International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 08 | Aug 2020 www.irjet.net p-ISSN: 2395-0072

MODELLING AND ANALYSIS OF EXTERNALLY PRESTRESSED STEEL I BEAM WITH CFRP BARS

Manjima Mohan[1], Dr. Shajil N [2]

[1]M-Tech Student, Dept. of Civil Engineering, Thejus Engineering College, Kerala, India
[2]Head of Dept., Dept. of Civil Engineering, Thejus Engineering College, Kerala, India

---***---

Abstract - *Steel beams are upgraded using locally prestressed reinforcing bar. This method increases the stiffness and the load carrying capacity of the steel structural member through adding reinforcing steel bars to the beam. In case of steel bridges the repairing and upgrading can done by prestressing without interrupting the traffic. In this study all the models are externally prestressed. Parametric studies were carried out in changing the diameter of bar which was used in prestressing. CFRP bars were used as prestressing cable. The study was carried out to analyse the behaviour of prestressed steel beams with externally prestressed CFRP bars. The steel beams were modelled and analysed using ANSYS 16.1. Six specimens were analsyed and comparitive study was done. From this study larger the diameter of rebars used, higher the load carrying capacity.*

***Key Words*: External prestressing, CFRP bars**

1. INTRODUCTION

Prestressing techniques for steel beams were developed many years ago, both for the construction of new structures and for the rehabilitation of existing structures. Although tensioning principles were initially formulated and developed for reinforced concrete structures, the prestressing technology began to be applied also to steel beams by Dischinger and Magnel and by other engineers. A number of prestressed steel structures in the following years have been built throughout the world, especially in the U.S.A., Russia, and Germany, which demonstrates that prestressed steel beams can present both structural and economic advantages when compared with non-prestressed beams. The prestressed steel technique has been adopted mainly for bridges and rarely for roof structures. Many steel bridges are rendered structurally inadequate with aging of the structure and the increase of traffic loads. Replacement of these structures is costly and will interrupt traffic. Therefore, different structural repairing techniques and strengthening mechanism have been used. Among these repairing and upgrading methods, bolting or welding of steel plates to existing steel beams is one of the most widely used techniques. However there are issues related to this method. For example, the added plates increase the self-weight of the structure. In addition, the welding or bolting process may introduce new stress concentrations in the repaired region, causing a reduction of structural fatigue life. Another strengthening method involves applying carbon-fibre reinforced polymer (CFRP), adding plates or sheets bonded to the web or soffit of steel beams. Benefits are light weight, good durability and ease of handling of FRP materials, and this method appeared to be efficient in increasing the load carrying capacity of the existing beams.

In addition to these methods, external prestressed tendons have been used to strengthen existing composite steel–concrete beam structures. This technique involves welding end anchorages and using conventional high-strength post-tensioning cables. Results proved that the initial force in the tendon and its eccentricity significantly affect the strength and stiffness of tested beams. Furthermore, this type of strengthening leads to a 25% increase in load carrying capacity in some cases. This method increases the stiffness and the load carrying capacity of the steel structural member through adding reinforcing steel bars to a segment of the beam. Prestress is achieved by elevating the steel bars from the soffit of the steel beam by using a manual screw jack that generates a tensile force in the steel bars. Due to the low cost and the ease of operation, this method is also used to prestress concrete beams.

1.1 External prestresing

The main concept of the local prestress process is to increase the load carrying capacity of a regular steel I-beam by attaching additional reinforcing bars. The reinforcing bars are then tensioned using a manual screw jack. In the external local prestress type, the bars were welded to the beam's tensile flange and they were pulled to reach the required tensile strength using a steel plate and a bolt.

