OF CONCRETE SPECIMENS USING GFRP

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Abstract

Strengthening of reinforced concrete structures using FRP has emerged as a potential solution to the problems associated with civil infrastructure. Many researchers have reported significant increases in strength and stiffness of FRP retrofitted concrete structures. The objective of this work is to evaluate the structural behaviour of reinforced concrete beams with externally wrapped with GFRP. The study parameters of this investigation included the ultimate load carrying capacity and their corresponding deflections and mode of failures of the tested specimens. The performance of GFRP specimens were compared with that of control specimens. The test results showed that the beams strengthened with GFRP laminates exhibited better performance.

Keywords: Compression, Flexural, Tensile, Strengthening, Glass Fibre Reinforced Polymer.

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1. INTRODUCTION

Many existing structures are inadequate based on current seismic design codes. In addition, a number of major earthquakes during recent years underscored the importance of mitigation to reduce seismic risk. Seismic retrofitting of existing structures is one of the most effective methods of reducing this risk. In recent years, a significant amount of research has been devoted to the study of various strengthening techniques to enhance the seismic performance of RC structures. However, the seismic performance of the structure may not be improved by retrofitting or rehabilitation unless the engineer selects an appropriate intervention technique based on seismic evaluation of the structure. Therefore, the basic requirements of rehabilitation and investigations of various retrofit techniques should be considered before selecting retrofit schemes.

2. EXPERIMENTAL INVESTIGATION

The purpose of this paper is to investigate the flexural, split tensile and compression strength of the concrete specimens which have been strengthened by using GFRP. Three sets of specimens were cast in order to determine those strengths. Specimens like cubes, cylinders and prisms were cast and tested. Strength between the conventional specimens and the strengthened concrete specimens was noted down by various tests. Test results were taken periodically to show the improvement in the strength of the concrete specimen in 7th, 14th and 28th days.

2.1 Test Specimens

The following specimens were used for this experiment work.

Cube – 150 X 150 X 150 mm

Cylinder – 100 X 200 mm – 100 mm diameter and 200 mm long

Prism – 100 X 100 X 500 mm.

3. MATERIALS FOR CASTING

3.1 Cement

Ordinary Portland cement (OPC) was used for investigation. It was tested for its physical properties in accordance with the Indian Standard specifications. The specific gravity of the cement is 3.13 based on the test results.

3.2 Fine Aggregate

The fine aggregate obtained from river bed of Karur, clear from all sorts of organic impurities was used in this experimental program. The fine aggregate was passing through 4.75 mm sieve and had a specific gravity of 2.68. The grading zone of fine aggregate was zone II as per Indian Standard specifications.

3.3 Coarse Aggregate

The coarse aggregates used were of two grades, non-reactive and available in local Quarry. One grade contained aggregates passing through 4.75 mm sieve and retained on 10 mm size sieve. Another grade contained aggregates passing through 10 mm sieve but retained on 20 mm sieve. The specific gravity of the coarse aggregate is 2.74 bases on the test results.

3.4 Water

Ordinary tap water was used for concrete mix in all mix.

3.5 Reinforcing Steel

HYSD bars of two numbers of 10 mm diameter and one number of 12mm diameters were used as main reinforcement. 6 mm diameter steel bars were used for shear reinforcement. The yield strength of steel is 415 N/mm^2.

3.6 Concrete

The existing RCC building was designed and constructed with M15 grade concrete. Therefore, nominal concrete mix of 1:2:4 of water cement ratio 0.5 was used. Three cube specimens were cast and tested at the time of beam test at the age of 28 days to determine the compressive strength of concrete. The average compressive strength of the concrete was 21N/mm^2.

3.7 GFRP Composites

E-Glass fiber in the form of woven fabric of 600gm/m^2 was used for strengthening purposes. For bonding these fabric mats with RC beams, 45% by weight of general purpose Iso resin was used. Mechanical Properties of GFRP laminates are design thickness of 1.3 mm, Ultimate strength of 552 MPa and Modulus of elasticity of 27579 MPa.

3.8 Strengthening Configurations

Two strengthening configurations adopted using GFRP mats for all specimens are shown in Figure 1. Externally they are wrapped by a (i) Single layer (GFRP$_1$) and (ii) Double layer (GFRP$_2$).

