International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 5 May 2022, pp: 1618-1630 www.ijaem.net ISSN: 2395-5252

Experimental Study of FRP Composites for Rc T-Beams With Web Openings For Shear Strengthening

Yadav S.K.[1], Kumar V.[2],
[1]*M.Tech Scholar, Dept. of Civil Engineering, PKGCET, Haryana*
[2] *Assistant Professor, Dept. of Civil Engineering, PKGCET, Haryana*

Submitted: 15-05-2022 Revised: 20-05-2022 Accepted: 25-05-2022

ABSTRACT: Shear failure of reinforced concrete (RC) members is a catastrophic event that occurs suddenly and without notice. Existing RC beams have been discovered to be shear inadequate and in need of reinforcement on multiple occasions. External post tensioning, member expansion with internal transverse steel, and bonded steel plates are all expensive shear strengthening methods that require a lot of equipment, time, and effort.The general goal of this research was to look into the shear performance and failure modes of RC T-beams reinforced with GFRP sheets that were externally connected. An intensive experimental programme comprising of testing eleven full scale RC beams was carried out to attain these goals. Steel stirrups, shear span-to-depth ratio, and GFRP quantity were among the variables evaluated in this study. The experimental results showed that externally bonded GFRP has a considerable contribution to shear capacity, which varies depending on the variable studied. The failure of reinforced beams begins with the debonding of FRP sheets, which is followed by brittle shear failure.However, when compared to the control beam, these beams have a higher shear capacity, which can be improved further provided debonding failure is avoided. To prevent these premature failures, a unique approach of anchorage technique utilising GFRP plates was developed, ensuring full utilisation of the strength of FRP.

Keywords: Shear strengthening, RC T-Beam, web opening, FRP composites.

I. INTRODUCTION:

Many natural disasters, the most devastating of which is the earthquake, have necessitated a rise in building safety standards. Because our understanding of earthquakes is growing, the seismic demands placed on structures must be changed. Retrofitting has become an acceptable means of boosting load carrying capacity and extending the service life of such defective structures because comprehensive replacement would cost a significant amount of public money and effort.Retrofitting is most commonly employed in relation to seismic upgrades of facilities, such as the use of composite jackets for column confinement. Making adjustments to an existing structure to safeguard it from flooding or other risks such as high winds and earthquakes is known as retrofitting.

One of the most important difficulties in civil engineering is the maintenance, rehabilitation, and upgrade of structural components. Furthermore, according to the new design regulations, a substantial number of structures built in the past utilising previous design codes in various regions of the world are structurally unsafe. Because replacing such weak components of structures costs a lot of money and time, strengthening has become a viable option for increasing load carrying capacity and extending service lives.The retrofitting is one of the best options to make an existing inadequate building safe against future probable earthquake or other environmental forces. There are many other factors, considered in decision making for any retrofitting strategy.

Ghazi investigated the shear repair of reinforced concrete (RC) beams reinforced with fibre glass plate bonding (FGPB) for structural and non-structural cracking behaviour. The findings of a study on reinforcing RC beams with low shear strength and large diagonal stress cracks were given. Fiber glass plate bonding (FGPB) procedures were used to repair beams with low shear strength to a preset level (the development of the first shear crack).Chaallal (1998) looked into a holistic design strategy for reinforced concrete flexural beams and unidirectional slabs reinforced with externally bonded fibre reinforced plastic (FRP) plates. The technique followed the Canadian Concrete Standard. Alex(2001) investigated the influence of shear strengthening on the stress distribution, initial cracks, crack propagation, and ultimate strength of RC beams in an experimental setting. In flexure, five types of beams with varying strengthening carbon-fiber–reinforced plastic sheets are commonly used. The experimental results suggest that strengthening the entire concrete beam surface is not essential. Strain gauges are used to investigate the general and regional characteristics of concrete beams with bonded carbon-fiber–reinforced plastic sheets.Chen and Teng (2003) investigated the shear capability of RC beams enhanced with FRP. These investigations have proven that such strengthened beams fail in shear primarily in one of two ways, namely FRP rupture or FRP debonding, and have resulted in preliminary design ideas. The goal of this research was to come up with a simple, precise, and reasonable design suggestion for the shear capacity of FRP-strengthened beams that fail due to FRP debonding. The non-uniform stress distribution in the FRP along a shear crack is clearly recognised by this novel model, which is governed by the bond strength between the FRP strips and the concrete.

II. EXPERIMENTAL PROGRAM:

The span of all eleven reinforced concrete T-beams was 1300 mm, with a 150 mm broad web, 350 mm wide flange, 125 mm deep web, 50 mm deep flange, and a 125 mm effective depth. Group-A beam reinforcement consists of two 20mm and one 10mm HYSD bars for tension reinforcement, four 8mm bars for hang up reinforcement, and no shear reinforcement. Two numbers of 20mm HYSD bars and one number of 10mm HYSD bars are provided as tension reinforcement, four bars of 8mm are also provided as hang up bars, and eight bars of 8mm are provided as shear reinforcement at 200 mm spacing.

OBJECTIVE

The main objectives of the present work are:

- To study the structural behaviour of reinforced concrete (RC) T-beams with a transverse hole under static loading condition.
- To study the contribution of externally bonded Fiber Reinforced Polymer (FRP) sheets on the shear behaviour of RC T-beams.
- To know the suitability of the FRP composites as repair materials for deteriorated RC Structures.
- To examine the effect of different parameters such as steel stirrups, number of layers, different shear span to effective depth ratio etc. on enhancement of load carrying capacity and load deflection behaviour.
- To investigate the effect of a new anchorage scheme on the shear capacity of the beam.