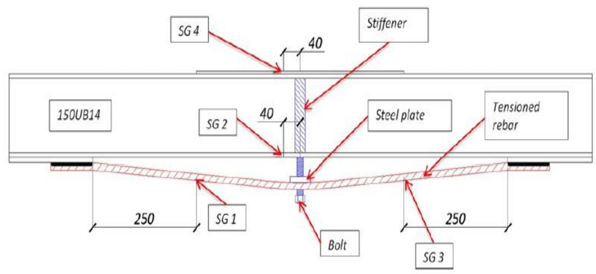


Fig -1: External prestressing

2. OBJECTIVES OF THE WORK

The work mainly carried out to analyse the behaviour of steel beams under external prestressing with CFRP bars as prestressing bar. Different diameter of CFRP bars were used in prestressing.

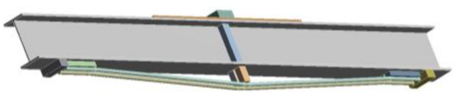
3. GEOMETRIC DETAILS

Six models of varying diameter of CFRP bars were used here. The cross section of I beam was same as six models. The diameter of CFRP bars were 10 mm, 12 mm, 14 mm, 20 mm, 24 mm and 28 mm. The models named as 2T DIA 10 CFRP, 2T DIA 12 CFRP, 2T DIA 14 CFRP, 1T DIA 20 CFRP, 1T DIA 24 CFRP and 1T DIA 28 CFRP for two bars of 10 mm, 12mm and 14 mm diameter CFRP bars and 20 mm, 24 mm and 28 mm diameter CFRP bars for single prestressing bar. Here external prestressing is done by reinforcing bars were attached symmetrically on either side of the beam. The bar was welded to the beam's web. The bars were pulled to reach the required tensile stresses then a rigid support was inserted between the mid span of each steel bar and the bottom surface of the flage to maintain the stresses in the bars. The tensile force in the rebar generates a reversebending moment in the mid span cross section that results in an increase of the load carrying capacity.

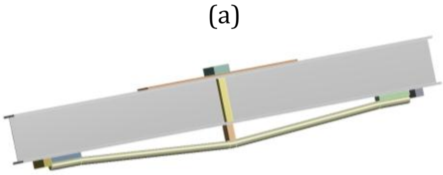
In the external local prestress type, the bars were welded to the beam's tensile flange and they were pulled to reach the required tensile strength using a steel plate and a bolt. In addition to the prestress bars, identical steel plates with dimensions of 500x75x6 mm were welded to the centre of the compressive flange of all beams. A non-linear static analysis was done in ANSYS workbench 16.1 software for the Steel I beam. The length of reinforcing bar is 1.2 m.

Grade 400 UB 14 beam is used for the test

- Overall depth = 150 mm
- Flange width = 75 mm
- Flange thickness = 7 mm
- Web thickness = 5 mm
- Length = 1.4 m



(a)



(b)

Fig -1: FEA model of Prestressed I beam with CFRP bar of (a) 2 bars of 12 mm diameter and (b) single bar of 20 mm diameter

4. MATERIAL PROPERTIES

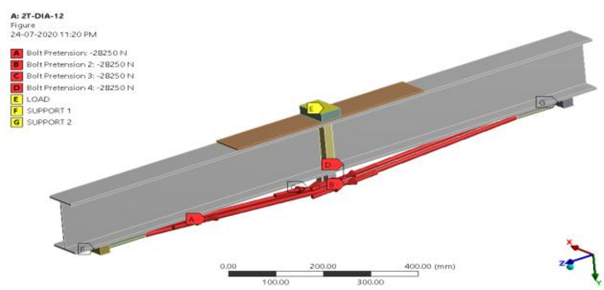
Table -1: Material Properties of the I beam

Yield stress	411.6 MPa
Ultimate tensile strength	541.3 MPa
Young's modulus	207.4 GPa
Poisson's ratio	0.3

