INFLUENCE OF GFRP WRAPPING ON DEFECIENT HOLLOW CIRCULAR STEEL COLUMN UNDER CYCLIC LOADING

Treesa Tintu[1], Merin T Saji[2]

[1]*M. TECH Scholar, SCMS School of Engineering & Technology, Karukutty, Kerala, India.*
[2] *Assistant Professor, SCMS School of Engineering & Technology, Karukutty, Kerala, India.*

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Abstract - T*ubular structures become typically used in steel construction industry, due to their structural efficiency. Circular hollow steel (CHS) sections have better lateral buckling resistance and more structural efficiency. The formation of imperfections reduces the performance of the structural component. This imperfections originated by several reasons such as fire, earthquakes, corrosion or environmental conditions. So strengthening of these structures are required to maintain its structural performance. FRP is the common method of strengthening the structures for the last two decades. This paper investigates the influence of GFRP wrapping on CHS column (one short and one long column) subjected to cyclic loading. As per ATC-24 loading protocol, the cyclic loading is provided. The studies showed that GFRP wrapping increases the performance of deficient CHS columns.*

***Key Words*: Circular hollow steel (CHS) column, imperfections, cyclic loading, ATC-24, GFRP wrapping, Hysteresis loop**

1. INTRODUCTION

Design is an interactive process between the functional and architectural requirements and the strength and fabrication aspects. In a good design, all these aspects have to be considered in a balanced way. Due to the special features of hollow sections and their connections it is even here of more importance than for steel structures of open sections. Tubular structures become typically used in steel construction industry, due to their structural efficiency. Circular hollow steel (CHS) sections have better lateral buckling resistance and more structural efficiency. Hollow steel section (HSS) is a type of metal profile with a hollow tubular cross section [5]. HSS members can be circular, square, rectangular or elliptical. The well designed hollow steel sections results in lighter weight, high load carrying capacity and superior energy absorption capacity.

Columns transfer all gravity and lateral loads to the foundation. The failure of the column may leads to the failure of the entire structure. So keeping the column strong means keeping the structure safe. Here comes the importance of this study. The formation of imperfections reduces the performance of the structural component. This imperfections originated by several reasons such as fire, earthquakes, corrosion or environmental conditions. Conventional method of repairing or strengthening steel structures is to cut the damaged portion and replace it with plating, or attach external steel plates to the damaged portion of the member. These plates are usually bulky, heavy, difficult to fix and prone to corrosion and fatigue. The methods of retrofitting which utilizes steel plates has some disadvantages like use of heavy lifting equipment to lift the plates and due to this additional dead load will be on the structure. So there is a need to look for alternatives. Repairing or retrofitting of steel structures with FRP composites costs far less than replacement, takes less time for construction, and the service interruption time can be reduced . FRP is the commonly used strengthening technique in construction industry. The most widely used FRP composites are glass fiber reinforced polymer (GFRP) composites and carbon fiber reinforced polymer (CFRP). This paper investigates the influence of GFRP wrapping on CHS column (one short and one long column) subjected to cyclic loading. The studies showed that FRP wrapping increases the performance of structural members that it wraps. The development of imperfection under cyclic loading increases the effect of imperfection . So studying the influence of GFRP wrapping on CHS column under cyclic loading is important. Cyclic loading is provides as per ATC-24 loading protocol. It is the one formal protocols developed in the U.S. for seismic performance evaluation of components using a cyclic loading history[1]. Different studies are conducted to evaluate the performance of circular hollow steel columns. Guo *et* al [6] investigated the influenced of initial geometric imperfection on thin-walled circular hollow section steel tubes for different D/t ratio and under axial load. Goto *et al*(11),carried out a cyclic bidirectional loading experiment to examine the ultimate seismic behavior of thin-walled circular steel columns by using an accurate three-dimensional (3D) experimental system. Yamshitha et al. (8) conducted a study on the crush behaviors of hollow cylindrical structures with various regular polygonal cross-sections using the FEM program code. Hana *et al.*(3) conducted study to understand the crushing behaviours of aluminum and steel tube with cutouts and the effects of cutout on energy absorption capabilities of these tubes. Huang *et al.*(9), examined the dynamic crushing characteristics of high strength steel cylinder with elliptical geometric discontinuities by varying the major axis length and aspect ratios. Huang *et al.*(2), conducted an experimental study to evaluate the compressive behavior of damaged circular hollow section (CHS) steel columns repaired by carbon fiber-reinforced polymer (CFRP). Karimian*et al.*(7),conducted a study to examine the structural behaviors and impact of CFRP on strengthening steel Circular Hollow Section (CHS) short columns with initial horizontal or vertical deficiency. Lin *et al.*(10), introduced a method for strengthening aged steel columns by using new construction materials such as glass-fiber-reinforced polymer (GFRP) plates.

