Experimental Study of CFRP & GFRP Strengthened Reinforced Concrete Beam in Flexure & Shear

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Abstract – *Reinforced Concrete is a highly used building material in the world. It's being damaged due to various reasons such as aging, weather condition, exposure to atmosphere, continuous increase in volume of concrete, corrosion of reinforcement, salt water interaction, temperature effect etc. Many times is not feasible to replace such damaged structure with new structure as it requires lots of investment of time and money every times. In such cases strengthen of damaged structure becomes best possible option. In this study, total 9 no. of reinforced concrete beams were casted. M25 grade of concrete mix is used for beams. Carbon Fiber Reinforced Polymer (CFRP) and Glass Fiber Reinforced Polymer (GFRP) were used for strengthening the beam which were procured from Fosroc Constructive solution. CFRP and GFRP were applied in different configuration in flexure and shear on that beam using epoxy primer and satursnt. The main objective of this paper is to present the optimized technique for strengthening the Reinforced concrete beam in shear and flexure using CFRP and GFRP with suitable pattern of wrapping the beam. To enable guidelines for future design recommendation. Beams were tested under 4 point bending load. Based on the results different comparisons were made and it was found that beam strengthen with CFRP show better result than GFRP.*

Key Words: Shear, Flexure, CFRP, GFRP, Strengthening, Wrapping, Pattern, Reinforced Concrete.

1. INTRODUCTION

Reinforced concrete is one of the commonly used building materials all over the world in various structures like bridges, chimney, flyover, residential building, marine structure, industrial building etc. Gujarat consist of large line of costal area with wide verity of marine structure and wide variety of industrial building which are being damaged due to various reasons such as exposure to sever weather condition, aging, adulteration in concrete mixture, insufficient protection to steel, insufficient cover to structural member, temperature effects, highly humid climate, fire damage, salt water interaction, ingress of chemical in reinforced concrete. All the reason leads to the deterioration of concrete and reduces the strength of the reinforced concrete. As replacing the damaged structure with new structure will lead to the heavy investment of money and time which does not prove to be a good option. As in such cases strengthening the damaged structure with various techniques become best option in terms of saving the time and money. By strengthening the reinforced concrete with FRP Composite it increases the strength, durability, load carrying capacity and stiffness. Various types of FRP composite material are available in the markets such as Carbon fiber reinforced polymer, Glass fiber reinforced polymer, aramid etc. FRP is being widely used all over the world but still lots of research is required to be carried out regarding optimized and economic way of strengthening the damaged structure. This can be done by wrapping the beam in required location instead of wrapping the whole beam this required lost of FRP materials and does not proves to be economical. The main objective of this paper is to present the optimized technique of wrapping the beam which would be economical in saving the money and recourse.

2. Experimental Program

2.1 Specification of Beam

In this experiment, total 9 no. beams were casted out of which 3 were control beam and 3 were strengthened using CFRP and 3 were strengthened using GFRP. The size of beam 150 x 150 x 700 mm size with 2-8mmΦ Top reinforcement and 2-10mmΦ Bottom reinforcement with stirrups at 8mmΦ @ 90 mm c/c.

2.2 Concrete mix

The fine aggregate were free from all sorts of organic impurities was used in experimental program. The fine aggregate was passing through 4.75 mm sieve and had a specific gravity of 2.64. The grade of zone of fine aggregate was zone 5 as per Indian specification. Ordinary Portland cement of 53 grades is used for the casting of the beam. It was tested for physical properties in accordance with Indian standard specification. The consistency was 32.00%, Initial setting time 90min, Final setting time 255mm, Le'chatlier soundness 1.06. The maximum size and specific gravity of coarse aggregate was 20 mm and 2.74. For mixing of concrete and curing of concrete ordinary clean portable tap water was used. The concrete mix proportion design by IS code 10262:2009 to achieve the strength of 25 N/mm^2 was 1:1.75:1:2.81 by weight. The compressive strength test results were obtained at 7 days, 14 days and 28 days were 26.53 N/mm^2, 29.01 N/mm^2 and 33.25 N/mm^2.

