Shear Strengthening Of Steel I-Beam With Cfrp Composites

P. R. Jagtap, S. M. Pore

Abstract: The current study is based on the use of carbon fiber reinforced polymers (CFRP) to strengthen the structural I- Beam to its shear zone. CFRP has light-weight and high-strength, it is very flexible and thus forms all shapes, and is easy to handle during construction, so instead of using conventional methods for repair it can be used for strengthening purpose. Two sections with different cross-sectional dimensions of beams were used for this purpose. The web of the I-Beam was sand-blasted and made rust-free to attach CFRP sheets. Then carbon fiber sheets were attached in different layers using the proper adhesive. The beam with CFRP is cured and experimentation is done on UTM of 100 Ton capacity. A four-point bending test was performed on eight beams and results show that the shear capacity of a strengthened beam is increased by 17% to 40% compared with the non-strengthened beam. The deflection at mid-point of the beam is checked and it is observed that the deflection of the strengthened beam and the non-strengthened beam is the same, thus CFRP strengthening technique is the best way to improve the performance of steel sections within permissible deflection limits. So, such a technique of strengthening steel sections can be used to enhance the properties of various old structures that undergo loss of strength due to corrosion and aging.

Keywords: Adhesive, CFRP, Deflection, I-Beam, Strengthening

1 INTRODUCTION

Steel structures are more susceptible to corrosion due to lack of proper maintenance. Repair and a retrofit may be the best option before taking a decision of replacing a section [1], [2]. In most of the cases the cost for rehabilitation and repair is also less as compare to conventional methods such as replacing. Repair and rehabilitation takes less time, which reduces service interruption. Thus the superior mechanical and physical properties of fiber reinforced polymers (FRP) make them excellent material for repair and retrofit of structures [1]. Steel structures also need to improve their properties such as load carrying capacity [3], fatigue performance, etc. This can be possible by strengthening the steel sections with the help of FRPs. There are so many types of FRPs, but Carbon FRP (CFRP) has a very high ultimate strength, low density, and very good resistance to fatigue compare to others. [4], [5], [6], [7], [8], [9], [10], [11]. Steel plate girders have good flexural capacity and serviceability performance due their deep webs. These members are damaged due to corrosion. So FRP laminates may offer an attractive alternative in such cases [1], [10]. CFRP plates or sheets with high-tensile modulus can be epoxy bonded to the tension face of the member to enhance the strength and stiffness of the steel girders. By addition of the CFRP sheet, the stress level in the original member will decrease, that in turn results in a longer fatigue life [1]. The objective of given paper is to study performance of CFRP sheets on shear zone of steel I-beams and to compare its behavior with non strengthened beam or control beam. The research also studies the deflection behavior of beams.

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2 MATERIALS

2.1 Steel I-Beam

The steel I-beams used for experimentation were having two cross sections. They are light weight beam (LB) 100 @ 5.1 Kg/m and LB 115 @ 8.1 Kg/m of length 1 meter. The other properties of steel sections are as per Table-1. The cross section of I-beam is shown in Fig. 1

Fig. 1 *Cross section of I-Beam ([4], [9])*

TABLE 1: *PROPERTIES OF STEEL I BEAM ([4], [9])*

Properties	*LB-100*	*LB-115*
Weight (Kg/m)	*5.1*	*8.1*
Length (mm)	*1000*	*1000*
Height (mm)	*100*	*115*
Width (mm)	*50*	*65*
Flange Thickness (mm)	*4*	*5*
Web Thickness (mm)	*3*	*4*
E-Modulus (N/mm2)	*200000*	*200000*
Yield Strength (N/mm2)	*250*	*250*

2.2 CFRP

CFRP composites are composed of a polymeric resin (matrix) material which is reinforced by carbon fibers. The carbon fibers is temperature resistant and the majority of its strength and stiffness can be retained up to 2000 °CThe experimentation work is carried out with the help of unidirectional woven carbon fabric strips (HinFab™ HCU403) of thickness 0.43 mm. The photograph of CFRP used is shown in Fig. 2. Also other properties of the CFRP strips are mentioned in Table 2.