MATERIAL PROPERTIES

Concrete

The proportions in the concrete mix are recorded in Table 1 according to IS: 456-2000 for conducting the experiment. The ratio of water to cement is set at 0.55. Concrete is used to combine the ingredients. For 28 days, the beams are cured. To assess the compressive strength of concrete at the ages of 7 days and 28 days, six 150x150x150 mm concrete cube specimens and six 150x300 mm cylinder specimens were prepared at the time of casting and kept for curing for each beam 1.

Table 1:Nominal Mix Proportions of Concrete

Description	Cement	Sand (Fine Aggregate)	Coarse Aggregate	Water
Mix Proportion (by weight)	1	1.67	3.33	0.6
Quantities of materials for one specimen beam (kg)	44.4	74.11	147.85	22.5

Fine Aggregate

Fine aggregate/sand is a collection of mineral grains formed by the breakdown of rocks. It differs from gravel only in terms of grain size or particle size, but not from clays that contain biological content. Sand is used in the production of mortar and concrete, as well as in polishing and sandblasting. Foundries use sands with a small amount of clay to make moulds. Filtering water is done with clear sands. The fine aggregate/sand has a specific gravity of 2.64 and passes through a 4.75 mm sieve. According to Indian Standard requirements IS: 383-1970, fine aggregate is graded in zone III.

Coarse Aggregate

Crushed stone is used to make coarse aggregates for concrete. Quarried, crushed, and graded commercial stone Granite, limestone, and trap rock make up a large portion of the crushed stone used. Two grades of coarse aggregates are employed. One grade comprised aggregates retained on a 10 mm filter, whereas the other grade contained aggregates retained on a 20 mm sieve. According to IS: 383-1970, the maximum size of coarse aggregate was 20 mm, with a specific gravity of 2.88.

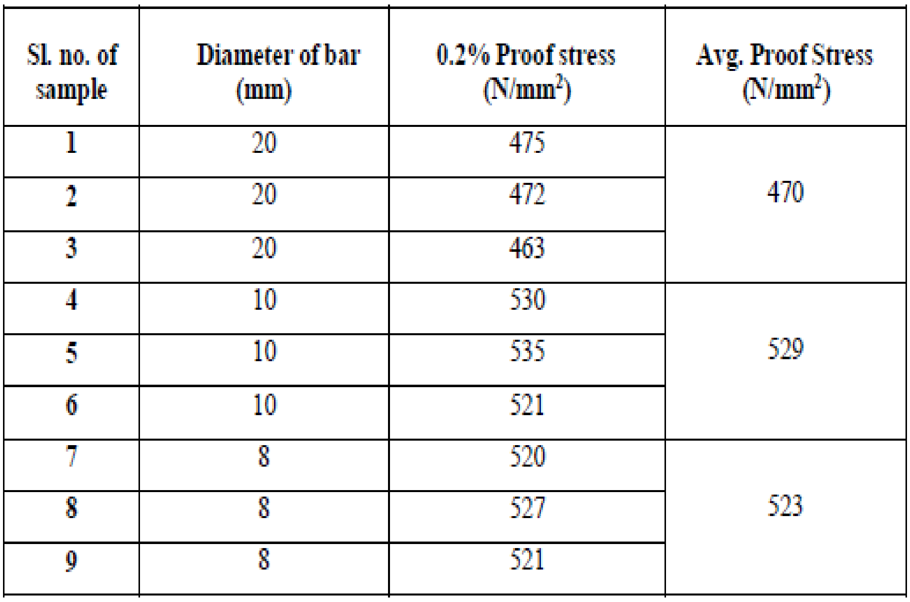
Water

Concrete is typically made with water that is OK for drinking. Acids, alkalis, oils, vegetables, and other organic contaminants should not be present in the water. Concrete is weakened by soft water. In a concrete mix, water serves two purposes. It first reacts chemically with cement to generate a cement paste, which keeps the inert aggregates suspended until the cement paste hardens. Second, it acts as a vehicle or lubricant in the fine aggregate-cement mixture. In all of the mixes, ordinary clean portable tap water is utilised for concrete mixing.

Reinforcing Steel

HYSD (High-Yield Strength Deformed) bars that meet IS 1786:1985. The 20 mm and 10 mm diameter longitudinal steel reinforcement bars were deformed, high-yield strength. The stirrups were manufactured from 8 mm diameter deformed steel bars. Three coupons of steel bars were examined, and the yield strength of the steel reinforcements utilised in this experiment was evaluated using ASTM requirements under uniaxial tension. Table 3.5 shows the average proof stress or yield strength of the specimens. Steel bars have a modulus of elasticity of 2 105 MPa.

Table 2:Tensile Strength of reinforcing steel bars



Sl. no. of sample	Diameter of bar (mm)	0.2% Proof stress (N/mm^2)	Avg. Proof Stress (N/mm^2)
1	20	475	470
2	20	472	
3	20	463	
4	10	530	529
5	10	535	
6	10	521	
7	8	520	523
8	8	527	
9	8	521	

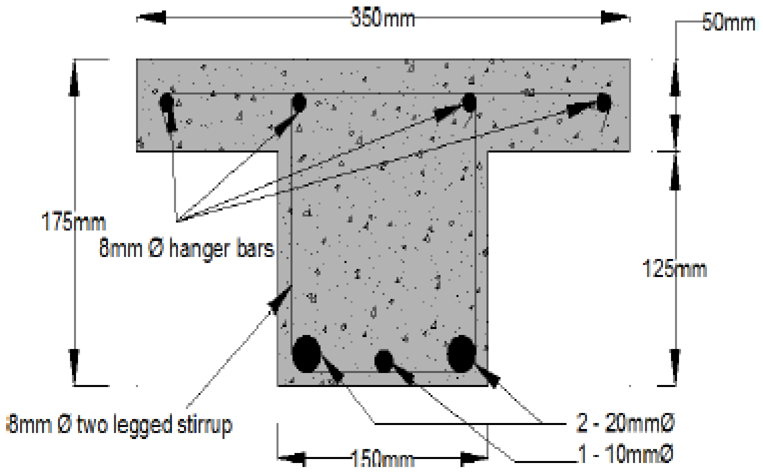


Figure 1:Detailing of Reinforcement

III. RESULTS:

The experimental program's results from the testing of eleven number RC T-Beams are interpreted. Their behaviour is defined in terms of initial fracture load and final load carrying capability, deflection, crack pattern, and modes of failure during the test..