2.3 CFRP and GFRP

CFRP, GFRP and Epoxy primer and saturant were procured from Fosroc Constructive solution. Carbon fiber reinforced polymer - Nitowrap EP(CF200) 200g/m^2, and Glass fiber reinforced polymer – Nitowrap EP(GF) 920g/m^2 sheets were used for strengthening of beam. Nitowrap 30 primer (Base and Hardener) and Nitowrap 410 Saturant (Base and Hardener) were used for wrapping CFRP and GFRP on beam.

After 28days of curing period of beam, the surface of the beam was made rough using grinder machine after the preparation of the surface of the beam as per required standard then Nitowrap 30 primer it comes with Base and Hardener it is mixed in accordance with manufacturer's instruction. The mixing was done until the mixture was in uniform color and then it was applied on the prepared surface of the beam with the help of brush and kept for curing for 24 hours. Then Nitowrap 410 saturant it is also a combination of base and hardener. Both base and hardener is mixed until uniform color is achieved and then it was applied on the surface of the beam were Nitowrap 30 primer was already applied and then immediately fabric was applied on the top surface of the Nitowrap 410 saturant and fabric was genteelly pressed, then again mixture of Nitowrap 410 saturant was applied on the top of the fabric and the it was kept for air cuing at room temperature.

2.4 CFRP and GFRP configuration for beam

Total 9 beams were casted out of which three beams were strengthened using CFRP and remaining three were strengthen using GFRP in different configuration in flexure and shear. To check the effect of strengthening, beam in flexure and shear zone. Three beam were control beam without CFRP and GFRP sheet (CB1, CB2, CB3)

CFRP- Three beams were wrapped using CFRP. First beam was wrapped by full bottom wrapping (CB4) Fig-1, Second beam was wrapped by rectangular strip of 50mm width @ 50mm spacing at both the side of beam (CB5) Fig-2, and Third beam was wrapped by full bottom wrapping and rectangular strip of 50mm width @ 50mm spacing at both the side of beam (CB6) Fig-3.

GFRP- Three beams were wrapped using CFRP. First beam was wrapped by full bottom wrapping (CB7)Fig-1, Second beam was wrapped by rectangular strip of 50mm width @ 50mm spacing at both the side of beam (CB8) Fig-2, and Third beam was wrapped by full bottom wrapping and rectangular strip of 50mm width @ 50mm spacing at both the side of beam (CB9) Fig-3.

Fig -1: CB4 and CB7

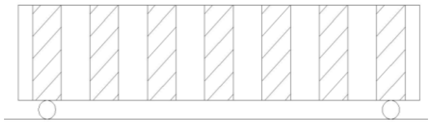

Fig -2: CB5 and CB8

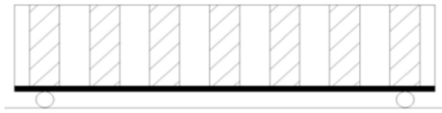

Fig -3: CB6 and CB9

2.5 Experimental Set-Up

All the beams were tested under four point loading using UTM machine of 600 kN capacity. The arrangement for four loading is shown in Fig-1. Supports were placed at 50mm from both the ends so the effective length was 600mm.

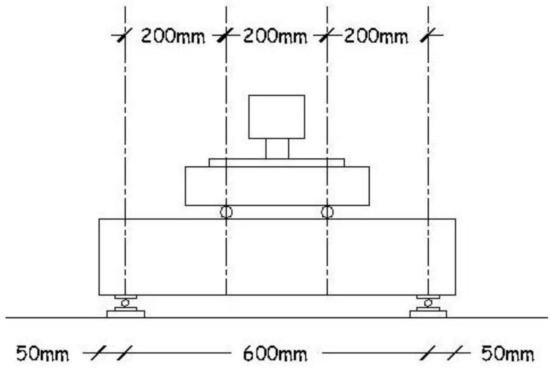

Fig -4: Arrangement for four point loading

Fig -5: UTM machine 600kN

2.6 Results and discussion

Total 9 beams were tested under 4 point bending using UTM machine of 600kN capacity. The load v/s Displacement graphs were obtained. Following are figure of the beam after testing

