International Journal of Scientific Research in Engineering & Technology
Special Issue, Volume 4, Issue 3 (May-June 2024), PP: 96-101.
Recent Advances in Civil Engineering and Technology (REACT)-2024
www.ijsreat.com ISSN No: 2583-1240

Axial Performance of GFRP Wrapped Partially Encased Composite Column with Corrugated Web

Sijin Varghese[1], Dr Abhilasha P. S[2]
[1]*M. Tech student, Department of civil engineering, Vidya Academy of Science and Technology, Thrissur, Kerala, India.*
[2] *Head of the Department, Department of civil engineering, Vidya Academy of Science and Technology, Thrissur, Kerala, India.*

To Cite this Article: *Sijin Varghese[1], Dr Abhilasha P. S[2], "Axial Performance of GFRP Wrapped Partially Encased Composite Column with Corrugated Web", International Journal of Scientific Research in Engineering & Technology Volume 04, Issue 03, May-June 2024, PP: 96-101.*

Abstract: *PEC columns are a remarkable advancement in steel concrete composite members. The H-shaped steel section is filled in between its flanges in a way that the outer side of flanges are exposed. Transverse links are provided between flanges to delay the local buckling of flanges. In this study the flat web of the PEC column is replaced with a corrugated web and an encasement of GFRP is provided around the column. The performance under axial loading over the column was studied experimentally. The result shows that the Corrugated web PEC column increase the load bearing capacity and also delays the local buckling when compared with the Flat webbed PEC columns. Also the GFRP wrap effectively increases the load bearing capacity as well as it prevents the flanges from corrosion.*

Key Word: *Partially Encased Composite Column, Corrugated web, GFRP.*

I.INTRODUCTION

1.1 General

Partially encased Composite Columns (PEC columns) is a noteworthy advancement in Steel-Concrete composite structures. PEC components have gained increasing popularity in recent engineering construction due to their reduced formwork requirements and excellent fire resistance, making them well-suited for assembly construction. The installation of transverse links between the H-shaped steel flanges and filling the web cavity with concrete is intended to postpone the occurrence of local buckling in the flanges.

1.2 Partially Encased Composite Columns

Partially encased composite columns find frequent application as structural elements in construction projects. These columns amalgamate steel and concrete to leverage the distinct advantages offered by each material. The term "partially encased" signifies that only a portion of the column is enveloped in concrete, leaving some steel exposed. Steel, known for its high strength and stiffness, is well-suited for supporting substantial loads. The exposed steel section is partially clad or encased with concrete. This concrete layer enhances the column's resistance to fire, provides extra lateral stability, and contributes to the overall strength of the column. The extent of encasement may vary depending on design specifications. The interaction between the steel and concrete is pivotal for the performance of the composite column. Sufficient bonding ensures efficient load transfer, enabling the two materials to function synergistically as a composite system. Transverse links are provided at regular interval to ensure the bonding between concrete and steel and also to prevent the flanges from local buckling.

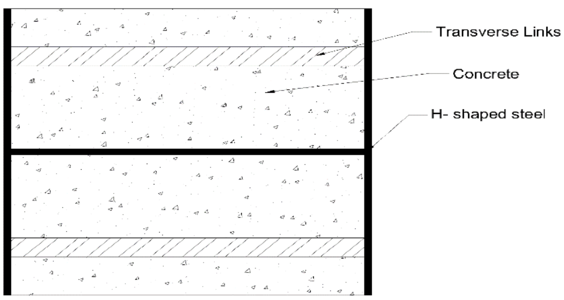

Fig. 1. PEC column

1.3 Corrugated Web and GFRP Wrapping

The use of a corrugated steel web in Partially Encased Composite (PEC) columns is a design approach that enhances the structural performance of these columns. In PEC columns, which are a combination of steel and concrete, the steel web is a critical component providing strength and stability. The term "corrugated" refers to the presence of corrugations or ridges in the steel web, creating a profiled or undulated surface. The corrugated design increases the surface area of the steel web, providing additional stiffness and strength without significantly increasing the weight of the column. Advantages of corrugated steel web are Enhanced strength, Ductility, Efficient use of material. The corrugated steel web is integrated with the surrounding concrete during the encasement process. This integration enhances the composite action between steel and concrete, ensuring effective load transfer and interaction. The utilization of a corrugated steel web in PEC columns represents an innovative approach to optimize the structural efficiency of composite columns.