Prisms

Cube

Cylinder

Figure 1. GFRP Specimens

4. TEST RESULTS AND DISCUSSIONS

4.1 Flexural Test

The load deflection histories of all the specimens were recorded. The mid-span deflection of each specimen was compared with that of their respective control specimens C1. It was noted that the behaviour of the specimens when bonded with GFRP sheets were better than their corresponding control specimens as shown in Table 1. The use of GFRP sheet had effect in delaying the growth of crack formation.

Specimens	Days	Maximum Load (kN)	Maximum Deflections (mm)
C1	7	2.08	0.8
GFRP1		3.62	2.9
GFRP2		5.1	5
C1	14	3.33	1.11
GFRP1		5.74	5.8
GFRP2		8.15	10.49
C1	28	4.43	1.7
GFRP1		7.73	13.7
GFRP2		11.03	22

From the Table 1, the improvement in the flexural strength of beam can be seen experimentally and it is explained below:

C 1 is the control beam; GFRP 1 is the single layer of GFRP sheet wrapped on the concrete surface and GFRP2 is the double layer of GFRP sheet wrapped above the single layer. During 7th

day, the maximum load and the maximum deflection carried by the specimen without wrapping were 2.08 kN and 0.8 mm respectively.

At the same time, the maximum load carrying capacity and its corresponding maximum deflection for the single layer of GFRP1 was improved by 72 % when compared to that of control beam C1. Similarly, for double layer of GFRP2 the strength was improved by 84 % when compared to that of control beam C1.

The same improvement happens during 14th and 28th day test. Finally the overall performance of the beam was improved gradually from 7th, 14th and 28th day. In order to determine the ductility, the load-deflection curve also has been plotted.

The Figure 1, 2 and 3 shows the load – deflection curve for 7th, 14th and 28th day test. From the curve, the ductile nature of GFRP has been determined.