Fig -6: CB1 after testing

Fig -7: CB2 after testing

Fig -8: CB3 after testing

Fig -9: CB4 after testing

Fig -10: CB5 after testing

Fig 11: CB6 after testing

Fig -12: CB7 after testing

Fig -13: CB8 after testing

Fig -14: CB9 after testing

Following are the Load V.s Deflection curves of all the beams

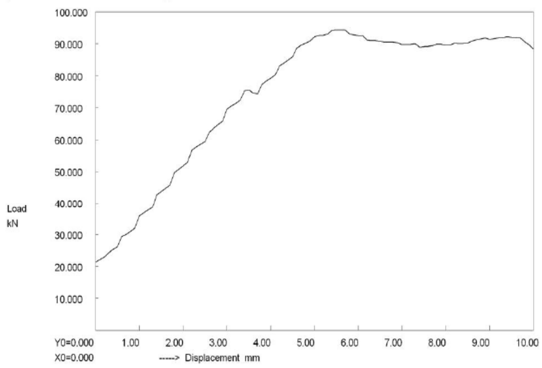

Chart-1: Load Vs. Deflection curve of CB1

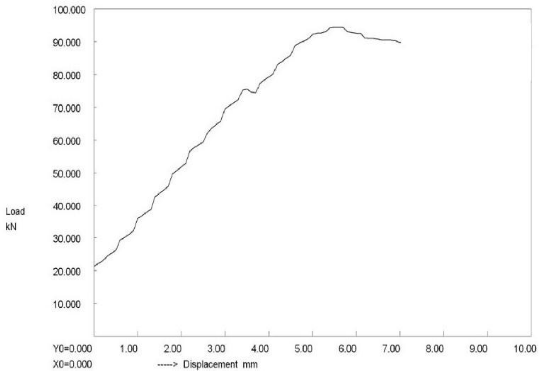

Chart -2: Load Vs. Deflection curve of CB2

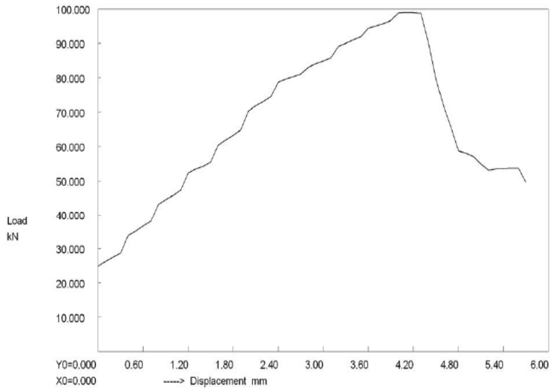

Chart -3: Load Vs. Deflection curve of CB3

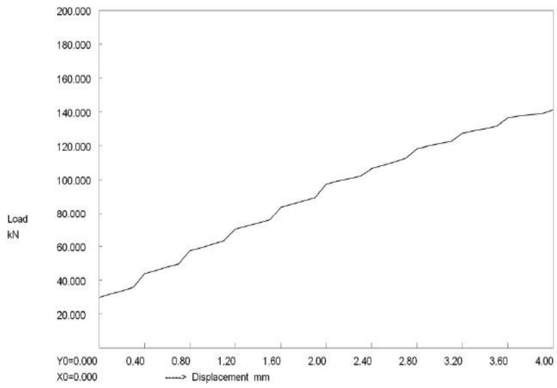

Chart -4: Load Vs. Deflection curve of CB4

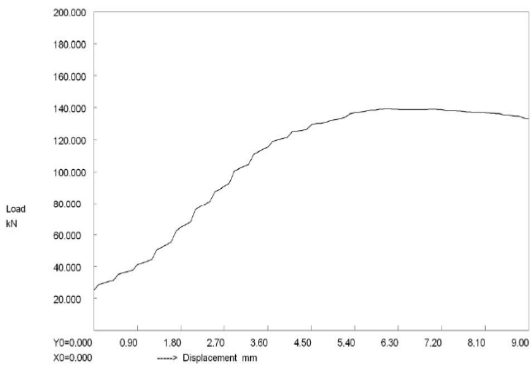

Chart -5: Load Vs. Deflection curve of CB5

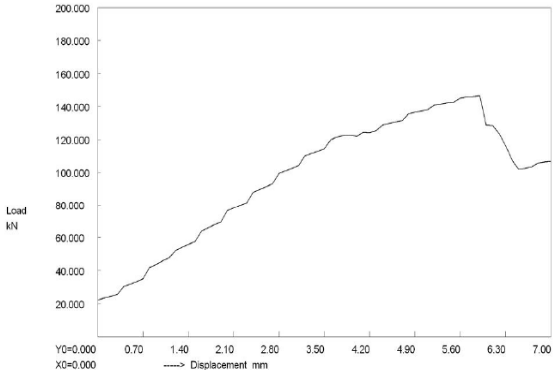

Chart -6: Load Vs. Deflection curve of CB6

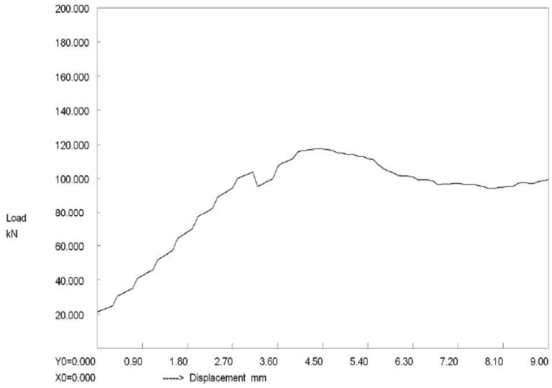

Chart -7: Load Vs. Deflection curve of CB7

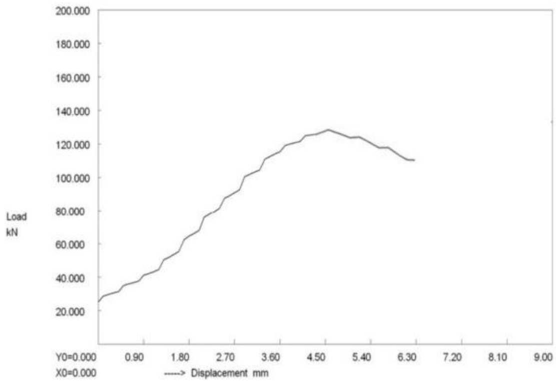