GFRP (Glass Fiber Reinforced Polymer) is a composite material made of a polymer matrix reinforced with glass fibers. It is known for its high strength-to-weight ratio, corrosion resistance, and versatility, making it a popular choice in various construction applications. The GFRP material is wrapped completely around the column for the complete protection. The GFRP material is fixed on the surface of the PEC column using the Adhesive resin. The resin brings the environmental and chemical resistance to the product, is the binder for the fibers in the structural laminate and defines the form of a GFRP part. The glass fibers add strength to the composite. This strength enables the PEC column to take better load carrying capacity, buckling strength. This also prevents the column from corrosion.

II.EXPERIMENTAL STUDY

2.1 Specimen Details

The H section was made but cutting and welding of the steel sheets of thickness 3mm. The same thickness was taken for the corrugated web as well. The flanges and webs were cut down and later welded together. The corrugated web was made using the same 3 mm steel sheets. The transverse links of 10mm dia are provided between the flanges at 110mm c/c distance throughout the height of the column. The design and dimensions for the corrugation is shown. 4 different types of specimens were prepared for the study.
The types and its details are provided in the table 1 & 2.

Table 1. Specimen Details

Specifications of specimen	
Height of specimen	800 mm
Web length	144 mm
Flange length	150 mm
Thickness of the steel	3 mm
Transverse link Diameter	10 mm
Transverse links spacing	110 mm c/c

Table 2. Specimen types

Specimen	Specimen Full form
PF	Partially Encase Composite Columns with Flat web
PC	Partially Encase Composite Columns with Corrugated web
GF	GFRP wrapped Partially Encase Composite Columns with flat web
GC	GFRP wrapped Partially Encase Composite Columns with Corrugated web

Table 3. Material Properties

Material	Density (kg/m3)	Elastic Modulus (in GPa)	Poissons Ratio	Yield Strength (in MPa)
Steel (H-section)	7850	200	0.3	240
Steel (Transverse links)	7850	200	0.3	500
GFRP	2000	10.4	0.275	14
Concrete	2400	22.36	0.18	2.7

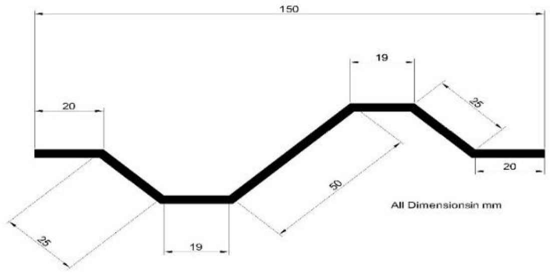

Fig. 2. Corrugated Steel Web

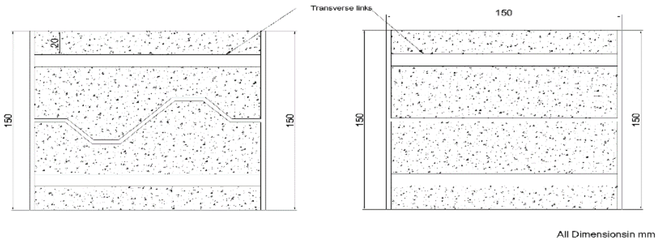

Fig. 3. PEC column with corrugated and Flat webs

2.2. Specimen Preparation

- Steel works: The H-section is cut and welded in the required dimensions. The transverse links were also welded at between the flanges.
- Formwork: It only needs limited amount of formwork, as it is partially encased.
- Casting of column: Casting was performed using M20 concrete and the mixing was performed manually.
- Curing: it was done for 28 days
- GFRP wrapping: The GFRP sheets were fixed using adhesive resin. A coating of resin is applied firstly all over the surface and the GFRP sheet is fixed on top of that. Later another layer of resin is applied for the bonding with the surface.

Fig. 4. PEC columns with Corrugated web

Fig. 5. PEC column with flat web

2.3 Test Setup

The test was conducted on Universal Testing Machine (UTM). The specimen was taken and kept on the UTM machine as in the figure. LVDTs were used to find the deformation while loading the columns. The LVDT is kept in touch with the top plate of the UTM machine. This LVDT is connected to Data Logger were the values of the deflection is shown. The load values corresponding to each point of deflection is taken from Dial in the UTM machine.

