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STRENGTHENING OF REINFORCED CONCRETE DEEP BEAM USING FRP WRAPPING

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ABSTRACT

This paper presents the results of an experimental investigation on shear strength enhancement of reinforced concrete deep beams externally reinforced with fiber reinforced polymer (FRP) composites. A total of sixteen deep beam specimens of size 150x350mm and 700mm long were cast. Eight beams of Set-I for Glass fiber reinforced polymer (GFRP) out of eight one as control beam and seven as retrofitted using Glass fiber reinforced concrete and Eight beams of Set-II one as control beam and seven retrofitted using Carbon fiber reinforced polymer (CFRP) as an external reinforcement is used extensively to address the strength requirements related to flexure and shear in structural systems. Two composite systems namely glass fiber reinforced polymer (GFRP) and carbon fiber reinforced polymer (CFRP) were used for retrofit evaluation. A comparative study of the experimental results using FEA software ANSYS and identify the influencing factors on the shear behavior of FRP strengthened reinforced concrete deep beams. Experimental results indicated that substantial increase in ultimate strength of strengthened beams as compared to the control beam specimen. The shear span-to-depth ratio (L/d) is an important factor that actively controls the shear failure mode of beam and consequently influences on the shear strength enhancement. Glass fiber reinforced polymer (GFRP) and Carbon fiber reinforced polymer (CFRP) as an external reinforcement is used extensively to address the strength requirements related to flexure and shear in structural systems.

KEYWORDS: Carbon Fiber Reinforced Polymer (CFRP), Glass fiber Reinforced polymer (GFRP), Deep beam, M20 concrete.

I. INTRODUCTION

Strengthening of structural elements such as beams and columns has become vital now-a-days due to many unavoidable circumstances such as revised loading conditions change in occupancy conditions and deterioration of existing structure due to environmental effects. Strengthening of structural elements by externally bonded FRP laminates is very effective technique adopted successfully worldwide. Externally bonded FRP laminates can be used to increase the shear and flexural strength of reinforced concrete beams and columns. Although bonding of FRP on the either side of beams or at the soffit does provide some shear strengthening to the beams. Many researchers have found that the FRP laminates applied to the reinforced concrete element provides efficiency, reliability and cost effectiveness in rehabilitation.

Advanced Fiber Reinforced Polymer (FRP) composite is very effectively being used worldwide for strengthening structures. It provides a cost effective and technically more superior alternative to the traditional techniques in many specific situations. It offers high strength with low self weight, corrosion resistance, high fatigue resistance, easy and rapid installation and minimal change in structural geometry. Conventional Strengthening methods such as external post tensioning, member enlargement along with internal transverse steel, and bonded steel plates are very expensive. In addition to that these methods are time consuming require extensive equipment and significant labor. FRP repair systems and materials. Literature survey indicates there is considerable scope for research work in this area of “Strengthening of beams with FRP composites.”

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II. MATERIALS AND METHODS

1. Materials:

i).Cement: Ordinary Portland cement (OPC)- 53 grades (Ambuja Cement) is used for the investigation.
ii).Fine Aggregate (River Sand): The fine aggregate used in this investigation was clean river sand, passing through 4.75 mm sieve with specific gravity of 2.68. The grading zone of fine aggregate was zone III as per Indian Standard specifications.
iii).Coarse Aggregate: The maximum size of coarse aggregate was 20 mm with specific gravity of 2.73.
iv). Water : Water fit for drinking is generally considered fit for making concrete.
v) Reinforcement: The longitudinal reinforcements used were high yield strength steel bars of 6,8,10 mm diameter. The stirrups were made from mild steel bars with 6 mm diameter. The yield strength of steel reinforcements used in this experimental program was determined by performing the standard tensile test on the three specimens of each bar. The average proof stress at 0.2 % strain of 8,10 mm diameter bars was 512 MPa and that of 6 mm bars was 263 MPa.
vi).Glass Fiber Reinforced polymer sheet: Glass fibers typically have a Young modulus of elasticity 70 GPa for E-glass abrasion resistance is relatively poor therefore; caution in their manipulation is required. FRP composites based on fiberglass are usually denoted as GFRP.
vii) Carbon Fiber Reinforced polymer sheet: The carbon fiber is an anisotropic material, and its transverse modulus is an order of magnitude less than its longitudinal modulus. The material has a very high fatigue and creep resistance.
vii)Epoxy Resin: These epoxy resins are generally two part systems, a resin and a hardener. The resin and hardener are used in this study is Araldite LY 556 and Hardener HY 951, respectively. Araldite LY-556, an unmodified epoxy resin based on Biphenyl-A and the hardener .