Chart -8: Load Vs. Deflection curve of CB8

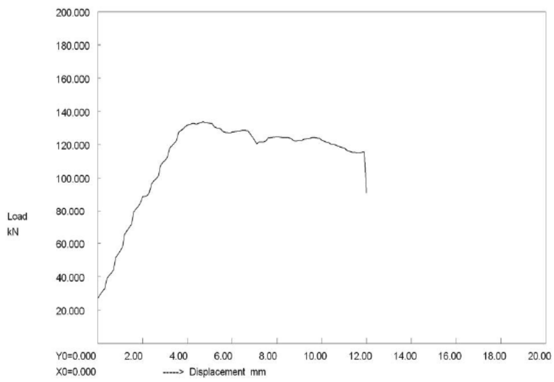

Chart -9: Load Vs. Deflection curve of CB9

Table- 1 shows the Load Vs. Deflection behavior of all the beam

Table- 1: Load Vs. Deflection

Sr NO.	Beam	Ultimate Load (kN)	Ultimate Deflection (mm)
1	CB1	94.71	6.1
2	CB2	96.78	6.5
3	CB3	99.06	4.1
4	CB4	141.66	4.1
5	CB5	139.38	6.1
6	CB6	146.79	6.0
7	CB7	117.78	4.4
8	CB8	125.18	5.5
9	CB9	134.19	4.8

2.7 Comparison of Ultimate load of beams

From the Chart -10 it can be easily understood that the strengthen beam have better ultimate load carrying capacity compare to the average of the three control beam (CB1, CB2, CB3). For beam strengthen using CFRP (CB4), (CB5), (CB6) show an increment by 46.27%, 43.91% and 51.56% compared to the average of control beam. For beam strengthen using GFRP (CB7), (CB8), (CB9) show an increment by 21.61%, 29.25% and 38.55% compared to the average of control beam.

