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Study of Flexural Behaviour of Steel I-Section Bonded With Basalt Fibre Polymer Sheet

Kamane Satish K.
Research scholar VTU, Belagavi Karnataka
Patil Nandkumar K.
Professor.SGI,Atigre, Kolhapur Maharashtra

ABSTRACT— *A large number of steel structures need strengthening and retrofitting after some time, as their durability and capacity reduces over time.Conventional strengthening technique for huge steel structures relies on enlarging the original steel section by welding additional elements such as steel plates or channels. The dead load of the enlarged section becomes larger which may result in a reduction in its effectiveness and the added steel plates are susceptible to corrosion in case of strengthening beams placed in a corrosive environment. Due to these reasons, considerable amount of research has been directed to the use of FRP materials for strengthening and retrofitting of steel structures. The conventional method of repairing is usually bulky, heavy, difficult to fix and prone to corrosion and fatigue so there is need for alternativeso use of FRP (Fibre Reinforced Polymer) appears to be an excellent solution for these difficulties.*

Keywords- Retrofitting, FRP, Fiber*.*

I. INTRODUCTION

Steel is one of the most widely used for almost every type of structure as it gives the advantages like speedy construction, long durability, cost saving due to recycling and flexibility in construction. Along with these advantages it is subjected to corrosion action due to different environmental conditions. And it is also deteriorated due to aging. These problems effect on the service life of the structure. [7] So as to regain the original strength and to increase the life span, structures are needed to retrofit. The conventional method of repairing or strengthening of steel structures is to cut out the old member and replace it with new one or to attach external steel plates. But these plates or steel parts are generally massive, heavy and difficult to fix and also have tendency to corrode. These conventional methods require considerable time and cost too. So, there is a need to look for an alternative solution. The use of Fiber Reinforced Polymer (FRP) appears to be an excellent solution. It boosts the strength and ductility of these structures. [2]

Now days, use of FRP(Fibre reinforced Polymer) to rehabilitate steel structures is also considerably increased. The introduction of fiber reinforced polymer was brought in a solution in steel structures to enhance the flexural strength. FRP has advantages like high strength with a great reduction in weight, resistance from chemical attacks, high resistance for corrosion, easy to drill and anchor with old steel constructions and flexible in nature. Its flexibility follows curved, different shapes and irregular surfaces of structures, which is not easy for heavy steel plates. [3]

II. BASALT FIBRE AND ITS PROPERTIES

a) BASALT FIBRE

Basalt fibre composites (BFRP) have been receiving increasing attention in civil infrastructures, due to their excellent mechanical and chemical properties and high cost-performance. The research and application of basalt fibres and the FRP composites (BFRP) have been received much more attention in different engineering fields, especially in civil & environmental engineering and automobile industry, due to its excellent mechanical and chemical properties and high cost performance. It is also a typical energy saving, environment-friendly natural green fibre. [8]

b) BASALT FIBRE PRODUCTION PROCESS

Basalt is avolcanic magma product. Basalt isterm for va variety of volcanic rocks, they may be grey, dark in colour, and these are formed from the molten lava after solidification.[8]Almost 9.6kg of steel reinforcement can be replaced by using only 1kg of basalt fibers .It is formation of basalt rock and as rock is in abundant quantity it is really cheap and has several excellent properties.[9] basalt stones are found in different compositions in nature ;but only certain compositions are useful for making continuous filaments with a diameter range of 9 to 24 microns. SiO_2 content about 46% (acid basalt) in basalt rocks are suitable for fiber production. [5]