Group-A:

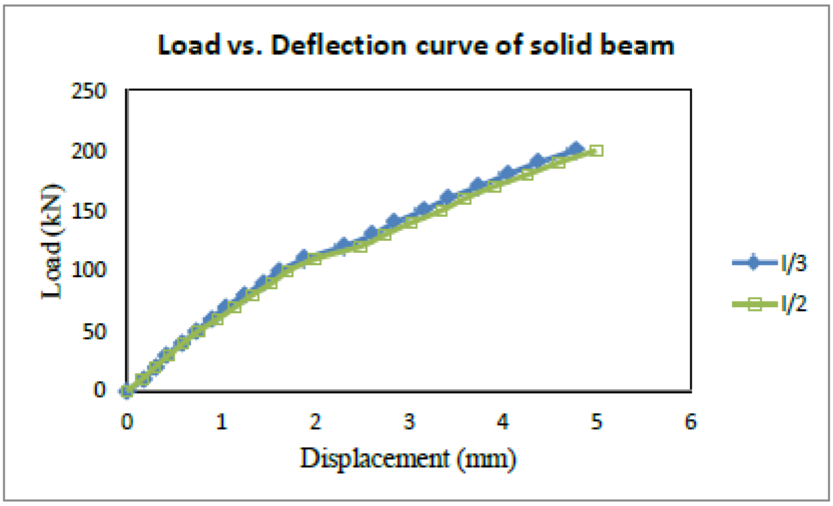


Figure 3. Load vs. Deflection Curve for Solid beam A

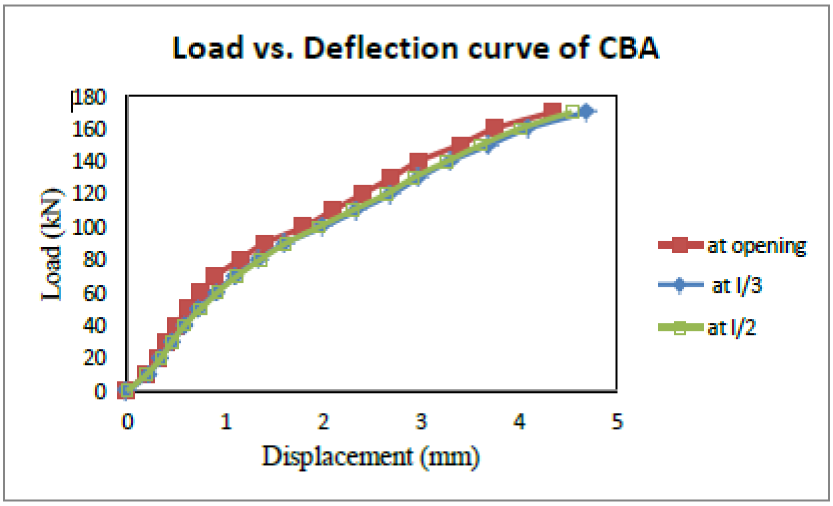


Figure 4. Load vs. Deflection Curve for CBA

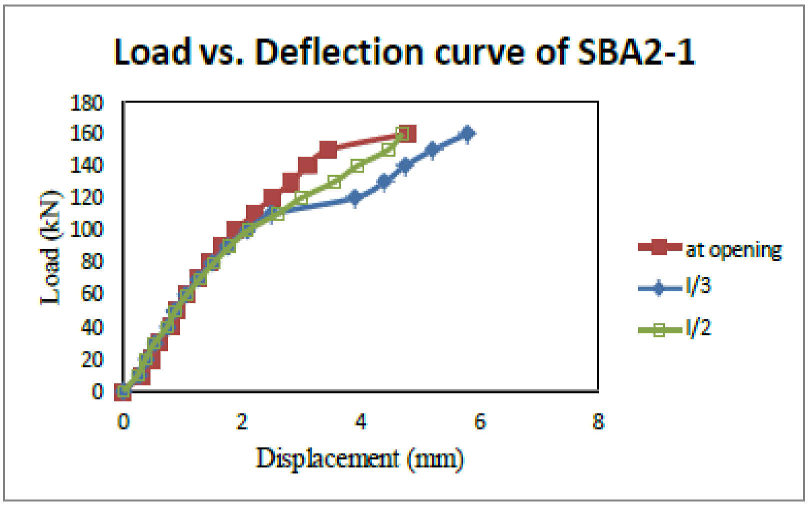


Figure 5. Load vs. Deflection Curve for SBA2-1