2. Experimental investigation:

Details of Beam Specimen:

The test program consisted of casting and testing 16 beams, of which one was control beams, all having size of 150mmx350mmx700mm length, reinforced with 2-10 diameter bar at top and 1-8mm diameter bar between the 2-10mm bars at top , 2-10 diameter bar at bottom and 1-8mm diameter bar between the 2-10mm bars at bottom using 2-6mm diameter stirrups wound spirally horizontally with 150mm spacing c/c and 6-6mm diameter stirrups wound vertically with 70mm c/c spacing. The beams were cast using M-20 grade concrete with 20mm maximum size of coarse aggregate, locally available sand and 53 grade ordinary Portland cement. These beams were cured for 28 days in pure water and were tested under two-point loading on a universal testing machine of capacity 1000KN.

Preparation of test specimen:

The test specimen is summarized in Table 1. The surface was cleaned using polish paper to get a good bond between the FRP strip and concrete surface. There are total 16 beams, which are divided into two sets. Set-I consists 8 beams, one as control beam and remaining as strengthened beam the strengthened beam of set-I was externally bonded with GFRP strips to concrete surface using Epoxy resin

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Table 1). Details of Strengthening Pattern of Beam

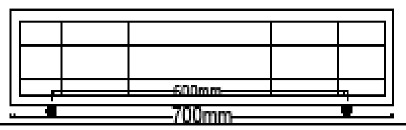
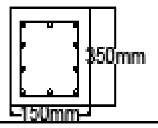
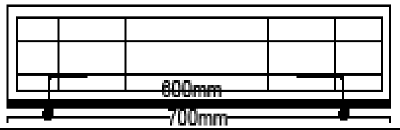
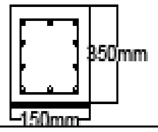
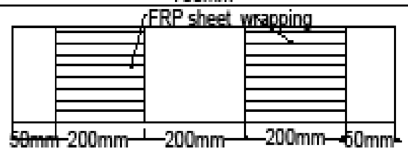
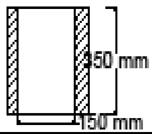
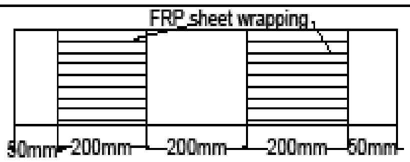
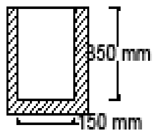
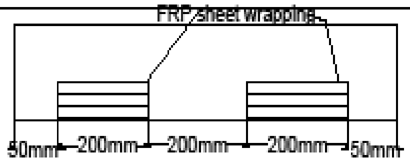
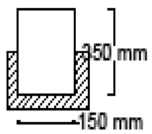
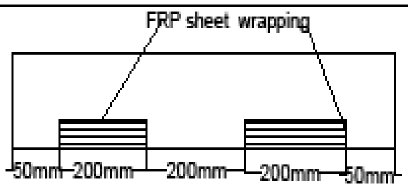
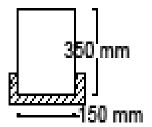
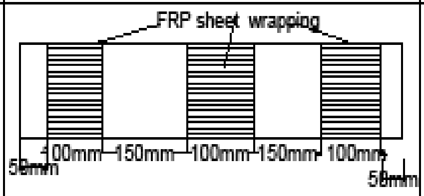
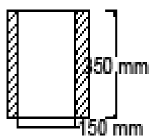
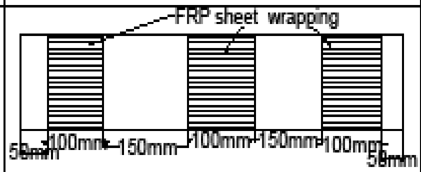
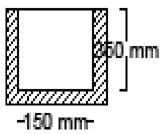
Table Details Of Strengthens Pattern		
DESIGNATION OF BEAM	L-Section	C/S section
CB_1		
SBG_1/SBC_1		
SBG_2/SBC_2		
SBG_3/SBC_3		
SBG_4/SBC_4		
SBG_5/SBC_5		
SBG_6/SBC_6		
SBG_7/SBC_7		