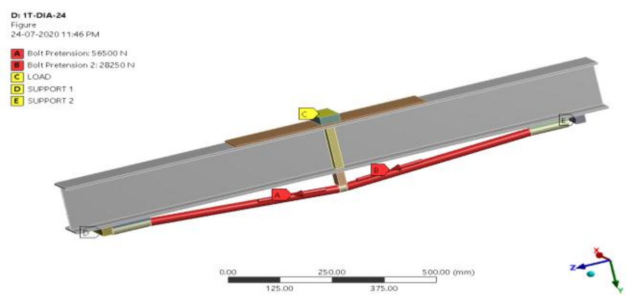
The CFRP bars were composed of 65% unidirectional carbon fibre by volume and 35% thermoset epoxy resin. The tensile strength of the bars was 2300 N/mm^2 and modulus of elasticity in tension was 165,000 N/mm^2. Poisson's ratio of CFRP bars were 0.3.

5. LOADING AND BOUNDARY CONDITIONS

Three-point bending tests were applied with a loading capacity of 1000 kN. Each beam specimen was simply supported on two roller supports with a span of 1250mm. The load was applied through a roller from above in the middle span of the beam. Local prestress was applied using deformed CFRP bars 500 N, typically used for reinforced concrete structures. The boundary condition was same as all models.



(a)



(b)

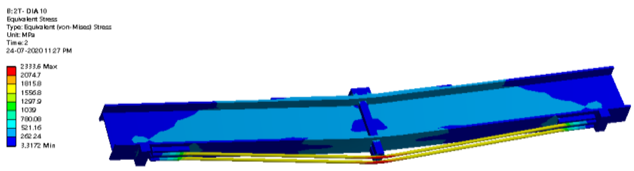
Fig -2: Boundary condition (a) 2T DIA 12 CFRP and (b) 1T DIA 24 CFRP

6. RESULTS OF FINITE ELEMENT ANALYSIS

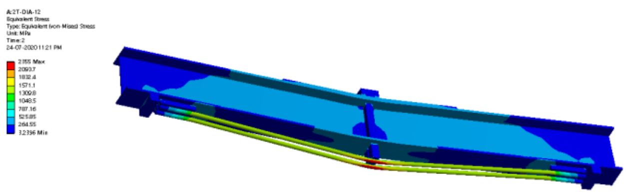
After the analysis of the study of the steel I beam with varying diameter of prestressing CFRP bars as10 mm, 12 mm, 14 mm, 20 mm, 24 mm and 28 mm. The Von-Misses stress distribution in the models was obtained from the analysis using ANSYS Workbench 16.1. The deformation in the models were also identified and graphs were plotted from the results.

6.1 Equivalent Stress Distributions

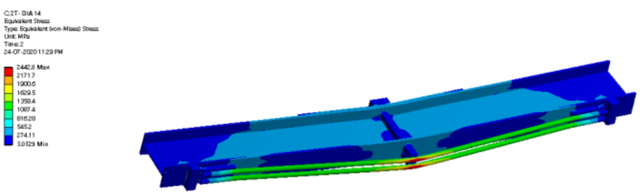
As we know about stress which referred to as the internal force which resist deformations. So while considering the failure of a structure the factor which likely to be considered is the stress, thus the equivalent stress distribution of the models were considered as the criteria for analyzing the performance of models as it were of steel. The stress distribution of all the models with varying diameter of 10 mm, 12 mm, 14 mm, 20 mm, 24 mm and 28 mm are shown in Fig-3.