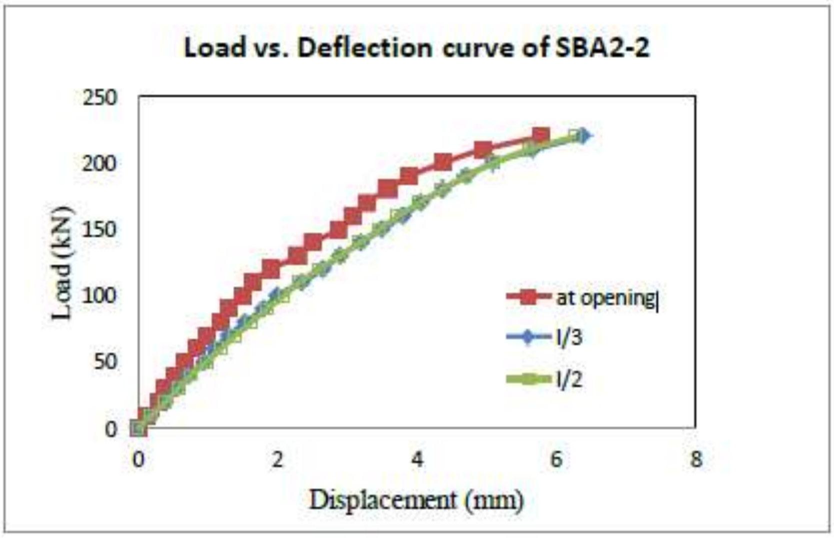


Figure 6. Load vs. Deflection Curve for SBA2-2

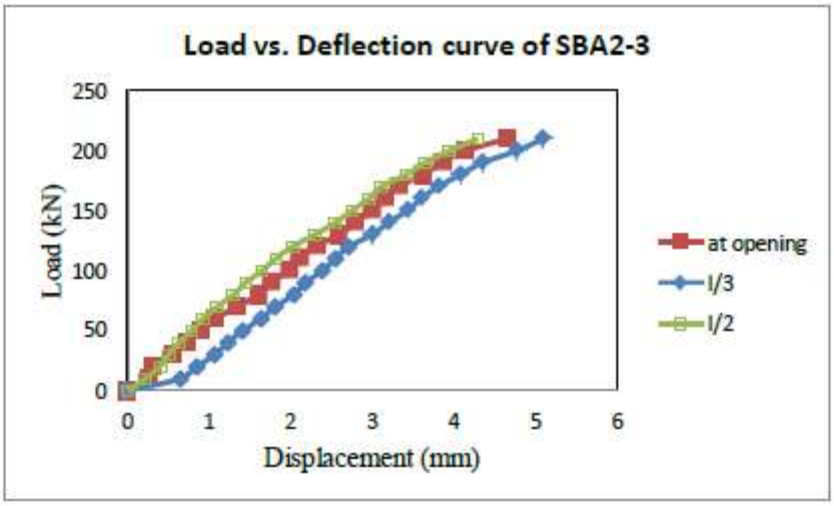


Figure 7. Load vs. Deflection Curve for SBA2-3

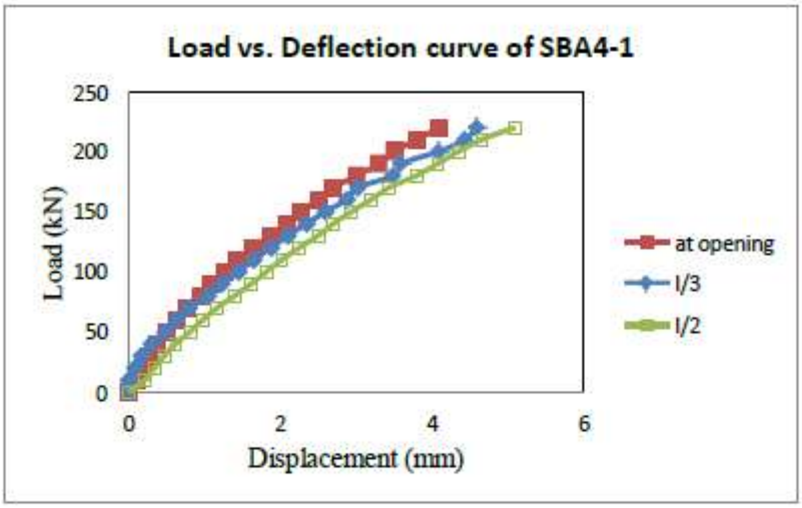


Figure 8. Load vs. Deflection Curve for SBA4-1

GROUP-B:

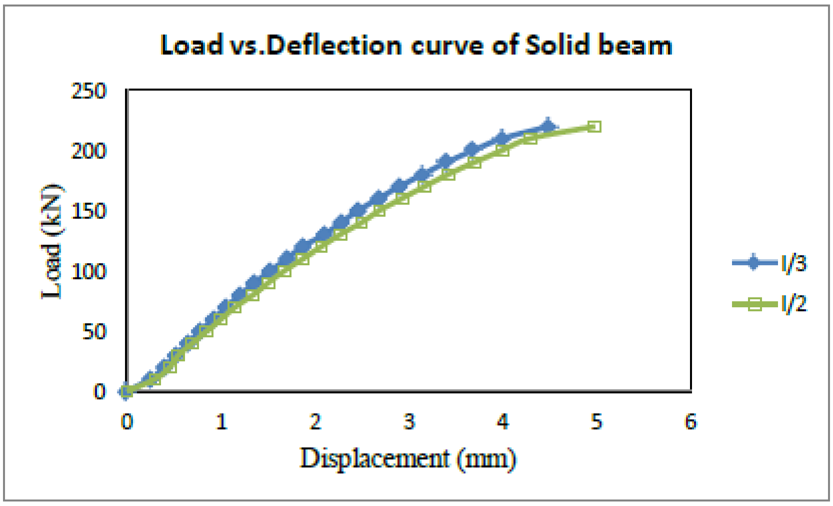


Figure 9. Load vs. Deflection Curve for Solid beam B

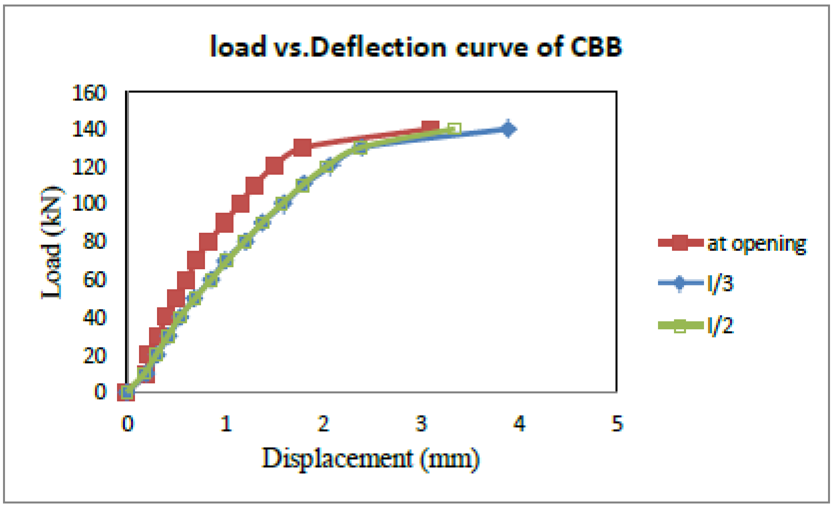


Figure 10. Load vs. Deflection Curve for CBB

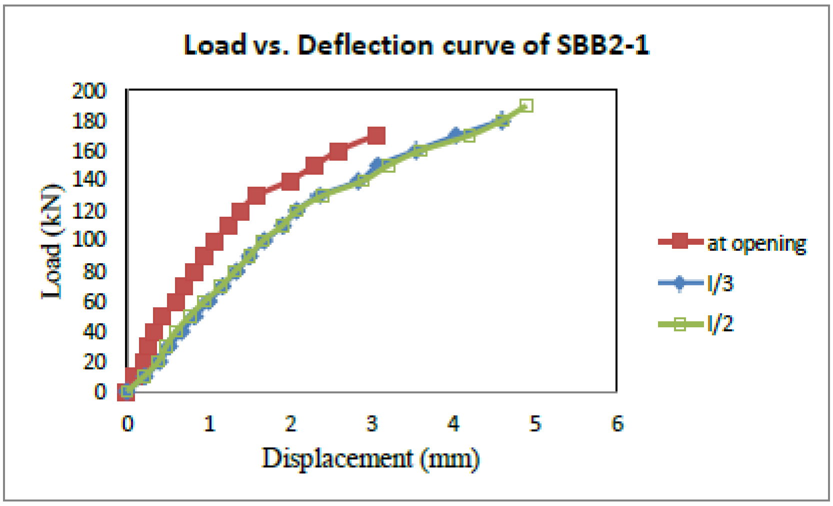


Figure 11. Load vs. Deflection Curve for SBB2-1

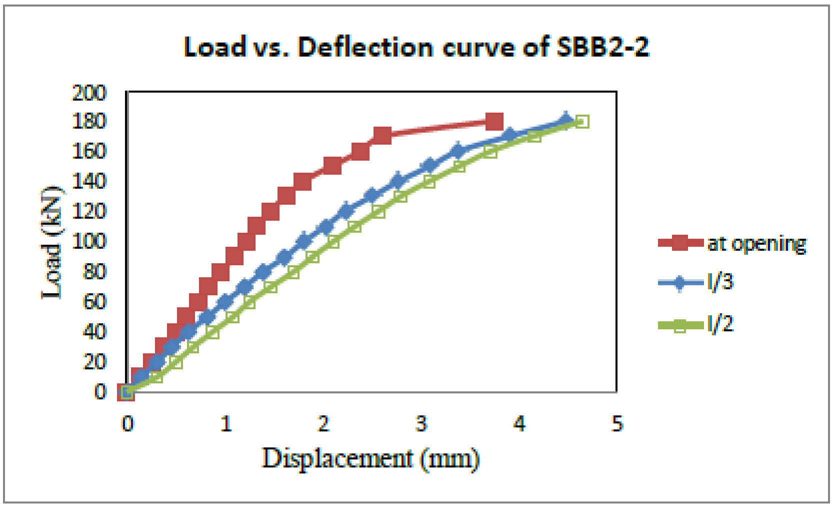


Figure 12. Load vs. Deflection Curve for SBB2-2

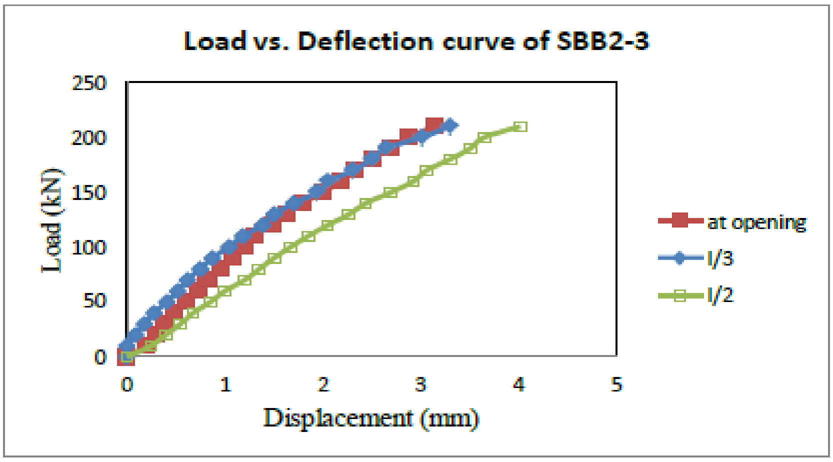


Figure 13. Load vs. Deflection Curve for SBB2-3

The deflection profile for the control beam CBA and beams SBA2-1 (strengthened with two layers continuous U-wrap on hole side), SBA2-2 (strengthened with two layers continuous Uwrap on both sides with flange anchorage system) and SBA4-1 (strengthened with four layers continuous U-wrap on both sides with flange anchorage system) are presented in figure 14.From the figure14, it is observed that SBA2-2 and SBA4-1 performs well compared to CBA and SBA2-1. The reduction in mid-span deflection of the beam SBA4-1 compared to CBA and SBA2-1 are 20.39% and 31.91% respectively under the applied load of 160 kN.