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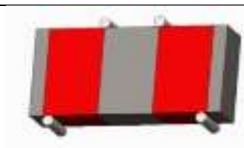
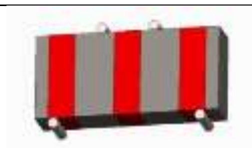
Table2). CREO 2.0 (Parametric) modeling of beam with FRP

Beam Notations	CREO modelling:	Beam Notations	CREO Modelling:
CB1		SBG4/SBC4	
SBG1/SBC1		SBG5/SBC5	
SBG2/SBC2		SBG6/SBC6	
SBG3/SBC3		SBG7/SBC7	

Test Setup:-

All the specimens will be test on the UTM of the "Structural Engineering" Laboratory of the SKN Sinhgad College of Engineering, Korti. The testing procedure for the entire specimen is same. After the curing period of 28 days was over, the beam as washed and its surface was cleaned for clear visibility of cracks. The most commonly used load arrangement for testing of beams will consist of two-point loading. This has the advantage of a substantial region of nearly uniform moment coupled with very small shears, enabling the bending capacity of the central portion to be assessed. Two-point loading can be conveniently provided by the arrangement shown in Figure1. The load is transmitted through a load cell and spherical seating on to a spreader beam. This beam bears on rollers seated on steel plates bedded on the test member with mortar, high-strength plaster or some similar material. The test member is supported on roller bearings acting on similar spreader plates.

The specimen was placed over the two steel rollers bearing leaving 70 mm from the ends of the beam. The remaining 600 mm will divided into three equal parts of 200 mm as shown in the figure. Two point loading arrangement was done as shown in the figure1. Loading was done by hydraulic jack of capacity 1000 KN. Cracks are formed on the faces of the beams were marked and identified. All beam specifications were loaded and simply supported as shown in figure 1.

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Figure1. Experimental Setup for Testing of Beams.

Load-deflection, stress and strains have been recorded for each specimen. Concrete having mean compressive strength of 21.54 MPa was used. For all the test beams, the parameters of interest were ultimate load, midspan deflection, composite action, and failure modes.

III. RESULTS AND DISCUSSION

Test Result:-

During the Experimental testing of beams it is observed that all the beams of set-I (Glass fiber) which are strengthened, there is considerable increase in load values for initial cracks. For control beam initial cracks appeared at 75KN and for all strengthened beams it was about 90 to 105KN.

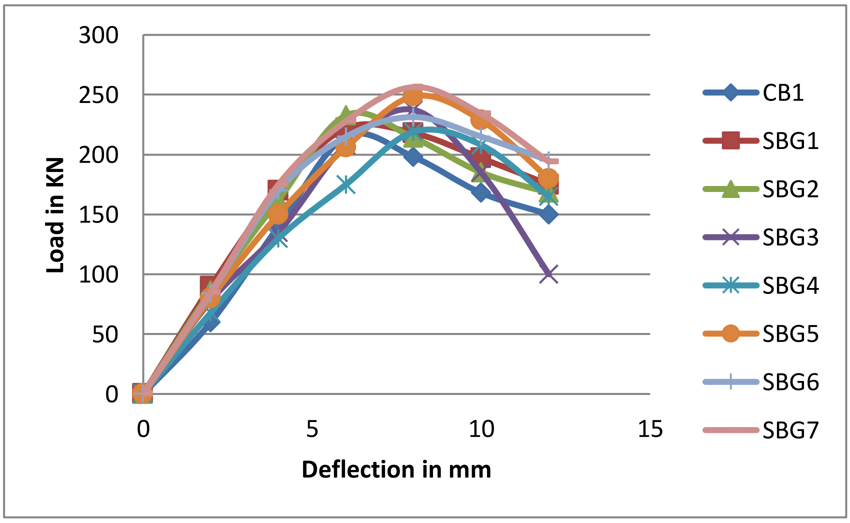

Figure 2. Load vs Deflection Curve for CB1 and SBG 1,2,3,4,5,6,7

And experimental testing of Set-II (Carbon fiber) beams which is strengthened, there is considerable increase in load values for initial cracks. For control beam initial cracks appeared at 75KN and for all strengthened beams it was about 90 to 108KN.