Fig. 6. Test setup in UTM

III.EXPERIMENTAL RESULTS

3.1 Observations and Failure modes

As all the specimen were short column, the failure happened in the columns were concrete crushing failure in general. But in few places the local flange buckling was visible. Also the GFRP encasement enabled a better confinement for the specimen. The observation on each column are described below:

- **PF:** The first cracks were visible at a load of 524 kN at 1mm deflection. These cracks then propagated as the loads increased. The column failed at a load of 716 kN at 1.5mm deflection. Before reaching the Ultimate load the concrete cover got detached. The column failed even before the local flange buckling could happen. So the reason for the failure was due to the concrete crushing.
- **PC:** The crack was first formed at a load of 582 kN at 1.1mm deflection. These cracks propagated axially upwards. Toward the ultimate load the concrete cover got detached. The ultimate laod at which the column failed was 762 kN at 1.5mm deflection. But the failure was completed after the local flange buckling at the bottom part of the column. The column withstood the failure even after the concrete detachment. The failure occurred only after the local flange buckling happened at the position above bottom most transverse link.
- **GF:** The GFRP improved the confinement of the PEC column. As the load was applied gradually over the column, the GFRP started De-bond from the surface of the PEC column due to the concrete bulging and local flange buckling within the encasement. The GFRP de-bonding occurred at a load of 680 kN at 1.2mm deflection. Until this point the crack was not able to observe as the wrap was encasing the PEC column. But as soon as the GFRP wrap was de-bonded the cracks were already present at that portion. The cracks developed were at the top and it was vertical in nature. It propagated vertically till 20 cm from the top of the column. At the same time there was development of local flange buckling in the column. Buckling was formed between the 2nd and 3rd Transverse links of the column. The ultimate load of the column at the time of failure was 802 kN at 1.5mm deflection. The failure was mainly due to concrete crushing. But the PEC column withstood the failure until the Local flange buckling occurred at the top part of the column.
- **GC:** The GFRP improved the confinement of the PEC column. As the load was applied gradually over the column, the GFRP started De-bond from the surface of the PEC column due to the concrete bulging and local flange buckling within the encasement. The GFRP de-bonding occurred at a load of 750 kN at 1 mm deflection. Until this point the crack was not able to observe as the wrap was encasing the PEC column. The cracks developed were vertical and positioned at the top of the column. Vertical Cracks were also present at the bottom portion of the column. It propagated vertically till 20 cm from the top of the column. Buckling was formed between the 1st and 2nd, 6th and 7th transverse links of the column. The buckling happened at both top and bottom of the PEC column. The ultimate load capacity of the Column was 862 kN at 1.6 mm deflection. The failure was mainly due to concrete crushing. But the GFRP wrap had delayed the concrete crushing as well as the local flange buckling.