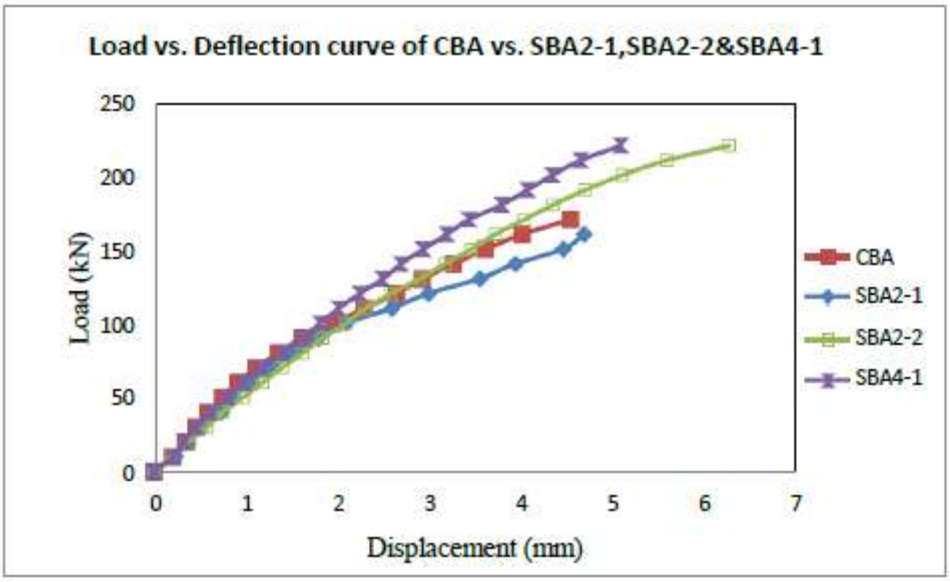


Figure 14. Load vs. Deflection Curve for CBA vs. SBA2-1, SBA2-2 and SBA4-1

Figure 15 shows the deflection profile for the control beams CBA and SBA2-3 (both strengthened with two layers continuous U-wrap on both sides and a flange anchorage system with a shear span of 250mm). Figure 15 shows that SBA2-3 operates admirablyin comparison to CBA The SBA2-3 beam has a lower mid-span deflection than the CBA beamis 26.36 percent when a load of 16kN is applied.

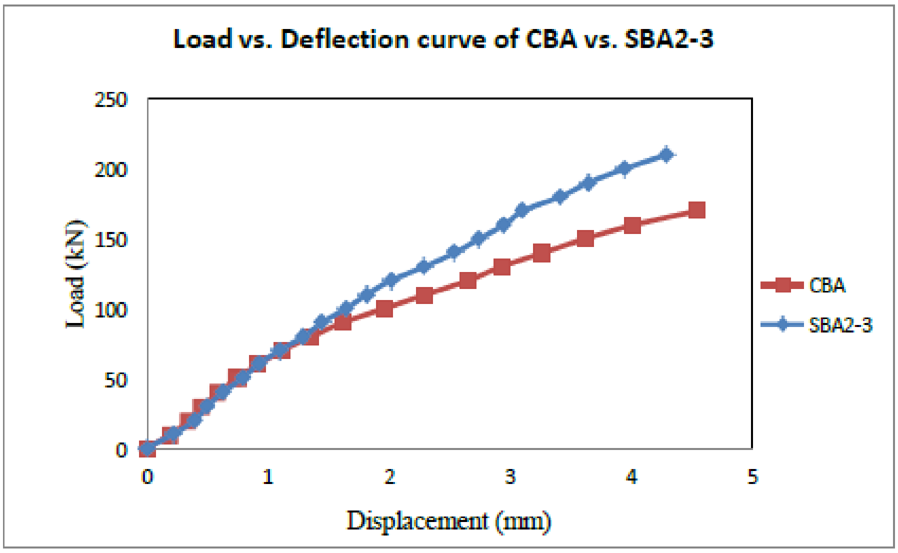


Figure 15. Load vs. Deflection Curve for CBA vs. SBA2-3

Figure 16 shows the deflection profiles for the control beam CBA and the solid beam (without transverse hole and no strengthening). In comparison to CBA, solid beam performs better, as shown in figure 16. The beam's mid-span deflection is reduced. a single beamUnder the applied load of 160 kN, it is 10.44 percent better than CBA.