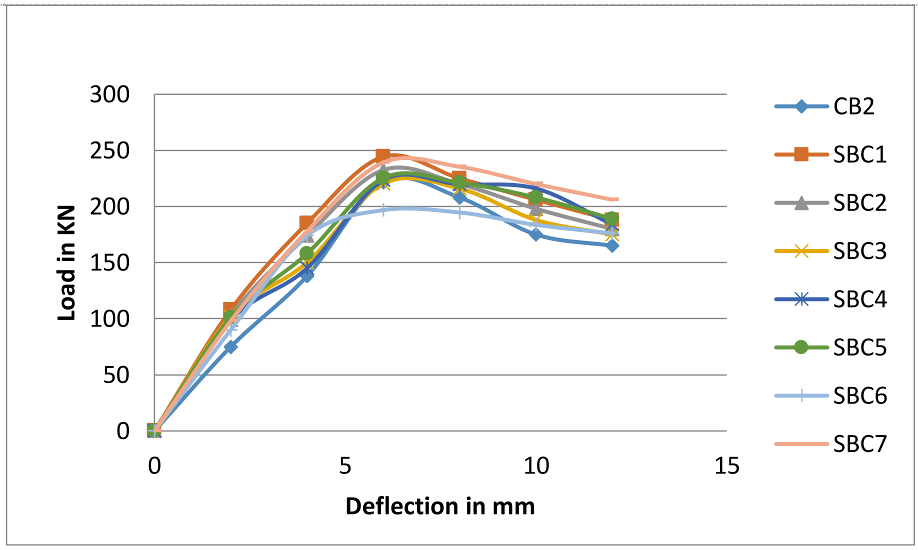

Figure 3. Load vs Deflection Curve for CB2 and SBC 1,2,3,4,5,6,7

Ultimate load carrying capacity (Glass Fiber Strengthening):

The load carrying capacity of the control beams and the strengthened beams were found out is shown in figure 4. The control beams were loaded up to their ultimate loads. It was noted that of all the beams, the strengthen beams SBG3, SBG5 and SBG7 had the higher load carrying capacity compared to the controlled beam. An important character to be noticed about the usage of GFRP sheets is the linear elastic behavior to failure (No ductility). It has low elasticity and shear moduli and high longitudinal strength. It has orthotropic behavior. The use of FRP can delay the initial cracks and further development of the cracks in the beam**.**

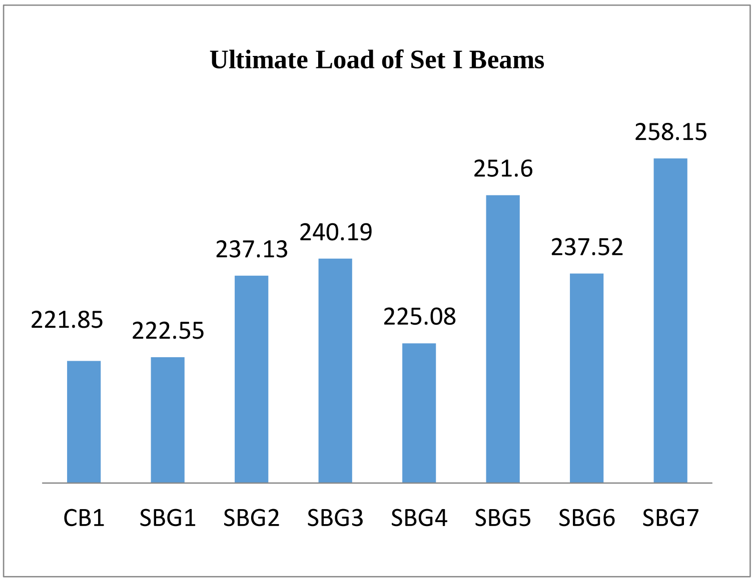

Figure 4. Ultimate load of beams CB 1 and SBG 1,2,3,4,5,6,7

Ultimate load carrying capacity (Carbon Fiber Strengthening):

The load carrying capacity of the control beams and the strengthen beams were found out as shown in figure 5. The control beams were loaded up to their ultimate loads. It was noted that of all the beams, the strengthen beam SBC1, SBC2, SBC7 had a higher load carrying capacity compared to the control beam. An important character to be noticed about the usage of CFRP sheets is the high ductile behavior of the beams. The shear failure being sudden can lead to huge damage to the structure. But the ductile behavior obtained by the use of CFRP can give

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us enough warning before the ultimate failure. The use of FRP can delay the initial cracks and further development of the cracks in the beam.