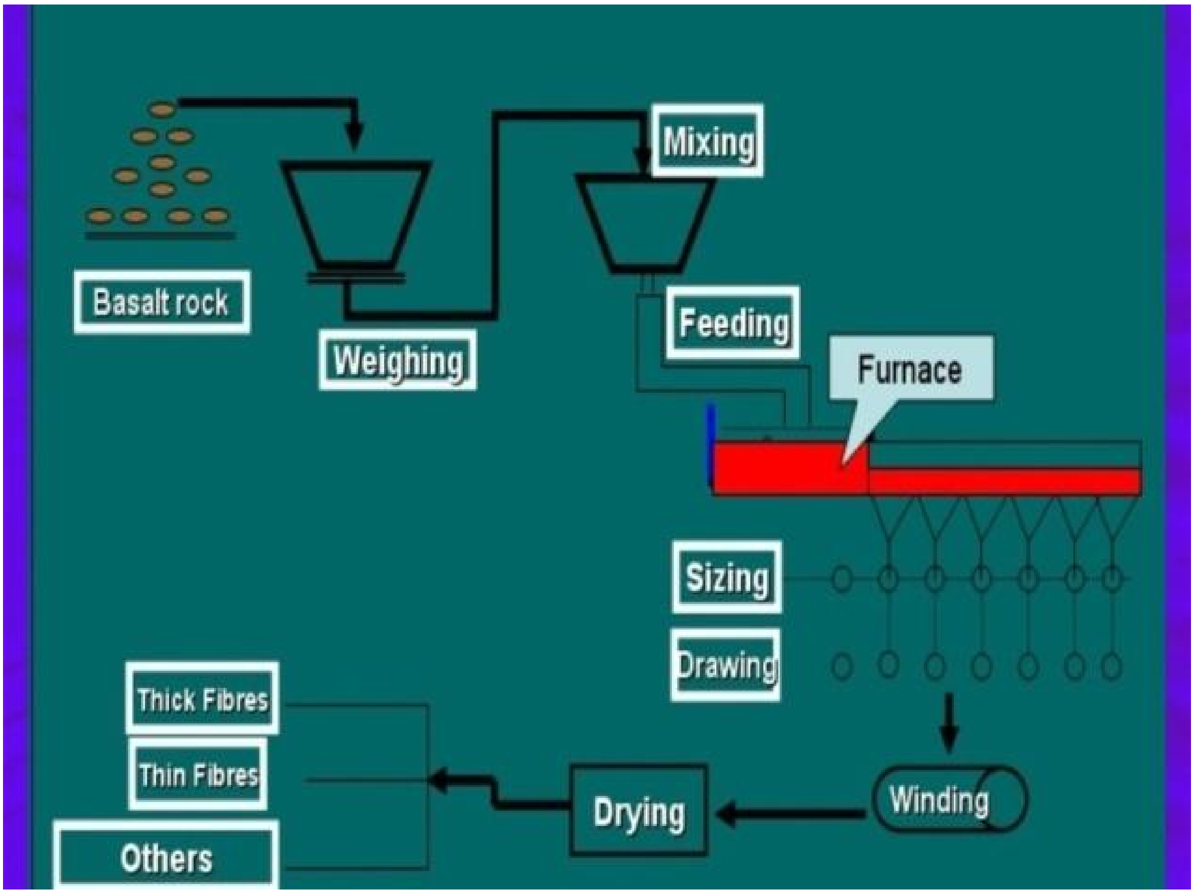

FIG.1 BASALT FIBER PRODUCTION. [12]

Basalt is quarried from the mine, then it is crushed and washed to remove impurities and dust, then melted at 1500° C in furnace. This molten rock is then extruded through small nozzles of different diameters to produce continuous filaments of basalt fibre. [4] With the development of the continuous basalt fibre industry, the performance advantages of this new material have been fully aware of and gradually accepted. [5]

III. EXPERIMENTAL WORK

Until now limited work has been done on strengthening of steel structures by using FRP and whatever work that has been carried out was on externally bonded GFRP and CFRP strengthening of steel structure. Experimental work is carried out with respect to flexural behavior of rolled steel I section.