2. FINITE ELEMENT VALIDATION

To verify the FEM software, the study conducted by Guo *et al*. "Behaviour of thin walled circular hollow section stub columns under axial compression" was selected. In this literature, both experimental and analytical work were conducted to determine the structural performance of hollow steel stub column. The experiment part of that study was validated by ANSYS WORKBENCH 15.0 using the material properties and specimen specification noted in that journal.

3. ANALYTICAL STUDY

A large number of steel structures, such as buildings, offshore platforms, large mining equipment and bridges get damaged due to various reasons and need repairing. Studies on enhancing structures have significantly increased recently. Different methods exist for strengthening various structures. Use of FRP (Fiber Reinforced Polymer) appears to be an excellent solution. Using FRP is more popular than other materials for strengthening structures because of their high tension strength, low weight, high strength to weight ratios and excellent resistance to corrosion and environmental degradation. It is very flexible and forms all kinds of shapes, and is easy to handle during construction.

This paper investigates the effect of GFRP wrapping over deficient hollow circular steel column. Assumed the specimen has the deficiency of 0.5% of total surface area. This deficiency in surface causes to reduce the strength of the column. If GFRP is provided over this deficiency it will increase the strength of the column.

3.1 Specimen Specifications

ANSYS WORKBENCH 15.0 was selected to model and analyse the CHS specimen under cyclic loading. One short column was for this study. The geometry of the selected specimens was as shown in table T.1. The boundary conditions were provided as fixed at one end and displacement at the other end. ATC 24 was adopted to develop the loading protocol. The yield strength of the CHS specimen was taken as 310MPa. The modulus of elasticity and poisson's ratio of the specimen was $2.1x10^5$ and 0.3 respectively.

Table 1. Properties of Geometry

Column	Notation	Length (mm)	Diameter (mm)	Thickness (mm)	L/D ratio	Weight (kg)
Short	S	558.8	139.7	5.4	4	10

3.2 Effect of imperfection on CHS column

For studying the influence of GFRP wrapping on deficient CHS column, first study the influence of imperfection on that column. For this study, the imperfection area is selected as 0.5% as described above. The imperfection was given as elliptical crack at 0.25L and 0.5L along and perpendicular to the loading direction.

Table 2. Parameters considered

Specimen indications	Imperfection dimensions		Direction of loading	Position of imperfection
S0.25X	50	8	X	0.25L
S0.5X	50	8	X	0.5L
S0.25Z	50	8	Z	0.25L
S0.5Z	50	8	Z	0.5L

