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A STUDY ON STRENGTHENING OF HOLLOW STEEL SECTION BY USING CFRP AND AFRP

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ABSTRACT

Retrofitting of the structure is better alternative instead of whole replacement of structure. Retrofitting by using Carbon fiber reinforced polymer (CFRP) and Aramid fiber reinforced polymer (AFRP) has been increasing interest. Recently, CFRP and AFRP are being used for steel structures also. The purposes of using CFRP and AFRP materials are i) High strength to weight ratio ii) Better durability in worst environment. CFRP and AFRP bonded structures have less cost as compared to cost of replacement of structure. It increases load carrying capacity and improves stiffness and buckling behavior of structure. In this paper study of behavior of hollow square section strengthened with carbon fiber reinforced polymer and aramid fiber reinforced polymer are carried out. Square hollow sections were used as columns and CFRP and AFRP as a strengthening material. CFRP and AFRP bonded columns with change in width of CFRP and AFRP strips and various numbers in layers were tested. These column sections were analyzed using ANSYS 14.5. In comparison of intact section and CFRP and AFRP bonded sections, load carrying capacity of CFRP and AFRP bonded sections were increased. Then it comparing by experimental work to be done.

Key words: Hollow column section, CFRP and AFRP, Retrofitting, Strengthening, Stiffness, Strength, Durability.

INTRODUCTION

Square hollow section (SHS) are often used for columns, however similarly to Rectangular hollow section (RHS), they are not often used as beam due to its shape that makes it difficult to bolt to other beams and vice versa. Because of its high strength –to – weight ratio, excellent compression support characteristics and excellent tensional resistance, is now used in construction industry. And new, improved method to fasten SHS to itself or to other materials are making its use simpler and faster. But they are exposed to deterioration, fire and corrosion due to severe environmental condition or to the development of fatigue cracks when the structure is subjected to cyclic load. Traditionally,

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the most common method to repair and/or rehabilitate a steel structure has been by welding additional steel plates. This not only adds weight to the structure, but involved in welding can affect the stress distribution and may be critical for structure exposed to fatigue loads. In addition, steel plates would be exposed to corrosion damage and frequently this repairing method requires the use of scaffolding and heavy machinery as well as long periods of service interruption. In contrast, rehabilitation method using fiber reinforced polymer (FRP) composites do not exhibit any of these drawbacks. The advantages of FRP over steel plates are the low weight of the bonded materials, easy applicability and the capacity to cover areas with limit access. High stiffness fibres, such as carbon fiber and aramid fibres can effectively enhance the steel structural properties of steel structures; additionally, composites could also enhance the fatigue life of steel structures. However, there has been limited research in this area. There are uncertainties concerning the long term behavior of these application and the bonding between the composite materials and steel, this is the focus of this study.

Table 1: Dimensions of the SHS

Section	Length (H)	Diameter (D)	Thickness (T)
Square hollow steel section	700 mm	100 mm	3 mm

Analytical investigation

The finite element program ANSYS Version 14.5 is a computational tool for the modelling structure with material and non –linear behaviour. ANSYS Version 14.5 was used to stimulate the mode and to find the buckling mode and the strength of hot formed steel column using axial loading. Modelling of intact and CFRP–AFRP and AFRP-CFRP wrapped column is done in ANSYS Version 14.5.

Table 2: Properties of CFRP

S. No.	Properties	Values of CFRP
1	Modulus of elasticity	285 × 10^3 N/mm^2
2	Tensile strength	3500 N/mm^2
3	Density	1.80 g/cc
4	Thickness for static design weight/density	0.30 mm
5	Safety factor for static design	1.5

Table 3: Properties of AFRP

S. No.	Properties	Values of AFRP
1	Modulus of elasticity	70500 Mpa
2	Tensile strength	3600 Mpa
3	Density	1.44 g/cm^3
4	Thickness for static design weight/density	1 mm
5	Safety factor for static design	1.5