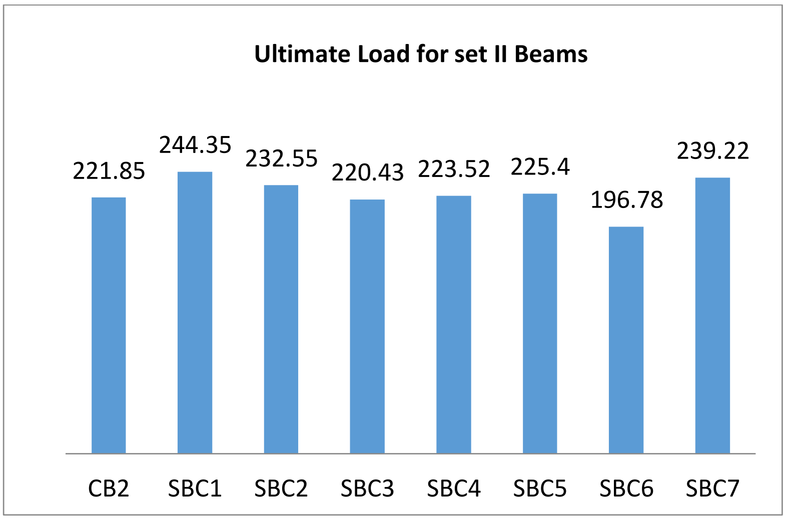

Figure 5. Ultimate loads of beams CB2 and SBC1.2,3,4,5,6,7

Finite element modeling:

Simulation has been carried out in ANSYS 12.0 which is a finite element package. In modelling 3D geometry of beams is drawn in CREO 2.0 parametric. Concrete is a nonlinear behavior material during loading. It is analysis in Ansys version 12.0 (workbench) to conduct analysis.

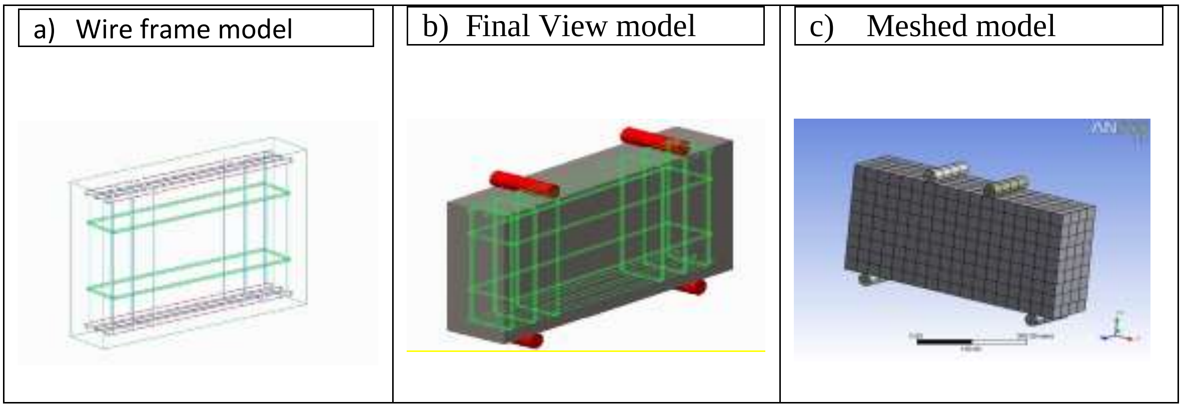

Figure6. Models of beam

Similarly different configuration of beams which are modelled in Creo 2.0 parametric. Creo model is imported in ansys and it is meshed. Before mesh material properties are input to the software. Non-linear material properties are taken into consideration. These properties are obtained from experimentation. Following graph shows nonlinear behavior for CB1.