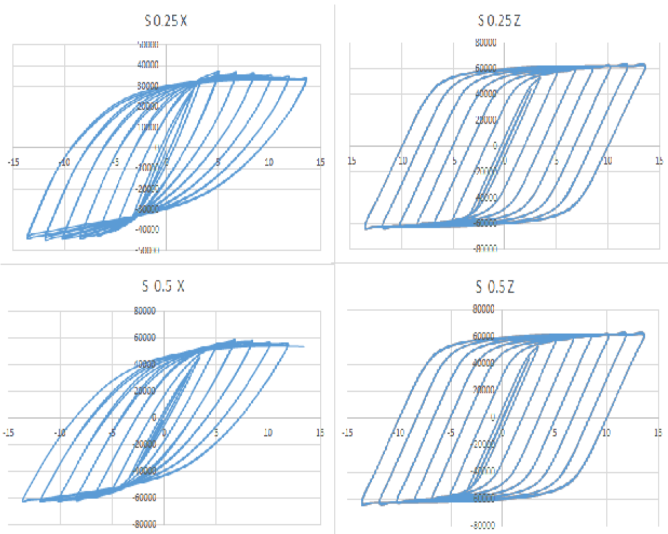

Fig 1. Hysteresis loops of deficient specimens

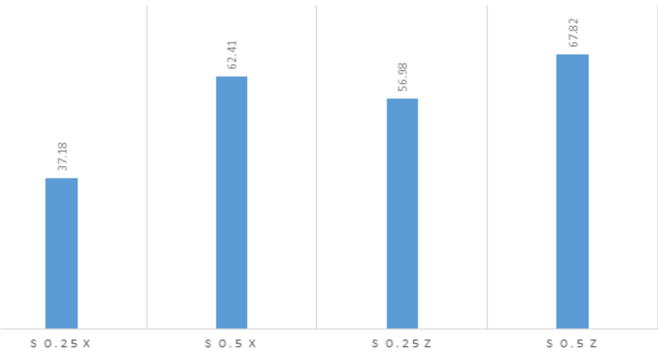

Chart 1. Load carrying capacity of specimen with varying parameters

3.3 Influence of GFRP wrapping on deficient CHS column

The design of steel buildings is often governed by lateral wind loads and not seismic loads. Also, studies showed, that during earthquakes, the failure of all types of steel buildings is significantly less compared to other types of buildings. Consequently, much effort has been invested to seismically retrofit the steel buildings. Recent research has expanded to meet the necessary strengthening technique for the lateral load-resisting system of the structure. The use of FRP in structural steel buildings' retrofitting can be often considered economical and efficient. The material properties of the GFRP wrapping was input as in the T 2.Two layer and four layer of GFRP wrapping was selected for the parametric study. The different cases considered for the parametric study of the influence of GFRP wrapping over the imperfections are listed in the table T3.

Table 3. Material Properties of GFRP

1	Modulus of elasticity, MPa	89000
2	Poisson's ratio	0.1
3	Density, kg/m^3	1850

Table 4. Parameters for studying the influence of GFRP wrapping

Specimen	No. GFRP layers
2S 0.25 X	2
2S 0.5 X	2
2S 0.25 Z	2
2S 0.5 Z	2
4S 0.25 X	4
4S 0.5X	4
4S 0.25 Z	4
4S 0.5 Z	4

2 and 4 indicates the number of GFRP wrapping layer. S indicates the short column and 0.25 and 0.5 indicates the position of imperfection. The GFRP wrapping increases the load carrying capacity of the deficient column.

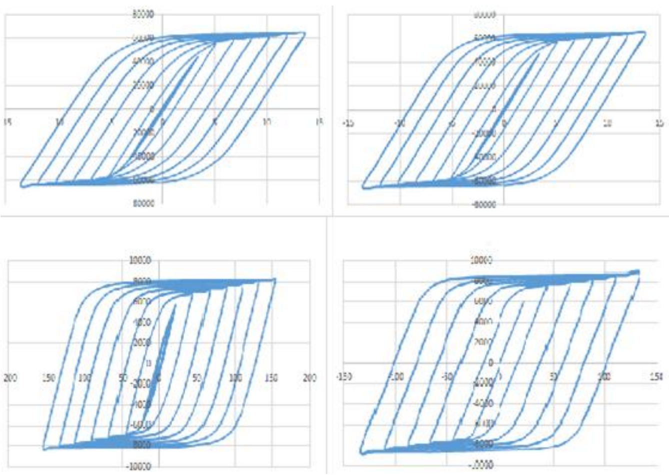

Fig 2. Hysteresis loops of GFRP wrapped specimens

4. RESULTS AND DISCUSSION

Finite element analysis of the CHS columns were done with varying parameters. From the analysis results it is observed that the imperfections on CHS column reduces the load carrying capacity. But the wrapping of the column with GFRP, over the imperfection area helps to go back to the performance level without imperfection.

From the results, it is clear that the maximum reduction in load carrying capacity was observed for the specimen with deficiency at 0.25L and load acted along the deficiency.

By the introduction of GFRP wrapping over the deficiency region the performance is increased and the increase in performance can be quantify as in the table T 4.1

Table 4. Performance improvement of GFRP wrapping for different specimens

Specimen	Load carrying capacity	
	Without GFRP layer	With GFRP layer
2S 0.25 X	37.18	64.62
2S 0.5 X	62.41	67.40
2S 0.25 Z	56.98	66.56
2S 0.5 Z	67.82	67.54
4S 0.25 X	37.18	65.23
4S 0.5X	62.41	68.52
4S 0.25 Z	56.98	67.21
4S 0.5 Z	67.82	67.89

From the table it is understand that, the load carrying capacity increased for the GFRP wrapped specimen. And also the number of layer is also effect the performance. In this case two layer of GFRP is enough, as within the increase of layer there is no increase in performance parameters. So two layer is enough for short columns.

5. CONCLUSIONS

- The ultimate load carrying capacity of deficient CHS column with deficiency at two location and two direction of loading are studied.
- The maximum reduction in load carrying capacity for CHS column was 45.18%.
- This paper work investigated, the effect of GFRP wrapping over the deficiency. It is observed that the GFRP wrapping increased the performance of the deficient column to the perfect column level.
- The results of GFRP wrapping suggested that, two layer of GFRP wrapping is apt for short column

- It is also observed that the variation of load carrying capacity is a function of second degree polynomial.

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