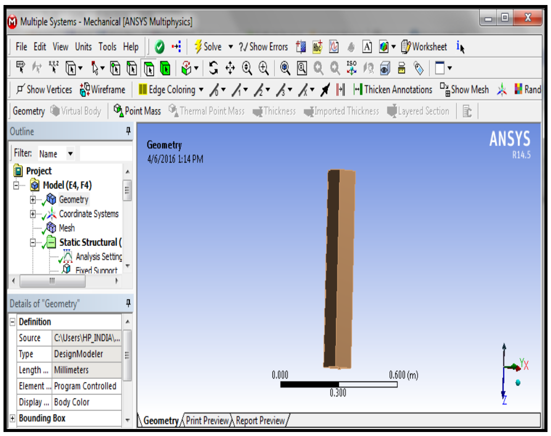

Fig. 1(A): The steel hollow section

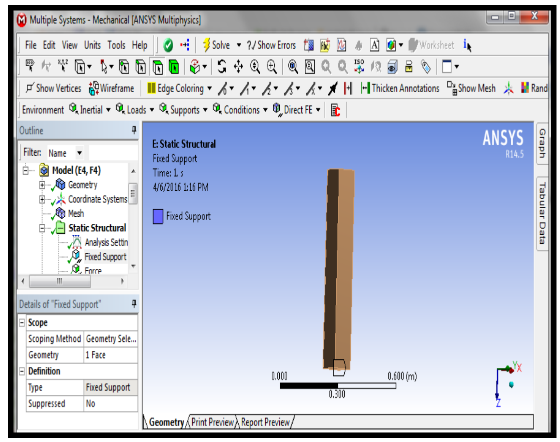

Fig. 1(B): Applying support conditions for SHS

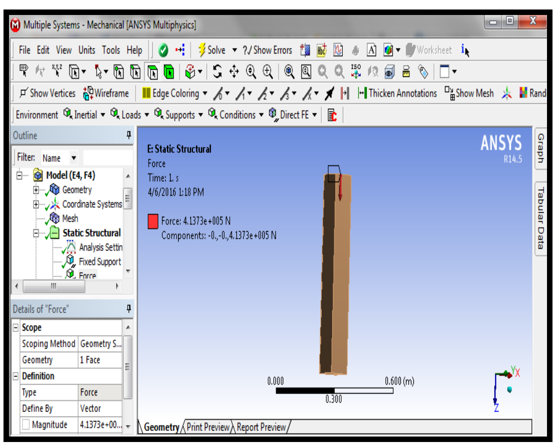

Fig. 1(C): Show the load of SHS

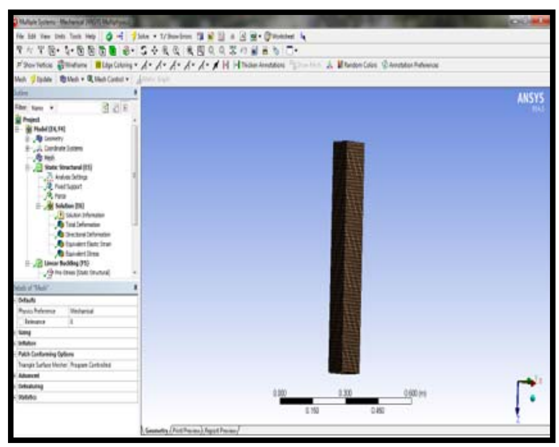

Fig. 1(D): Show the meshing of SHS

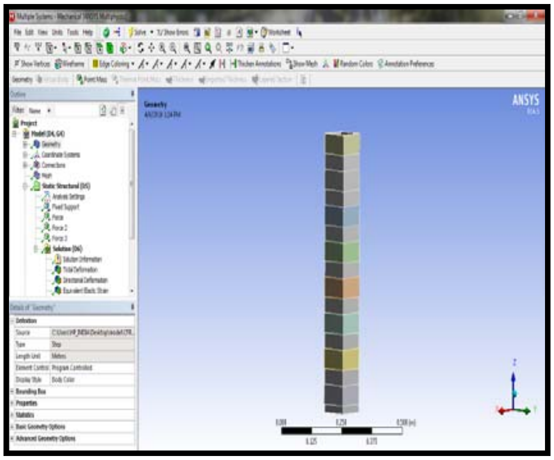

Fig. 1(E): Shows wrapping of CFRP-AFRP (50-40)

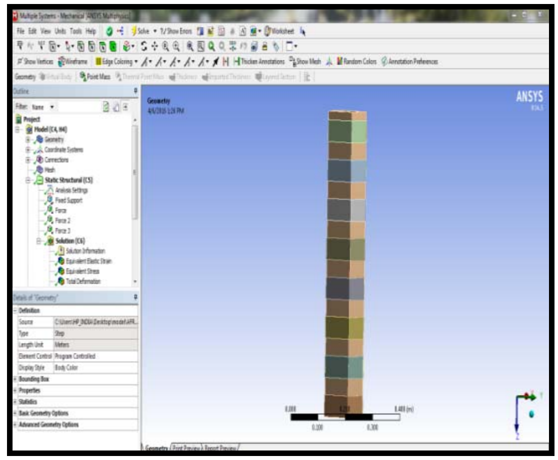

Fig. 1(F): Shows wrapping of AFRP – CFRP (50-40)