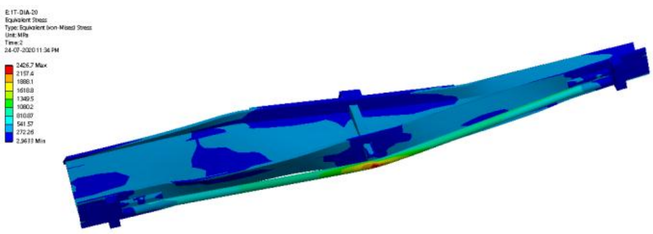
(a) 2T DIA 10 CFRP



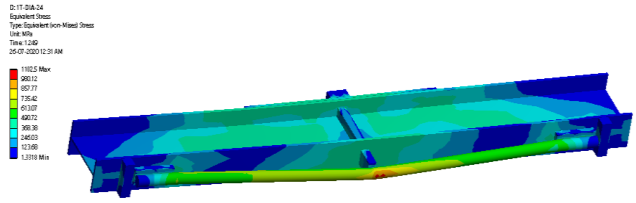
(b) 2T DIA 12 CFRP



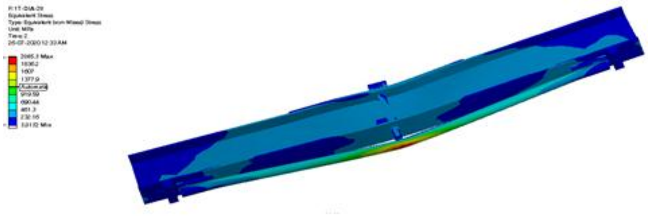
(c) 2T DIA 14 CFRP



(d) 1T DIA 20 CFRP



(e) 1T DIA 24 CFRP



(f) 1T DIA 28 CFRP

Fig -3: Equivalent stress distribution with different diameter of CFRP bar

Table-1: Equivalent stress distribution

Model	Equivalent stress, MPa
2T DIA 10 CFRP	2333.6
2T DIA 12 CFRP	2355
2T DIA 14 CFRP	2442.8
1T DIA 20 CFRP	2426.7
1T DIA 24 CFRP	1102.5
1T DIA 28 CFRP	2065.3

Stress is located at the midspan of the CFRP bar. The model with 14 mm diameter CFRP bar subjected to more stress of about 2442.8 MPa.

6.2 Total deformation of models

The total deformation of all the models with varying diameter are shown in Table-2. The total deformation is the vector sum of all the directional displacements of the systems. The moment deflection curves are given in Chart -1.

Table - 2: Deformation and moment details

Specimen	Moment, kNm	Deflection, mm
2T DIA 10 CFRP	98.342	37.253
2T DIA 12 CFRP	105.1	37.261

2T DIA 14 CFRP	109.51	37.286
1T DIA 20 CFRP	92.6	10.307
1T DIA 24 CFRP	97.364	9.54
1T DIA 28 CFRP	108	33.08

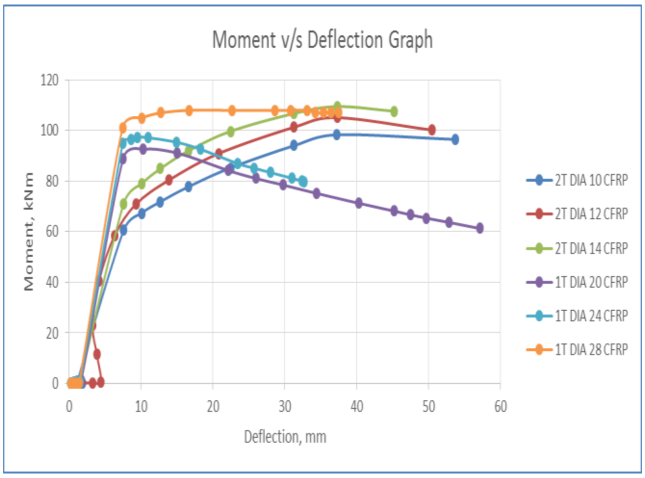
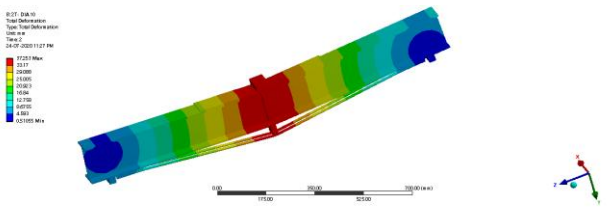
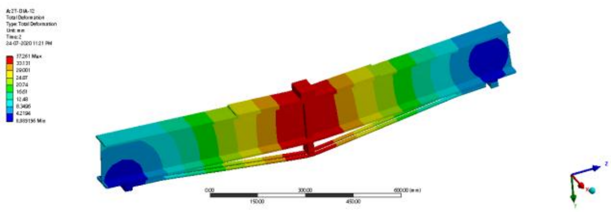