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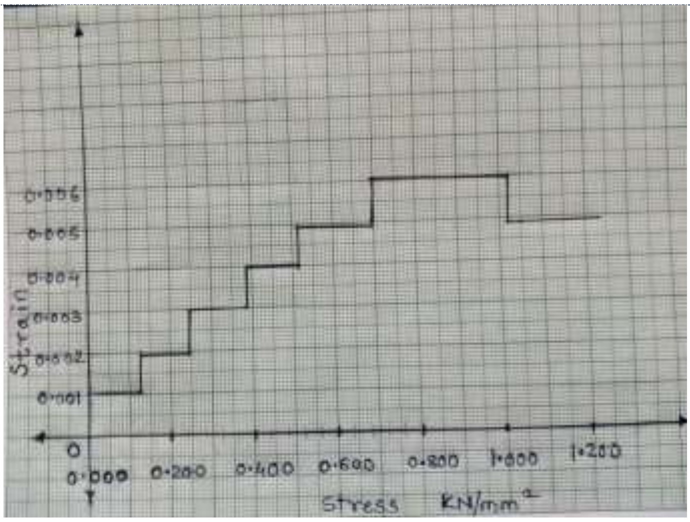

Figure7. Stress strain graph for CB1

While meshing 10 node Tetrahedron and Brick 4 noded 20 element are selected. Tetrahedron has been used for meshing steel bars and Brick 4 noded 20 elements was used for meshing remaining structure. Conta 174 element element is used to model pair of steel with concrete and concrete with FRP. Therefore, 20807 number of nodes and 6392 number of element is generated after meshing. Nonlinear static analysis has been carried out.

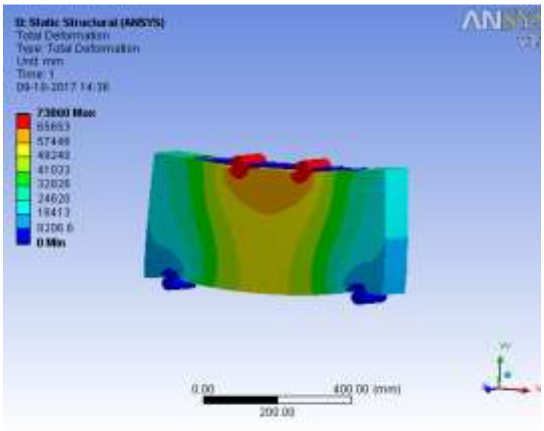

Figure8. Deformation in Beam

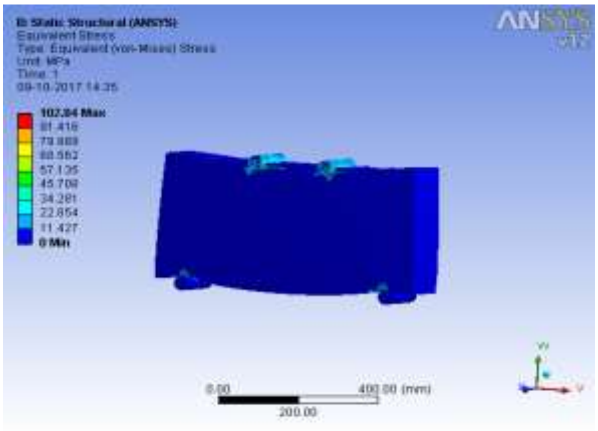

Figure 9. (Von-Mices) stress in Beam (ANSYS)

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Table 3. Comparison of results for SET I (glass FRP)

Name of Beams	Ultimate Strength (KN)		% Deviation
	By Expt	By FEA	
CB1	221.85	214.950	3.21
SBG1	222.55	221.950	0.27
SBG2	237.13	232.750	1.88
SBG3	240.19	237.350	1.19
SBG4	225.08	219.050	2.75
SBG5	251.60	248.650	1.18
SBG6	237.52	231.350	2.66
SBG7	258.15	256.350	0.70

T able** 4. **Comparison of results for SET II (Carbon FRP)

Name of Beams	Ultimate Strength (KN)		% Deviation
	By Expt	By FEA	
CB2	221.85	214.950	3.21
SBC1	244.35	239.750	1.91
SBC2	232.55	227.450	2.24
SBC3	220.43	215.950	2.07
SBC4	223.52	219.750	1.71
SBC5	225.40	221.150	1.92
SBC6	196.78	194.650	1.09
SBC7	239.22	235.350	1.64

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Ultimate Load Carrying capacity of Set I and Set II :

Finite element analysis has also carried out to find the ultimate load carrying capacity and compared with the experimental results. It was found that analytical analysis predicts lower value than the experimental results. It is observed that there is maximum 3.21% deviation in ultimate strength obtained by experimentation and FEA. From the results, it is observed that the maximum deviation in case of glass fiber as well as carbon fibers control beams is same and the value is 3.21%; whereas, for both cases the minimum deviation is 0.27% and 1.05 % respectively. The different, may occur because as during software analysis it considers all the ideal conditions for analysis.