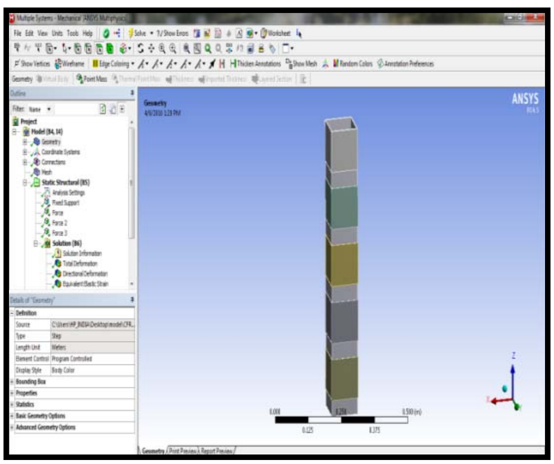

Fig. 1(G): Shows wrapping of CFRP-AFRP (100-40)

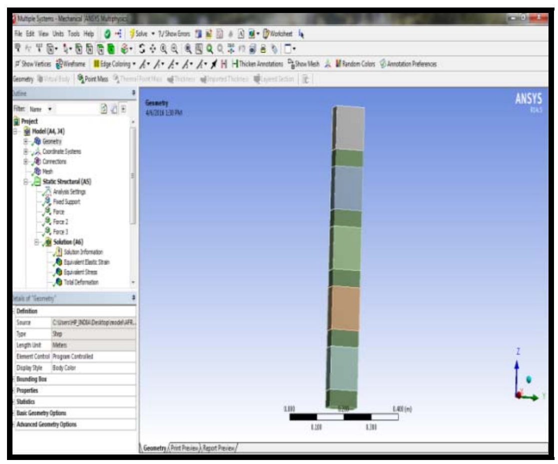

Fig. 1(H): Shows wrapping of AFRP-CFRP (100-40)

The modelled hollow section columns are show in Fig. (A), (B), (C), (D) and (E) with loading detail and support condition. Section modelling was done by assuming homogeneous and isotropic material in which part module was solid and deformable type shown in Fig. (A). Fixed- fixed boundary condition were assigned at both end of section. CFRP and AFRP materials were assumed as isotropic having thickness 0.3 mm and 1 mm.

EXPERIMENTAL

To get the compressive strength of hollow square section on strengthened with CFRP and AFRP, all specimens were tested in universal testing machine having both ends fixed. The hollow square section having dimension 100 mm × 100 mm × 3 mm was used. The length of this section was 700 mm. The bulking behavior of the parent and CFRP-AFRP wrapped columns for displacement under compressive loading was studied. The geometrical details of the square hollow column are given Fig. 2.

Fig. 2: Experimental set up

Section properties

The properties of square hollow section is as follows:

Table 4: Properties of square hollow section

Section (mm)	Mass (per meter)	c/s area mm^2	Ixx 10^6 mm^4	Rxx mm
100 × 100 × 3	8.96	1140	1.77	39.4

CFRP-AFRP material

Carbon fiber reinforced polymer aramid fiber reinforced polymer sheets having thickness 0.3 and 1 mm were used for experiment. These CFRP- AFRP sheets were cut into strips as per parameters. Strips were cut into two widths, 50 mm and 100 mm strips. These strips wrapping is shown in Fig. 3 tensile strength and elastic modulus of CFRP is 3500 N/mm^2 and 285 × 10^3N/mm^2 and of AFRP is 3600 Mpa and 70500 Mpa, respectively.