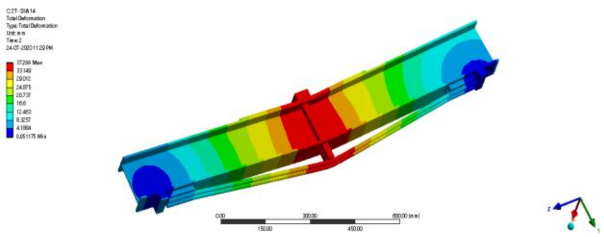
Chart – 1: Moment v/s Deflection Graph for CFRP bars



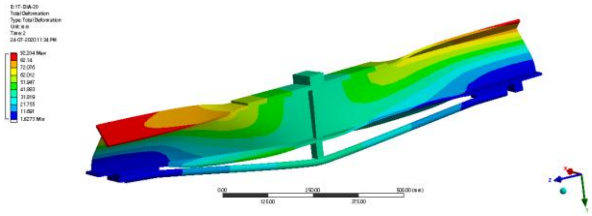
(a) 2T DIA 10 CFRP



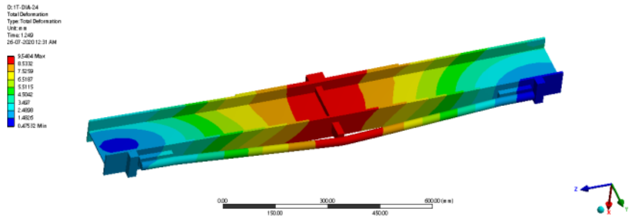
(b) 2T DIA 12 CFRP



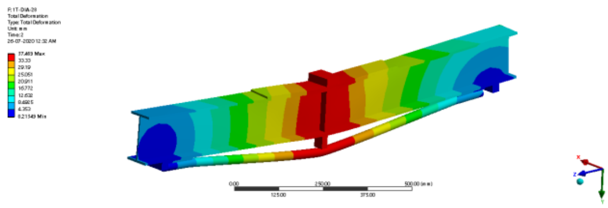
(c) 2T DIA 14 CFRP



(d) 1T DIA 20 CFRP



(e) 1T DIA 24 CFRP



(f) 1T DIA 28 CFRP

Fig - 4 : Total deformation of CFRP bars subjected to prestressing

From this study 2T DIA 12 CFRP has 6.43% increase in moment capacity than 2T DIA 10 CFRP. AND 2T DIA 14 CFRP shows 10.2% increase in moment capacity than 2T DIA 10 CFRP. In case 1T DIA 20 CFRP bar used for prestressing shows 4.9% of increase in moment capacity than 1T DIA 24 CFRP. And 1T DIA 28 CFRP shows 14.26% moment carrying capacity than 1T DIA 20 CFRP. Diameter of the prestressing bar highly influence the moment carrying carrying capacity. As diameter of the bar increases moment carrying capacity also increases.

7. CONCLUSION

The finite element analysis of externally prestressed steel I beam was carried out in ANSYS. The diameter of prestressed CFRP bar influence the load carrying capacity. As the diameter of bar increases moment carrying capacity is also increases. The local prestress method is a cost effective and easy to operate method that can be used to increase the load carrying capacity of beams when compared to other structural strengthening methods. CFRP bars are light weight, good durability and ease of handling of FRP materials, and this method appeared to be efficient in increasing the load carrying capacity of the existing beams.

REFERENCES

[1] Yusuf Ozcatalbas and Alpay Ozer, "Investigation of fabrication and mechanical properties of internally prestressed steel I beam," Materials and Design, Vol. 28, 2007, pp. 1988–1993.