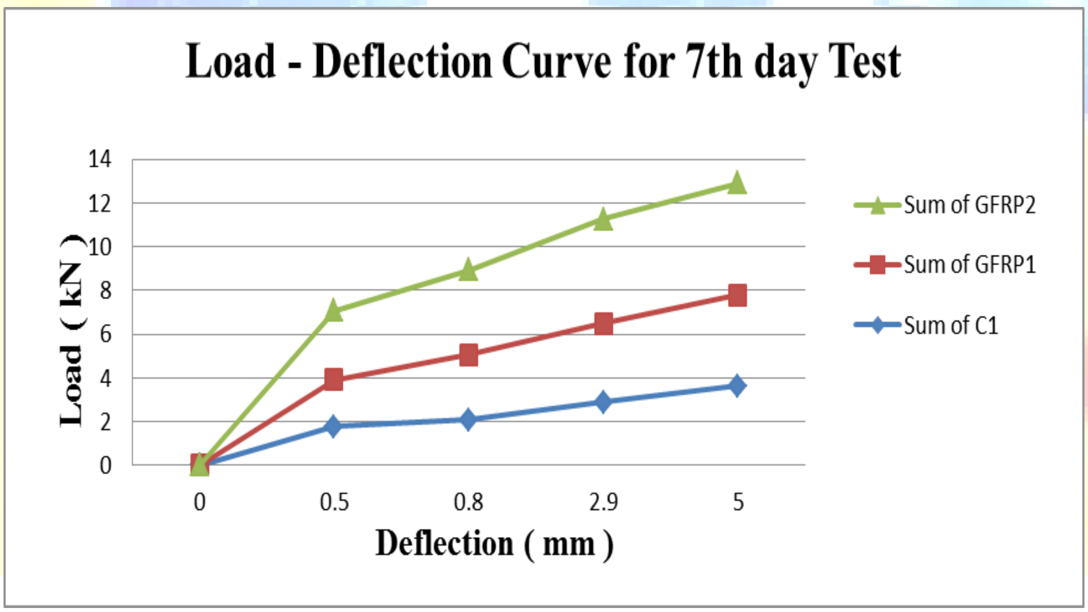

Figure 2 Load – Deflection Curve I

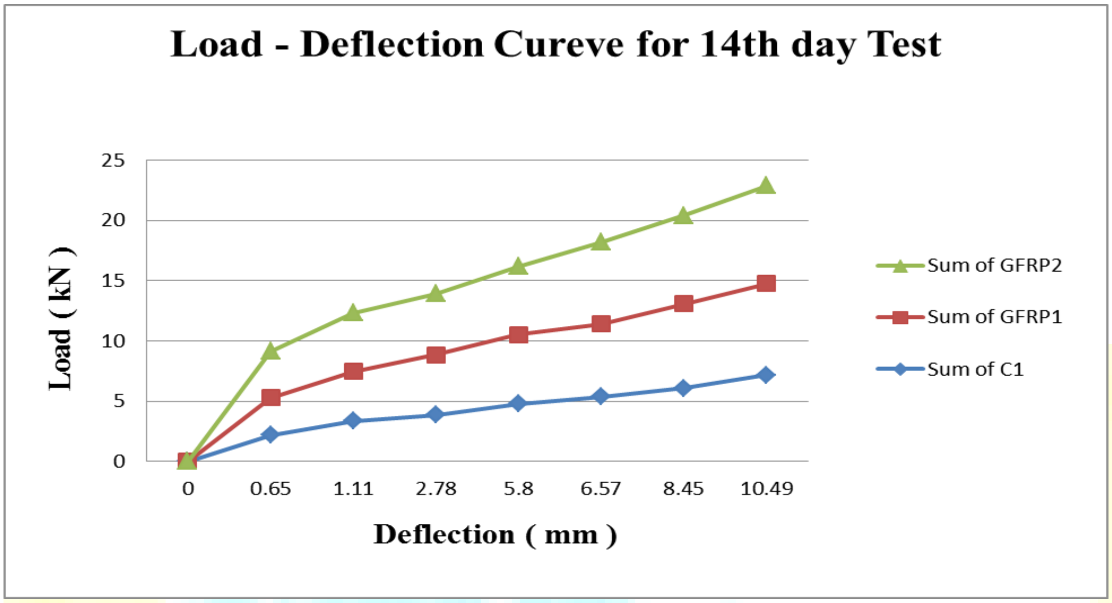

Figure 3 Load – Deflection Curve II

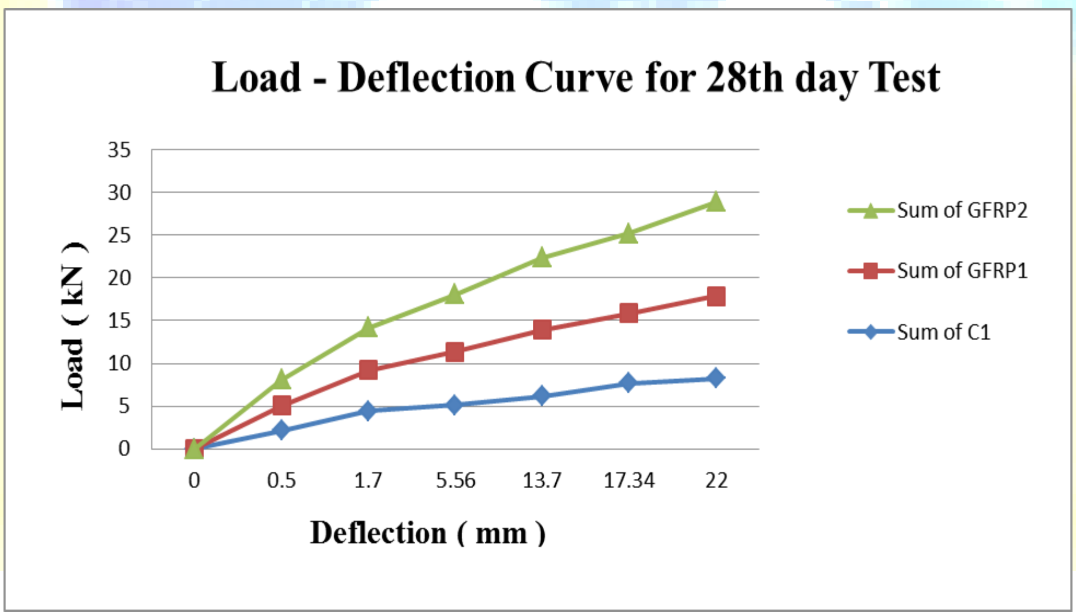

Figure 4 Load – Deflection Curve III

4.2 Compressive Strength

The universal truth, the concrete is very good in compressive strength. In the experiment the GFRP sheets were wrapped over the concrete specimens. The compression test was carried out on the cube specimen with and without GFRP. The test results were tabulated below:

Specimens	Days	Maximum Load (kN)
C1		8.8
GFRP1	7	13.3
GFRP2		17.8
C1	14	13.54
GFRP1		20.32
GFRP2		27.1
C1	28	21.98
GFRP1		33.18
GFRP2		44.4

From the Table 2, the improvement in the compressive strength of beam can be seen experimentally and it is explained below:

C1 is the control beam; GFRP 1 is the single layer of FRP sheet wrapped on the concrete surface and GFRP2 is the double layer of FRP sheet wrapped above the first layer. During 7^{th} day, the maximum load carried by the specimen without wrapping is 8.8 kN.

At the same time, the maximum load carrying capacity and its corresponding maximum deflection for the single layer of GFRP1 was improved by 33 % when compared to that of control beam. Similarly, for double layer of GFRP 2 the strength was improved by 50 % when compared to that of control beam.

The same improvement happens during 14^{th} and 28^{th} day test. Finally the overall performance of the beam was improved gradually from 7^{th}, 14^{th} and 28^{th} day. Strength comparison chart is plotted below:

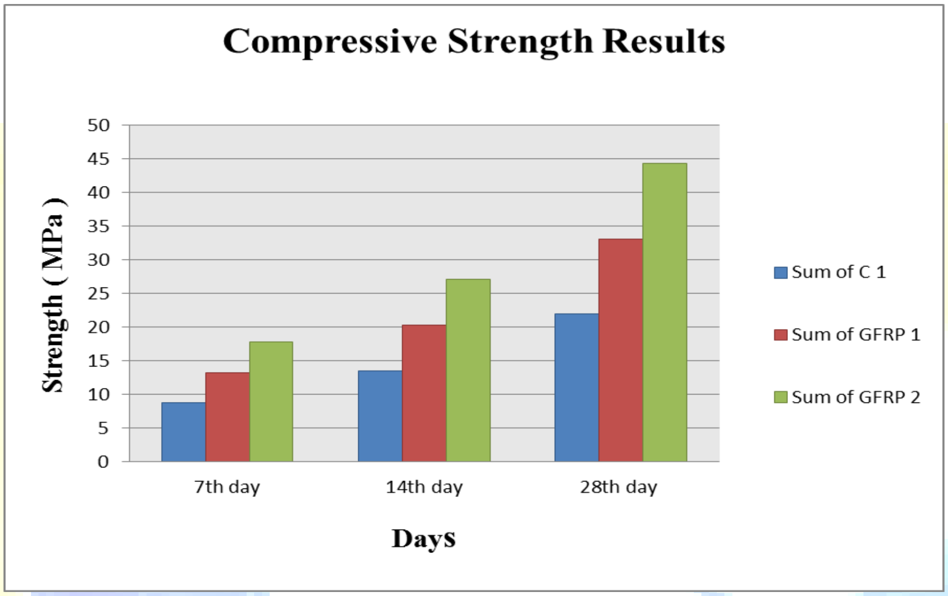

Figure 5 Compressive Strengths Results

4.3 Split-Tensile Strength

Concrete is good in compression but weak in tension. In order to improve the tensile strength, the steel reinforcements were provided whereas here the fibres were used which can also improve the tensile strength as shown in Table 3.

Specimens	Days	Maximum Load (kN)
C1	7	1.11
GFRP1		2.38
GFRP2		3.65
C1	14	1.91

GFRP1		3.18
GFRP2		4.45
C1	28	2.66
GFRP1		4.13
GFRP2		5.6

From the Table 3, the improvement in the tensile strength of beam can be seen experimentally and it is explained below:

C1 is the control beam; GFRP1 is the single layer of GFRP sheet wrapped on the concrete surface and GFRP2 is the double layer of GFRP sheet wrapped above the first layer. During 7th day, the maximum load carried by the specimen without wrapping is 1.1 kN.