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EXPERIMENTAL SETUP

Experimental setup prepared which is placed under the UTM (600kN) and flexural behavior of steel I section is tested. Setup consisted loading beam on which load was applied through loading jack and it distributed load on test specimen. Using LVDT strain is measured. [3]

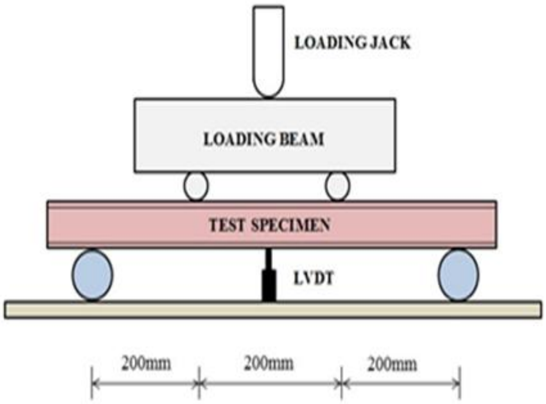

FIG.2 LINEOUT OF EXPERIMENTAL SETUP

IV. MATERIALS

For the experimentation hot rolled steel I-beam of total depth 100 mm and flange width of 50 mm has taken. Cross sectional details of rolled steel I-beams used for experimentation are shown in fig.2

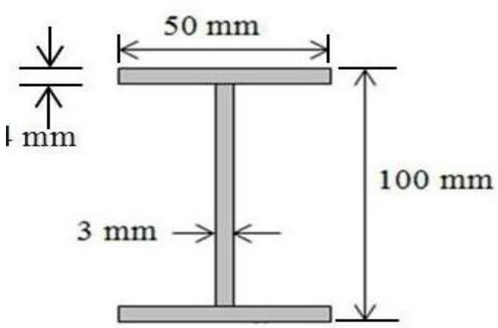

FIG.3 CROSS SECTIONAL DETAILS OF TESTED I-SECTION

These beams were tested under four point bending test using Universal Testing Machine (600 KN). Linear Variable Differential Transducer (LVDT) was used to measure deformation of beam precisely. LVDT was placed at the mid-span of the steel beam.Fig.1.

Twelve locally available rolled steel I-beams were used to study the flexural behavior bonded with and without BFRP sheets. A beam section was chosen such that there will not be any local buckling sand vertical stiffeners will not be needed. Length of I-beam is 700mm. An epoxy resin namely "Araldite" as resin and hardener in separate packages has been used for installing the FRP strips on the steel beams as stronger bond is essential in transferring the interfacial stresses between the common surfaces.

V. FINITE ELEMENT MODELLING

Finite element program (ANSYS v.12.0) used to build three-dimensional model of steel beam. Two type of element were used to represent the beam namely SOLID185 and SOLSH190. To develop precise model, the actual boundary conditions as well as loads were applied on 3D finite element model. Deformations at the mid-span of beam in finite element model are found to be similar as that of actual tested beam. [1]

I. RESULTS AND DISCUSSIONS

Average mid-span deflection results observed are summarized in table.

AVERAGE MIDSPAN DEFLECTIONS OF THREE CONTROL BEAMS

Load (kN)	Control Beam	Beams with BFRP at Tension Flange	Beams with BFRP at Compression Flange	Beams with BFRP at Both Flange
1	0	0	0	0
3	0	0	0	0
6	0.02	0	0	0
9	0.06	0	0	0
12	0.1	0	0	0
15	0.13	0	0	0
18	0.16	0	0	0
21	0.19	0.02	0.01	0
24	0.21	0.07	0.11	0
27	0.215	0.16	0.24	0
30	0.23	0.285	0.36	0
33	0.255	0.35	0.44	0
36	0.27	0.39	0.5	0
39	0.28	0.44	0.56	0.02
42	0.28	0.5	0.64	0.05
45	0.3	0.56	0.71	0.09
48	0.42	0.615	0.77	0.15
51	0.6	0.66	0.815	0.2
54	0.89	0.7	0.87	0.25
57	1.4	0.76	0.95	0.31
60	2.4	0.82	1.02	0.37
63	3.3	0.92	1.195	0.46
66	4.2	1.02	1.56	0.52
69	4.8	1.29	1.95	0.63
70	5.1	1.41	2.31	0.68
70.4	5.28	-	2.31	-
71	-	1.54	-	0.8
72	-	1.77	-	0.99
72.7	-	2.18	-	1.04