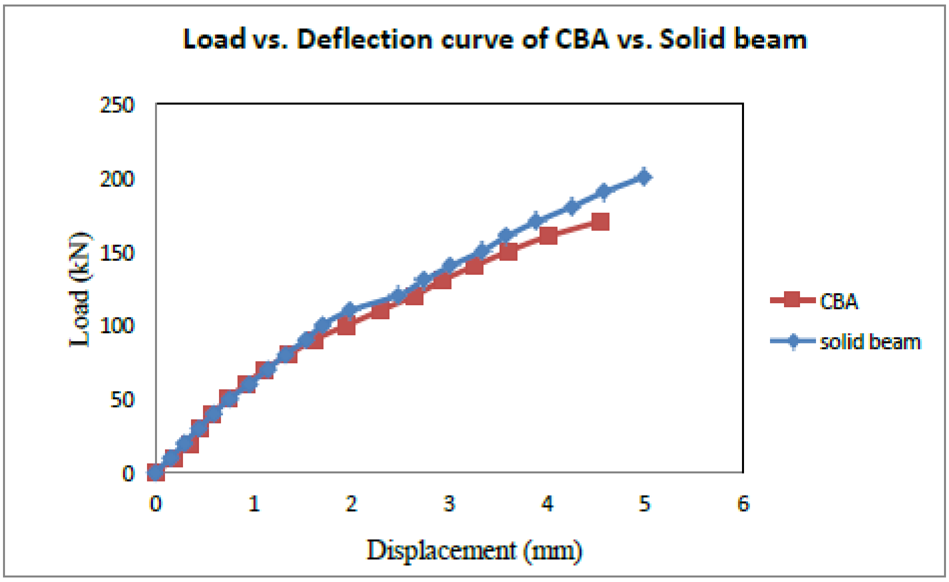


Figure 16. Load vs. Deflection Curve for CBA vs. Solid beam

Figure 17 shows the deflection profile for the control beam CBB, as well as beams SBB2-1 (two layers continuous U-wrap on hole side) and SBB2-2 (two layers continuous U-wrap on both sides with flange anchorage system). In comparison to CBB, SBB2-1 and SBB2-2 perform well,as seen in Figure 17. The decrease inBB2-1 and SBB2-2 have a 13.43 percent and 7.76 percent mid-span deflection, respectively, when compared to CBBcorrespondingly, when a load of 140 kN is applied.

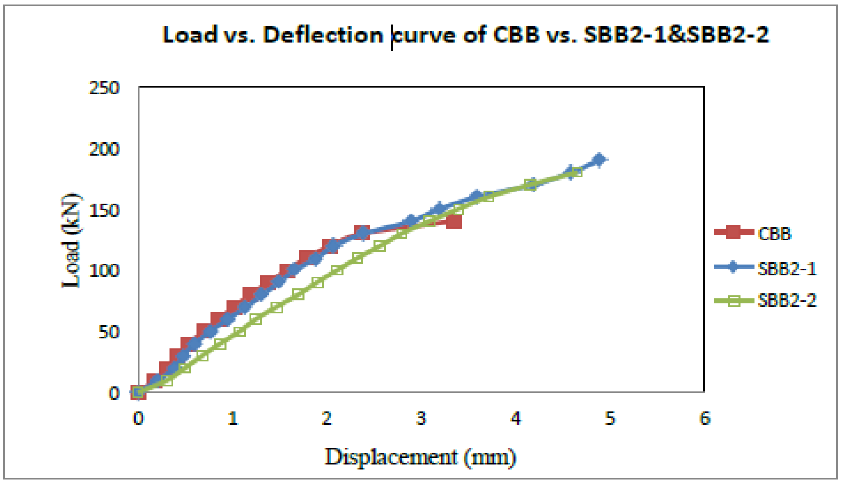


Figure 17: Load vs. Deflection Curve for CBB vs. SBB2-1 and SBB2-2

The deflection profile for the control beam CBB and SBB2-3 (strengthened with two layers continuous U-wrap on both sides with flange anchorage system having a shear span of 250mm) are presented in figure 4-27. From the figure 18, it is observed that SBB2-3 performs well compared to CBB. The reduction in mid-span deflection of the beam SBB2-3 compared to CBB is 27.16% under the applied load of 140 kN.

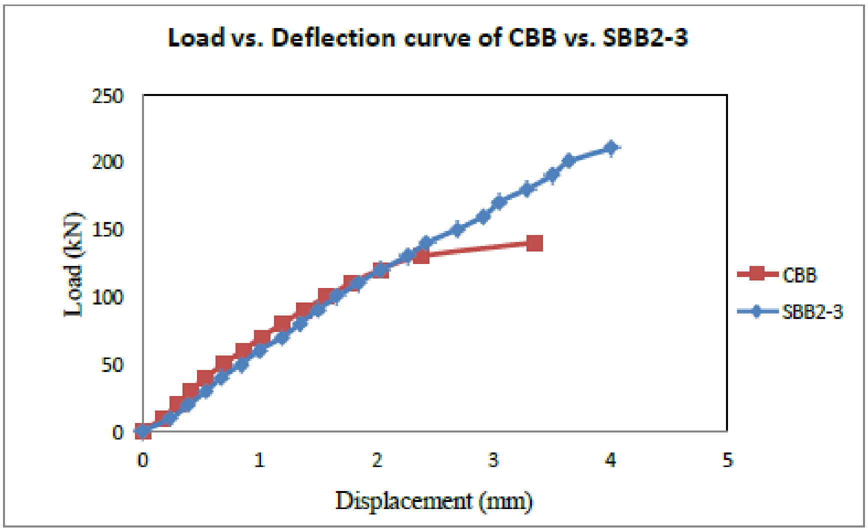


Figure 18. Load vs. Deflection Curve for CBB vs. Solid beam B

The ultimate load carrying capacities of all the beams along with the nature of failure are summarized in Table 3. The ratio of ultimate load carrying capacity of strengthened beam to control beam are computed and presented in Table 3.

Table3:Ultimate load and nature of failure for various beams

Beam Designation		Nature of Failure	P_u (kN)	$\lambda = \frac{Pu(Strengthened\ Beam)}{Pu(Control\ Beam)}$
Group-A	Solid beam	Shear failure	208	1.2
	CB	Shear failure	172	-
	SB1	Shear failure	180	1.04
	SB2	Tearing and Debonding of GFRP + Shear failure	220	1.28
	SB3	Tearing and Debonding of GFRP + Shear failure	210	1.22
	SB4	Debonding failure + Shear failure	230	1.33
Group-B	Solid beam	Shear crack shifted to the non-strengthened zone of shear span	240	1.71
	CB	Shear failure	140	-
	SB1	Tearing and Debonding failure + Shear failure	198	1.41
	SB2	Tearing of GFRP + Shear failure	204	1.45
	SB3	Tearing of GFRP + Shear failure	214	1.53

IV. CONCLUSIONS:

Based on the experimental and theoretical results, the following conclusions are drawn:

- The test results show that the FRP system strengthening technique is effective in increasing the shear capacity of T-beams..
- The flange anchorage system's efficiency in enhancing the shear capacity of RC beams has been demonstrated experimentally.
- Evidence suggests that the anchorage system can make FRP strengthening more appealing

and cost-effective for concrete repair and strengthening.