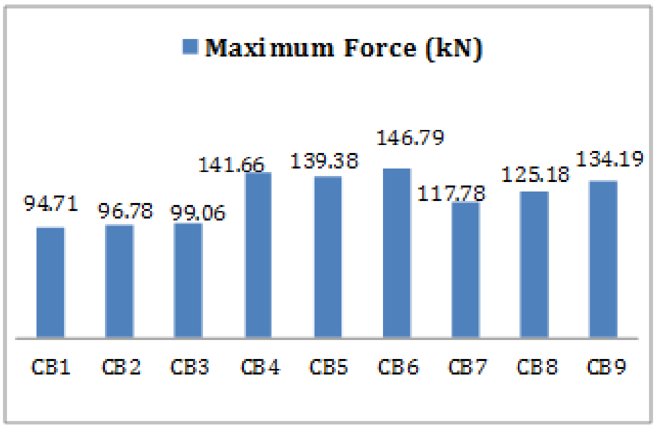

Chart -10: Maximum Force (kN)

2.8 Comparison of Deflection of beams

From the Chart -11 it can be easily understood that the strengthen beam have better decrement in ultimate deflection compare to the average of the three control beam (CB1, CB2, CB3). For beam strengthen using CFRP (CB4) show good decrement by 21% compared to the average of control beam. For beam strengthen using GFRP (CB7), (CB8), (CB9) show good decrement by 21%, 1.25% and 13.82 %.

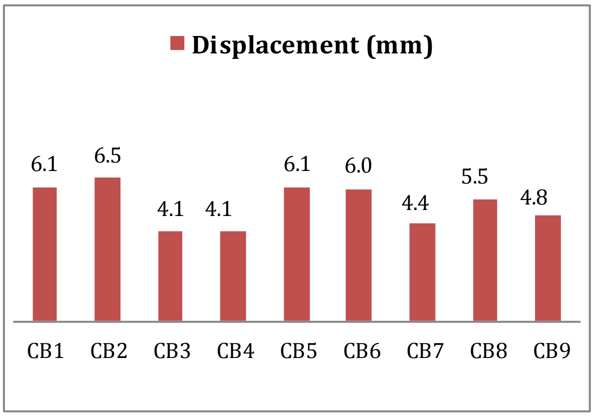

Chart -11: Ultimate Deflection (mm)

3. CONCLUSIONS

In this experiment, total 9 no. of beams were tested with 2 different type of material used for strengthening

1. Beam (CB4) and (CB7) wrapped by full bottom for strengthening in flexural zone by CFRP and GFRP. Beam (CB4) shows better result than (CB7)
2. Beam (CB5) and (CB8) wrapped by rectangular strip of 50mm width @ 50mm spacing at both the side of beam for strengthening in shear zone by CFRP and GFRP. Beam (CB5) shows better result than (CB8)
3. Beam (CB6) and (CB9) wrapped by Full bottom and rectangular strip of 50mm width @ 50mm spacing at both the side of beam for strengthening in flexure and shear zone by CFRP and GFRP. Beam (CB6) shows better result than (CB9)
4. Beam (CB4, CB5, CB6) strengthen using CFRP, beam (CB6) shows better load carrying capacity among the three beams and it proves to be a better technique for strengthening the beam using CFRP in both flexure and shear.
5. Beam (CB7, CB8, CB9) strengthen using GFRP beam (CB9) shows better load carrying capacity among the three beams and it proves to be a better technique for strengthening the beam using GFRP in both flexure and shear.
6. The Overall performances of beam strengthen using CFRP increased load carrying capacity of beam compared to the entire beam.

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