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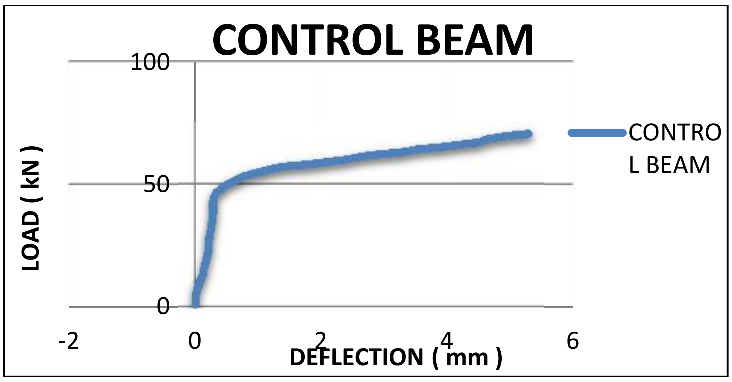

FIG. 4 LOAD VS. DEFORMATION GRAPH FOR CONTROL BEAM

From result table and Load vs. Deflection plot we can say that load carrying capacity of control beam is 70.4 KN Beam showed elastic behavior up to 54 KN and then reached to yield point. Beam carried load of 70.4kN and then failure occurred with deflection of 5.28 mm. From results obtained during the flexural test of control beams, we can consider average load carrying capacity of beam as 70.4 KN.

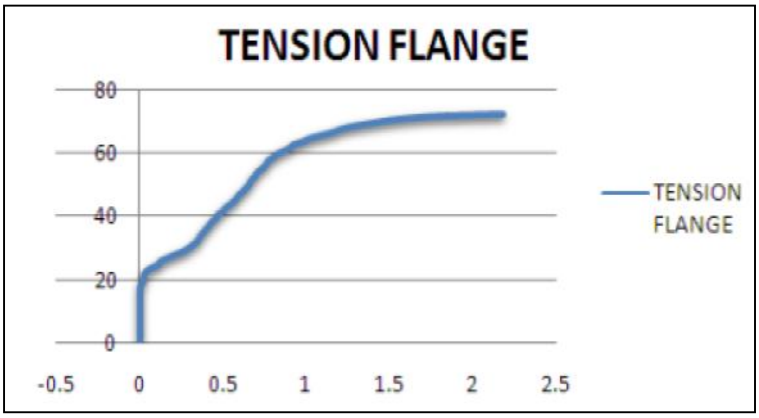

FIG5.LOADVS. DEFORMATION GRAPH FOR BEAM WITH BFRP AT TENSION FLANGE

From result table and Load vs. Deflection plot we can say that load carrying capacity of beam when BFS is applied at Tension Flange is 72.7 KN Beam showed elastic behavior up to 63kN and then reached to yield point. Beam carried load of 72.7kN and then failure occurred with deflection of 2.18 mm. From results obtained during the flexural test of beams with BFS at Tension Flange, we can consider average load carrying capacity of beam as 72.7 KN