[2] Yanmin Jia, "Nonlinear Analysis of Prestressed Steel Box Beams" Journal of Constructional Steel Research,Vol. 65, 2009, pp. 1198-1202.

[3] Sunkyu Park, Taewan Kim, Kwangsoo Kim and Sung-Nam Hong," Flexural behavior of steel I-beam prestressed with externally unbonded tendons" Journal of Constructional Steel Research, Vol. 66, 2010, pp.125-132.

[4] Shiming Chen and YuanlinJia, "Numerical investigation of inelastic buckling of steel–concrete composite beams prestressed with external tendons" Thin-Walled Structures, vol.48 , 2010, pp. 233–242.

[5] B. Belletti and A. Gasperi, "Behavior of Prestressed Steel BeamsJ. Struct. Eng., Vol.136, 2010, pp. 1131-1139.

[6] Jianguo Nie and Muxuan Tao,"Analytical and Numerical Modeling of Prestressed Continuous Steel-Concrete Composite Beams,"J. Struct. Eng., Vol. 137, 2011, pp. 1405-1418.

[7] Sang-Hyo Kim, Jung-Yeun Joung , Kyu-Tae Choi and Chi-Young Jung, " Experimental load-carrying capacity evaluation of thermal prestressed H beam with steel brackets,"Journal of Constructional Steel Research, vol.88, 2013, pp. 309–320.

[8] Jonathan Gosaye, Leroy Gardner, M. Ahmer Wadee, Murray E. Ellen, "Tensile performance of prestressed steel," elements Engineering Structures, vol.79 ,2014, pp. 234–243.

[9] Jonathan Gosaye and Leroy Gardner, "Compressive behaviour and design of prestressed steel elements,"Structures, Vol. 5, 2016, pp. 76–87.

[10] Assaad Taoum, Hui Jiao, Damien Holloway, "Upgrading steel I-beams using local post-tensioning," Journal of Constructional Steel Research, vol.113, 127–134

[11] Tiejiong Lou a, Sergio M.R. Lopes, Adelino V. Lopes.2016, "Numerical modeling of externally prestressed steel–concrete composite beams" Journal of Constructional Steel Research, Vol.121, 2015, pp. 229–236.

[12] Wen-Fu Zhang,"Symmetric and antisymmetric lateral–torsional buckling of prestressed steel I-beams", Thin walled structures, Vol.122, 2018, pp. 463-479.

[13] Yangzhi Rena and Yuanqing Wanga," Flexural behavior of steel deep beams prestressed with externally unbonded straight multi-tendons," Thin walled structures, Vol.131, 2018, pp. 519-530.

[14] Nicolas Hadjipantelis, Leroy Gardner and M. Ahmer Wadee, "Prestressed cold-formed steel beams: Concept and mechanical behaviour", Engineering Structures,Vol. 172, 2018, pp. 1067-1072.

[15] Nicolas Hadjipantelis, Leroy Gardner and M. Ahmer Wadee, "Design of prestressed cold-formed steel beams" Thin Walled Structures, Vol.140, 2019, pp. 565-578.

[16] Nicolas Hadjipantelis, Leroy Gardner and M. Ahmer Wadee, "Finite-Element Modeling of Prestressed Cold-Formed Steel Beams"J. Struct. Eng., Vol.14, 2019.

[17] S. Afshana, M. Theofanousb, J. Wangc, M. Gkantoud and L. GardnerTesting, "numerical simulation and design of prestressed high strength steel arched trusses" Engineering Structures, Vol.183, 2019, pp. 510–522.

[18] M. Ahmer Wadee , Nicolas Hadjipantelis, J. Bruno Bazzano , Leroy Gard, "Stability of steel struts with externally anchored prestressed cables" Journal of Constructional Steel Research, vol. 164, 2020, pp. 105-790.