At the same time, the maximum load carrying capacity and its corresponding maximum deflection for the single layer of GFRP1 was improved by 53 % when compared to that of control beam. Similarly, for double layer of GFRP 2 the strength was improved by 69 % when compared to that of control beam.

The same improvement happens during 14th and 28th day test. Finally the overall performance of the beam was improved gradually from 7th, 14th and 28th day.

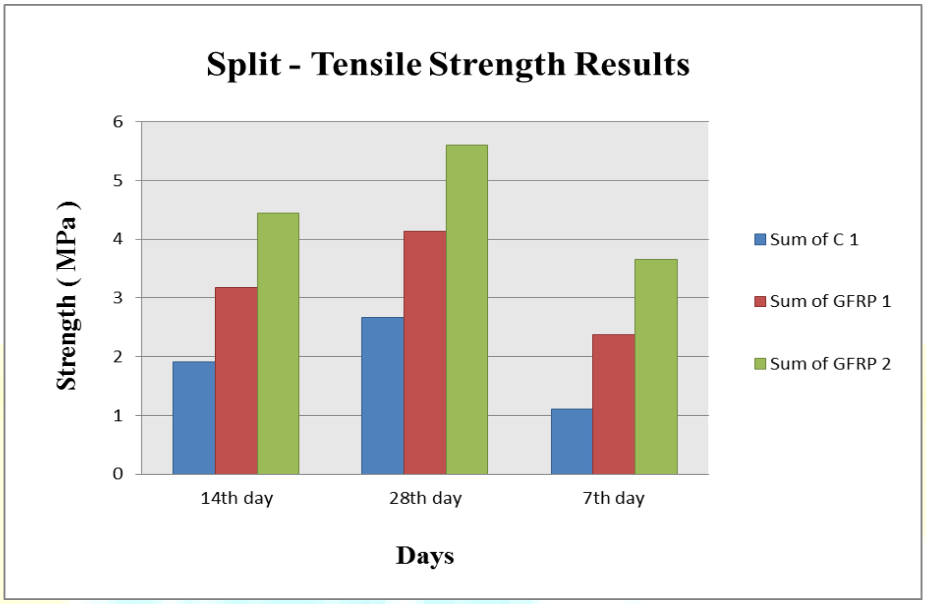

Figure 6 Split Tensile Strengths Results

5. CONCLUSION

- The use of FRP in civil structures is not uncommon anymore. FRP composites are readily used for strengthening applications mainly due to the relative ease of installation.

- The material costs of the FRP composites are several times more than that of conventional materials (e.g. steel and concrete). However, the life-cycle cost, including fabrication, application, protection and projected maintenance costs, is comparable and can be less than that of conventional materials.

- Many engineers believe that FRP composites must be used as a complementary material and not as a substitute for concrete and steel. FRP composites have significant advantages over conventional materials in particular situations, but composites cannot replace steel or concrete in every single application. Design guidelines and recommendations are essential for the wider use of FRP composites in strengthening of civil and structural engineering.

- The information presented in this thesis is applicable to repair damaged or deteriorated concrete structures, to overcome design or structural deficiencies as well as to increase the capability of structures to accommodate new uses beyond the original design. In principle, the findings of this research program will enable engineers to make more informative decisions regarding the repair and strengthening of flexural members and will assist in developing reliable design procedures for concrete structures strengthened with near surface mounted FRP reinforcement.

6. REFERENCES

1) Cheryl M. Burwell, John D. Hooper, M.Eeri Robert D. Anderson, "Seismic Strengthening of Harbor View Medical Centre Using FRP Reinforcement"
2) Tarek Kamal Hassan Mohamed, "Flexural Performance and Bond Characteristics of FRP Strengthening Techniques for Concrete Structures"
3) M Ehsani, "Strengthening of Concrete and Masonry Structures with Fibre Reinforced Polymer (FRP)"
4) Gunnar Bergman, "The choice of Glass-Fibre for FRP Structures to be used in Pulp and Paper Mill Applications".