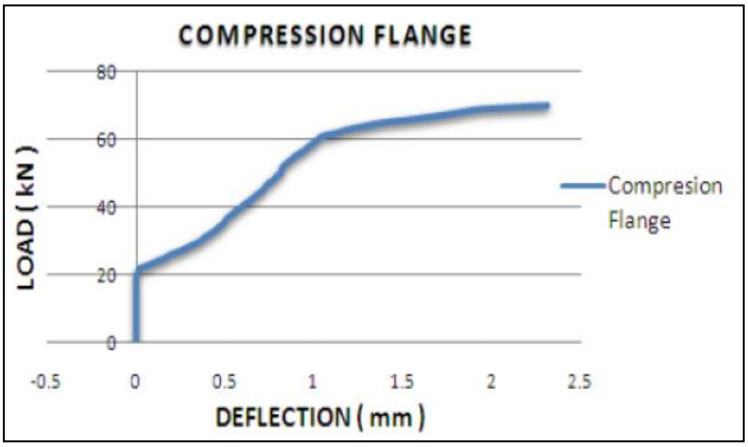

FIG.6 LOAD VS. DEFORMATION GRAPH FOR BEAM WITH BFRP AT COMPRESSION FLANGE

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From result table and Load vs. Deflection plot we can say that load carrying capacity of beam when BFS is applied at Compression Flange is 70.1 KN Beam showed elastic behavior up to 59kN and then reached to yield point. Beam carried load of 70.1kN and then failure occurred with deflection of 2.31 mm. From results obtained during the flexural test of beams with BFS at Compression Flange, we can consider average load carrying capacity of beam as 70.1 KN

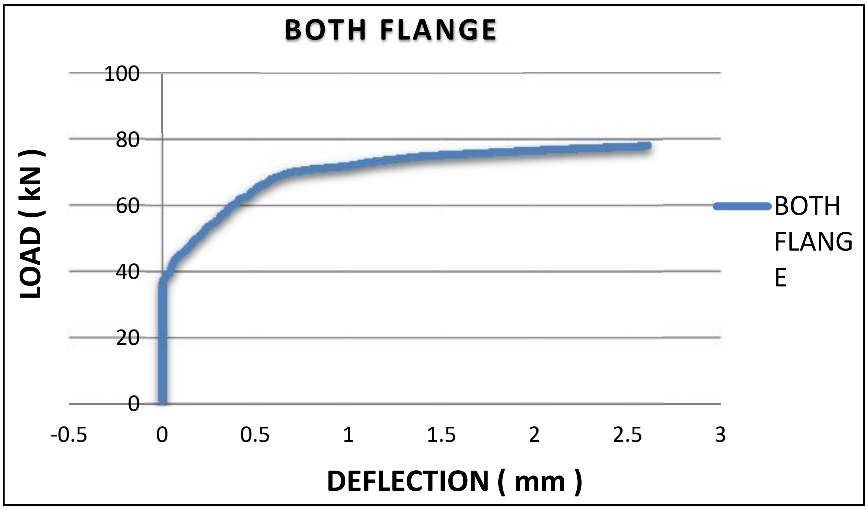

FIG.7 LOAD VS. DEFORMATION GRAPH FOR BEAM WITH BFRP AT BOTH FLANGES

From result table and Load vs. Deflection plot we can say that load carrying capacity of beam when BFS is applied to Both Flange is 78.1 kN Beam showed elastic behavior up to 69kN and then reached to yield point. Beam carried load of 78.1kN and then failure occurred with deflection of 2.6 mm. From results obtained during the flexural test of beams with BFS at Compression Flange, we can consider average load carrying capacity of beam as 78.1 kN