- According to the test results, the contribution of GFRP improves shear capacity more for beams without steel shear reinforcement than for beams with adequate steel shear reinforcement.
- The shear span-to-depth ratio (a/d) influences the contribution of externally bonded GFRP reinforcement to shear capacity, which increases as the a/d ratio decreases.
- The adoption of an anchorage system prevents the GFRP sheet from debonding, resulting in a greater exploitation of the GFRP sheet's maximum capacity.

REFERENCES:

[1]. ACI 440.2R-02, “Guide for the Design and Construction of Externally Bonded FRP Systems for Strengthening Concrete Structures”, Reported by ACI Committee 440.

[2]. Al-Amery R., and Al-Mahaidi R. (2006), “Coupled flexural-shear retrofitting of RC Beams using CFRP straps”, Construction and Building Materials, 21, 1997-2006.

[3]. Alex L., Assih J., and Delmas Y. (2001), “Shear Strengthening of RC Beams withexternally bonded CFRP sheets”, Journal of Structural Engineering, Vol. 127, No. 4,Paper No. 20516.

[4]. Balamuralikrishnan R., and Jeyasehar C. A. (2009), “Flexural behaviour of RC beamsstrengthened with Carbon Fiber Reinforced Polymer (CFRP) fabrics”, The Open Civil Engineering Journal, 3, 102-109.

[5]. Bousselham A., and Chaallal O. (2006), “Behavior of Reinforced Concrete T-beams strengthened in shear with carbon fiber-reinforced polymer –An Experimental Study”, ACI Structural Journal, Vol. 103, No. 3, pp. 339-347.

[6]. Ceroni F. (2010), “Experimental performances of RC beams strengthened with FRP materials”, Construction and Building materials, 24, 1547-1559.

[7]. Chaallal O., Nollet M. J., and Perraton D. (1998), “Strengthening of reinforced concrete beams with externally bonded fibre-reinforced-plastic plates: design guidelines for shear and flexure”, Canadian Journal of Civil Engineering, Vol. 25, No. 4, pp. 692-704.

[8]. Chen J. F., and Teng J. G. (2003), “Shear capacity of FRP-strengthened RC beams: FRP debonding”, Construction and Building Materials, 17, 27-41.

[9]. Deifalla A., and Ghobarah A. (2010), “Strengthening RC T beams subjected combined torsion and shear using FRP fabrics: Experimental Study”, Journal of Composites for Construction, ASCE, pp. 301-311.

[10]. Esfahani M. R., Kianoush M. R., and Tajari A. R. (2007), “Flexural behaviour of reinforced concrete beams strengthened by CFRP sheets”, Engineering Structures, 29,2428–2444.

[11]. Ghazi J. Al-Sulaimani, Alfarabi Sharif, Istem A. Basunbul, Mohhamed H. Baluch, and Bader N. Ghaleb (1994), “Shear Repair for Reinforced Concrete by Fiberglass Plate Bonding”, ACI Structural Journal, Vol. 91, Issue No. 4, pp. 458-464.

[12]. Lee H. K., Cheong S. H., Ha S. K., and Lee C. G. (2011), “Behaviour and performance of RC T-section deep beams externally strengthened in shear with CFRP sheets”,Composite Structures, Vol. 93, Issue 2, pp. 911-922.

[13]. Khalifa A., and Antonio N. (2002), “Rehabilitation of rectangular simply supported RC beams with shear deficiencies using CFRP composites”, Construction and Building Materials, Vol. 16, No. 3, pp. 135-146.

[14]. IS: 456-2000, “Plain and Reinforced Concrete - Code of Practice ”, Bureau of Indian Standards.

[15]. IS: 383-1970, “Specification for Coarse and Fine Aggregates from natural sources for Concrete”, Bureau of Indian Standards.

[16]. Mansur M. A. (2006), “Design of reinforced concrete beams with webopenings”,Proceedings of the 6th Asia-Pacific Structural Engineering and Construction Conference (APSEC 2006), Kuala Lumpur, Malaysia, pp.104-120.

[17]. IS: 1786-1985, “Specification for high strength deformed steel bars and wires for concrete reinforcement ”, Bureau of Indian Standards

[18]. Maaddawy T. E., and Sherif S. (2009), “FRP composites for shear strengthening of reinforced concrete deep beams with openings”, Composite Structures, 89, 60–69.

[19]. Martinola G., Meda A., Plizzari G. A., and Rinaldi Z. (2010), “Strengthening and repair of RC beams with fiber reinforced concrete”, Cement & Concrete Composites, 32, 731–739.

[20]. Mosallam A. S., and Banerjee S. (2007), “Shear enhancement of reinforced concrete beams strengthened with FRP composite laminates”, Composites: Part B, 38, pp. 781-793.

[21]. .Norris T., Saadatmanesh H., and Ehsani M. R. (1997), “Shear and Flexuralstrengthening of RC beams with carbon fiber sheets”, Journal of Structural Engineering,Vol. 123, No. 7.

[22]. Ozgur A. (2008), “Strengthening of RC T-section beams with low strength concreteusing CFRP composites subjected to cyclic load”, Construction and Building Materials 22, 2355–2368.

[23]. Saadatmanesh H., and Ehsani M. R. (1992), “RC beams strengthened with GFRP plates:experimental study”, Journal of Structural Engineering, Vol. 117, No.11, ISSN 0733-9445/91/0011, Paper No. 26385.