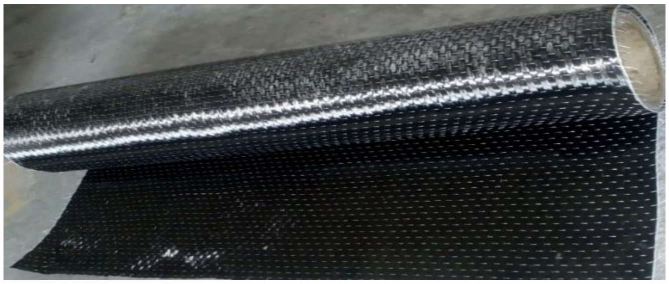

Fig. 2. *Unidirectional CFRP Role*

TABLE 2: *PROPERTIES CFRP STRIPS ([4], [9])*

Weight (g/m2)	*Width (mm)*	*Thickness (mm)*	*Density (Kg/m3)*	*Filament Diameter (micron)*	*Tensile Strength (N/mm2)*	*Tensile Modulus (N/mm2)*	*Elongation (%)*
400	*500*	*0.43*	*1800*	*7*	*4000*	*240000*	*1.7*

2.3 Adhesive

An adhesive used for attaching CFRP to web of steel section consists of two components Hinpoxy C Resin and Hinpoxy C Hardener. Hinpoxy C Resin is a Bisphenol- a based liquid epoxy resin and Hinpoxy C Hardener is a colorless, low viscosity, modified amine hardener. The mixing ratio of the epoxy was 100 part of component A (resin) to 30 part of component B (hardener) by weight (Resin: Hardener = 100: 30). The other properties of adhesive are as per the Table 3.

TABLE 3: *PROPERTIES OF ADHESIVES ([4], [9])*

Characteristic	*Resin*	*Hardener*
Density (Kg/m^3)	*1150-1200*	*940-950*
Viscosity at 25°C (mPas)	*9000-12000*	*< 50*
Flash Point (°C)	*> 200*	*> 123*
Storage Life (Yrs)	*3*	*1*

3 METHODOLOGY

The web of I beam is well prepared to attach CFRP strips. All corroded portion is cleaned with sand papers and made smooth so that adhesive layer can be sprayed uniformly on it. CFRP strips were cut to a proper size and then it is attached one by one to both sides of web with the help of adhesive as shown in Fig.3. An adhesive is a combination of resin and hardener in proportion 100:30 by weight respectively. These two components are mixed together properly to have a homogeneous paste and then a layer of approximately 1 mm thickness is formed on web of I-section and CFRP strips were pasted on it. The tests were carried out after 48 h of curing when adhesive is hardened properly.

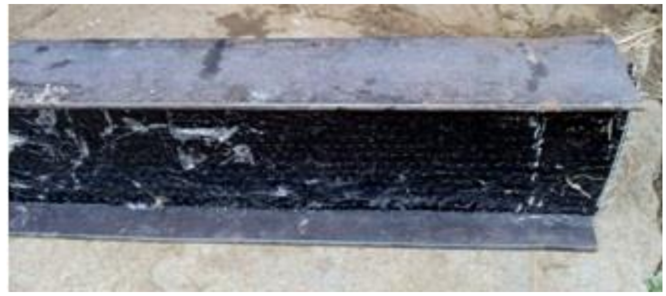

Fig. 3. *Beam with CFRP layer on Shear zone*

The transfer of load between steel and CFRP is depends on the adhesive quality and surface of the steel. Surface of the steel must be clean and smooth before application of CFRP; therefore surface preparation is one of the most important steps for strengthening of steel structures. It is the key to a strong and durable adhesive bond.

4 EXPERIMENTATION

For testing purpose the beams were placed in universal Testing Machine (UTM) of 100 T capacity. Then, a load cell with a maximum capacity of 200 kN was placed over a loading beam which have two point loads and this beam is kept over a test specimen at one third position as shown in fig. One linear variable deformation transducer (LVDT) was installed at the mid span of test specimen for measuring vertical deflections. The load cell and LVDT were connected to the Data Logger to record the readings. The arrangement of four point bending test is shown in Fig. 4

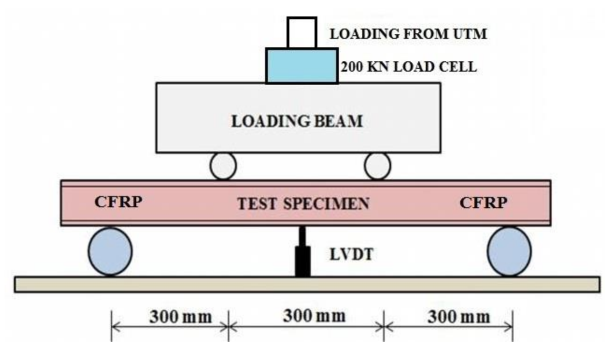

Fig. 4 *Schematic Arrangement of Four point Bending Test*

To examine the effects of CFRP strips on shear zone of steel I-beams total eight beams were considered: four for LB-100 and four for LB-115. Four point bending (FPL) test were performed on all these beams. The actual set up is shown in Fig.5 and general specification of beam sections is indicated in table 1. First four specimens (B1 to B4) were used for LB-100, from which first specimen (B1) was not strengthened. The web of second beam (B2) was strengthened by using one layers of CFRP strip, third beam (B3) was strengthened by using two layers of CFRP strip and fourth beam (B4) was strengthened by using three layers of CFRP strips. Remaining four specimens (B5 to B8) were used for LB-115 and strengthened in similar manner as LB-100.