II. COMPARISON BETWEEN TEST RESULTS FOR ALL BEAMS

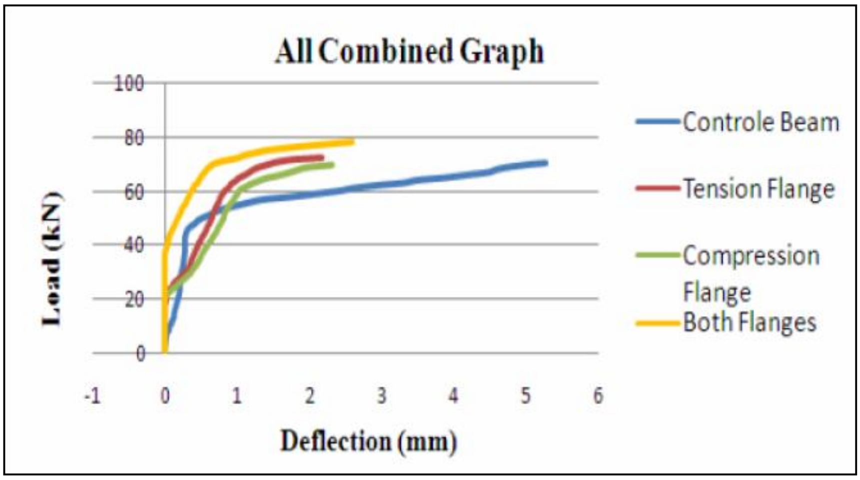

FIG.8 COMPARATIVE LOAD VS. DEFORMATIONGRAPH FOR ALL BEAMS

From the combined graphs it is observed that all the strengthened beams shows better strength compared to control beam. However, BFRP bonded at both flanges of beam indicates more load carrying capacity as compared with the beam bonded with BFRP at Tension and Compression flange. The elastic response of strengthened beams is also observed to be increased over the control beam. The Yield points of strengthened beams also indicated relatively higher magnitude of load than that of control beam.

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From the load v/s deflection curve it is observed that the flexural behaviour of beams bonded with BFRP sheet at tension, compression and both flanges is somewhat similar in nature. Also, it can be said that bonding of FRP sheets on compression flange of beam in addition to tension flange definitely contribute to increased load carrying capacity of the steel beam. But to achieve economy FRP at tension flange can be used.

III. ANSYS RESULTS CONTROL SECTION

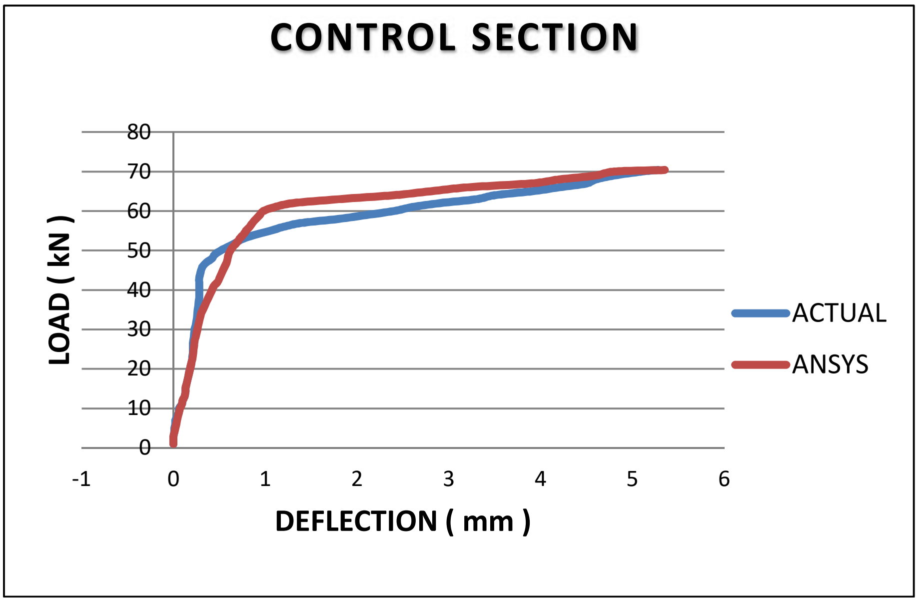

FIG.9 LOAD VS. DEFORMATION GRAPH FOR BEAM WITH BFRP AT BOTH FLANGES

A) TENSION FLANGE BEAM:

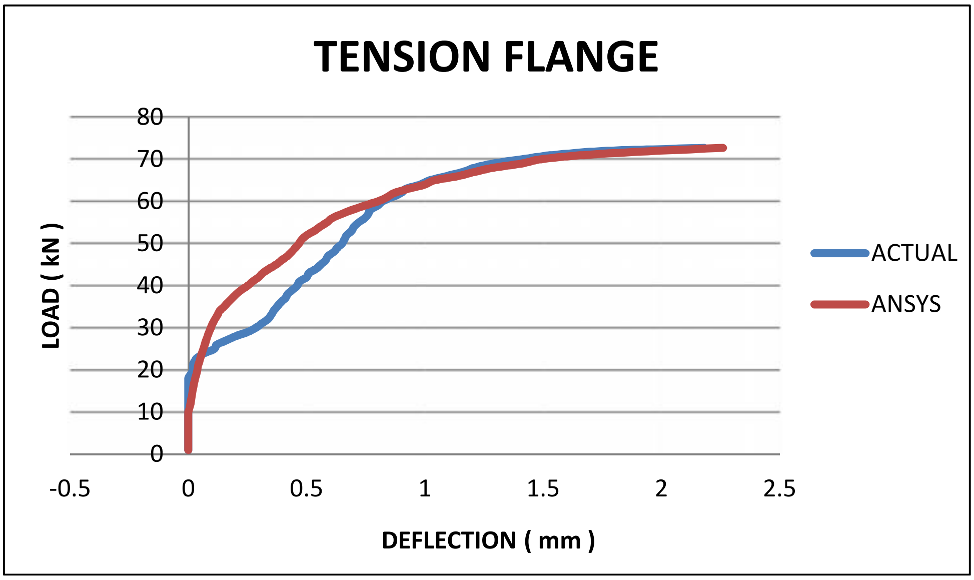

FIG.10 LOAD VS. DEFORMATION GRAPH FOR BEAM WITH BFRP AT BOTH FLANGES LOAD VS. DEFORMATION GRAPH FOR TENSION FLANGEBEAM FROM ANSYS FINITE ELEMENT MODEL

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B) COMPRESSION FLANGE BEAM:

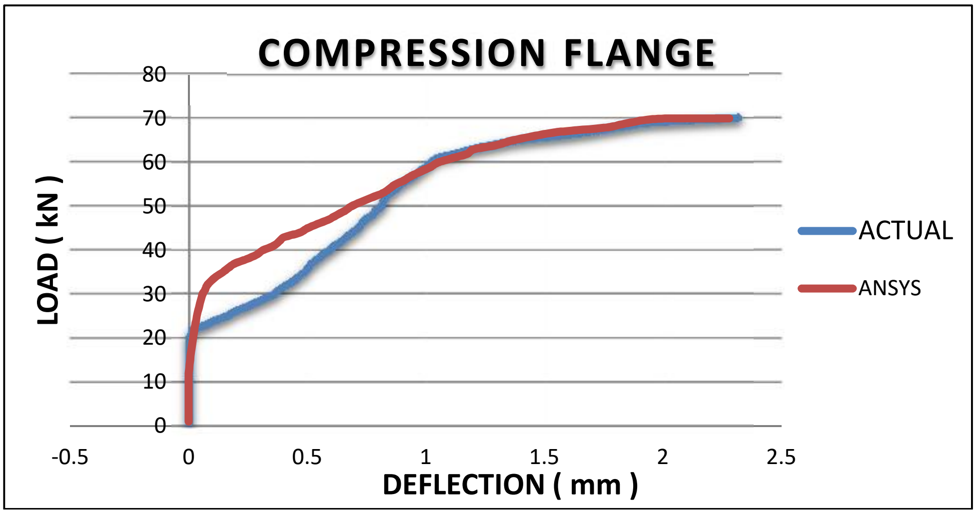

FIG.11 LOAD VS. DEFORMATION GRAPH FOR COMPRESSION FLANGE BEAM FROM ANSYS FINITE ELEMENT MODEL

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c) BOTH FLANGE BEAM

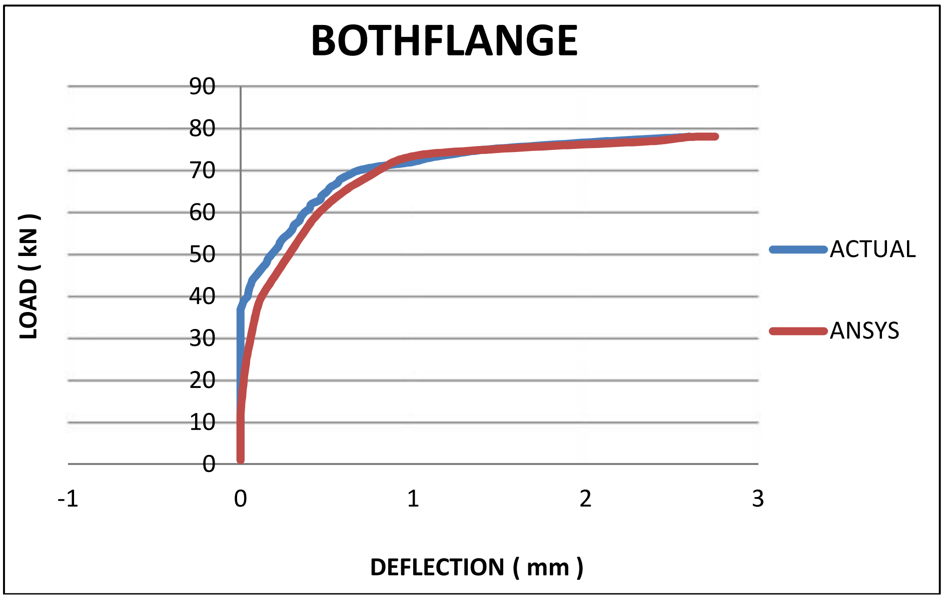

FIG.12 LOAD VS. DEFORMATION GRAPH FOR BEAM WITH BFRP AT BOTH FLANGES LOAD VS. DEFORMATION GRAPH FOR TENSION FLANGE BEAM FROM ANSYS FINITE ELEMET MODEL

Fig.8 shows load vs. deformation graph for control beam from ANSYS finite element model and Fig.9 shows load vs. deformation graph for beam bonded with BFRP at tension flange. Fig.10 shows plot for beam bonded with BFRP at compression flange. Results obtained from actual experiments and 3-dimensional finite element models in ANSYS software are found to be matching exactly. Thus, using properties of different FRP sheets for similar finite element 3-D model it is possible to find out exact deformation of that FRP bonded beam and to predict behavior of that structural element.

IV. CONCLUSIONS

Observing various experimental as well as mathematical studies it has been clear that the bonding of steel structures with different types of FRPs is a relevant technique to strengthen the existing steel structures. From the observations of experimentation, it can be concluded that BFRP may be an economical and possible alternative to strengthen the steel beams. Various conclusions that can be drawn are listed below;

1) Bonding of FRP sheets on the flanges of the steel beam causes increment in elastic behavior of beam and ultimately gives higher yield point value.

2) The load carrying capacity of the strengthened beam (BFRP bonded at tension flange) is found to be increased by 6.5% than that of control beam.

3) Beam bonded with BFRP at both the flanges carried load of 54kN and it shows increment of load carrying capacity by 10.70%.

4) Load carrying capacity of beam having depth 125 mm found to be equal (i.e. 79.7kN) to that of beam of 100 mm depth which was bonded with BFRP on both the flanges. Thus, it is possible to use smaller steel sections after bonding with FRP sheets as an alternative equivalent section for larger sections.

5) Finite element model of beam developed in ANSYS v.12.1 software has provided precise results which were found during experimental work, therefore it can be used to predict behavior of different sections before actual testing.

6) Considering future scope in this field it has become essential to compare other types of FRPs (carbon, armide, glass, coir etc.) with each other for their effectiveness, economy and to study their modes of failure. [10] Also it will become topic of interest for investigators to conduct such experimental studies when numbers of layers (single layer, double layer or multiple layer bonding) of FRP sheets are bonded over steel structure.

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