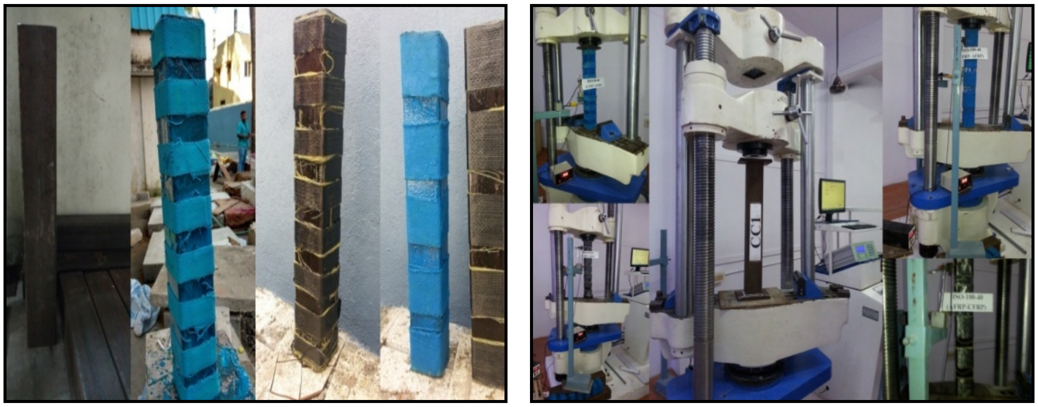

Fig. 3: Test specimens

Adhesive material

Epoxy resin (MH31914) was used as adhesive material. Epoxy resin having mix ratio of component 1(resin) and component 2 (hardener) as (1:1) by weight.

Preparation of test specimen

Hollow section (100 mm × 100 mm × 3 mm) having 700 mm length were both ends fixed. For a aching CFRP- AFRP sheets on hollow section on, it was required to prepare smooth surface. Sand paper was used for rust free surface preparation and achieve proper boding between steel column and CFRP-AFRP. AFRP-CFRP sheets. CFRP-AFRP sheets were cuttted as per required dimensions and a sched to the section by using standard epoxy resin as an adhesive material. Standard epoxy resin having mix ratio component 1 (resin) and component 2 (hardener) as (1:1) by weight was mixed and apply it on section.

Experimental results

CFRP-AFRP and AFRP-CFRP doesn't make any change in mode shape of buckling; it just delays buckling. The failure mode of the specimensare shown in Fig. 4.

From testing result, it was observed that the loading carrying capacity for the controlled column and CFRP& AFRP wrapped column. The ultimate load obtained for the controlled column is 413.730 kN, HS(L1)-50-40 is 459.030, HS (L2)-50-40 is 494.920, HS(L1)-100-40 is 522.790 and HS(L2)-100-40 is 584.92. It shows that the ultimate load of all the CFRP and AFRP wrapped specimens, AFRP and CFRP wrapped specimens got increased. The ultimate load for the HS (L2) -100-40 is higher than that of all obtained specimens.

Fig. 4: Modes of failure

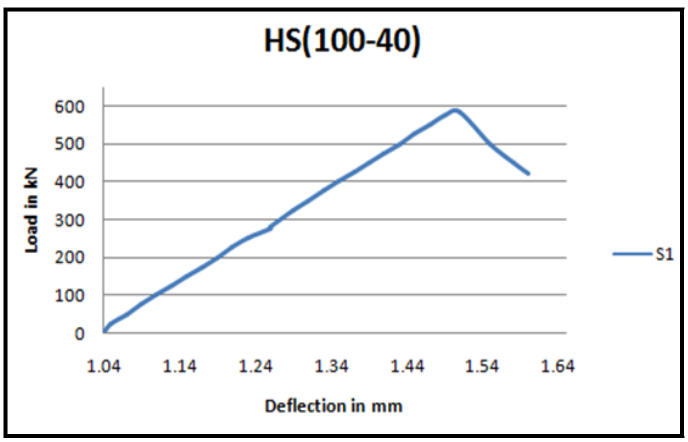

Fig. 5: Load vs. deflection graph

ANSYS 14.5 results

The result of load, displacement of the section analyzed by using ANSYS Version 14.5 so were are discussed below:

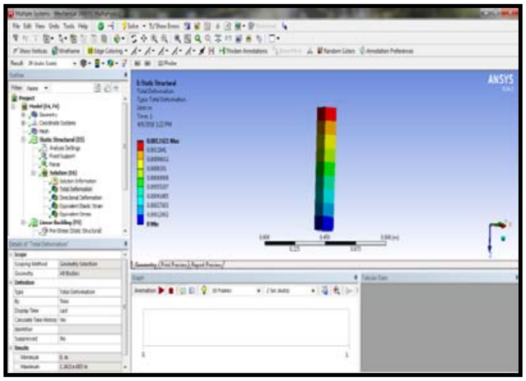

Fig. 5: Deflection for controlled column

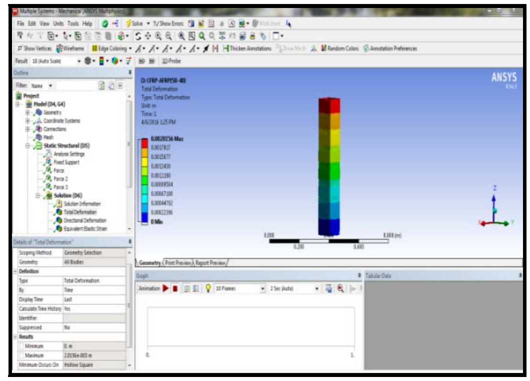

Fig. 6: Deflection for CFRP-AFRP (50-40) column

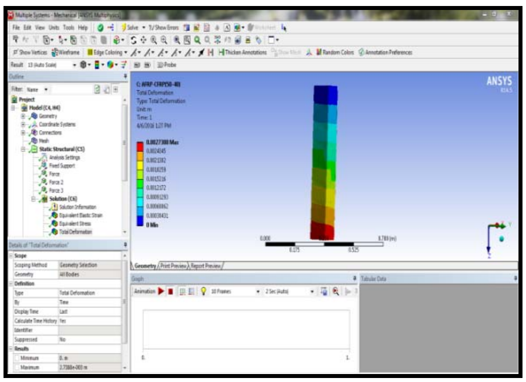

Fig. 7: Deflection for AFRP-CFRP (50-40) column

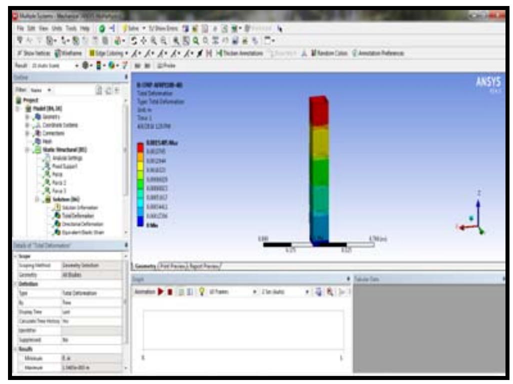

Fig. 8: Deflection for CFRP-AFRP (100-40) column

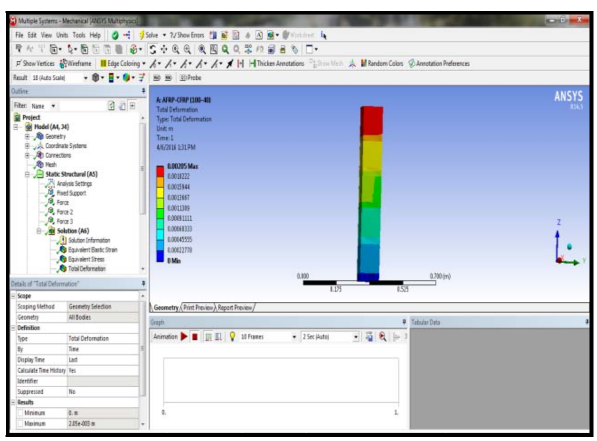

Fig. 9: Deflection for AFRP-CFRP (100-40)

Comparison results

Comparison between experimental results and ANSYS 14.5V results in table and validation of hollow column optimized.

Table 5

Profile name	Experimental results		ANSYS 14.5V results
	Failure load (kN)	Cross head (mm)	Total deformation (mm)
CC	413.730	3.130	0.0012421
HS-(CFRP-AFRP) 50-40	459.030	6.245	0.0020156
HS-(AFRP-CFRP) 50-40	494.920	7.230	0.0027388
HS-(CFRP-AFRP) 100-40	522.790	8.450	0.0015485
HS-(AFRP-CFRP) 100-40	584.920	9.230	0.00205

CONCLUSION

CFRP and AFRP strengthening just delays buckling; it doesn't make any change in the mode shape of the buckling. CFRP and AFRP strengthening improves the load carrying capacity of square hollow section thus, it can be used as an alternative strengthening method. For section with changing CFRP and AFRP strips, it was for 100 mm of AFRP strips and its overlaped by CFRP as same as 100mm strips wrapping as it covers more buckling region of section than 50mm.

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