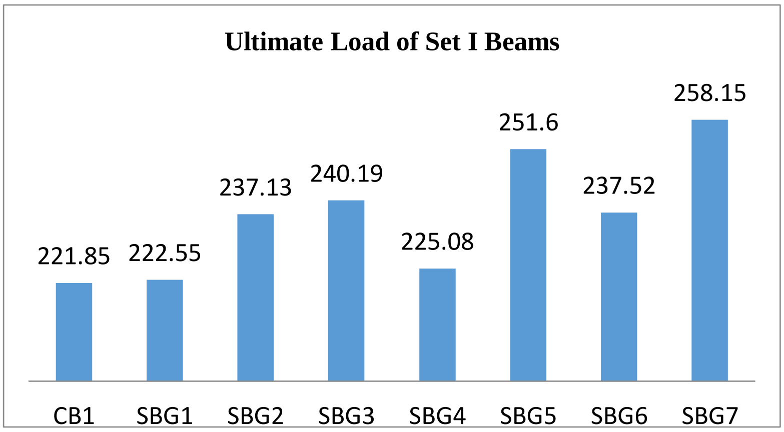

Figure 10) Ultimate load Carrying Capacity of Set I

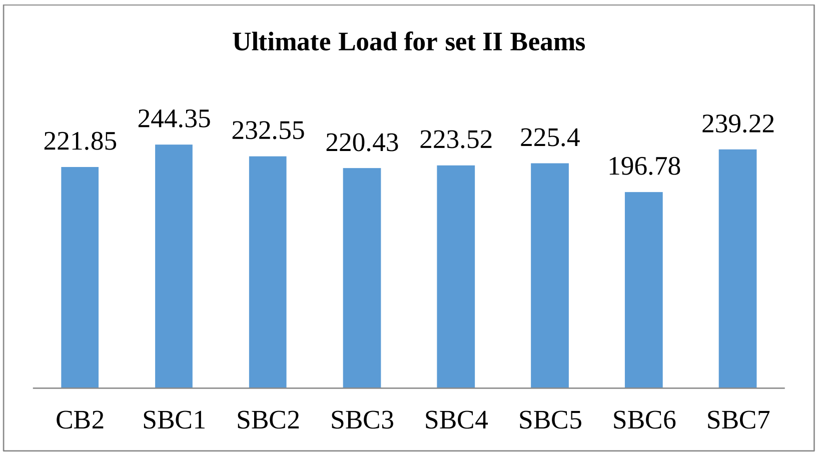

Figure 11) Ultimate load Carrying Capacity of Set II

IV. CONCLUSION

In this experimental investigation the flexural and shear behavior of reinforced concrete beams strengthened by GFRP or CFRP sheets are studied. Two sets of reinforced concrete (RC) beams, in SET I and SET II total sixteen beams were casted and tested. From the result and calculated strength values using ANSYS, the following conclusions are drawn:

1) FRP composites are promising materials, presenting several advantages over traditional materials for both new construction and rehabilitation: strength, lightness, ease of application, durability under aggressive environments and low maintenance.
2) Firstly it is observed that load at initial cracks was increased for all strengthened beams.

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3) When the beam is not strengthened, it failed in shear but after Strengthening the beam fails in, the flexure- shear failure.
4) Shear Strengthening and flexural Strengthening of beam increases the load carrying capacity, but the cracks developed are not visible up to higher loads.
5) The strengthened beams gives less warning due to invisibility of cracks compared to the control beam.
6) The Set-I strengthened beams Patterns for SBG3, SBG5 and SBG7 had the higher load carrying capacity compared to the controlled beam.
7) It was noted that of all the beams of Set-II, the strengthen beam SBC1, SBC2, SBC7 had a higher load carrying capacity compared to the control beam.
8) It is found that, U-wrap of GFRP (3 Nos of 100mm width) bonded on the RC deep beam can enhance the shear strength up to 16%.
9) Bottom layer CFRP fabric properly bonded on the tension face of RC deep beams can enhance the shear strength up to 10%.
10) Finite element analysis has been carried out for result validation. There is maximum 3.21% deviation in ultimate strength obtained by experimentation and FEA.

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