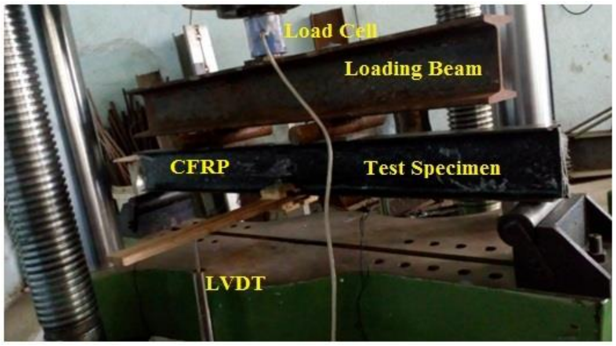

Fig. 5 *Experimental Set-up in UTM for testing of beam*

5 RESULT AND DISCUSSION

5.1 Load carrying capacity

Generally local failure of compression flange of beam is occurred in control beam. This local failure of beam is due to application of point load directly on flange. This is common in various sections due to insufficient thickness of flange and also due to web crippling. The beam will not fail due to plastic hinge formation but fails so earlier than its actual load carrying capacity. So to avoid such earlier failure of beam the web of section is strengthened with different layers of CFRP strips at both sides of sections in shear zone. Then load is applied on top flange through load cell. The beam continues to take load until it fails by plastic hinge formation. The load carrying capacity of the beam increases as compared to non-strengthened beam (control beam) as shown in Table 4 and local failure of the compression flange is also not observed.

TABLE 4: *RESULTS OF EXPERIMENTAL STUDY*

Name of Beam	*Control Beam*		*Strengthen Beam (1 Layers)*		*Strengthen Beam (2 Layers)*		*Strengthen Beam (3 Layers)*	
	LCC (kN)	*Defle (mm)*	*LCC (kN)*	*Defle (mm)*	*LCC (kN)*	*Defle (mm)*	*LCC (kN)*	*Defle (mm)*
LB-100	*B1*		*B2*		*B3*		*B4*	
	46.70	*11.20*	*47.20*	*11.30*	*58.50*	*9.90*	*65.70*	*12.20*
LB-115	*B5*		*B6*		*B7*		*B8*	
	79.50	*9.90*	*90.1*	*10*	*93.40*	*10.10*	*99.90*	*10.20*

* LCC- Load Carrying Capacity and Defle-Deflection

5.2 Deflection

To measure the vertical deflection at the mid span of beam, LVDT was installed at the bottom side of the tension flange exactly at middle point of beam. The deflection in control beam and strengthened beam has values as per Table 4, but in case of strengthened beam LCC increases at minimum deflection. Also deflection in beam with three layers of CFRP is less as compare to two layers of CFRP

6 CONCLUSIONS

An IJSTR copyright form must accompany your final This paper has presented and discussed the results of several beams strengthened with CFRP to its web to understand the effects of the strengthening on shear zone area. The results and discussions presented in the paper allow the following

conclusions:

1. Application of CFRP strips on the web of steel I-beams is a successful method for increasing the load carrying (LCC) capacity and its shear behavior.
2. One layer of CFRP on both sides of web does not give any significance change in the LCC and deflection.
3. When two layers of CFRP strips were used the LCC of LB-100 is increased up to 25% but that for LB-115 it is increased up to 17% compare to control beam.
4. When three layers of CFRP were used, LCC of LB-100 is increased up to 40% but that for LB-115 it is increased up to 25% compare to control beam.
5. Smaller sections show remarkable effect of CFRP strengthening compare to bigger sections.
6. It shows that increase in CFRP layers causes significant increment in the load carrying capacity.
7. Results show that the deflection remains same for all cases so, CFRP strengthening technique is the best way to improve the performance of steel sections within permissible deflection limits.

7 FUTURE SCOPES

(1) Different types of adhesives can be used which may result in a stronger bond between the stiffener and the steel sections.
(2) Fire resistance of FRP-strengthened steel structures can be checked for various temperatures
(3) The effect of cyclic load on strengthened beam has still not been investigated, which is important to understand the fatigue behavior.

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