Fig. 7. Failure modes in ordinary PEC column with flat and corrugated web

Fig. 8. Failure modes in GFRP wrapped PEC column with flat and corrugated web

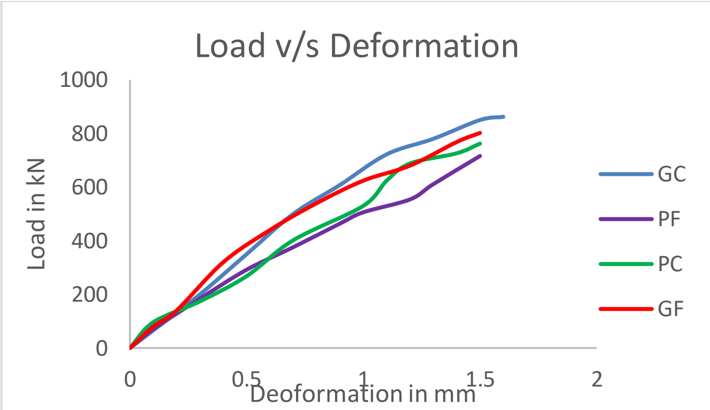

Fig. 9. Load v/s Displacement graph of all specimen

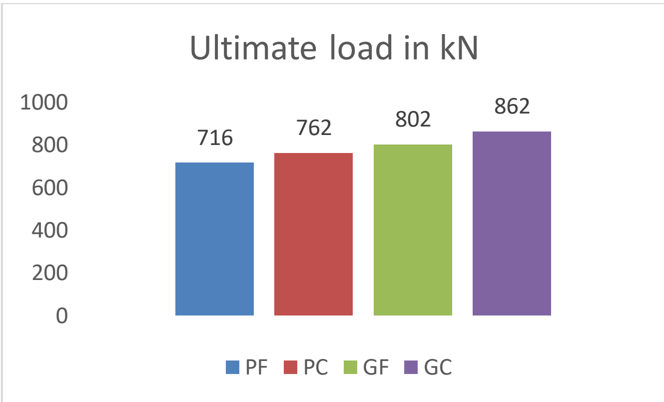

Fig. 10. Ultimate load capacity of each specimen

IV.CONCLUSIONS

- Experimental evidence has shown that the load-carrying capacity of PEC columns is significantly enhanced by incorporating a corrugated web, surpassing the performance of columns with a flat web. The addition of corrugated web increased the surface area than in flat web.
- In all instances, the load-carrying capacity of the PEC columns was improved by the application of GFRP wrapping. This improvement can be attributed to the confinement imparted by the hardened glass fiber.
- Besides minor instances of local flange buckling, the failure of all specimens occurred due to concrete crushing. The reason for the superiority of concrete crushing is because of the slenderness of the columns. The corrugated shape of the web had also increased the buckling strength of the column, thus delayed and reduced the flange buckling.
- The local flange buckling was delayed due to the confinement provided by the GFRP wrapping and corrugated web. The transverse links also did a major part in resisting the flange buckling.
- Experimentally the PC obtained 6.4% more load carrying capacity than the PF. The GC obtained 7.4 % more loading carrying capacity than GF

- Experimentally the GFRP increased the load carrying capacity of PF by 12.01 % and PC by 13.12 %.
- Due to exposure to the surroundings, the flanges are highly susceptible to corrosion. Wrapping them with GFRP will effectively inhibit corrosion.

REFEENCES

1. *Junhong Zhou, Zhongjun Hu, Boxin Wang, Xuepeng Li, Jingyi Han, "Experimental investigation of CFRP-confined partially encased composite columns under axial compression," Journal of Building Engineering, Volume 81, 108094, ISSN 2352-7102, (2024).*
2. *Wei Wang, Hengli Cai, Congyou Bai, Haiyang Bao, Boyuan Gao, Zhiwei Yuan, Kai Wang, "Seismic performance of partially encased concrete composite columns with corrugated web," Journal of Building Engineering, Volume 77, 107481, ISSN 2352-7102, (2023).*
3. *Thierry Chicoine, Bruno Massicotte, AU - Robert Tremblay, "Long-Term Behavior and Strength of Partially Encased Composite Columns Made with Built-Up Steel Shapes," Journal of Structural Engineering, 129(2): 141-150, (2002).*
4. *Thierry Chicoine, Robert Tremblay, Bruno Massicotte, James M. Ricles, Le-Wu Lu, "Behavior and Strength of Partially Encased Composite Columns with Built-up Shapes," Journal of Structural Engineering ,128(3): 279-288, (2003).*
5. *Yiyi Chen, Tuo Wang, Jing Yang, Xianzhong Zhao, "Test and numerical simulation of partially encased composite columns subject to axial and cyclic horizontal loads," International Journal of Steel Structures, Volume 10, Number 4, Page 385, (2010).*
6. *Zhenghao Qian, Jingfeng Wang, Yong Liu, Qiuyu Xu, "Axial compressive performance of partially encased steel-concrete composite stub columns filled with lightweight aggregate concrete," Engineering Structures, Volume 291, 116422, ISSN 0141-0296, (2023).*
7. *Mehdi Ebadi Jamkhaneh, Masoud Ahmadi, Pedram Sadeghian, "Simplified relations for confinement factors of partially and highly confined areas of concrete in partially encased composite columns," Engineering Structures, Volume 208, 110303, ISSN 0141-0296, (2020).*
8. *Hua Huang, Zhen Chen, Yanxia Ye, Yifan Yao, "Axial compressive behavior of middle partially encased composite brace," Journal of Constructional Steel Research, Volume 205, 107890, ISSN 0143-974X, (2023).*
9. *Jiong-Feng Liang, Wan-Jie Zou, Zeng-Liang Wang, Da-wei Liu, "Compressive behavior of CFRP-confined partially encased concrete columns under axial loading," Composite Structures, Volume 229, 111479, ISSN 0263-8223, (2019).*
10. *Qihan Shen, Jingfeng Wang, Jiaxin Wang, Zhaodong Ding, "Axial compressive performance of circular CFST columns partially wrapped by carbon FRP," Journal of Constructional Steel Research, Volume 155, Pages 90-106, ISSN 0143-974X, (2019).*